Web-GIS based crowd sourcing aiming at producing inland lake charts in Denmark

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Abstract:

One kind of spatial data is still not in the national databases, and this is bathymetric data from lakes. This paper describes the data standards associated, the methods of surveying including historic. It describes the history of Danish lake mapping, and produces an inventory over surveyed Danish lakes. It discusses how to choose standards for lake mapping. The paper suggests that crowd sourcing might be applied to collect data, and discuss the various aspects in crowd sourcing VGI. Vertical accuracy in consumer echo sounders is tested. Parsing data from echo sounders are demonstrated. Finally a Web-Gis is constructing visualizing Danish lake maps and VGI data, presenting a upload functionality and addressing issues with metadata necessary for further post processing of data.

Keywords: Bathymetry, VGI, echo sounder, Volunteer Geographic Information, ArcGis, Attribute data, GPX, Garmin.

Front page:
Surveyed Danish Lakes marked on a hill shade (KMS Kort10 DTM).

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1 - Introduction

The subject for this thesis is webgis based crowd sourcing, aiming at producing inland lake charts in Denmark. The thesis will demonstrate how to construct a web based solution to present existing data and to collect new data. The new data falls with in the category of Voluntary Geographic information[1]. An inland lake "chart" is in this context understood, as a chart or map in general terms, regardless of purpose, as long as it provides information about the morphology of a lake inside the coastline.

1.1 Surveying of Danish lakes

The landscape beneath the water surface is by its nature hidden to the observer, unless the clarity of the water and the present light, or the absence of water, makes the bottom visible. The basic map to display the morphology[2] and topography is a bathymetric[3] map. If this map is combined with data about additional features of the lake, a hydrographic[4] map is the result.

A traditional hydrographic chart shows water depth, obstacles essential for navigation, aids for navigation, structures at or in the water, names of places including fishing spots, land marks etc. The purpose of most navigation charting, is to show the bottom, potential dangerous objects and navigation aids. But the surveying of a water body can also be justified from other aspects. It is essential for purposes like fishing where location of underwater features is important or for environmental investigations where morphologic studies are very important.

The lake map has come a long way since charting started, and surveying methods have developed significantly over time. The basic method through time is a lead and line technique, measuring the depth to which the lead penetrates into the water. The Danish term is a "lodskud" or a sounding. Most elder charts both marine, and of inland lakes, are made this way. The method is very cumbersome and delivers only few results when applied, due to the high costs in man hour.

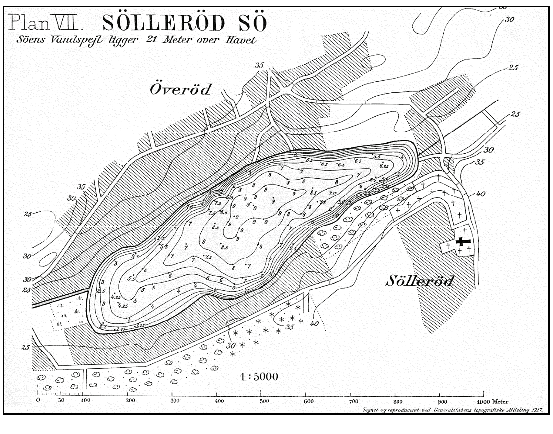

Figure 1.1 Lake Søllerød surveyed 1912 using 74 soundings (Wesenberg-Lund 1917)

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[1] Volunteered geographic information (VGI) is the tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild [1], 2007).

[2] The study of the form or structure of a surface (Maune 2007)

[3] The measurement and study of water depths (Maune 2007).

[4] The measurement and description of the physical features of the navigable areas, with special reference to their use for the purpose of navigation (Maune 2007).

Contemporary bathymetric surveying methods have developed into remote sensing, and can be divided into two groups. One group that uses sound waves (echo sounding) which operates from ships, and the other group using electro magnetic radiation, and operating from the sky, using light or radio penetrating capabilities in the water, i.e. bathymetric lidar[5], radar or photogrammetry analysis (Maune 2007, Breman 2010). The methods in both groups also implement positioning using Global Positioning System (GPS). Before GPS positioning was available, triangulation, radio based systems or even guessing were used.

The data is collected into a grid or TIN[6] very similar to a DTM[7], from where contours are derived. The contours and selected spot depths is the basis for depth data in charts.

Given the method employed, there are several problems to overcome before a coherent value set of depth and position can be determined, regardless of geographic system and datum. The vertical part consists of defining the bottom, correcting for tides, mechanical corrections connected to the vessel and equipments used, correcting for the waters ability to be used as the medium for transmitting sound waves, and clearing data for errors. The horizontal part deals primarily with problem related to positioning in a GPS or/in a GPS/DGPS system or radio based navigation system. In earlier time's measurements errors from a triangulation was the main error. From this, it is obvious that a bathymetric map to some extent will be fuzzy in its data, and that uncertainty plays a major role when assessing the quality.

Data standards for hydrographic surveying is handled by the International Hydrographic Organization (IHO), and applied for marine surveys, and in some cases also for inland surveys where ship traffic is present. There is not yet a set of general standards specific for inland waters like lakes. The new INSPIRE standard for elevations is meant to include depth data from inland still water bodies. This draft is closely related to the standards from IHO.

There is not a complete inventory over surveyed Danish lakes. From published maps it is however clear, that Danish lakes to a large extent are surveyed, although in most cases with old methods, and properly not up to present day's general standards. It might be argued that the Danish lakes, compared to the surrounding terrain, are the last unknown areas inside the coastline.

Surveying of lakes is mainly done by/or commissioned by local stakeholders, apart from a select few mapped by Geodætisk Institut from 1929 to 1934. Most of the surveying made since (1961-1997), was done by charted surveyor Thorkild Høy. He later handed over all his work to Kort & Matrikelstyrelsen (National Cadastre).

The future surveying of Danish lakes is uncertain. When lakes are surveyed today, it's either done on a private basis, or commissioned by local authorities within environmental projects, and most often not done by surveying professionals. There is no national plan for a systematic surveying effort, and the cost of professional surveying could be prohibiting. However there is a need for updated maps for environmental work, and for recreational use. Therefore alternative ways of updating Danish lake maps are relevant to consider.

1.2 Voluntary Geographic information

Recent years have seen several new emerging phenomena and trends regarding spatial data. Both the development of the Internet into Web 2.0, and in consumer GPS products, has nursed new interests and new possibilities for spatial data harvesting using crowd sourcing,

[5] Airborne Laser Scanning with green laser able to penetrate water.
[6] Triangulated Irregular Network
[7] Digital Terrain Model.

understood as collecting data from the public, and specifically among spatial interested non professionals.

The term "Voluntary Geographic information" is defined as spatial data collected and given to others in a sharing content. The data harvesting tools used are typically consumer GPS products. The contributors can be everybody. It is the situation where the citizen becomes the data producer (Goodchild 2007 [2]), and the user also becomes data producer ("produser") (Coleman 2009).

It is relevant to distinguish between VGI data, and spatial tagged input from citizens as a result of Public Participation Geographic Information systems. The latter is aimed at a political or administrative process, where citizen through the web can participate in a democratic process. PPGIS systems are therefore not data collection to support databases with spatial data.

The harvest process of VGI is well suited for use of the Internet. Anybody can easily via a web page upload data, view data, view project status and other relevant information regarding the process, even some training can take place at a web site.

Data does not necessarily consist of raw GPS data, but might also comprise of any kind of relevant data amateur or professional data alike.

Using VGI instead of spatial data collected by a professional, raise some questions about the quality of data. It is essential that data collected in a VGI framework can meet the given spatial standards if used in an authoritative context. It is also essential that data is reliable. The quality of consumer GPS products has risen substantially in recent years. The real difference in professional measure techniques and Produser techniques has to be assed and if possible, the difference reduced, if data from consumer products are to be used compared to professional data.

There is a task identifying both stakeholders and contributors, to ascertain their motives, actions and deliveries, and if it is accomplished, to produce data of a good quality as a consequence of this (Hjelmager et al 2008).

There are also legal considerations involved in using this kind of data. Does data belong to the contributor or to the receiver? Should it be public domain? And how do we handle this in an age where digital rights are a central legal issue?

1.3 VGI in Spatial Data Infrastructures

The development of Spatial Data Infrastructures (SDI), which by nature is centred on data, and the rising economic restraints on national spatial databases, has prompted research into the possibilities of including VGI data into SDI's (Hjelmager 2008). As the Danish SDI implementation includes considering VGI data (labelled "crowd sourcing" KMS 2010) this path to updated data is relevant to discuss.

Bathymetric data is closely related to elevation data, as a lake is defined as a hole in the ground filled with water. Inland bathymetric and similar data are not at present included in the Danish national spatial databases. Considering this status to change with the implementation of the INSPIRE Elevation theme, the inclusion of new bathymetric data from VGI sources might be an option.

1.4 Initiating problem for this thesis

Given the status of Lake Surveying in Denmark the developments and possibilities in harvesting and use spatial data from non-professional voluntary sources (VGI) is relevant to explore. Raw depth data will mostly come from single beam echo sounders and GPS. Maps from the public can originate from any kind of data professional or non-professional alike.

There are several issues to discuss and clarified, before such a model for updating the bathymetry of Danish lakes can be implemented. The logical way to collect data is using the Internet. For this purposes, a prototype Webgis system using existing relevant spatial data, combined with a user interface for uploading data will be considered. Therefore this thesis has the following initiating problem:

"Can a web based system be constructed to collect data using crowd sourcing, and can the data collected, form the basis for bathymetric data for inland lake charts according to relevant standards?"

The problem consists of several underlying problems.

"What are the relevant standards?"

"How is lake charts made?"

"What issues in crowd sourcing VGI data are important?"

"What is the present survey status for the Danish lakes?"

"How good is the vertical accuracy of consumer echo sounders?"

2 - Data & lake surveying

2.1 Data, standards & charts

It is relevant to see, which definitions and standards actually apply to the data types that these maps are built from. Present day bathymetric raw data is always digital data. The data is used to calculate the lakebed or seabed surface, and to identify objects on the bottom, and in the end to produce either printed maps or digital maps.

Through history many nautical charts and bathymetric maps have been made using primitive or undocumented methods. Many present maps including lake maps, have therefore no validation to any standards. Such maps are still being used and being produced.

There is some confusion about definitions of bathymetry and related subjects. Bathymetry and hydrography is often mixed, and used to describe the same kind of data. In the following some distinctions between definitions will be explained.

2.1.1 Definition of bathymetry

"Bathymetry" is understood as the water depth relative to water. Depth values may be either negative or positive, but should always be understood to be negative. Usually the depths at low water tide will be used for navigation safety reasons in marine areas and in areas with changing water levels. Bathymetry may not meet hydrographic standards, as it may not reveal all features important for navigation (Maune 2007).

In still standing inland waters like lakes, depth is defined relative to “normal” or regulated water level, or to the water surface level defined in a surrounding DTM model. The water surface is always relative to the local vertical reference (Maune 2007). The bathymetry of a lake is the underwater terrain, from which contours are derived.

2.1.1.1. Definition of Bathymetric Chart

This is defined as a topographic chart of the bed of a body of water. Generally, bathymetric charts show depths by contour lines and relief’s. Bathymetric surveys are conducted to find the location and depth contours in water depths and areas, where safety of surface navigation is not considered important. This type of surveying might be done with a vertical beam echo sounder, or multi beam sonar (Maune 2007).

2.1.2 Definition of hydrography

Hydrography is defined as the applied science which deals with the measurement and description of the physical features of the navigable portion of the Earth's surface and adjoining coastal areas, with special reference to their use for the purpose of navigation.

”Hydrography is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection.” (IHO [1] 2011)
Hydrography also includes the collection of other oceanography, geodesy and geologic data (e.g., bottom classification) in conjunction with the depth data, and it may be used for other

coastal engineering purposes to nautical charting. This definition of hydrography covers every surveying and mapping aspect, and use of bathymetric data. Hydrographic surveys may include tides and currents, and data on temperature and salinity of the water and their effects on the measurement of depths by echo sounding (Maune 2007).

2.1.2.1 Definition of hydrographic charts

Hydrographic charts are based on hydrography surveys. Hydrographic surveys are conducted with the purpose of safe navigation, and require very accurate bathymetry, and detection of all hazards to surface navigation like wrecks and obstructions (Maune 2007).

The International Hydrographic Organization (IHO) defines the standards for hydrographic charts. The standards for surveying and mapping set by IHO for its members are also followed by many other charting offices and other institutions. Denmark is a member of IHO and is represented by Danish Maritime Safety Administration (DaMSA) and Ministry of the Environment through The National Survey and Cadastre (KMS).

2.1.3 Projection and datum in Danish waters

In Danish areas, datum's WGS84 and ETRS89 are used as standard. Marine charts use Mercator, and topographic maps use UTM systems. As vertical datum Denmark use DVR90 for internal waters (KMS 2010) and inland areas including lakes i.e. water surface elevation. WGS84 and ETRS89 are closely related, as ETRS89 is the European realization of the internal WGS84 used i.e. in the GPS satellite system. The main difference is that ETRS89 is tied to stations on the European plate thus eliminating positional errors occurring due to plate movements. The vertical datum DVR90 is strictly a Danish datum adjusted to mean sea level in Danish waters. Although the WGS 84 is a three-dimensional datum providing Cartesian coordinates, these will not be accurate compared to DVR90.

The former vertical datum use in Denmark is Danish Normal Nil (DNN), which for several regions and islands individually defined the standard mean sea level. This vertical reference is use on most elder maps including Danish lake maps. The absolute difference in DNN and DVR90 measurements is relatively small i.e. between +10 & -20 centimetres (KMS 2005).

2.1.4 ISO & OGC data standards

Bathymetric data are generally collected for maps for navigation. Other kinds of surveys include morphological studies, engineering and habitat studies etc (Maune 2007). Spatial data standards in general are described within the ISO 19100 family, and within Open Geographic Consortium (OGC) of standards for geographic information. The ISO standard covering depth is under development. It is called 19130-2 and covers "Geographic information - Imagery sensor models for geopositioning - Part 2: SAR, InSAR, Lidar and Sonar". (ISO 19130-2) (Kresse 2010, ISO [1]) The standard for sonar is defined in ISO 4366:2007 **(**Hydrometry - Echo sounders for water depth measurements (ISO [2])**.** So in fact there is not an approved ISO or OGC standard specifically for spatial bathymetric data.

2.1.5 INSPIRE elevation data specification

Proposed standards for deliveries for INSPIRE elevation data including lakes, comprises of standards for vector data, grid data and TIN data (INSPIRE 2011 Elevation). These standards rely heavily on standards by IHO (Paradell 2011). Denmark implement most INSPIRE initiatives, however the proposed new INSPIRE Elevation standard is not ready yet. As it belongs to Annex II, it is to be implemented during 2012 (KMS 2011).

The proposed INSPIRE texts describes that "Land-elevation and bathymetry of sea and inland (standing) water bodies are included in the scope of this specification as end-product data sets, regardless of the processes and measurements from which this information had been captured." Bathymetry within river courses is not included in this specification (INSPIRE 2011).

The INSPIRE specification draft contains three types of data:

1. A vector model with bathymetry contour lines, spot heights and depths, as well as break lines as used in topographical maps and nautical charts.
2. A grid representation based on coverage geometry, with elevation values points of a rectified grid.
3. A TIN, where the geometry of points representing the terrain follows the rules of a 2D-Delaunay triangulation.

A collection of bathymetric features describing the bottom of a lake to the corresponding lake datum is to define the characteristics of the local datum corresponding to the lake using the feature type Elevation Reference. There is an exception for lake bathymetry, as there is no need to register lake datum's, but specify the ETRS89 coordinates of the datum position.

As for gridded lake bottom data, general requirements for gridded data (RMSv/grid spacing) are followed. RMSv requirements for the sea floor description are described in the draft. However this subject is not fully ready, but IHO specifications have been used. And it could be applicable also in lakes, if they were divided in areas with different order (Paradell 2011).

2.1.6 Transfer Standards

Transfer standards for Navigation Vector data (ENC) used in electronic maps, are described in The International Hydrographic Organization IHO S-57 Data Model, later replaced or supplemented by S-100 & S-57 Annex. With S-100 (The Universal Hydrographic Data Model) IHO introduces grid and TIN data standards. S-100 I built on ISO 19100 standards (Ward 2008). S-100 is a very flexible and large standard which covers many geospatial aspects including inland data. The latest S-57 appendix (not implemented yet) also describes vector data for lakes, both for navigation and otherwise**.**

2.1.7 Survey standards

In general three kinds of surveys and standards are used. One for ordinary bathymetric survey, one for hydrographic survey and one for construction works implementing high precision surveying standards (Maune 2007). The latter is not relevant in this context. The primary scope for the survey standards is marine use for navigation charts, but inland use is wide spread where shipping is taking place including rivers. Hydrographic (& Bathymetric) survey standards for nautical maps are defined by The International Hydrographic Organization (IHO), and adopted by international and national geospatial and hydrographic organizations including the Danish. The latest version is S-44 5.th edition from 2008 (IHO [2] 2008). In US the Federal Geographic Data Committee (FGDC 2005) have adopted the standards while the US Corp of Engineers follows their own (USACE 2004), however not that different from the IHO standards. Areas where IHO surveys standards are used in freshwater, are waterways, large lakes and canals. Examples are Sweden, Finland, Germany and Holland.

In Denmark, the national hydrographic office is a part of The Danish National Survey and Cadastre (KMS) and is responsible for hydrographic surveying, charting, issuing Chart Corrections and related nautical publications inside the maritime boundary of the Danish waters (IHO [3] 2010). Presently there are no standards implemented for inland water surveying in Denmark, although such would properly follow IHO standards as Denmark being a member.

2.1.7.1 IHO S-44

As IHO S-44 is the reference for many surveys, the details are relevant to examine. As these standards seems adopted by INSPIRE for implementation in the elevation theme, there is a kind of consensus about precision regarding harvesting depth data. The IHO S-44 standard, divides the marine areas into 4 kinds (“orders”): ***Special, 1a, 1b and 2***. It is the national authorities (hydrographic offices) who decide which order a given area belongs to. The most demanding of the four is the order “Special”. Surveying in these areas demands very precise measuring and detecting of any underwater obstacles, as safe navigation is critical. The other three orders reflect less critical areas.

The S-44 minimum standard operates with horizontal accuracy, vertical accuracy, density, feature detection and metadata. The 1b order seems most appropriate for inland lakes without navigation issues. Order 2 surveys are limited to areas deeper than 100 meters and not relevant with regard Danish inland waters.

S-44 Chapter 1 describes the classification of surveys, and defines the areas in orders, which are “considered acceptable to allow hydrographic offices/organizations to produce navigational products that will allow the expected shipping to navigate safely across the areas surveyed. Because the requirements vary with water depth and expected shipping types, four different orders of survey are defined; each designed to cater for a range of needs”.

“Special order” is the most rigorous of the orders and it’s applied “for those areas where under-keel clearance is critical. Because under-keel clearance is critical a *full sea floor search* is required and the size of the *features* to be detected by this search is deliberately kept small”. Special Order surveys will not be conducted in waters deeper than 40 meters, as no features there presents a problem. Special Order surveys are typically applied at berthing areas, harbors and critical areas of shipping channels.

“Order 1a” is “intended for those areas where the sea is sufficiently shallow to allow natural or man-made *features* on the seabed to be a concern to the type of surface shipping expected to transit the area but where the under-keel clearance is less critical than for Special Order above. Because man-made or natural *features* may exist that are of concern to surface shipping, a *full sea floor search* is required. However the size of the *feature* to be detected is larger than for Special Order”. Under-keel clearance is less critical as depth increases, so *feature size* to be found by the *full sea floor search* is increased where the water depth is greater than 40 meters. Order 1a surveys may be limited to water shallower than 100 meters.

”Order 1b” is “intended for areas shallower than 100 meters where a general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area. A *full sea floor search* is not necessary, and it is expected that some features will be missed as the maximum permissible line spacing will limit the size of the *features* that are likely to remain undetected. This order of survey is only recommended where under-keel clearance is not considered to be an issue. An example would be an area where the seabed characteristics are such that the likelihood of there being a man-made or natural *feature* on the sea floor that will endanger the type of surface vessel expected to navigate the area is low”.

“Order 2” “This is the least strict order and is intended for those areas where the depth of water is such that a general depiction of the seabed is considered adequate” (IHO [2] 2008).

S-44 Chapter 2 describes the horizontal uncertainty in positioning, defined as “the *uncertainty* at the position of the sounding or *feature* within the geodetic reference frame”. Positions should be referenced to WGS84. The contributions of all parameters to the *total horizontal uncertainty* (THU) should be accounted for. The position *uncertainty* at the 95% *confidence level* should be recorded together with the survey data. The capability of the survey system should be demonstrated by the THU calculation. The position of soundings, dangers, other significant submerged *features*, navaids, *features* significant to navigation, the coastline and topographical *features* should be determined such that the horizontal *uncertainty* meets the requirements specified in Table1 (see above). This includes all *uncertainty* sources not just those associated with positioning equipment.

S-44 Chapter 3 describes depth including vertical uncertainty, feature detection and corrections for tides. The measured depths “shall be referenced to a vertical datum that is compatible with the products to be made or updated from the survey e.g. chart datum”. The vertical datum is also referred to as the *sounding datum.*

(To be read in conjunction with the full text set out in this document.)

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95% *Confidence level***	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95% *Confidence level***	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	***Full Sea floor Search***	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	***Feature Detection***	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)**	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95% *Confidence level*)**	10 metres	10 metres	10 metres	20 metres

Figure 2.1 IHO S-44 (IHO [2] 2008)

“Vertical *uncertainty* is to be understood as the *uncertainty* of the *reduced depths*. In determining the vertical *uncertainty* the sources of individual *uncertainties* need to be quantified. All *uncertainties* should be combined statistically to obtain a *total vertical uncertainty* (TVU). The maximum allowable vertical *uncertainty* in Table 1 specifies the *uncertainties* to be achieved to meet each order of survey. *Uncertainty* related to the 95% *confidence level* refers to the estimation of *error* from the combined contribution of random *errors* and residuals from the correction of systematic *errors”* (IHO [2] 2008).

There are both depth independent and depth dependent *errors* that affect the *uncertainty* of the depths. The formula below is used to calculate the 95% *confidence level*, or the maximum allowable TVU. The parameters “a” and “b” for each order, as given in Table 1, together with the depth “d” have to be introduced into the formula in order to calculate the maximum allowable TVU for a specific depth (IHO [2] 2008):

[1]

$$\pm\sqrt{a^2 + (b \times d)^2}$$

Where:

a	represents that portion of the *uncertainty* that does not vary with depth
b	is a coefficient which represents that portion of the *uncertainty* that varies with depth
d	is the depth
b x d	represents that portion of the *uncertainty* that varies with depth

Feature detection is covered in detail in this chapter, as are sounding density or Line Spacing. When a ***full sea floor search*** is required, the equipment used most be able detect all features. In practical surveying this means multi beam systems (se later). A sufficient density of soundings can be achieved with single beam surveying, but it is not a viable method in Special order and Order 1a surveys. The line spacing for Order 1 b surveys reflects this. Note that Bathymetric Lidar is included, with a spacing of 5x5 meters. The recommended line spacing is depended on the depth in the area of orders 1b, unless it is less than 25 meters which is the minimum. In lake surveying, 25 meters might be sufficient, but to collect all significant morphological features, this recommended line spacing might be too great.

S-44 covers others aspects of a survey. Among these is data attribution mentioned in chapter 5. Metadata is a very important element when assessing the quality of survey data. This information is important to allow use of survey data by different kinds of users with different requirements.

Metadata requirements (IHO [2] 2008):
“*Metadata* should be comprehensive but should comprise, as a minimum, information on:

- the survey in general e.g. purpose, date, area, equipment used, name of survey platform;
- the geodetic reference system used, i.e. horizontal and vertical datum including ties to a geodetic reference frame based on ITRS (e.g. WGS84) if a local datum is used;
- calibration procedures and results;
- sound speed *correction* method; - tidal datum and reduction;
- *uncertainties* achieved and the respective *confidence levels*;
- any special or exceptional circumstances;
- rules and mechanisms employed for data thinning.

Metadata should preferably be an integral part of the digital survey record and conform to the “IHO S-100 Discovery *Metadata* Standard”, when this is adopted. Prior to the adoption of S-100, ISO 19115 can be used as a model for the *metadata*. If this is not feasible similar information should be included in the documentation of a survey. Agencies responsible for the survey quality, should develop and document a list of *metadata* used for their survey data” (IHO [2] 2008).

To sum up, the IHO S-44 is used in many areas, and it covers many aspects of surveying. When applied to freshwater, the distinctions between waterways (trafficked waters), and other areas are very clear. In this respect, and the fact that IHO defines hydrography to include lakes, it is clear that IHO S-44 also applies to lakes as far as navigation maps are concerned.

2.1.8 Data sources in nautical charts

Electronic nautical charts, operates with Category of Zones of Confidence (CAC) according to IHO S-57. Each zone is defined from accuracy both vertically and horizontally, as well as data intensity. There are 5 zones each with a corresponding order in S-44 from IHO. These CAC zones, provides the seafarer with knowledge about the quality in the map, and includes information about the method and time for surveying in a given area (Balstrøm 2010).

Printed maps has a source (Danish: Kildediagram) attached, showing when the map were made. In this context it is important to be aware, that most of the Danish nautical areas, were surveyed before present days techniques were implemented, and that only the most busy areas are constantly being surveyed (KMS 2010).

2.1.9 Bathymetric data in Danish national spatial databases.

There are two kinds of products. These are printed charts and Electronic Navigational Charts (ENC,) that follow IHO S-52 & S-57 standards (KMS 2010). For inland areas within the coastline, bathymetric data is not included in the national databases, although maps have been produced for many Danish lakes trough time. A spatial corporative within the Danish municipalities (Fælleskommunalt Geodatasamarbejde), is developing a spatial data model which expands FOT data types, to data types relevant for functions in the municipalities. These data types, includes depth data for lakes in the form of polygons, and metadata about surveying. The metadata requirements does not include information to asses the quality of data (FKG 2011).

2.1.9.1 Bathymetric lake data in other countries

Lake maps are produced in many countries. Many are surveyed to IHO standards for navigational reasons like the large Swedish lakes. Sweden has approx 33.000 “important” lakes (SHMI 2011). Of these are approx 7000 surveyed by very different means, and very few are included in the national dataset. Many local regions (“Län”) and municipalities have inventories of their surveyed lakes. The quality of these maps differs very much. Some are just hand drawn sketches while others are made by professional surveyors. Very few have references to standards and methods used. One example of a more detailed description is a lake inventory from County of Skåne (Skåne Len 2012). The same mixture of maps, are found many places around the world. Two good examples is Oklahoma and Indiana (Indiana DNR) in the US, where Oklahoma Water Resources Board (OWRB) offers map and data for free, and also conducts surveys, using guidelines from U.S. Army Corps of Engineers.

2.1.10 Interoperability with implemented water level data

In order to implement bathymetric data into a spatial database, there are some interoperability issues. Lakes have clear definitions in Danish national datasets. A lake is defined as a water filled cavity on land and the shore of a lake, is defined as the border between the water surface and land at the time i.e. when objects are registered based on photogrammetry. Only water areas larger than 100 square meters are included, apart from areas of special interest. The geometry is a closed polygon (KMS 2001). This definition is extended in the FOT Denmark dataset to include salty lakes and temporarily lakes, if these lakes have significant importance. Water level at shore is also included (FOT 2010). A rising water level will influence the water covered area (the polygon) unless the bank is vertical.

The Danish Digital Terrain Model includes lakes as fixed surface using the standard methodology of hydro-enforcing (Maune 2007). The method used is called the “lakefix” routine.

It was applied in areas already registered as lakes both in 2005 and 2008 (i.e. permanent lakes), and identified lakes surfaces as areas with low laser point density and a variance between laser measurements that less than 10 cm (Rosenkranz & Frederiksen 2011). The water level measured is the water level at the moment of data harvesting.

A standard bathymetric lake map will include the water level as reference to the depth data. The water level in a lake will vary over time. In some cases the level is regulated at outfalls or dams. This regulation may be legally founded. But natural lakes without regulation, depends on rainfall and inflow ao. If the lake has water level regulations, surveyors like Thorkild Høy would use the standard level as reference. If not the present water level was determined using standard surveying methods.

When comparing the standard vector data set (polygon), the Digital Height Model and Bathymetric maps, it is evident that there will be differences in water levels in each dataset. As the water level is a constantly changing parameter, some sort of standard fixed water level definition for each lake as reference in all datasets, would be preferable.

2.2 Methods for bathymetric surveying in lakes

Bathymetric surveying is foremost harvesting depth measurements with positions. Through history this has been a demanding task. In this context the basic historical and present methods will be explained, and focus will be on the method most often used in present lake surveying i.e. the single beam echo sounding method. Lake surveying methods has not been systematized but one source attempts this (Harnett 2005). The following description of methods is based on this.

Bathymetric lake surveying

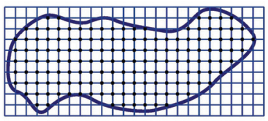
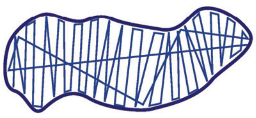
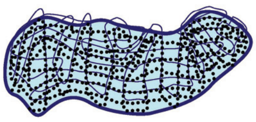
General method	Period (approx) & Principle
GRID SURVEYS 	**? – 1960** **Depth: Soundings** **Positioning: Triangulation**
TRANSECT SURVEYS 	**1960 – 2000** **Depth: Echo sounder** **Positioning: Triangulation, Fix points, Photogrammetry, Early GPS**
X Y -Z POINT SURVEYS 	**2000 +** **Echo sounder and GPS (Mass xyz data harvesting)**

Figure 2.2 Lake survey methods (Harnett 2005)

2.2.1 Grid surveying based on soundings

The oldest and simple way of obtaining a depth measurement, is by lead and line. This method results in relatively few depth and positions due to its nature. Many depths on present charts are in fact made this way a long time ago (Hare 2008, KMS 2010). This is due to the fact that marine surveying is both costly and time consuming, so present day expensive surveying will only take place were traffic is tense and leave the rest unattended.

The method of soundings has two major elements: The *depth* to which a lead will penetrate and the horizontal *position* of the sounding. A lead can penetrate quite a lot into a soft lakebed. The recorded depth will therefore not necessarily be the true depth beneath the keel of a vessel. This is a major problem as most lakes often have a soft lakebed. There are some studies into when the correct lake depth is measured (Olsen 1955), but the general conclusion is that unless the bottom is hard (i.e. sand), depths obtained by this method will be to large (Høy & Dahl 1995).

The positioning of a sounding was based on triangulation with objects on land (Sand 1917), or by two simulations sextant angles to fixed points on shore (Hare 2008). In winter surveying could be done from ice employing standard surveying methods (Høy & Dahl 1996). This method of surveying lakes has been used into 1950's (Hare 2008), and in Denmark properly used as the only method until echo sounding was introduced in fresh water in the 1960'ties (Høy 1965).

The surveying of Bathymetrical Survey of the Fresh-Water Lochs of Scotland, 1897-1909 (Murray 1910) was a great project, which employed the state of the art soundings techniques for the period. 562 lakes were surveyed with primitive but reliable methods resulting in 60.000 soundings. The preferred survey strategy was depth sounding on a line i.e. making depth profiles (National Library of Scotland 2011). This project no doubt inspired the surveying of the lakes in Mølleåsystemet (Wesenberg-Lund 1906). The surveying project of the lakes in the "Mølleåsystemnet" in 1912 used the following numbers of soundings for each lake (Wesenberg-Lund 1917).

1912 survey Lake	Area (ha)	Soundings	Average grid (meters)
Bagsværd	119	160	86
Lyngby	59	258	48
Furesø	930	633	121
Farum	120	250	69
Bastrup	32	171	43
Søllerød	13	74	42

Table 2.1 Soundings used for each map (Wesenberg-Lund & Sand 1917)

In the 1912 project the survey strategy would consist of sounding made in a grid, or along transects to establish the depth profiles. All these sounding were of course planned with some pre knowledge of the lake morphology, in order to establish robust depth profiles with a minimum of soundings, but the density measured as an average grid is very low by today's standards. It was up to a high degree, an individual task, to guess where depth contours are (Høy & Dahl 1995).

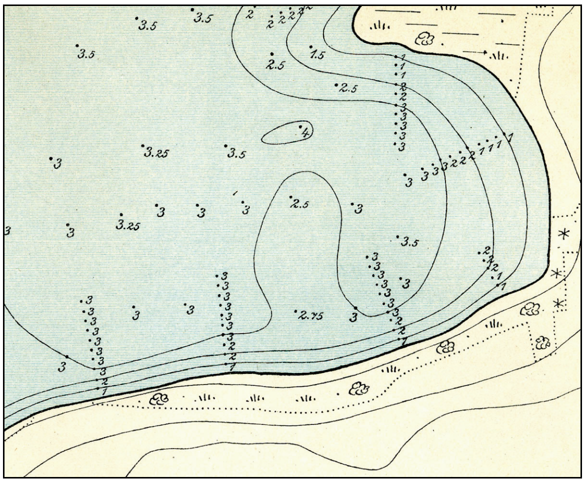


Figure 2.3 Soundings in Lake Bagsværd 1912 (Wesenberg-Lund 1917)

2.2.2 Surveying based on acoustics

The methods using acoustic to measure depth was developed during the start of the 1900 century but first employed in surveying in the 1930's (Hare 2008). During the WW2 the acoustic under water science developed significantly and during the 1950's acoustic surveying became the standard method. SONAR is an acronym for Sound Navigation and Ranging. The SONAR method first used was single beam echo sounder, later evolved into arrays of single beam systems called Sweep systems. Later systems uses several beams in same setup, and are called Multi beam echo sounders, and is the standard system for surveying today. Side scan echo sounders works a different way making 3D images of structures on the seabed. (Hare 2008; Lurton 2002), and a not used for depth determination (IHO [2]2008).

2.2.2.1 Measuring depth using acoustics

The science into this matter is quite a big area, so this description is limited to the basics related to single beam echo sounders used in fresh shallow water.

Sound travels in water with a velocity (***c***) depending on the physical composition of the water. If an acoustic wave is transmitted into water, objects or the lakebed will reflect it. By measuring the time (***ΔT***) before an echo returns, the distance can be measured given the speed of sound in the water.

[2] $$\text{Depth} = c \cdot \frac{\Delta T}{2}$$

I. e. if ***c*** is 1500 meters/second and the time elapsed is 2 milliseconds then the depth is 1.5 meters, or if the time elapsed are 100 milliseconds the depth is 75 meters (IHO [4] 2011).

In a single beam echo sounder setup, the sound pulse is sent in a vertical direction towards the lakebed. The sender and receiver are typically built into one called a transducer. The transducer consists of an encapsulated piezoelectric ceramic. When electrically put in motion, it transmits sound waves in an angle of spread with a given frequency, and effect. The area on the lakebed within the spread of the sound pulse is called a "footprint". The echo sounder will analyze the echo, and determined if it originates from an object (like a fish or a plant) or the lakebed. The lakebed echo can then be used to calculate a depth. The echo varies given the composition of the bottom. How different echo sounder products identifies lakebed echoes, and how they are used for depth readings are considered propriety information. This fact has the consequence that data comparisons between sonar's, has to have allowance for this uncertainty (Lurton 2002).

The sound wave has frequencies from 10 to 200 (standard) up to 700 kHz. The lower frequencies (10–32 kHz) have a stronger penetrating force, and will thus go into the sediment and even hard bottom, while the higher frequencies will reflect fish, plants and even suspended mud. IHO accepts double frequency systems in shallow areas to differentiate soft sediments from the bed rock, as unconsolidated sediments usually are detected by high frequency echo sounders (IHO [4] 2011).

Generally lower frequency transducers has wider angle of beam. For a given frequency the effect or energy measured in db can change the beam width. The standard setting for a beam is -3 db thus determined the normal angle for a given transducers beam. A standard consumer grad 200 kHz transducer has an angle of 9 – 11 degrees measured at 3 db, while a standard 50 kHz transducer has a 40 degrees angle (Garmin 2011).

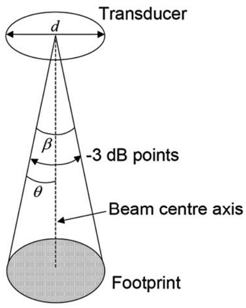


Figure 2.4 Transducer beam (Hydrography 2010)

The footprint diameter on the seabed depends on the depth given the angle. A 200 kHz transducer with a 10 degrees beam will perform a 1.75 meter in diameter foot print at a depth of 10 meters.

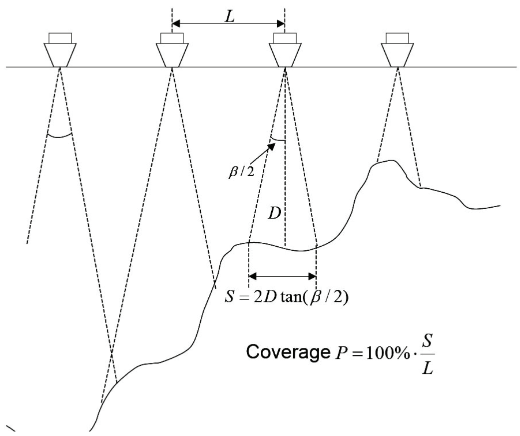


Figure 2.5 Relationship between depth and foot print (Hydrography 2010)

The first echo identified being from the lakebed, will result in a depth reading. This can be a problem over hilly under water terrains. The choice of transducer must there reflect both the energy needed to identify the lakebed as well as the resolution needed for an accurate depth reading given the topography.

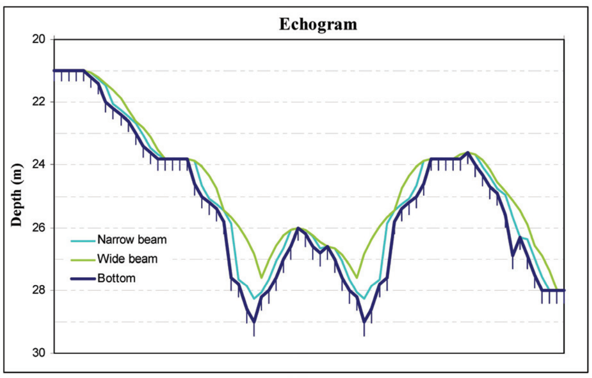


Figure 2.6 The difference in narrow and wide beam depth determination **(IHO [4] 2011)**

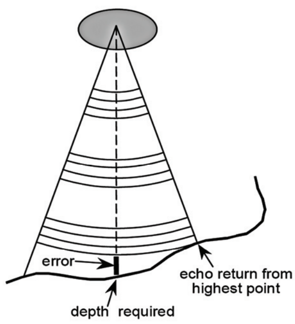


Figure 2.7 First echo marks the depth (Hydrography 2010)

The resolution of an echo sounder can be measured both vertical (depth measurement) and horizontal (object measurement). The vertical resolution is determined by length of sound pulse from the transducer, and the sound speed in water divided by 2. Acoustic signals are not bursts of sound but vibrations. They are characterized by their frequency (f) expressed in vibrations per second in Hertz (Hz) or by their period T. T = 1/f. The wavelength is the spatial correspondent to a time interval. It is the spacing between two points in the medium. This is the distance travelled by the wave during one period of the signal with velocity c and therefore the measuring unit for a given sound wave (Lurton 2002).

[3] The theoretical vertical resolution = c * T = c/f

A 200 kHz transducer has a resolution at c=1500 meters per second /200 kHz = 0.75 cm

The power an echo sounder pulses trough the transducer ranges in size depending on how strong an echo is needed. Water and objects will absorb energy from the sound waves, and to compensate for this, the effect can be set higher. However for shallow water use, normal effects are amble for depth measuring.

2.2.2.2 Velocity of sound in water

The sound speed in water (or velocity when dealing with vertical beams) is a critical factor. If this factor is neglected in calculations, errors in depth determination can be severe (IHO [4] 2011. The basic conditions of the sound propagation in water, is the temperature, salinity, pressure and turbidity. The sound velocity can vary from 1400 m/s to 1525 m/s under normal conditions. This deviation is too large to be ignored or replaced with an assumed value, if depth measurement is to lie within i.e. 1 % of the true value (Lurton 2002). A 1% error in used velocity results in a 1% error in calculated depth. Temperature is the largest single factor.

Most studies in sound speeds, deals with ocean related models and assume clear water. Under these circumstances salinity and pressure plays a much bigger role compared to the conditions in a freshwater lake where the effect is less important.

There are several models describing speed in water. The latest reference for choice of speed model is Chen-Millero equation (Lurton 2002) or as it is named the “UNESCO algorithm”. This model is very large so simplified models is introduced.

C is the sound velocity (meters/second), T the temperature in Celsius, S is the salinity in parts of 1000 and Z is the depth. (Lurton 2010):

[4]

$$c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.016z$$

Equation [2] is valid for 0ºC ≤ T ≤ 35ºC, 0 ≤ S ≤ 45 ppt, and 0 ≤ z ≤ 1,000 meters. In Danish lakes the salinity will vary up to 0.5‰. Brackish lakes (often part of the marine area) have salinity between 0.5‰ and 17‰. Note that a measure for turbidity is not included in this equation or in others. This will contribute to the uncertainty especially when surveying in muddy lakes.

Equation [2) can be further reduced for inland lakes given a salinity S = 0.5‰, and if the max value of z is 40 meters, which corresponds to 0.64 meters/sec, this factor is negligible:

[5] C= 1402.97 + 4.945T – 0.055T*2 + 0.00029T*3

Temperature	Sound velocity
2 °C	1413 m/s
5 °C	1426 m/s
8 °C	1439 m/s
10 °C	1447 m/s
14 °C	1462 m/s
15 °C	1466 m/s
20 °C	1482 m/s
25 °C	1497 m/s
26 °C	1500 m/s

Table 2.2 Sound velocity in clean fresh water using above formula

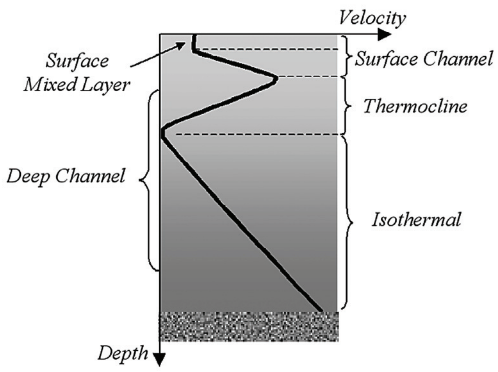


Figure 2.8 Oceanic sound velocity profile and its elements (Lurton 2002)

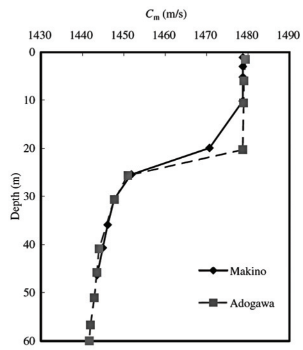


Figure 2.9 A Typical sound velocity profile from a inland lake (Kitamura & Watanabe 2008)

The illustration (left) shows the sound velocity changes into the depth. This is an example of an ocean profile. The illustrations at right are a SVP from a Japanese lake showing how speed develops. The sudden drop in speed happens in the thermocline where the lake water is stratified into cooler segments. The difference between the profiles in the two examples shows the difference between deep ocean water and relative shallow lake water bodies. A thermocline in Danish lakes develops from May until it disappears start November (Larsen 1980). Thermoclines develop as water temperatures rise but wind fails to mix the water layers in a lake. The cooler and heavier water will remain in the deep unless pushed up and mixed by the wind. This means that, a thermocline isn't confined to larger water bodies, but also appears in quite small lakes given the wind exposure. Some lakes keep their thermoclines permanently (Boehrere & Schultze 2008).

Measurement of water velocity is done with a velociometer. The instrument is lowered down trough the water, and an average sound speed is calculated as ***c*** can be the average speed if the sound waves travel direction is vertical (IHO [4] 2011). This applies to single beam echo sounding techniques. There are some guide lines for procedure (NOAA 2011) handling different kinds of situations. Even a continually sound velocity measuring, will result in some errors in the calculated depths. In a lake with a thermocline, depending on overall temperature and weather, the corrections will not be precise. The important aspect is to cover the water depth surveyed, and to take into account the temperature profile of the water at relevant locations. However if the number of significant factors can be reduced to the temperature, a simulation of the sound speed is within reach.

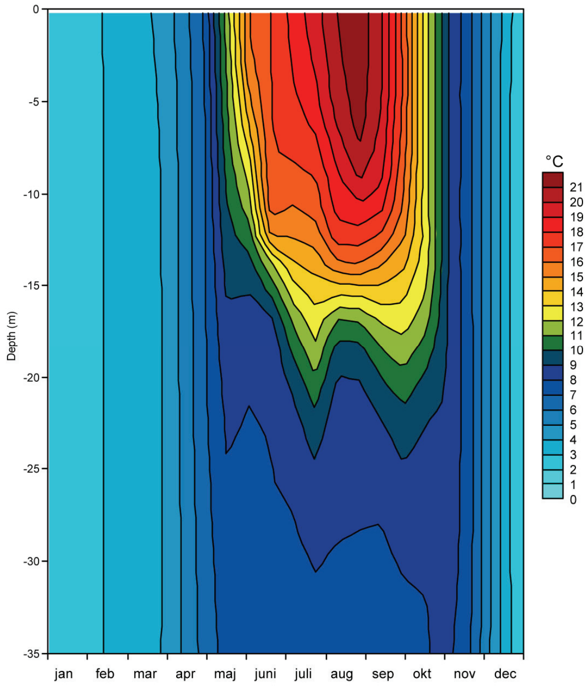


Figure 2.10 Temperatures in depth Lake Furesoe (Københavns Amt 2002)

As this temperature chart (figure 2.8) demonstrates, the stratification in temperature layers makes sound velocity measurements difficult, if surveying is done in the warmer half of the year, and all depth zones are included. One strategy to avoid errors due to a thermocline is to conduct surveys outside the period where they form.

2.2.2.3 Surveying based on transects and fix points

This method was used in Danish lake surveying 1961-1997 by Thorkild Høy. It is interesting to see how the then new technology, in the form of an early version single beam echo sounder with writing capabilities (the echo graph), could be used in a prearranged survey network to produce depth profiles (transects) from which a map could be generated.

The principles in his method are well known (Harnett 2005). Establishing transects and position them using fix points, existing maps, aerial photos or GPS is a well established method. To insure amble coverage of the lake morphology some pre knowledge about the same is an advantage, when deciding where to place the transects.

Thorkild Høys method depended on the number of fix points and depth transects (depth profiles), and on a correct calibration of depth at the buoys, and constant speed on track between buoys. He established a network, based on temporary fix points laid out from official fix points. Strung out between the fix points were buoys in the water. A boat with a single beam echo sounder (echo graph) sailed between these buoys at a constant speed. The printed soundings were then used to establish the depth. The depth at the buoys was measured precisely as a control, and the equalling print were identified on the paper scroll. The density of profiles in this case was fairly high as seen on the map. The distance between buoys was approx 50 meters. From the map it looks like the buoys were laid out with some pre knowledge about local basins. Later data from spot measurements were added where data seemed sparse. The water level was measured against nearest official fix point.

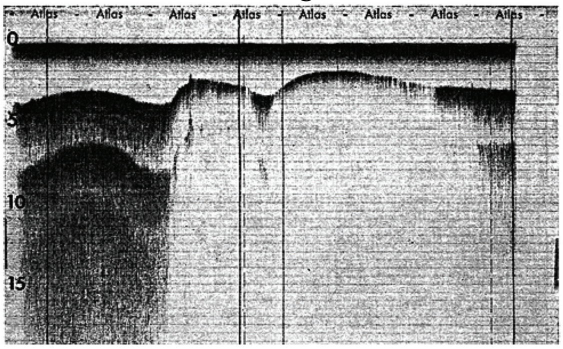


Figure 2.11 Original echogram from Thorkild Høy (Høy 1965)

The depths were later corrected with the water level, and depth contours drawn up on a map in 1:5.000 based on a map from Geodætisk Institut. Arial photos, when available, were used to make final corrections ((Høy 1965).

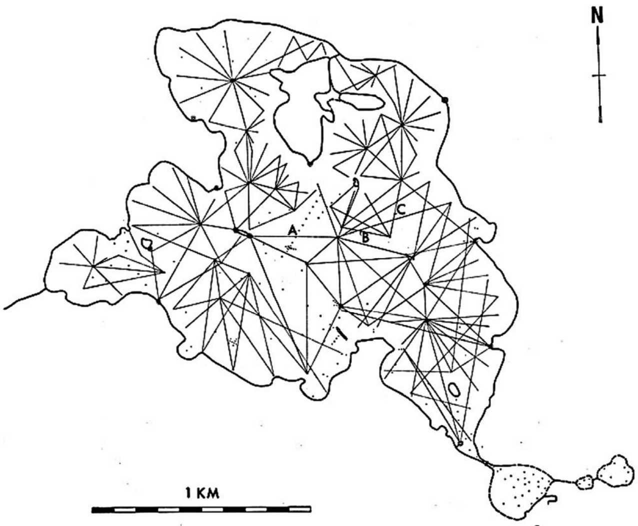


Figure 2.12 The buoys strung out (Høy 1965)

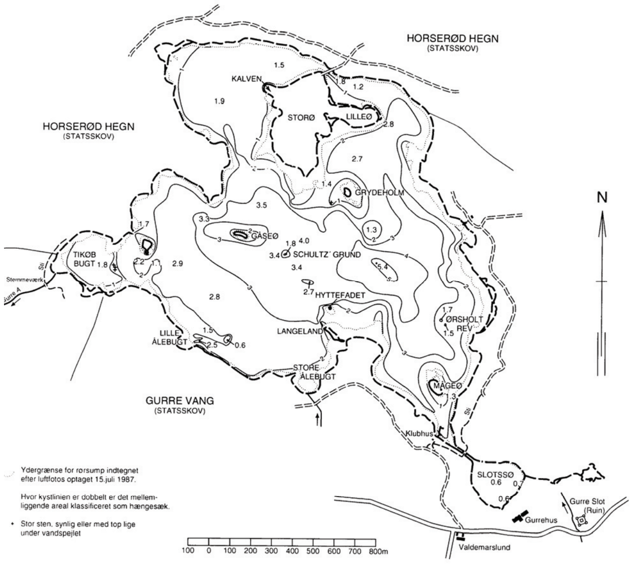


Figure 2.13 The resulting map of Lake Gurre (Høy 1965)

As modern methods involves data harvesting in tracks with various spacing and even total bottom search, it is clear that, compared to present survey techniques, the data intensity is low and would vary a lot.

As to a quality assessment of these maps, we lack maps showing the used transects positions (except the shown one). Furthermore it is evident that large lakes with deeper water combined with few well positioned objects on land to use as fix points, would increase the uncertainty of data (Harnett 2005). Unlike modern GPS and echo sounder measurement, where errors would surround individual points (IHO [2] 2008), in Thorkild Høy's case errors would spread through the whole chain of data.

It would not be fair to conclude about the general quality of the maps from Thorkild Høy without some sort of control. Based on personal experience, the maps seem to be accurate.

2.2.3 Overview - Alternative surveying methods

Bathymetric surveying methods are developed aimed at marine surveys. These methods involve large vessels and expensive equipment, and are not the preferred equipment for inland lake surveying. They are mentioned here to give an overview of methods in general.

Sweep Sounders: A sweep system consists of several single beam echo sounders, installed on a transversal support. This method increases the number of depth readings as a sweeper. This method was developed to enhance surveying using single beam techniques, before the implementation of multi beam surveying (Breman 2010).

Multi beam echo sounders: Multi beam echo sounders are a recent invention enabling full seafloor coverage. Instead of a single beam, multi beams are used covering the seafloor from one point of origin. This gives a much better coverage, and is therefore the standard method for bathymetric surveying. This method has several factors has to be considered when employed, and is therefore very difficult to handle. More over the cost of multi beams systems is so large that it is prohibitive (TeamSurv 2011). However as multi beam echo sounder system are not the instrument of choice for the expected contributors of VGI, further description is omitted, although IHO standards for shallow waters ("Special Order") usually results in such method being used. Multi beam for inland waters in small scale is under development (Kongsberg 2011).

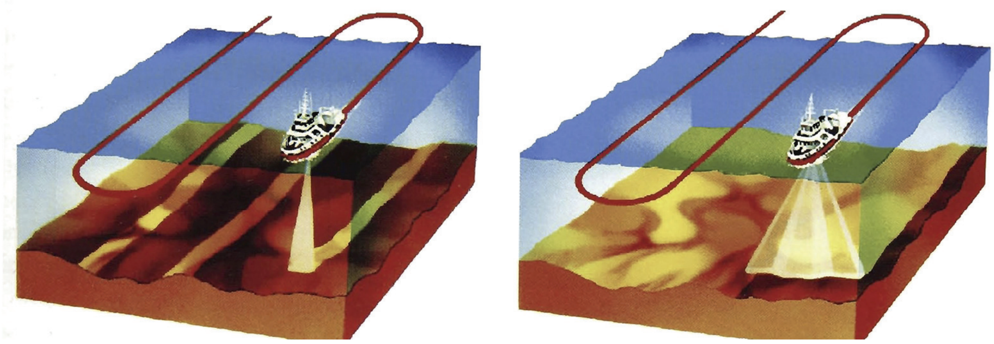


Figure 2.14 A single beam sonar compared to a multi beam sonar (Breman 2010)

Side scan sonar's: Side scan sonar's are used to make images in the water. They operate in very high frequencies about 400 - 800 kHz, reflecting almost anything with its high resolution, thus making a photo like image possible. Some consumer products actually have side scan capabilities. The potential of this as bathymetric tool is too vague at present, but professional side scan operations suggest that this are only used for object surveying rather than bathymetric surveying (Breman 2010) (IHO [2] 2008).

Sediment profilers: Sediment profilers are echo sounders working at very low frequencies between 10 (some times even lower) and 40 kHz. The low frequencies results in a greater penetration thus being able to go deep in sediment before reflected (IHO [4] 2011). The echo sounder is used for localization of deposits and water reservoir surveying where sedimentation is of great importance. It is very common to combine low and standard frequencies in the same professional echo sounder system, in a dual system for multiple tasks (USGS 2011).

Bathymetric Lidar Laser techniques: Power full laser in the green spectrum used from the air, can penetrate water. The penetration depends of the clarity of the water and density. As a normal guideline green laser can go down to 3 times the sechi depth i.e. visual depth from the surface of a circular white disc). It is a very demanding and costly techniques, however much is done in this area to improve results and cost. One major source of error is laser reflection from plants, loose sediments and high turbidity (IHO [4] 2011, Breman 2010). This method is employed in fresh water surveying more often in recent years, as it provides a relative fast and cheap way to collect data (Maune 2007). Swedish contractors use this technique (http://www.airbornehydro.com/) and it is also tested for stream surveying (McKean et al 2009). This method could be feasible to use surveying Danish lakes, providing water visibility is high and vegetation growth is minimal at the time of data harvesting.

Photogrammetry: When looking at clear water lakes from Arial photos the lake bed often is visible to a certain degree depend on the clarity of the water. Some investigations into using this for shallow water bathymetry has been tried in areas with clear water sun light in high position and limited alternative options, like distant Corel reef. The methods tested employed algorithms to determined depth from water color and bottom composition (IHO [4] 2011, Campbell 2006). In relations to Danish lakes, aerial photos are useful in clear water lakes to position low water areas and thus check that potential dangerous areas are well surveyed.

Radar based systems: Radar based systems have been employed for deep water bathymetry in low resolutions. The technique is special and not in use for lakes nor is it relevant in this context (IHO [4] 2011).

2.2.4 Single beam echo sounding surveying with GPS

Bathymetric surveying with single beam echo sounding is the cheapest way to gather depth information, and therefore the method most often used in low budget surveys, producing series of depths in a regular or irregular pattern. The present standard method of obtaining positions and depths is using a echo sounder/GPS setup.

To insure precise depth recordings the synchronization of position and depth has to be perfect. The depth and the position used must be coherent in timestamp. The time span from measuring a depth to attaching it to a position is called the latency. The latency between depth recording and GPS positioning is a typical problem. The Latency must be assed and entered into the system (USACE 2004).

The spatial resolution of single-beam bathymetry data varies with survey route, depth and transducer. The data resulting from a single beam echo sounder will be series of discrete positions with a depth attached. This data them form the basis of a 3D model including calculating depth contours from interpolation. The survey strategy has to include many soundings to obtain a high resolution. Greater depth means greater foot print hence more generalization.

Compared to IHO S-44 standards and assumed necessity to use multi beam surveying techniques when a full seafloor search is required, it is obvious that single beam surveying techniques in normal circumstances is reserved for survey of IHO order 1b surveying and similar tasks. This also implies that given order IHO Special and 1a surveys would be conducted under strict control, no data from VGI sources or even professional single beams surveys would be allowed use.

2.2.4.1 Vertical measurement

As described, the basic principle in acoustic depth measurement is to measure the elapsed time for an echo to return from the bottom, using information about sound propagation in water, and then calculate the distance travel i.e. the depth. The correct depth from the water surface depends on various factors. Among them only the measured time will vary during a survey interval. It is therefore assumed that other factors are constant locally. Should they change, post processing or recalibration would be necessary. To illustrate applied surveying standards and methods, the American Corps of Engineers guideline is used as a reference (USACE 2004).

The standard platform is a boat. The transducer can be placed transom, or inside the ship in the hull or trough the hull. The vertical distance from the transducer to the surface must be measured. An overall relation between the measured data and the depth is:

[6] Depth corrected to referenced water surface: $d = 1/2 * v * t + k + dr$

Where:
- d = corrected depth from reference water surface
- v = average velocity of sound ("c" is used elsewhere) in the water column
- t = measured elapsed time from transducer to bottom and back
- k = system index constant
- dr = distance from reference water surface to transducer

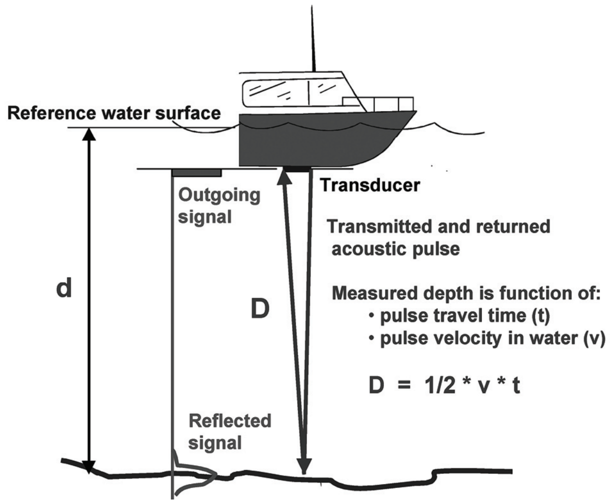


Figure 2.15 Acoustic depth measurements (USACE 2004)

The parameters v, t and dr are not constants over time in a survey, and must be determined during the process. k is determined from calibration of the equipment.

As described above, the average velocity of sound is the most critical factor. If a velocity meter measuring is impossible, the velocity can be measured indirectly using a bar check calibration. That is a bar (or another solid) object connected to a measuring tape, lowered down into the water, which produces clear echoes on the echo sounder. The reading from the tape is compared to the reading from the echo sounder. The relative difference is a measure for the relative difference between the actual sound velocity and the velocity set in the echo sounder. For measurement over deeper water, with varying sound velocity depending on depth (in waters with a thermocline), the bar check will yield a depth depended estimate used either in the equipment, or used in post processing (USACE 2004).

The distance from the water surface to the transducer is measured physically, and the distance to the reference water surface is added, to correct for varying water levels. The reference water surface is according to local vertical datum and either a measurement or a fixed level. In lakes with water level restrictions and real time metering the reference is set, but in lakes without a robust water level reference must be chosen.

Present days echo sounders all present data in digital form. The accuracy of the sounding instruments is a factor. The nominal accuracy is usually rated as +/- 0.1 (meters or feet) plus 0.1 to 0.5 % of the depth. At a depth of 10 meters this will result in an acoustic independent precision range of +/- 0.11 to +/- 0.15 meters. USACE use 0.1 feet depth data as standard norm.

For surveying using single beam USACE standards demands a 200 kHz transducer frequency with an 8 degrees beam width (USACE 2004).

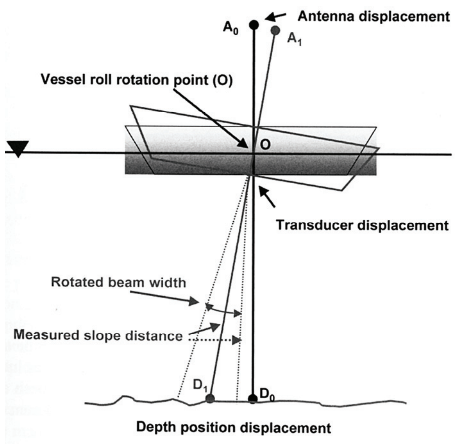


Figure 2.16 Displacements (Maune 2007)

From the figure 2.13 the different kinds of both vertical and horizontal displacement are shown. The vessels movement in different directions will create displacements. Heave, Pitch and Roll has all to taken into account. Measurements to advert this are gyroscope installations with corrections after surveying. Wind pressure can influence the water level in windy areas on larger lakes. When all possible boat movements, and wind pressure are taken into account, it seems best to do surveying in calm conditions. In the simplest case, a strict surveying tactic for lakes is avoiding rough water, and using stable boats to limit all displacements.

2.2.4.2 Horizontal positioning

For horizontal positioning a GPS system is used, a code bases system (standard for consumer products), a carrier based and RTK GPS system (high precision), or before GPS were introduced, a radio based system was used (like Syledis (Høy 1996)). The system of choice reflects both the budget involved and the precision standards. The USACE recommended standard for other general surveys aside for navigation, is 5 meters (95% confidence accuracy). The IHO standard for Order 1b is also 5 meters. This is a relatively low precision standard compared to IHO Special Order and general positioning. Most GPS setup will yield such precision, even consumer products, which specified horizontal accuracy is 3 – 5 meters.

The error sources for GPS positioning consists of (Dueholm 2005):

1. Clock errors in the atomic clocks with in satellites:	*1-2 meters*
2. Ephemeredes:	*1-2 meters*
3. Atmospherics conditions in Ionosphere and troposphere:	*1-50 meters*
4. Numerical errors in algorithms:	*0.2 -1 meter*
5. Multi path errors:	*1-2 meters*

GPS radio signals are easily blocked by buildings, other kind of structures, plants, trees, persons etc. A general rule describes that anything that blocks sunlight; also block GPS signals. The condition for optimal receiving is there for a good GPS unit (better GPS receiver chips are developed continually) and a position with a clear and unobstructed view to the satellites. However GPS signal can deflected by hard surfaces including water, and cause "multi-patch" interference, where the GPS can't distinguish between a direct signal, and the reflected signal, causing and extra error to the position calculation. (Lange & Gilbert 2005).

The recorded depth will have a position projected on the water surface. In order to achieve this, the GPS antenna and the transducer have to be located horizontal together, or a local system positioning the GPS antenna relatively to the transducer has to be used (Jensen 2005). The horizontal distance between the two will otherwise be added to the uncertainty.

Last errors due to lack of capabilities in the GPS receiver also influence the positioning. This is most evident when using lesser grade GPS equipment like consumer products, adding a further error source to the positioning.

2.2.4.3 Survey strategy

Single beam echo sounders can collect depth data up to 5-20 soundings per second (USACE). The term is "ping speed". Data density and bottom coverage is set as required to cover the whole lakebed beneath the track. The update rate is a function of the depth (areas), vessel speed and the transducer beam width.

[7] Update rate (milliseconds) = 1185 * (D/v) * tan (a/2)

Where:
D = average depth in area
v = velocity in knots
a = Transducer beam width

This formula will calculate the number of recorded sounding per second given the vessel speed and transducer beam width in order to cover the bottom completely in the traveled track.

The planed survey route must be planned in accordance with the standards, and must take into account the minimum survey coverage density for the given kind off survey. Both IHO S-44 and USACE Hydrographic surveys Standards have different varying standards. Single beam echo sounding will generated a string of depth values along the track. The intensity of this track is measured by the line spacing. By combing the line spacing and the sounding update rate, a grid with an average density can be calculated.

USACE standards reflect surveys in waterways (selected lakes, canals and rivers), and are very relaxed in other areas. A survey in a lake outside areas with navigational concerns will therefore according to IHO follow Order 1b and according to USACE follow “Other General Surveys & Studies (USACE).

Standard outside navigational concern	Maximum line spacing
IHO (S-44)	3 x average depth or 25 meters, whichever is greater. For bathymetric Lidar a spot spacing of 5 x 5 meters.
USACE (EM 1110-2-1003)	150 meters

Hydrographic lake surveying is an integrated part of many American States and University research programs. In these programs lakes are mapped, and method employed studied. The present methods of lake surveying, involves 200 kHz single beam echo sounders and DGPS positioning with high standards. (Hartnett 2005, Johnson et al 2008). The line spacing in these surveys covering large lakes (100 ha+) were 3 – 5 meters. In the Danish case (and in relations to INSPIRE elevation draft), the recommended line spacing and thus data density has to be decided, unless IHO S-44 standards are considered appropriate.

2.3 Summery

Bathymetry and hydrography are often used describing the same subject. The main difference in definitions is a bathymetric chart show the topography of a lake, and a hydrographic chart show all features essential for navigation.

Standards are set by ISO and OGC covering the different use of spatial data. Whereas most spatial data is described and fined by these institutions definitions for depth data is not. An ISO standard for echo sounders exists, but the spatial version for positioning depth, using contemporary methods, is only in development.

Surveying of water bodies usually follow standards from the International Hydrographic Organization (IHO). The INSPIRE draft incorporates these. The standards are describes in IHO S-44. The standard divides any water bodies into four (4) orders, with respect to necessity of surveying details, based on need for hydrographic charts. It is the national hydrographic offices privilege to decide which order a water body belong. These standards are also applied in lakes and other freshwater trafficked areas according to need. The surveying standards reflect this, and therefore bathymetric data for other purposes, has not any standards apart from the ISO and OGC standards for raw data and spatial data in general.

Lake bathymetry is not a part of the national Danish spatial databases. The INSPIRE elevation draft combines the existing data and survey standards in an effort to include bathymetric data in a general elevation model. The IHO standards are applicable for lakes, as it is up to national hydrographic offices, to decide what order an given lake or area in a lake belongs, and subsequent what surveying standards should be applied. The Danish national hydrographic Office has not made such decision yet regarding inland waters. The main link between bathymetry and digital terrains models is that both describe the morphology of a surface. The INSPIRE draft combines land and lake-/seabed data in both vector, TIN and grid representation. Rivers and moving water bodies excluded. The draft is still under development, but it might serve as the basis upon Denmark can include lake bathymetry into its national spatial databases.

In DTM the combination of lakes and land morphology is done by enforcing a lake polygon into the DTM. In Denmark the method does not reflect any set standard for water level but merely reflect the water level at time of data harvesting. A bathymetric lake map always carries a vertical reference. This reference might reflect the water level at time of surveying or a preset water mark. In order to combine a DTM model with bathymetric data a definition of water level is needed or as in the INSPIRE draft, depth have the local ETRS89 vertical reference.

Trough history bathymetric maps have been made using various methods. Lake maps are produced to both high surveying standards and very low. Despite the age and quality of these maps, they are still being used regardless. This points towards a general implemented “any map is better that no map” policy when a map is called for. Examples of this are Denmark, Sweden and USA.

Studies into methods for lake surveying are scarce. However one methodology reflects the nautical surveying methods. Soundings (lead and line), transects and XYZ data. Today methods include echo soundings and bathymetric lidar. Echo sounding is the standard method. Surveying using echo sounding from a boat has a number of errors to consider, both vertically and horizontally. These errors are reduced trough extra measurements and survey strategy, and equipment calibration.

3 - Crowd sourcing & Volunteered Geographic Information (VGI)

The task of harvesting, managing and controlling spatial information and mapping is traditionally done by agencies in the public sector. In the past 10 years and longer, this has changed towards the private sector as government agencies decrease in activity (McDougall & Corcoran 2009). While the private sector has business related reasons for harvesting spatial data, authorizes has legal obligations and a history. However the financial budgets for harvesting and handling spatial data are steadily diminishing, and therefore alternative and cheaper methods to harvest spatial data is of interest including emerging types from alternative sources like VGI.

New trends like crowd sourcing, Web 2.0, NeoGeography and VGI have emerged in the last decade, providing the spatial society with new opportunities. In the same period spatial data infrastructures (SDI) have developed, and the some interaction and converging between SDI and VGI is seen as a option (Mooney 2011).

3.1 Crowdsourcing

The traditional relationship between producer of data and user is a one way road, and normally the spatial data is owned by the producer or contractor. We have seen in the past that exactly this issue has been a limiting factor the use of same data, spurring free alternatives internet and user data based mapping services as Openstreetmap. Here sharing data is the key instrument of production.

Integration of user-generated into government data is a significant change in the expert-only GIS data world, because it is allowed for the citizen to interact with the government (or private data producer) modifying and contesting official data (Johnson & Sieber 2011). For governments, citizen sensors and scientist this have several benefits, including promoting citizen participation (Elwood 2009), improving governments response time (Goodchild & Glennon 2010) and efficient use of reduced budgets (Craglia et al 2008).

Openstreetmap where users with GPS data, or input made on the Openstreetmap web page, passes these on to Openstreetmap with the aim of making updated and free maps. The result is vector maps with routing functions, and raster maps. Similar commercial data are available but high cost, and lack of maps in some areas, was the main driving force behind the project. The data available are updated by many users. Everybody can contribute with data, and use Openstreetmap data. This can result in loss of data quality and consistence, as there is no guarantee that data are sufficient. One of the main tasks for a crowd sourcing project is to validate the data before use. In Openstreetmap uploaded data is passed on to volunteers before used for mapping.

Projects using crowd sourcing to update maps and databases are well established like Openstreetmap. Commercial GPS vendors and map producers like Garmin, TomTom and Navteq use web based crowd sourcing for registering map errors. KMS (National Cadastre) collects errors in the vector topographic map data base Kort10, via a web based service called "GeoAjour" (http://www.geoajour.dk).

One project, now abandoned due to lack of resources, were the USGS National Map Corps "Adopt a Map" program, who invited contributors via web site to upload any kind of spatial data and comments regarding their map product. This project was later cancelled due to success, as the volunteers flooded the USGS with VGI data about suggested map revisions. As the resources to handle all the input lacked, the project was stopped in 2005 (Coleman 2010).

There is a difference between crowd sourcing for errors in existing map products, thus pointing out problems to professionals, and crowd sourcing for VGI that will serve as raw data. Projects like this are truer in a NeoGeographic sense. One such project, crowd sourcing raw nautical depth data, is the EU supported TeamSurv (http://www.teamsurv.eu). It seems to be the only one of this kind in Europe. TeamSurv is a VGI project where mariners contribute with depth data, by logging depth and position during trips at sea, and uploads the data via the web for processing. The reason for this project is the present state of surveying in coastal regions. In many areas the nautical charts are old or of poor standard (referring to IHO C-55), and as professional surveying is very expensive (about €25.000 pr square mile) hydrographic offices prioritize surveying in high traffic shipping lanes, thus avoiding coastal water most frequently visited by smaller boats. TeamSurv aims to collect depth data from these coastal areas, in order to produce new and updated charts. The project uses electronic data loggers connected to onboard echo sounders and GPS, or GPS data logs from said instruments. The goal is to generate data of sufficient quality comparable to other survey techniques i.e. Multi Beam, under the assumption that high density of data from single beams echo sounders can be processed to enhance the quality (Thornton 2011).

3.2 Web 2.0

Web 2.0 is a general description for internet based services which incorporates user generated data in interaction between webpage and user. With Web 2.0 the Internet is becoming more an interactive network than the arcade like presentations is started from. From the start the Internet consisted of more or less static web-pages written in HTML and some scripts. Later on when new tools were implemented the Web 2.0 was named, as at trend towards more complex web pages containing applications with large degree of interaction between user (citizen) and the web page. "Creating and visualizing data is now a central part of the web experience." (Hudson-Smith 2009) O'Reilly describes it's like an Architecture of Participation and formulates the core competencies of Web 2.0 companies as:

- *Services, not packaged software, with cost-effective scalability*
- *Control over unique, hard-to-recreate data sources that get richer as more people use them*
- *Trusting users as co-developers*
- *Harnessing collective intelligence*
- *Leveraging the long tail through customer self-service*
- *Software above the level of a single device*
- *Lightweight user interfaces, development models, AND business models (O'Reilly 2010)*

Examples of Web 2.0 services are Wikipedia and Openstreetmap (Goodchild 2007 [1]). Apart from this, Web 2.0 services are at risk using copy right infringed data. This also applies to spatial data, and a legal validation is therefore necessary in the long run (Goodchild 2007 [2]).

3.3 NeoGeography

NeoGeography is a term describing spatial data collected and used by non professionals. The term reflects the non professional method in contrast to the professional. Generally it can be described as a movement in behaviour, method and use of spatial data, by the ordinary user, the well educated user and the professional user from the narrow map producing by professionals towards the wide where definitions for data and maps are diluted and redefined. ”Neogeography means “new geography” and consists of a set of techniques and tools that fall outside the realm of traditional GIS, Geographic Information Systems. Where historically a professional cartographer might use ArcGIS, and resolve land area disputes, a NeoGeographer uses a mapping API like Google Maps, talks about GPX versus KML, and geotags his photos to make a map of his summer vacation. Essentially, NeoGeography is about people using and creating their own maps, on their own terms and by combining elements of an existing toolset. NeoGeography is about sharing location information with friends and visitors, helping shape context, and conveying understanding through knowledge of place (Turner 2006).

The standard tool of the Neogeographer is a consumer GPS of any kind, and properly a computer with Internet access.

Goodchild discusses the distance between the amateur with a standard handheld GPS, and the specialist with a Trimble station or a high accuracy aerial photo. Who does it best? And can we compare them? Goodchild argues that even the professionals in some part of time used instruments considered primitive today, and still we use their data. Maybe they have better knowledge about the mapping issues, but the distance between amateur and specialist in terms of data quality is diminishing. And amateur data is still being used by agencies more and more often (Goodchild [1] 2009). There is a distinction in this concept that has not been made clearly. This is the distinction between the amateur and the amateur’s tools. I might be argued that “amateur” data can originate from amateurs using professional gear, or professionals using amateur gear! In any case, the quality associated with data from NeoGeography has many grades.

3.4 Volunteered Geographic Information

The spatial interested citizen can produce data when using a GPS unit and assigning extra information to the stored data, and thus the citizen becomes a data producer. With the large number of spatial enabled gadgets around, the possibilities seems vast. It is important to recognize that spatial data collection from a citizen not necessarily is voluntary or evident to the citizen. In this case the focus is on data from citizens who knowingly and voluntary share it.

Traditionally map production and positioning are reserved professionals and authorities, both legally and if the result shall carry weight. This is still true but the scene has changed in recent years with the wide spread use of GPS equipment by everybody, and induced new interest in mapping and hence the upcoming of NeoGeography. But sharing data is not possible without the advancements in the Internet especially Web 2.0 (Goodchild 2007 [1]). The whole picture of maybe 7 billion citizens on the planet with a GPS sensor, or an inclination towards making maps better, invites to a different view of collection of spatial data:

“The widespread engagement of large numbers of private citizens, often with little in the way of formal qualifications, in the creation of geographic information, a function that for centuries has been reserved to official agencies. They are largely untrained and their actions are almost always voluntary, and the results may or may not be accurate. But collectively, they represent a dramatic innovation that will certainly have profound impacts on geographic information systems (GIS) and more generally on the discipline of geography and its relationship to the general public. I term this volunteered geographic information (VGI), a special case of the more general Web phenomenon of user generated content.” (Goodchild 2007[1])

Volunteered Geographic Information always represents knowledge. The willingness to share this knowledge, and the means to do it, is the condition for making use of the Internet for this purpose. In many cases are VGI projects like Openstreetmap triggered by lack of access to cheap spatial data i.e. maps for GPS units. In line with NeoGeography VGI projects may also be a way of collecting data just for a special interest outside any quality considerations which applies to official spatial data. It is a concept that is both chaotic and diffuse. Willingness to share data may be abused, and research is clearly needed to define the limits of VGI (Goodchild 2008).

Basically VGI is about sharing data collected by users with the purpose of providing spatial data for the benefit of others. If a citizen got tools, the equipment, the resources, and a subject for data collecting and the will, VGI will be considered an option for updating spatial data. This data can be dived into 2 groups. The first group is data (free of charge) to vendor/firms like NavTeq asking the users for error reports on their website, or government, and the second data is aimed at social networks in the public (Coleman 2009) like Openstreetmap.

3.5 Collaborative GIS

Systems incorporating citizens in decision making is called Public Participation Geographic Information Systems (PPGIS). A PPGIS system is primarily a system to let the public participate in government planning or similar processes. It is a system to facilitate the decisions makers with stakeholders view. The information supplied by a PPGIS system can vary given the setup. Spatial data (like GPS data from "produsers") are an option. PPGIS systems have in Denmark (& Europe) its political foundation in the "AArhus Convention" declaring that the public should be heard directly. So the difference between VGI and PPGIS is that VGI is more unconditional sharing of spatial data with the data as the subject, while PPGIS is sharing opinions backed up with spatial data (Tulloch 2008).

3.6 Quality of VGI data

A critical subject given a data type is data quality. Professional data are characterized by high precision, completeness, metadata, high credibility, visibility and control to specific standards, but also high cost and sometimes slower data harvesting. The bonus is highly reliable data. While mapping agencies have standards to follow, and reputations to maintain, amateur data from unknown sources is without standards and reputations, without control, in large quantities and free!

Studies into assessing the quality of VGI data are important. If authorities mapping organizations are to use data from VGI sources they need a better understanding of potential accuracy. When a feature is correctly identified, the accuracy depends on the technologies and processes employed (Coleman 2010). VGI data does not have to be made by consumer GPS units, or amateur equipment in general. It might also originate from professionals with state of the art GPS.

An assessment involves examine at least three different aspects related to geographic data quality (Goodchild & Glennon 2010, Mau'e & Schade, 2008):

- Positional accuracy and attribute accuracy;
- Completeness of data
- Credibility of data sources

3.6.1 Positional accuracy and attribute accuracy

GPS vendor specifications claim to 3-5 meters accuracy in good conditions (Garmin 2010). Ever since relative cheap consumer GPS were introduced, many articles have discussed and analyzed these units. As consumer units are designed for recreational work (handhelds and plotters), or network locked aids (car navigators), they are as such not suited for professional work, and professional testing of their positional abilities are therefore scarce.

Testing VGI GPS data sources can be dived into a static test or a kinematic test. A test testing current commercial handheld GPS receivers showed good overall performance (Tiberius 2003).

One research project in Canada tested VGI data and technologies (Sabone 2009). In this project it was assessed to which degree VGI data could meet Canadian National Road Network and National Topographic Data Base specifications for positional and attribute accuracy. Two approaches were used including a method Goodchild and Hunter (Goodchild & Hunter 1997) to asses the percentage of VGI linear feature that fell within the accuracy specified. The result of the Canadian test showed the positions obtained using handheld GPS units from Garmin a.o. in 90% percent of the cases were within 10 meters of a known street Centerline when testing (Sabone 2009).

As part of the project TeamSurv, consumer GPS units were tested, and it was found that they perform very well with accuracies between 1.7 – 2.4 meter RMS*2 (Thorton 2011).

Studies of attribute accuracy of echo sounders have not been found.

Generally the future is bright in regard of improvements of accuracy from GPS handheld devices, so contributions in the future from individuals to authoritative databases (Gakstatter 2010).

3.6.2 Completeness of data

Completeness of data might be a large problem when collecting VGI, as there is no one to decide, when or where VGI is harvested contrary to a professional survey. A project collecting depth from vessels will only have data from the areas mariners choose to sail, even it they set out with the purpose of collecting data in a given area.

Figure 3.1 VGI Tracks (TeamSurv, Google Maps)

The map from TeamSurv, showing uploaded user tracks illustrates the problem with lack of completeness. The tracks seem to a depicting of the preferred routes. Another example is from a Danish lake Furesøen. All these tracks are used for depth collection, but it is evident that they also show the water passage from the harbour to the main lake. This is unavoidable but not a problem in it self, as the data density from highly trafficked areas have to be very high. However the picture also shows, that areas outside the typical routes, receives less attention except from deliberate efforts. It must be expected that the user will have to combine, both the recreational purpose of sailing and collecting data, and the density of data will show that.

Figure 3.2 Tracks Lake Furesø (Vedel 2009, KMS)

3.7 Credibility of VGI data

A key question discussing VGI is how to determine the credibility of contributors and the reliability of their contributions. This problem have been addressed several times (Goodchild 2007 [2]), (Flanagan & Metzger 2008) & (Haklay 2010) a.o. The overall quality of VGI data is a mixed subject, as it comprises of many different kinds of errors. On the outset any spatial data harvesting process has its sources of errors, which as part of the process is well documented under "normal" professional processes. In VGI context the process involves many approaches to understanding and using spatial data.

A view on the matter presents some suggestions to solutions (Grira, Bedard & Roch, 2009). Factors upon uncertainty rely in a VGI framework, in conjunction with professional data and agencies, or between the volunteer and the authoritarian are analyzed. One aspect of uncertainty in VGI data is the lack of understanding of spatial data uncertainty among VGI contributors. They argue that involving VGI contributors in the spatial data uncertainty handling may benefit the designed system. When volunteers contribute with their data, it might be as goods as it needs to be before sharing it with other volunteers or it might not be so when sharing data aimed at professional use.

The quality of data is not communicated sufficient to other users (Comber et al 2006), as they do not have the same understanding or perception, of the quality in data. If the volunteered data are to used, resources for quality monitoring, validly check, and post processing might be an obstacle for data producers, unless volunteers also address quality issues, as perception of data quality and metadata in professional datasets, compared to the end users need and capabilities can be insufficient. The standard procedure until now is that the data provider is the ultimate judge of the uncertainty in data, and a set of metadata according to standards is sufficient. When the users are expanded with volunteered users and contributors, with very different educational backgrounds, the needs for data quality vary. Metadata files might be inadequate to describe the data qualities to the general user as it assumes a perfect knowledge of a specific set of requirements and because "it does not provide full descriptions of data uncertainty and allow assessments of data fitness". This poses a dilemma for the spatial data provider, as it is impossible to create metadata sets to fit everyone's need, and the same time it would not be reasonable think about training thousands of voluntary users to a sufficient degree of spatial knowledge (Grira, Bedard & Roch, 2009). By using interactive tools and Web 2.0 interfaces it seems viable to bring the consumer's perception of quality closer to that of the data producer and to reduce the perception gap between them (*Seeger* 2008; *Haklay et al* 2008; *Scharl & Tochtermann* 2007) i.e. educate the user through the Internet.

3.8 Uncertainty management in VGI

Managing uncertainty is a key problem, and if not solved, prohibits VGI data to be used either comparable to professional data, or if VGI data is aimed at other VGI members or users with lesser quality preferences. Errors in data are a problem for both volunteered contributions and authoritarian ones. Some are due to normal sources of errors, especially if both uses the equipment of the same quality, but others is caused by lack of training, incompleteness in data and shortcomings in equipment. It is proposed that Web 2.0 tools are used to bring information about data quality closer to the user perceptions, as this would engage user's spatial data quality assessment, and consequently improving the quality of the datasets. Thus it is to establish process to manage uncertainties in a VGI context which implies a mechanism consisting of:

- Visualizing spatial data quality
- Collecting users' entries about quality throughout Web 2.0 forms
- Integrating quality information within the model.

They assume that users are able to "contribute greatly to identifying, defining, and presenting the risks of inappropriate uses of geospatial data. They also assume the users to be motivated enough to participate voluntarily in quality improvement by fulfilling the Web 2.0 forms". The visualization of data and data quality, and hence the scope for contribution is not part of said work, but they assume a proper visualization implementation (Grira, Bédard & Roch, 2009).

The result of initiatives towards better data quality perception among VGI contributors would result in better and useful metadata containing origin and history are necessary (Frew 2007).

3.9 Characterizing the Contributors in VGI

The skill of a contributor is significant. It is assumed that better skills result in better data. One characterization is this (Coleman et al 2009):

1. ***"Neophyte"*** *–no formal background in a subject, but possessing the interest, time, and willingness to offer an opinion on a subject;*

2. ***"Interested Amateur"*** *- "discovered" their interest in a subject, begun reading the background literature, consulted with other colleagues and experts about specific issues, is experimenting with its application, and is gaining experience in appreciating the subject;*
3. ***"Expert Amateur"*** *- someone who may know a great deal about a subject, practices it passionately on occasion, but still does not rely on it for a living;*
4. ***"Expert Professional"*** *- someone who has studied & practices a subject, relies on that knowledge for a living, and may be sued if their products, opinions and/or recommendations are proven inadequate, incorrect or libelous;*
5. ***"Expert Authority"*** *- someone who has widely studied and long practiced a subject to the point where he or she is recognized to possess an established record of providing high-quality products and services and/or well-informed opinions -- and stands to lose that reputation and perhaps their livelihood if that credibility is lost even temporarily.* (Coleman et al 2009)

However these categories may not be sufficient to describe VGI participants. There is clearly a need for distinction between motives and means (Coleman et al 2009). A contributor can be skilled and trained but without the tools to generate spatial data of high quality, or the contributor can be lesser skilled but equipped with professional instruments.

3.10 Motivations to contribute

To better understand why individuals contribute geographic information some results were collected (Coleman et al 2009):

1. *Altruism*
2. *Professional or Personal Interest*
3. *Intellectual Stimulation*
4. *Protection or enhancement of a personal investment*
5. *Social Reward*
6. *Enhanced Personal Reputation*
7. *Provides an Outlet for creative & independent self-expression*
8. *Pride of Place*

The above list clearly shows positive motivations. The meaning of "volunteered" is strongly emphasized. But as in PPGIS systems, where contributions have a political agenda, VGI data contributors may also show similar behaviour.

1. *Mischief: Mischievous persons or "vandals" hoping to generate scepticism or confusion.*
2. *Agenda: Independent individuals or representatives motivated by beliefs in a given community, organization or cause.*
3. *Malice and/or Criminal Intent: Individuals possessing malicious (and possibly criminal) intent in hopes of personal gain.* (Coleman et al 2009)

This leads to categories of reliability of contributors. They are divided into two main groups; *Constructive* and *Damaging* (Coleman et al 2009).

3.11 Institutional considerations

When looked at from the cartographers view the first issue is data quality, but at the other end the produsers participating, must have theirs mind made up to why they bother, and for free! The nature and motivation behind VGI are key issues. Can it be assumed that VGI participants will act like voluntary contributors in Open Source software and Wikipedia and other open networks? Are there conditions which may influence VGI contributor's behaviour, and thus the nature, frequency and quality of contributions? If VGI does represent a method for large mapping organizations to update data in their databases, how do they evaluate the advantages and risks involved? Coleman refines the questions to:

1. *Can it be assumed people will want to contribute to government in the same way they contribute to social networks and even to commercial databases?*
2. *What questions should an organization ask in determining how it should employ geographic information provided volunteers?*
3. *How does an organization assess the credibility of a new contributor and the degree of trust?*
4. *How do organizations attract new volunteer contributors and maintain the present?*

Public and private organizations, has to consider several issues before implementing VGI in their data harvesting. Some questions are put forward by Coleman and among those are:

1. *What is the rationale for VGI in this context?*
2. *To what extent, if at all, should VGI be adopted?*
3. *How may credible VGI contributors be distinguished from those who may be incompetent, mischief-makers, or outright vandals?*
4. *How much control over content and quality are such organizations prepared to relinquish?*
5. *Who makes the final decisions regarding the reliability of a given update? These are not new questions. The extent to which control is held by the contributor, the institution, or "the crowd" of contributors assessing each other's contributions will be different in each organization.*
6. *Will individuals remain interested in making contributions?* (Coleman 2009)

One reason for using VGI data is a constraint budget. VGI data is cheaper, but at a price in quality loss. And if mapping organizations choose to use VGI, some adjustment to the culture of sharing information should be considered or even adapted (Coleman 2009). This make a VGI implementation in SDI a two-way street where the VGI communities helps the professional data producers in maintaining an SDI, and the professionals both listen to the VGI sources and adopt practices beneficial to them.

3.12 Spatial Data Infrastructures (SDI)

A framework of data, technologies, policies, standards and human resources, all necessary to facilitate the sharing and using of spatial information. The term infrastructure is used to emphasize not just hardware and data but also the need for coordinating structures and international standards and agreements without which the system cannot operate consistently and safely (Cragilua 2007). The European INSPIRE is an attempt to coordinate the local European SDI's. As such the Danish SDI is a part of this effort, and works in this direction (Jarmbæk 2011).

3.12.1 VGI data and Spatial Data Infrastructures

The possibilities of including VGI in SDI, being a alternative to traditional spatial data from authoritative mapping agencies and corporations and in particular building a SDI, being a looser defined structure than normally assumed, is a tempting option cost wise. But the inheritable difference in VGI data and traditional professional data has raised some serous concern about its quality (Mooney et al 2010). The emerging Web 2.0 and the vast growing numbers of GPS units, applications, makes the introduction of VGI data very easy and convincing, and maybe too easy. VGI data is on its way towards implementation in a lot of fields and one of these might be working among professional data. Increasing cost of official mapping efforts and the possibilities of including VGI data as a cheap and fast way of updating spatial data, have led to integrations of VGI data in some SDI's (Hjelmager et. al 2011, Goodchild 2010), and to several studies into theses possibilities (Coleman, 2010; Mooney & Corcoran, 2011; McDougall, 2009). The potential use of spatial data from social networks is possible as the necessary institutions are available. Local government agencies, has both the appropriate organization to implement VGI within their corporate SDI's, and also access to volunteers or employees able to contribute with data (McDougal 2009). SDI's can cover all kinds of spatial data. Only the narrowest definitions would exclude data from spatial enabled citizens (Coleman 2010).To some extent VGI and SDI converge. As pointed out some convergence is already taking place (Craglia 2007). When comparing the institutional considerations and the discussion on quality of VGI data, it is clear that there similarities which suggests that quality issues is the main problem when considering VGI into SDI's, and not just a case of making VGI data a part of SDI's on its own merits.

3.13 Summery

There are several trends in the spatial society:

- The spatial society has moved from a strictly one way "producer to user" network with very few data producing agencies and a certain number of users, to at very large patchwork of networks all producing and/or using spatial data. This has formed the basis for constructing Spatial Data Infrastructures.
- The ordinary citizens have now the possibilities with cheap but good GPS units, and the internet (using Web 2.0 methods) to collect and share spatial data, or simply share information with spatial references. Users able to produce spatial data are labelled "Produsers" in this context (Coleman 2009).
- Spatial data is dived into proprietary and free data.
- Spatial Data portals and communities have emerged in competition with national mapping agencies.
- Citizens are becoming more spatial aware.
- National mapping agencies are considering using spatial data from the citizens (the crowd) as a source, hence the term "Crowdsourcing".

Figure 3.3 show the general trends in spatial society today with regard to users, vendors and "Produsers". The direction of the shifting relations clearly indicates a move from the highly costly, closed and authority datasets and data productions environments, towards a more loosen environment. This trend might also be visible elsewhere as the use and understanding of spatial data expands. So the apparent diminishing average quality in data when expanding towards new data sources, may also be an indicator of growth in spatial awareness in the general society, and as such is very welcome.

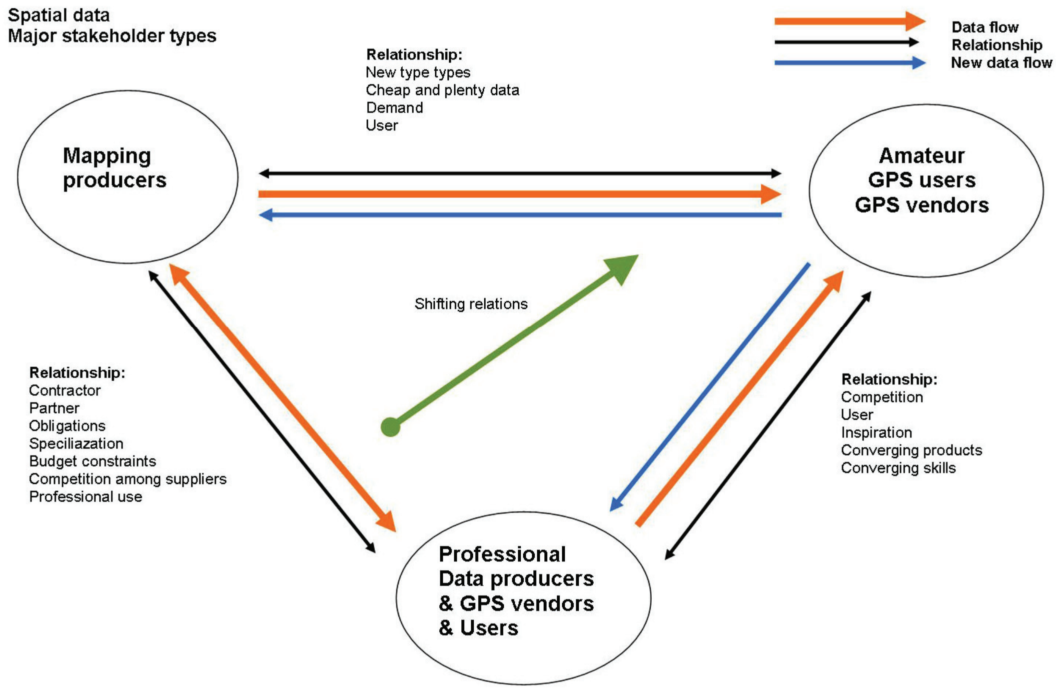


Figure 3.3 Present trends (Vedel)

Crowd sourced VGI data has several issues in comparison with professional data such as spatial accuracy, quality, completeness and credibility. All these potential errors in data, suggests a validation and control/filtering of data before use. Any system collecting data from the Internet will be vulnerable to erroneous or fake data. Added contributors motives to this, and we have some issues to tackle before using VGI data. At the receiving end, issues about data quality, given the planned use, are a main concern.

The primary argument for considering VGI data into SDIs, is to get spatial data cheap, easy and quickly. It is tempting in an age with limited resources to crowd source data, even data that otherwise would be made by professionals. The figure demonstrates the benefits in theory in cost, but also the cost in quality. The challenge would be a data post-processing process to lift quality to a sufficient standard, or to redefine the standards for data. Or simply to redefine which data that are useful.

Figure 3.4 shows a perception of the principles in the relationship between data quality and cost, and data source (supply) and the quality gab, a post processing process must be able to close. The linear relationships are merely for illustrating. The illustration is also not an assumption of continuality in the relationships. This would properly be a very bold assumption.

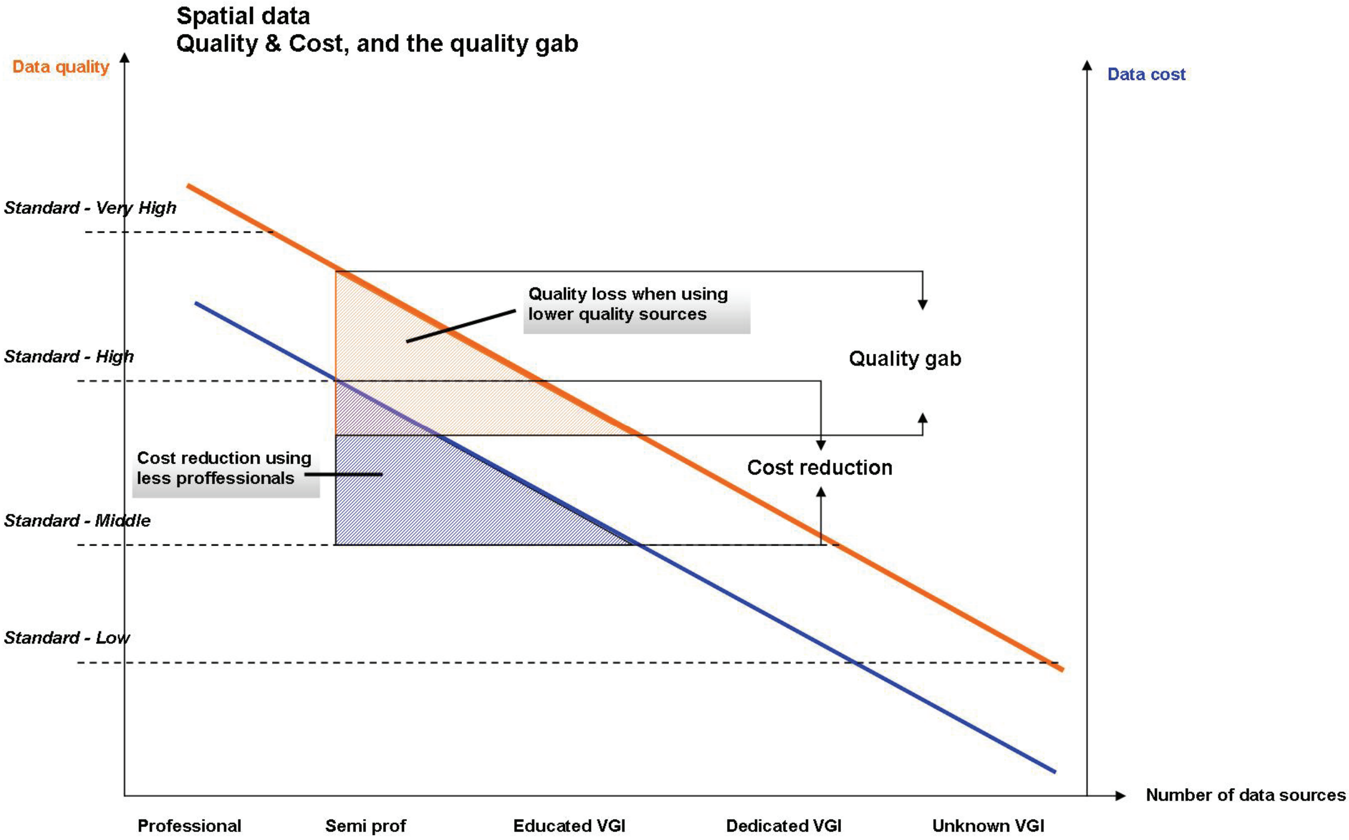


Figure 3.4 Quality versus cost (Vedel)

To sum up on the issues following problems needs to be addressed:

- *How to handle skills among VGI contributors?*
- *How to handle lack in completeness in data?*
- *How to handle uncertainties in VGI data?*
- *How can visualization assist the VGI process?*
- *How to ensure metadata?*
- *How to recognize the efforts from contributors?*
- *Who owns VGI data?*

4 - Internet GIS, Distributed GIS & Web mapping

Internet GIS and Web mapping portals are closely related, as Internet GIS often incorporates web mapping, and web mapping often supports Internet GIS directly or indirectly. Both are they part of distributed GIS. Distributed GIS is the latest development in GIS computer service evolving from Mainframe GIS to Desktop GIS into Distributed GIS consisting of Internet GIS and Mobile GIS (Peng & Tsou 2003). This chapter will explain the main principles and techniques.

4.1 Key concepts

GIS is the abbreviation for Geographic Information Systems. GlServices illustrates the service perspective of GIS which is delivering geographic information and processing tools to users over the Internet:

- *Internet GIS is the framework of network-based GIS that utilizes the Internet to access remote geographic information and geoprocessing tools.*

- *Distributed GIS represents a broader framework including both Internet GIS and mobile GIS. This term emphasizes the software characteristics of Internet GIS and mobile GIS, which are distributed and dynamic.*

- *Distributed GlServices focus on the on-line processes of information services and task-oriented Internet GIS applications. (Peng & Tsu 2003)*

Distributed GIS is client/server setup. On networks such as the Internet, the TCP/IP communication protocol establishes the connection. The client calls on the server and receives data. It is apparent that data at one place (the server) has to be transferred to another place (the client) and used here. In the case where most of the data processing is done on the server side, the remaining job for the receiving client is limited. A client in this case is called a *thin client*. Otherwise if raw data is sent to client before processing, the processing task at the client will be greater (even much) and the client will be a *thick client*.

4.2 Standards for Geographic data formats

The wide spread exchange and need for data interoperability has induced several moves towards standards for geographic data and the ways they can be exchanged between applications, including through the Internet. A standard diminishes problems when exchanging data using different data formats. Thus internal recognized and accepted standards are essential for Internet GIS and distributed GIS in general. Two major organizations set the industry standards for distributed GIS services; The Open GIS Consortium (OGC), and the International Organization for Standardization (ISO).

- *The main goals of OGC are the full integration of geospatial data and geoprocessing resources into mainstream computing and the widespread use of interoperable geoprocessing software and geodata products throughout the information infrastructure (OGC, 1998). (Peng and Tsou 2003)*

- *ISO/TC 211 emphasizes a service-oriented view of geoprocessing technology and a balanced concern for information, application, and systems (Kuhn, 1997). The following* *sections will briefly introduce the two organizations and their Internet GIS and distributed GIServices standards as well as metadata standards. (Peng and Tsou 2003)*

OGC delivers the preparing work on a voluntary basis among associated parties (like countries and large corps), while ISO develop and publish the final standards which is then made official, and in the EU by law.

4.2.1 OGC web standards

Spatial data for maps are usually either raster (image) or vector data. Vector data needs to be given styles and forms before rendered but raster maps are ready to be shown. OGC has fostered the two very popular standards: Web Map Services (WMS) and Web Feature Service (WFS). Both standards allow a respond to a HTTP GET request with dependent on the parameters in the request (Davis 2007).

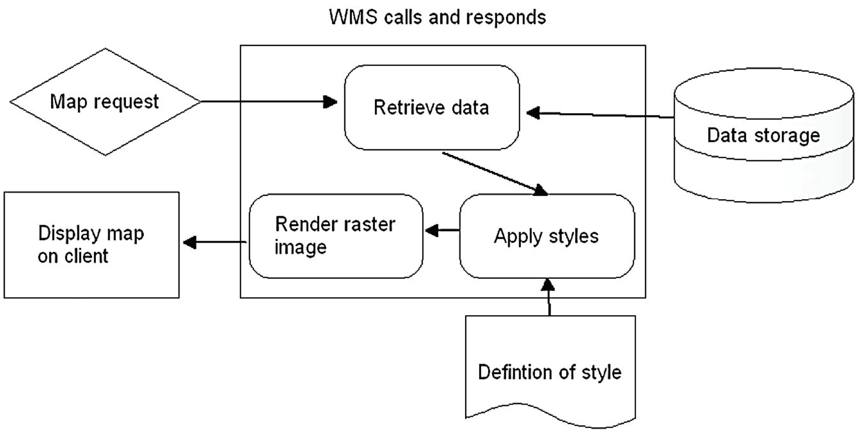


Figure 4.1 WMS flow chart

OGC standards are open and non-proprietary. From a map rendering viewpoint a WMS call resulting in a compressed raster image ready for the screen is preferable. On the other hand, if the user need the client to retrieve spatial data within in area either for analysis or map rendering a WFS call is relevant. This demands a richer or thicker client due to the extra processing before data can be shown as a map. There are other considerations concerning vector data versus raster data. The size alone of uncompressed vector data (could be in XML) would be prohibitive for most use, alone from the fact that most vector data are subject to intellectual right, and therefore nor freely can be distributed for processing elsewhere.

For a map client or a browser to see which data a map server can supply, a GetCapabilities method is used. The request will send a XML string back to the client listing which raster maps and raster data (layers) the server has to offer. The GetMap request to a WMS server returns a raster image (map). The request GetFeature will prompt a WFS server to return vector data. If the vector data is in Geographic Markup Language (GML) the size of this data transfer can be very large, thus being a hinder for use. There are other alternative for transferring vector data including compressing before transfer, ESRI shape format, and a careful selection of data for minimizing size (Davis 2007).

4.2.2 Metadata

Metadata (1.0) or data about data describes data. Geospatial metadata describes geospatial data, web services, and other geospatial resources (Fu & Sun 2011). The simple standard for metadata is defined in the Dublin Core metadata later adopted by ISO, and developed into DS/EN ISO 19115 Geographic information - metadata, DS/EN ISO 19119 Geographic information - Services and DS/CEN ISO/TS 19139 Geographic information - XML schema implementation (XML being the standard data format for exchanging metadata). The standard set of Danish metadata for spatial data found at www.geodata-info.dk.

Metadata 2.0 is the trend towards implementing Web 2.0 trends in spatial data, into a metadata standard thus enabling data to consist of easy comprehendible elements. Metadata 2.0 should be user-centric, easy for contributors to create and easy for users to understand (Goodchild 2008). Metadata 2.0 and Metadata 1.0 represents two spheres of spatial data production and use, that trends towards integrations via VGI and other user generated content. They may be applied side by side to different kinds of data given its nature and use (Fu & Sun 2011).

4.3 Internet GIS

The Internet is a giant network using Hypertext Transfer Protocol (HTTP) for communication and File Transfer Protocol (FTP) a.o. Internet GIS has four dominant components: The client, the web server (with application server), a map server and the data server. The client is the application running on the user's computer providing an interface (GUI) which interacts with GIS applications on the Internet. The web server receives the requests and process them relying on an application server, calling a map servers that in turn retrieves data from the data server and its connected databases. The different components, also refers to each kind of tiers reflecting model in the architecture.

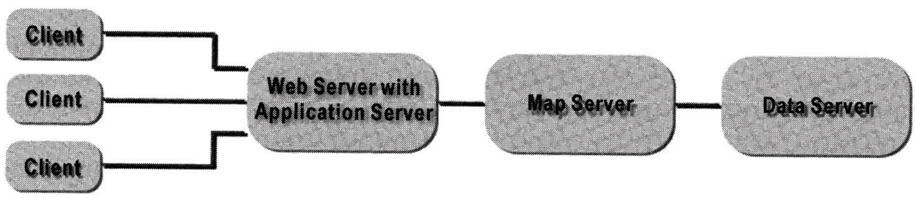


Figure 4.2 Basic components in Internet GIS (*Peng & Tsou 2003*)

4.3.1 The data server

The Data server serves spatial and non spatial data. The data will be in a database. Data can be added or retrieved. Database middleware is often used to access different databases. The client application gains access to the database elements using a query language like SQL (see below). The data server is normally running at the same locations of the web server. The database is accessed trough scripts in typically java, JavaScript or PHP (PreHypertext Procesor).

4.3.2 Databases

A database is a collection of data organized in such a way that a computer can efficiently store and retrieve the data (Worbye & Duckham 2004). It provides speed, support for many users at the same time and enables queries. Queries are central in the use of databases in GIS. The database tier is the most complex part of the tiers in Internet GIS Web structure. A spatial database is a database capable of handling spatial data, and plays a central part in any bigger GIS.

Databases can be dived into several kinds. Generally databases are divided into models or principle of design. Larger database systems uses software for the handling called DBMA (Data Base management systems). The DMBS is fitted to the database model in use. Today three models are considered relevant handling spatial data (Balstrøm et.al. 2010).

- ”The Relational Model” – This model or design uses tables for the data and the relationship between them. The model consists of table with unique structures. Each row in a table is a record and the model is therefore called “Record Based”. This model is often called RDBMS.

- ”The Entitiy relationship model” – This database model is based on unique objects or entities, and the relations between these. The analysis tool for this is called E-R-diagram. This concept is very often used in database design including for a GIS and in relational databases.

- ”Object oriented model” – This model can be considered as a further development of the E-R model, where object definitions and relations are further expanded. Object orientated database design is not used in this context. (Balstrøm et al 2010.)

Queries in a database are done with a spatial set of instructions or commandos i.e. a Query Language. SQL (Structured Query Language) is a variant developed for a special kind of database model. The query language as such is bases on relational Algebra. To improve query and reduce search times database must be optimized using normalization, indexation and the removal of redundant data.
Relational databases are often used for handling spatial data like the PostGis extension for PostgreSQL. While the relational model is best suited for collecting data for further processing like attribute data, object oriented models (OODBMS) are best suited for handling objects in a graphical context or likewise where the spatial object is in focus (Balstrøm et al 2010). To understand further how this extension works in order to enable a normal relational database (RDBMS) to handle spatial data two ways are used (Chen & Xie 2008):

- Spatial Database Engines (SDE)

- Spatial extensions of RDBMS (SE)

Both PostgreSQL with PostGis and MySQL with MySQL Spatial extension works SE based as (old) rational databases with spatial extensions, whereas ESRI ArcSDE and MapInfo are based on Microsoft’s SQL server as the engines. SE based databases works faster and better than SDE based, and are easier to maintain and work with for developers.

Standards for spatial databases is given by OGC but often further accompanied by the vendors own functions like in PostGIS.

4.3.3 The Web server and the application server

The web server is the central component in the system. It will respond to an http request and send HTML code to the clients browser, or and application, or requesting services from other serves. The web server might also be the application server, but in larger systems the application server will run separately.

It will generally perform the following tasks:

- **Wait for and respond to client requests**. The server spends most of its time waiting and receiving client requests. Once it receives the requests, it will respond by assigning a dedicated session to every client, by creating a dynamic pool of reusable sessions, or by providing a mix of the two.

- **Process client requests**. This is the main function of the server. A server has to respond to many simultaneous client requests, so it needs to have the multithread capability. That is, the server can fulfil many user requests simultaneously. Servers without multithread capability are only good to handle few requests and their performance is thus slow. Some existing desktop GIS and Internet GIS servers still do not have multithread capability.

- **Perform other service chores on the background.** Besides the main tasks, the server has to take care of other chores like backup, data downloading, load balancing, security checking, and task prioritizing (Peng & Tsou 2003).

4.3.4 Map Servers

A map server is needed to retrieve spatial data from a data server and display it on the client. A true GIS distributing system will have a map server doing the requests to the data server. The data can be transferred different ways. Two kinds of data are used. Spatial data (filtered when selected) or an element in a graphic format. Traditional graphic formats supported by browsers, includes Graphics Interchange Format (GIF), Portable Network Graphics (PNG), Joint Photographic Experts Group (JPG) and Bitmap Image File (BMP). These graphics have different capabilities and therefore different uses. GeoServer, MapServer and ESRI ArcIMS are well known examples of map servers and can handle spatial data in OGC standards.

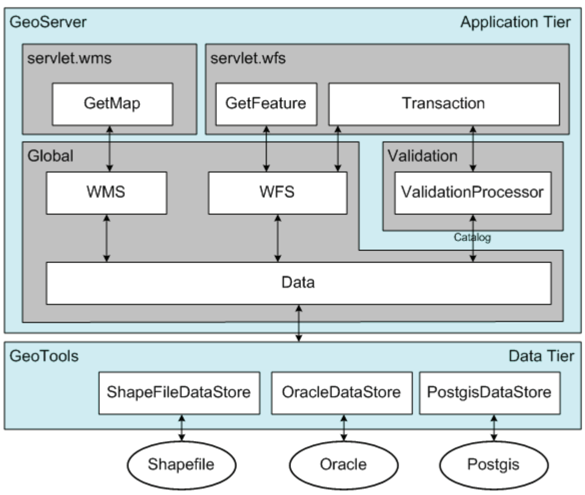


Figure 4.3 The application tier structure in GeoServer (geoserver.org)

4.3.5 The client

The client tier is the basis for user interaction with the Internet GIS, performing the task chosen. This can be viewing data (maps), handling data (spatial objects) or having analyses done in the Internet GIS system. In general terms the functions are:

- Presents an interface for human interactions
- Formats requests for data or services from a server
- Displays data or query results it receives from the server (Peng & Tsou 2003).

The client is the GIS and web software running on the user's computer (maybe presenting a graphical interface (GUI)). Basic web browsers uses HTML code, but several other programming languages has emerged enabling functions taking place both client side and server side on the users request whereas the traditional setup would comprise of static webpage, i.e. html code written pages retrieved and displayed on the user's computer. With the aid of JavaScript, PHP etc., web pages has become interactive instead of static. Data transfer from or to the users computer has always been a possibility, but inclusion of PHP and Java Script has made this process much more dynamic. The choice of programming tools and applications, for web pages interacting with servers and other clients on the Internet, is undergoing constant revisions due to a combination of software advances and security issues.

4.4 Distributed GIS

Distributed GIS involves a wide range of applications. They can be organized into four general groups from data sharing and disseminations, to simple geospatial data search and queries, to online data processing, and to location-based services. (Peng & Tsou 2003) In this context location based services are not relevant.

- **Data sharing:** Exchanging data, retrieving data or submitting data via the Internet is plainly a very common activity, and one distributed GIS is very well suited for. Data can be exchanged using FTP or browser presented solutions.
- **Geospatial Information Disseminations:** Presenting geospatial data like maps to a large crowd via the Internet is be haps the most wide spread use of distributed GIS (Peng & Tsou 2003). Presenting data this way is a one way process. Before this technology was implemented maps had to be printed and sent. So it is obvious that the time and resources saved distributing GIS data this way is very large. Web mapping combined with search facilities and choice of layers, are very suited for displaying specific spatial data.
- **Online Data Processing:** Online data processing is a special case as it allows the user client side, to alter, update or contribute spatial data. This is a task reserved for those allowed into the system which has the rights to influence data and hence to directly publish spatial data via this service.

4.5 Geoportals and their characteristics

Geoportals serves as gateways to spatial data and information. A Web portal is a Web site that functions as an entry point to the World Wide Web. A portal provides tools that help users find information on the Web (Fu & Sun 2011).

A Geoportal, also referred to as a spatial portal, is a Web site that provides a single point of access to geospatial data, Web services, and other geospatially related resources. Put more simply, a geoportal is a Web site where geospatial resources can be discovered (Fu & Sun 2011).

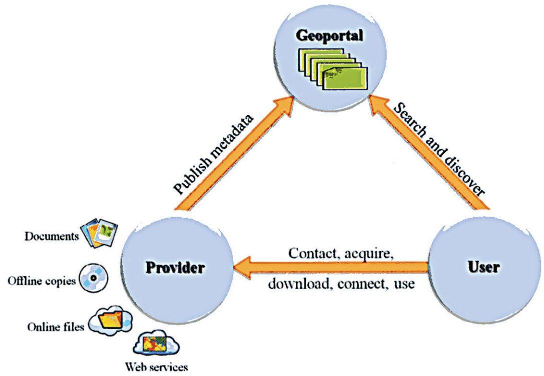


Figure 4.4 The Geoportal elements (Fu & Sun 2011)

A geoportal can serve many purposes. The key data is metadata. The publisher is the initiating part providing metadata and presenting it. A geoportal can present one aspect of spatial data i.e. status of wild life in a given area, or the can serve as the front of an SDI. They are a concept of delivering spatial data and opportunities to the user. Functions they perform include presenting gateways to geospatial information, support sharing of information, and present metadata.

4.6 WebGis

To what Peng & Tsou labelled "Geospatial Information Disseminations" the term WebGis would be applied today (Fu & Sun 2011). WebGis has evolved from static map display into distributed GIServices using a large array of internet programming components. In the same period programming has evolved, and the methods described in earlier works may not be applied in the same way today.

The client in web mapping is build with HTTP code (called the Glue as it acts as the middleware between the web client and the Web server), so that the code fetched from the web server upon a call (loading the web page using an url (internet address), presents a series of options tot the user in html code. This can be a GET code, which fetch an image from the web server an presents in a box on the web browser.

In the figure 4.3 the evolution of distributed GIS is shown. This figure dates from 2003 and much has passed since. The main part of a web mapping web page still consist of html code, but the interactive components both client side and server side has evolved a lot. The client side code will typically consist of html as the frame, but with components in PHP running either client side or server side, like wise some JavaScript's. On the server side connections are made to map servers for the spatial data intended for the client and in this context the standards from OGC plays and important role.

Webgis services usually have Web mapping as an integrated part using geobrowsers. The central part of any web map is the map it self. With the relatively large number of free or freely accessible maps on the internet, it is no surprise that the base map very often is a third party map. Combined with the map display are several functions and special overlays determined by the purpose of the maps site. A map web page will add value and functionality to the base map, or simply present its own spatial data. And this makes the connection to Internet GIS as a web mapping site to some extent is a GIS or is displaying data from a GIS using techniques and standards from Internet GIS.

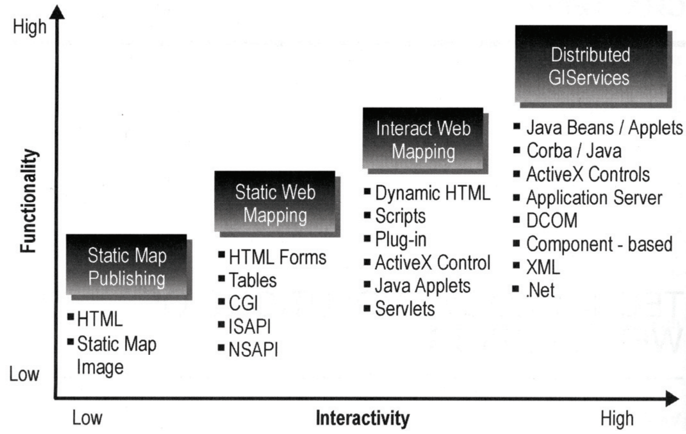


Figure 4.5 Evolution of Internet GIS services (Peng & Tsou 2003)

This structure is similar to at normal website structure. The main difference lies in the kind of data handled by the tiers. In this context it is important to remember that Internet GIS not necessarily means building a map for display. It is just a system to handle spatial data.

The interaction with the user is a central part in Web 2.0 GIS. Contributing with data and/or spatial enabled knowledge trough a map application, is the primary method when crowd sourcing data. Adding a data interface to a mapping display makes a data sharing GIS. A very good example of this is Openstreetmap. Hence a similar method can be used to collect any kind of spatial or spatial related data from users.

4.7 Map clients or Geobrowsers

A GUI (Graphical User Interface) in HTML can choose between having the application server run its script either on the browser running in the client; in this case the programming language for the script will typically be Java, or we can make the browser call a script on the server; in this case using PHP language, and only return with a result from this script. The latter is often preferred. The client can communicate via the Internet directly with other clients, servers outside a browser.

Clients running spatial services are also called map clients. To make them work with a remote map server the programming language AJAX is often used. JavaScript has its limitations for interacting, and so AJAX was developed to combine the JavaScript and XML format into web pages. This way interaction is possible. Google Maps API (Application Programming Interface) and OpenLayers uses AJAX framework in their clients using WMS calls.

The best known map client for implementation in a web site is Google Maps API and is free to use but with proprietary code. Google Maps was one the first to use AJAX for this purpose. The best known open source alternative is OpenLayers. There are others of both kinds like MapBuilder and Yahoo Maps using AJAX. OpenLayers use Openstreetmap following OGC standards, or can use map data from Google Maps, Yahoo Maps and more. Both Google Maps API and OpenLayers operate with a HTML code calling JavaScript’s, and both Google Maps and OpenLayers enables a map, add zoom and panning tools and the possibilities of adding layers to show trails i.e. from a GPS on the map (Davies 2007). Google Maps is restricted to Google s own maps (three kinds) but OpenLayers can import any data from sources using

OGC standards like WMS. Google Maps (and Google Earth) does not have open WMS servers to collect data from due to limitations in distribution rights. The two map clients have a lot in common, but also some differences which can decide what to use. OpenLayers has more options for alternative map import but are slower in rendering because it uses WMS calls. Google Maps are faster. This is partly due to showing (small) tiles directly (Davies 2007) and superb database management which Google is exceptionally good at (Balstrøm et. al. 2010).

Web mapping portals or web pages with interactive or static maps are common on the World Wide Web (WWW). Their aim is to present spatial or geographic information in form of maps. The maps can be arranged in separate layers to accommodate different kinds of data viewing. Adding to these functions different kinds of map viewing tools and drawing functions are also used. Very often these portals are integrated in larger web sites as support to government functions, local municipalities or other relevant purposes, including access controlled editing facilities.

Map data can be either a scanned paper map or a raster depiction of vector data. The latter are becoming the most common map form. This is mainly due to the fact that paper maps are becoming less used and the fact that vector based raster map is much less in size thus contribution to a faster load of the map image on the web page. Vector data are also used but mainly to support functions server side in the map like route calculations or feature attribute handling like addresses.

4.7.1 MashUps

The term MashUp is borrowed from the music world but describes a product mixed with elements from different sources. Like a dish in the pot web mapping portals are often based on a combination of data from different sources.

“Others, such as remix and mashup, have more recently arisen in the context of discussions around Web 2.0 to apply to the combination of data from disparate sources, often via the use of XML and XML web services. In some ways, mashups has won out as the term to refer to web interfaces and applications that combine content into something new, whereas the term remix is generally about reusing media while still having broader usage (as in remix culture).” (Yee 2008)

To produce a web portal with one layer from Google Maps, one from open street map and a vector layer is a typically MashUp.

4.8 Summary

This concludes the description of the basic components in Internet GIS and related concepts and functions. It is obvious that this area have many concepts and definitions, and that the implementation of networking and computerized GIS have many aspects and approaches.

The internet network provides the base for exchanging data between clients and servers representing users and suppliers. To ensure interoperality in this network, standards are applied by ISO, and with reference to exchange over the Internet, by OGC.

The Web 2.0 methods and evolving GIS distribution methods now presents the elements for a web based service to collect and share spatial data. Such services are already well established and integrated.

5 - Inventory of surveyed Danish lakes

A database with metadata for surveyed lakes in Denmark was assembled using published and unpublished material. Only lakes found within the coastline are included, and only the latest surveying or mapping effort is included. In recent years, many new lakes are formed as part of environmental efforts. The bathymetry of these mostly shallow lakes, are known beforehand as dry land surface. These lakes are not included in the inventory, even if a map is published; however they will appear among data in Kort10. Some areas belonging to the nautical area are not mapped as a nautical chart, but have been surveyed independently. This is typically brackish shallow back waters, with little or no surface traffic. These are not included in the inventory, as they lie outside the coastline. Rivers and canals are not included, as they are not subject for surveying, unless they are a part of a lake in which case they appear on the maps.

5.1 Danish lakes

The lake theme from Kort10 (Hydro/soe) was used as reference. Denmark has approx 140.000 lakes within the coastline, with a surface size over 100 m2. The size 100 m2 is considered the minimum for a still standing water body to be considered a lake (KMS 2001.), unless special interest applies. The vector data consists of polygons covering the water surface area as seen from aerial photos (KMS 2001). This theme is not entirely precise as the shoreline of a water body may be obscured by trees.

Size of lakes	Total number	%	Total area (ha)	%
<100m2	1.284	1	83	0
100m2 < 1000m2	97.879	70	3.917	6
1000m2 < 1 ha	37.229	27	9.707	15
1 ha < 10 ha	3.497	2	8.331	13
>= 10 ha	404	0	41.793	66
All lakes	**140.293**	**100**	**63.831**	**100**

Table 5.1 Distribution of Danish lakes measured in size

Every bathymetric lake map refers to the lake by name. Far from all lakes have names especially the smaller ones, but surveyed lakes has names or been given names. Those names official recognized are a part of the vector data in Kort10/FOT. The vector data “lakes” was combined with the vector data “Names” (“Navne”) also from Kort10, in order to attach a name attribute. In al approx 1200 lakes were found to have a name in the vector data theme. To this number must be added an unknown quantity of park areas, containing one or more lakes not separately named. When investigated it is very obvious that the “name” theme in the vector data set badly needs an update, as many well known named surface water areas are missing.

Geometry problems arise when contributing name attributes to lakes as the two themes do not match. This occurs when a larger lake surface covers two or more named polygons. In some cases a physically long lake are separated in two by names (like Stilling and Solbjerg). In other cases two independent lakes are connected trough a surface area which actually is a moving water body, and not a lake (Like Julsø connected to Borresø via the river Guden). In those cases the surface areas were split to fit names, or as in the case with Solbjerg and Stilling Lake, the names were combined into one if used in this way on the bathymetric map.

5.2 Sources about surveyed lakes

Sources about surveyed lakes in Denmark are scattered. However we do have some very good sources. The basic reference is a list over lake maps at KMS (KMS 2007), that contains maps made by KMS, and maps made by Thorkild Høy. On this list each map is identified by a reference number, the name of the lake, the map scale and in some cases the year. In the six volume books "Danmark's Søer" (Høy et al.), many lakes are described in detail. However this very detailed work does not cover all of Denmark yet. Before this work was undertaken, Thorkild Høy made a list with known surveyed lakes at the time (Høy 1987).

Many lakes were surveyed for the first or second time, in connection with environmental reports ordered by local authorities. Some of this work was done by Thorkild Høy, but many were done by firms like BioConsult who's specialized in environmental projects. These lakes are mentioned some times in "Danmarks Søer", but most often references were found in library databases and articles. Finally some lakes are surveyed by private persons or by municipalities, and only by chance has come to this works attention.

Bathymetric lake surveys have been done with very different methods, and hence the data will vary a lot in quality and density. This does not imply that the maps are bad, but only that data quality comparisons to i.e. data made within IHO standards is impossible. Most of these maps were made when "any map is better than no map", and before efforts were made to standardize data and methods. Furthermore metadata is missing in many cases. It is in general, very difficult to asses the quality of the maps, even if they seem of sufficient standard. For this reason, and because no standard is decided for Danish lake surveying, any survey or map regardless of quality and standard, are included.

5.2.1 The database

The database was made in ArcGis as a point data layer. Spatial data were kept in UTM 32N ETRS89 (EPSG: 25832). The name is the local name as found in the name theme in Kort10 or used on the map.

Metadata

Shape	Geometry	point data
Name	Name from Kort10 or name used on printed map	String
Area	Area in hectares	Double
LON	Longitude in UTM 32N ETRS	Integer (6)
LAT	Latitude in UTM 32N ETRS	Integer (7)
Data type	Description of data	String
Map_scale	Scale of printed map	Integer (5)
Vert_DNN	Water level in DNN*	Double
Method (Code)	Method in surveying	Integer (1)
SurveyMeth	The survey method used (3 values)	String
Surveyor	Name of surveyor	String
Year	Year of latest surveying	Integer (4)
Age_2011	The age of the surveying	Integer (2)
KMS_map_archive	Map archive reference at KMS	String
Reference	The best reference for data	String

**DNN=Dansk Normal Nul (Old Danish national altitude reference)*

5.3 The result

The total number of surveyed lakes in Denmark is relatively low only 322 out of 140.000. If only lakes larger than 1 ha is considered it is still only 7% of the total number. However if the size of the lakes are compared, 46% beneath the total surface area is surveyed. Most lakes surveyed has a surface area of 10 ha and larger. This suggests that the surveying efforts have been aimed at the most dominant lakes in the landscape. The total number of bathymetric lake maps is larger than the inventory suggest due to remapping of lakes, as Lake Furesø which has been mapped three (3) times since 1912.

Size of lakes	Surveyed	Surveyed area (ha)
<100m2	0	-
100m2 < 1000m2	0	-
1000m2 < 1 ha	4	2
1 ha < 10 ha	104	530
>= 10 ha	214	31.430
All lakes >= 100 m2	**322**	**31.962**

Table 5.2 Numbers and size of surveyed Danish lakes

5.4 The timeline

Most Danish lake surveying was done 1912-2010. There are few examples of earlier works (Høy 1987). The history suggests that the surveying were done in three periods. First period before 1961 when KMS (Then "Generalstabens Topografiske Afdeling" & "Geodætisk Institut" (from 1928-1978)) (Sørensen 1978), undertook surveying in 1912 and 1929-34. The second period 1961-1996, was dominated by Thorkild Høy's surveying, and the third period up till today. The oldest maps from 1912 are later replaced by newer maps, and do not appear in the final database.

Period	Number	%
1929 - 1957	26	8
1957 - 1996	287	89
1997 - 2010	9	3
Total	**322**	**100**

Tabel 5.3 Distribution per period

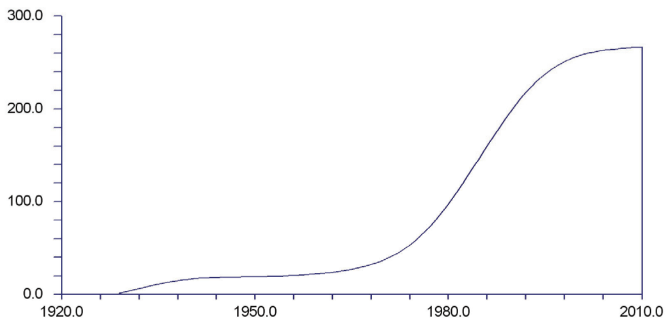


Figure 5.1 Cumulative distribution

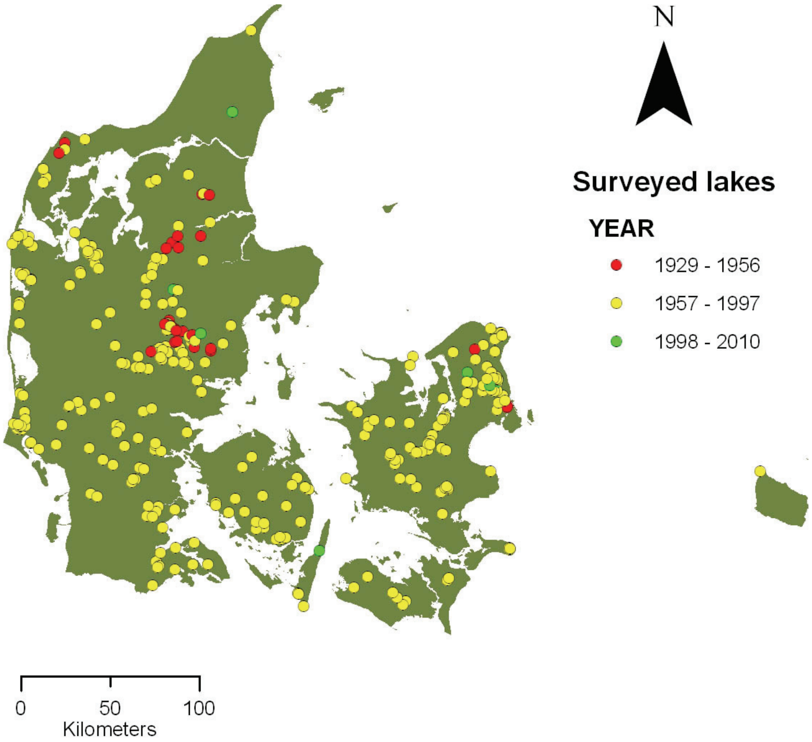


Figure 5.2 Year of latest surveying

The geographical distribution of the maps shows that the surveying 1929-1956 was done mainly in Jutland, while the later surveying seems to be distributed evenly. In fact all of the lakes surveyed by Geodætisk Institut 1929-1934 are in Jutland. On average the maps are 32 years old, and the average surveying per ha is 36 years old.

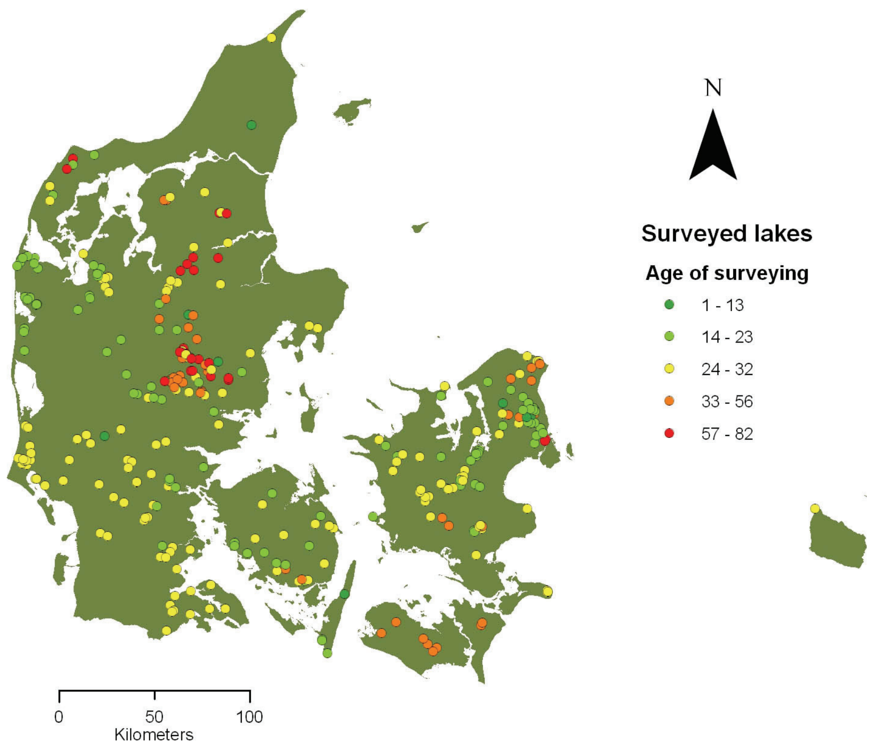


Figure 5.3 Age of latest surveying

5.5 Methods used for surveying

The method used for each map, were established when possible, from a description of the surveying. It was not always possible to find data about the method used, or indeed if and how data were checked. Most were surveyed with typical techniques given the period. The surveying effort in 1912 was the first done with relatively modern techniques, undoubtedly inspired by the surveying project in Scottish Lochs (Murray 1910). It is presumed that Geodætisk Institut used soundings and triangulation for all their work, as described in 1917 (Sand 1917). This method was the preferred method for any bathymetric fresh water survey at the time (Hare 2008). The surveyor best at describing methods is without doubt Thorkild Høy (Høy 1962). Thorkild Høy starting with soundings (often from the ice), but developed his transect method with echo sounder, and surveyed many lakes until 1997. There is a large number coded with an unknown method. The majority of these are surveying were done by BioConsult. The fact that the method in unknown, is not an indication of lesser quality, but merely that the methods BioConsult used, yet has to be published.

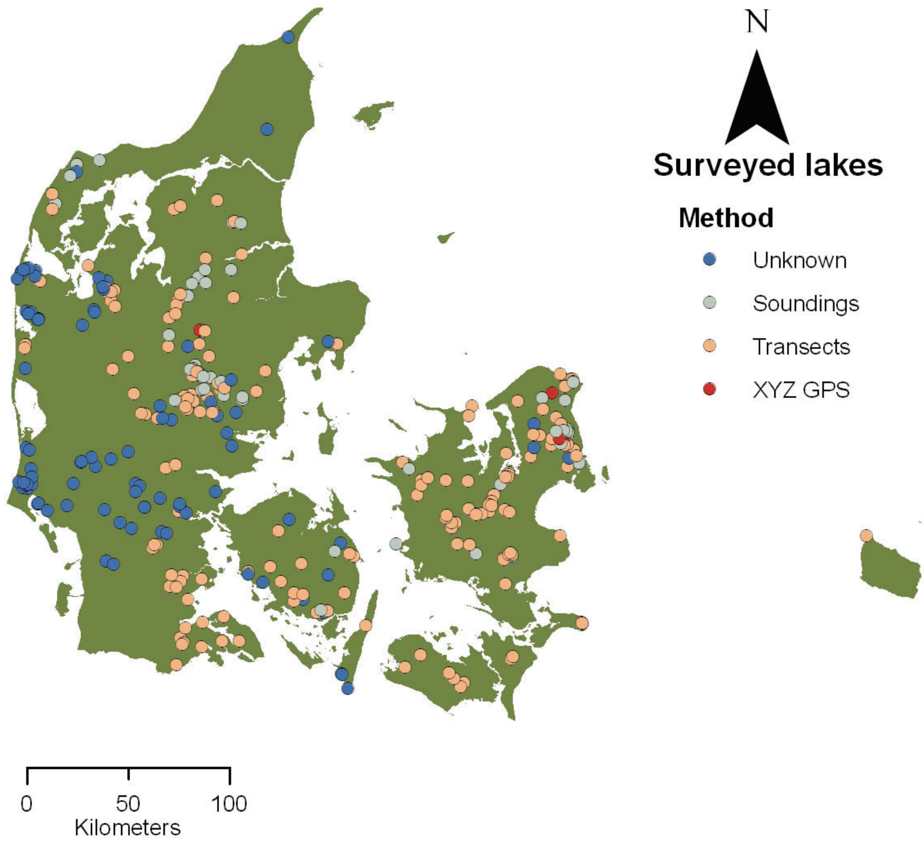


Figure 5.4 Method used for surveying

Code	**0**	**1**	**2**	**3**
Method	"Unknown Method"	"Grid Survey (Soundings)"	"Transect Survey"	"XYZ Point Survey"
Description	Unknown Method	Soundings (lead & line) from boat or ice + triangulations	Positioned single beam echo sounder transects	(Single beam) Echo sounding with GPS or radio positions
Total number	93	50	175	4

Table 5.4 Method used for surveying

From table 6 it is evident that the majority of Danish lake surveying is done by relative primitive methods or with an unknown method.

5.6 Published data types

The majority of the lake maps (321) are printed maps. They contain depth contours, spot depths, names for features both under water and on land, structures like harbours etc., and in some cases vegetation. The spatial reference on elder maps from Geodætisk Institut is local points with height, and a reference to which topographic map they were drawn upon, and a single geographical position. The maps contain some objects from it (like roads and buildings), and have a surface water level measured to DNN (Dansk Normal Nul). Thorkild Høys maps contain only some structures like roads (not to scale), streams and buildings which properly served as fix points. On some later maps a geographical grid were printed as well. None of the printed maps contain data indicating data density, or any other form of data suitable for quality assessment.

5.7 Summary

From the inventory it is evident that only a part of Danish lakes have been surveyed. Most of the surveying was done with methods now considered obsolete producing data with low density and low horizontal precision. None were done for navigation, or to IHO specifications. The average age of the surveying is over 30 years, and a large portion is much older. Nearly all maps are published as printed maps.

The database containing all surveyed lakes contains data mostly available through standard sources like libraries, books, environmental reports etc. Some private data is also included. As this data is the first of its kind, it must be assumed that data is far from complete.

The database contains data about every surveying including, year, method, surveyor and most important source to this data.

In all 322 different lakes have been surveyed. They cover 50% of the total areas covered by lakes. The number of lakes in Denmark is approx 140.000 but the area distribution is very uneven. Approx 53% of the lakes larger that 10 hectares are surveyed.

The geographic distribution is fairly even. Most significant Danish lakes have been surveyed regardless of location. The lake surveying effort 1929-1934 by Geodætisk Institut was located in Jutland, including very remote locations. At the time several major lakes on Sjaelland were already surveyed earlier (Lake Furesoe, Lyngby and Bagsværd in 1912), and maybe this mapping effort was an attempt to rectify the lack of mapping in Jutland.

When Thorkild Høy picked up in the 50'ties, nearly every part of the country was included, and during the last period many lakes were surveyed in conjunction with environmental tasks.

There are two major problems with the lake surveying. The first is the methods used. Apart from the undocumented cases, most lakes were surveyed with old methods properly not adequate. And if they were subject to a further analysis it is probable, that new surveys are necessary. The second problem is the documentation. In most cases we know the method or has a idea what is was, but in order to validate data much more is needed, like transects positions, data density in general, equipment used, post processing methods etc.

6 – Depth data from consumer echo sounders

In order to use depth data from consumer echo sounders, a method of extracting data is needed, and both the nominal and the actual vertical accuracy has to be determined.

6.1 Professional and consumer single beam echo sounders

This comparison outlines the main differences between a professional and a consumer grade echo sounder. The characteristics based on manuals, user guides and articles

Single beam echo sounders and GPS setups, provides depth with positions. This kind of data is also labelled "xyz" data. It is xyz data from consumer products that is the potential alternative data source to xyz data from professional setups.

It is important to distinguish between surveying single beams echo sounders, and the rest which are aimed at locating fish, as much as warning the navigator about hazards. For this comparison only professional surveying echo sounders are included when compared to consumer equipment.

Functions (Selected only)	**Professional echo sounders**	**Consumer echo sounder**
Correction for sound velocity in water	Yes. Value added to data during recording, or in post processing.	No. The units uses one or two unknown constants*
Depth resolution, accuracy 50 kHz (digital output)	10 cm or 0.1 feet + 1% depth	10 cm or 0.1 feet
Depth resolution, accuracy 200 kHz (digital output)	1 cm or 0.1 feet + 1% depth	10 cm or 0.1 feet
Sounding rate (ping speed)	20-40 / sec	1-30/sec
Frequencies (for typical surveying)	50 – 200 kHz	50 – 200 kHz
Transducer beam cone	1-40 degrees	10-40 degrees (typically)
Depth Range (shallow water)	0,5 – 200 meters	0,5 – 200 meters
Pulse lengths	Yes	No
Gyro corrections	Yes	No
Complies to ISO standard 4366	Yes	No

Table 6.1 Differences between professional and consumer echo sounders (Hydro International 2009, Garmin 2011).

In this table some key features are compared. The difference between the two kinds of instruments is significant, and it is evident that consumer products are not capable of the same as professional units. While professional instruments have very detailed specifications, and of course several more functions, consumer instruments has very few specifications. Consumer echo sounders are not built to ISO standards. They perform as "black boxes" delivering info about fish, bottom, thermocline, weed and bottom structures. The consumer products vendors are omitting information on purpose, as they do not apparently do not want their products to be compared with professional products.

6.2 Corrections for Sound velocity in water

When surveying with echo sounders it is vital for accuracy to adjust the data with the correct speed of sound. This can be done during surveying or as part of the post processing. The most important and obvious fault in consumer products, is the lack of adjusting echo sounder readings with the correct velocity of sound, and the fact that their depth calculations uses an unknown sound velocity. This will result in substantial errors, if the used sound velocity differs significant from the true one. Several requests have been made to the vendors for this information but to no avail (Humminbird 2011). The closest to an adaptive approach, is from one Garmin Unit (GPSmap 178c) using an elder setup, which allows the user to select between salt or fresh water in echo sounder setup menu. The company Lowrance mentioned a sound velocity of 4800 feet pr second in their tutorial, and this is accepted as the used velocity in one case (Childs et al 2003). It is to be expected that a standard value of 1500 m/s, as often referred to a standard speed in saltwater, will be used unless otherwise stated (USGS). If an echo sounder using 1500 m/s as the constant measures the depth in freshwater at 20 meters depth, and the water temperature is around 8 C which calculates to about 1440 m/s, then the resulting error in depth would be around 4% or 0.8 meters i.e. the echo sounder would show a depth of 20.8 meters.

6.3 Vertical accuracy

As with sound velocity the vertical accuracy is not among the specifications. The nominal accuracy is 0.1 meters or feet. This does not tell any about the true capabilities of the instruments. A standard consumer transducer operates at 200 kHz or 50 and 200 kHz, or 83 and 200 kHz. The double frequency ensures better penetration through plants etc, and thus gives a stronger bottom reading.

6.4 Horizontal accuracy

As consumer GPS products have accuracy between 3 – 5 meters (Garmin 2011, Thorton 2011), this issue is not a big problem comparing to the horizontal standards from IHO (5 meters for order 1b). As the geographical position on a lake with open access to the sky minimize GPS faults as multi path or obstructions, it would be fair to assume that consumer GPS units perform adequate for general lake surveying.

6.5 Latency

The echo sounder is an independent unit delivering a depth. The position attached to it (or the depth attached to the position) is generated outside. However many consumer products have both echo sounder and GPS in the same unit which is very handy. The latency time is unknown. The latency time is a well known problem in professional setups, where a network with a separate GPS (typically) and echo sounder has to deliver coherent positions and depths. There is no reference to which depth or position that is linked to one another in consumer products. It must be assumed that when logged data is GPS based (track settings are controlled by settings relevant to the GPS), the instrument collects the latest depth from the echo sounder when a position is calculated.

6.6 Data formats in consumer echo sounder / GPS products

GPS data in consumer units are basically a combination of points (waypoints and track points), lines (routes or tracks), and attribute data dependent on the sensor or sensors attached. As a rule every GPS instrument vendor such as Garmin, use a proprietary data format for GPS data. The product lines of combined GPS and single beam echo sounders, all offers possibilities of logging positions and coherent depths. To overcome difficulties when exchanging GPS data, the open format GPX where developed.

GPX is a light-weight XML data format for the interchange of GPS data (waypoints, routes, and tracks) between applications and Web services on the Internet. It is developed by Topografix and open for variants using its xml structure. The GPX format uses a fixed geographical system and uses the GPS systems native datum WGS84. Present GPX version is 1.1 (Topografix) The GPX (XML) format use extensions called "children" for attribute data (Topografix.com). There are in theory no limitations for adding extensions to the GPX format, and therefore it is a very potent format for exchanging GPS data with attribute data. Garmin uses this feature in GPS data from marine units with echo sounder attached (Garmin), and to assign special values to waypoints etc. and for other GPS units. From the schema, measured temperature (in degrees Centigrade) and depth (in metres) are present in the data. Note that the units for attribute data are not included in the GPX data.

6.7 Parsing GPS data with attributes from Garmin units

Garmin stores the depth reading in the track log in the memory, along with GPS positions, waypoints and routes. The track-log interval can be set to 1 second corresponding to best GPS update interval. The track-log must not be manually saved as a track in the memory of the unit before transfer of data from the GPS, as this will generalize the track and remove the coordination between positions and depths.

The propriety data format used in Garmin marine units differs. In elder units the GPS data is transferred from the GPS/Echo sounder to a Garmin memory card, which content is transferred to the MapSource program via a Garmin card reader. On newer units the GPS data is saved in a closed *.adm format on a standard SD memory chip, from which MapSource can import the file and save it in Garmin's proprietary *.gdb format.

The track-log data is imported into Garmin software MapSource (Garmin 2011), from where it is exported in GPX format (Garmin GPX schema), containing the depth and temperature data in the track segments. Waypoints, routes, track points without depth and erroneous data can be removed before export. The keel offset and the transducer frequency are not included in the track-log depth data and must be recorded manually. If the transducer is capable of recording the temperature, this data is included in the track data points.

The MapSource program offers export in some open formats: *.txt, *.dxf and *.gpx. In *.dxf format, the depth data is exported with one decimal. In *.gpx the whole value is exported. This makes gpx export option somewhat better.

The final task is to extract the depth and positions using a GPX (XML) parser. Garmin does not offer a GPX parser to extract coherent positions and attribute data. The nearest option is to export data in DXF format using decimetre (one tenth of a foot).

The open source GPS Babel can convert Garmin to GPX data formats, including attribute data such as depth. It has however not been possible to extract xyz data suited for a further interpolation process.

This leaves the data harvesting process in need of a suitable GPX/XML parser.

6.7.1 ArcGis Toolbox GPX python parser

The ArcGis (9.31) native parser delivers a ArcGis database with metadata (area covered), tracks (polyline) and waypoints (point). However ArcGis falls short with GPX files with marine data attributes (Garmin schema v3). Tracks and waypoints are imported, but attribute data, such as depth is left out. Data from ordinary GPX files with elevations are not processed completely, as only elevation data in waypoints are parsed, not the elevation data in track points.

```
<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<gpx xmlns="http://www.topografix.com/GPX/1/1" creator="MapSource 6.13.7" version="1.1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.garmin.com/xmlschemas/GpxExtensions/v3
http://www.garmin.com/xmlschemas/GpxExtensions/v3/GpxExtensionsv3.xsd http://www.topografix.com/GPX/1/1
http://www.topografix.com/GPX/1/1/gpx.xsd">
  <metadata>
    <link href="http://www.garmin.com">
      <text>Garmin International</text>
    </link>
    <time>2009-12-28T13:28:48Z</time>
    <bounds maxlat="55.8055544" maxlon="12.4268987" minlat="55.7940275" minlon="12.4186774"/>
  </metadata>
  <trk>
    <name>ACTIVE LOG</name>
    <extensions>
      <gpxx:TrackExtension xmlns:gpxx="http://www.garmin.com/xmlschemas/GpxExtensions/v3">
        <gpxx:DisplayColor>DarkMagenta</gpxx:DisplayColor>
      </gpxx:TrackExtension>
    </extensions>
    <trkseg>
      <trkpt lat="55.7942407" lon="12.4192351">
        <time>2009-08-05T06:23:55Z</time>
        <extensions>
          <gpxx:TrackPointExtension xmlns:gpxx="http://www.garmin.com/xmlschemas/GpxExtensions/v3">
            <gpxx:Temperature>19.3221340</gpxx:Temperature>
            <gpxx:Depth>17.6810532</gpxx:Depth>
          </gpxx:TrackPointExtension>
        </extensions>
      </trkpt>
```

Figure 6.1 Example of Garmin GPX from a GPS with echo sounder

To be able to extract the positions and attribute point data, a xml parser were written in Python and implemented in a ArcGis Toolbox (Vedel 2011). The python script for parsing GPX files, are relative simple. They are "event" type parsers searching the xml file for tags of different kinds, and using the fact that the gpx format uses a fixed spatial system and datum (LatLon & WGS84) from the GPS data. The parsers were based on a script found at ESRI (GPS to layer 2010). The extracted elements are used to create a shape point file. The parsed GPX file is used in the script to create a shape point geometry. As the GPX file consist of several elements like waypoints, tracks and routes, each parser has to handle only one of these elements. The first version of this parser included five variants:

1. Parse track points in gpx file with elevation attribute (standard GPS).
2. Parse waypoints in gpx file with elevation attribute (standard GPS).
3. Parse track points in gpx file with depth attributes (marine "combi" GPS).
4. Parse track points in gpx file with depth and temperature attributes (marine "combi" GPS).
5. Parse waypoints in gpx file with depth and temperature attributes (marine "combi" GPS).

The reason for including GPX file types (defined by its schema) from standard units, is that marine GPX files (Garmin Schema v.3) when processed outside Garmin MapSource software, is treated as Topografix standard GPX i.e. schema v1 applied as standard.

Before parsing, positions in the track without attribute data must be removed, as the parser will fail without attribute data. This cleansing is best done in Garmin MapSource. The shape file generated from the GPX can be used directly for interpolation, or used in post processing using standard editing tools.

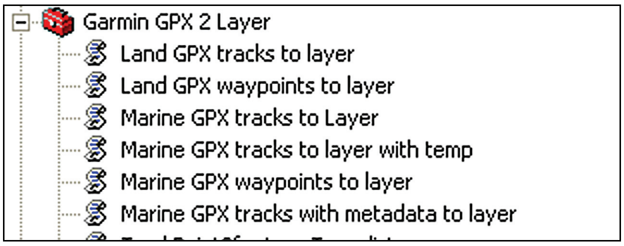


Figure 6.2 ArcGis Garmin GPX 2 Layer toolbox

As explained, the survey process using single beam echo sounder involves an array of supplemental data for necessary corrections. For practical work with marine GPX files, a revised python gpx parser was constructed to include this data. The GPX parser produces a feature class file using both the parsed elements from the GPX file and input from a GUI in ArcGis.

The extra data (which also have elements of metadata) are:

Offset	The distance from the transducer to the water surface (double).
SVC	The sound velocity constant used in the instrument (double).
Kote_DVR90	The water level during data harvesting (double).
Frequency	The frequency used in transducer (text).
Instrument	The name of the used instrument and transducer (text).
Latency	The latency in the setup (double).
Measured Temp	The temperature measured alternatively to the logged temperature

The added data and metadata will not always be available. But if they are, they will be valuable. As a value must be added or the script will fail, the instruction tells the user to add a "0" in case of no data. The whole script is listed in Appendix C.

The latency is included although this value may not be known. This is also an unknown factor when using consumer GPS/Echo sounder units. In this context the values is only included as it is a typical factor to be included in calculations or calibrating. If it is known, the value combined with the speed can give a estimate of added error to the positioning.

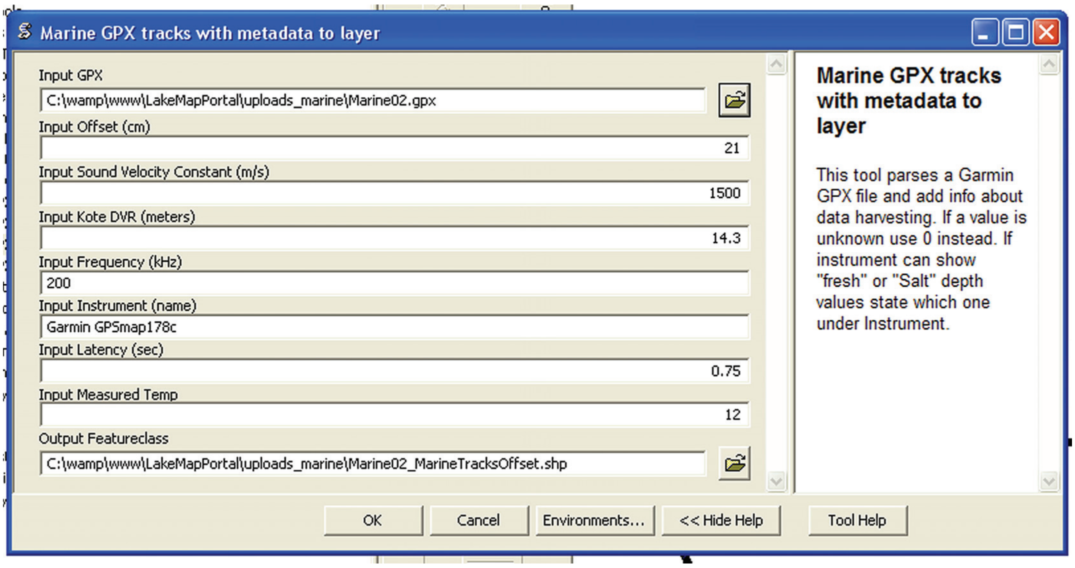
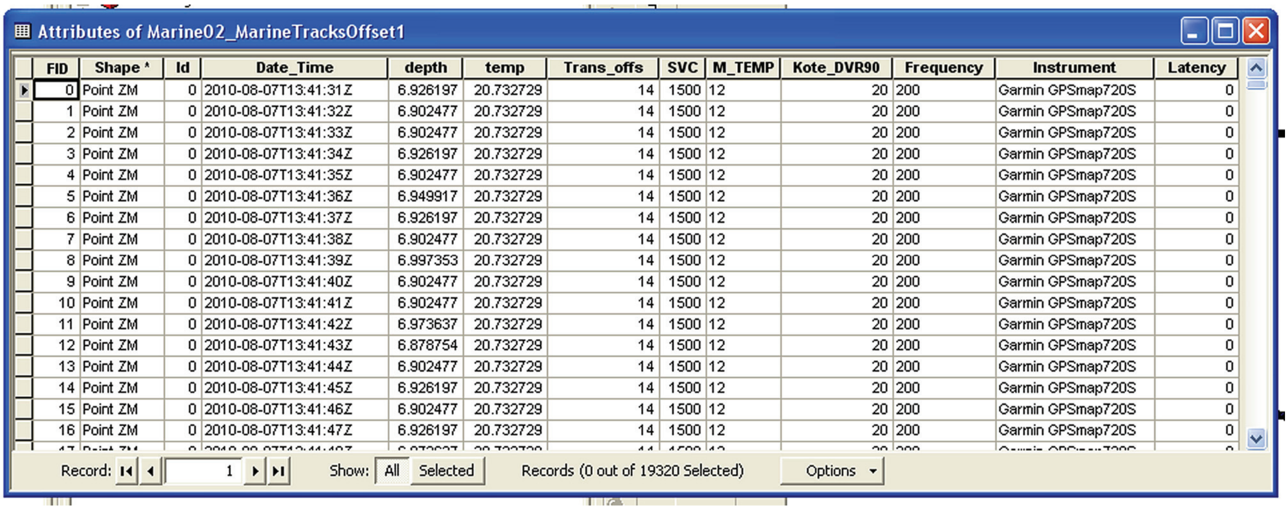


Figure 6.3 Dialog box for the new GPX parser.

The resulting shape (point geometry) now includes most of the necessary data for post processing depth data. Note that the temperature is measured by the transducer, and is therefore the surface temperature, not to be confused with a real average from the water column.


Attributes of Marine02_MarineTracksOffset1

FID	Shape *	Id	Date_Time	depth	temp	Trans_offs	SVC	M_TEMP	Kote_DVR90	Frequency	Instrument	Latency
0	Point ZM	0	2010-08-07T13:41:31Z	6.926197	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
1	Point ZM	0	2010-08-07T13:41:32Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
2	Point ZM	0	2010-08-07T13:41:33Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
3	Point ZM	0	2010-08-07T13:41:34Z	6.926197	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
4	Point ZM	0	2010-08-07T13:41:35Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
5	Point ZM	0	2010-08-07T13:41:36Z	6.949917	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
6	Point ZM	0	2010-08-07T13:41:37Z	6.926197	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
7	Point ZM	0	2010-08-07T13:41:38Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
8	Point ZM	0	2010-08-07T13:41:39Z	6.997353	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
9	Point ZM	0	2010-08-07T13:41:40Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
10	Point ZM	0	2010-08-07T13:41:41Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
11	Point ZM	0	2010-08-07T13:41:42Z	6.973637	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
12	Point ZM	0	2010-08-07T13:41:43Z	6.878754	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
13	Point ZM	0	2010-08-07T13:41:44Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
14	Point ZM	0	2010-08-07T13:41:45Z	6.926197	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
15	Point ZM	0	2010-08-07T13:41:46Z	6.902477	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0
16	Point ZM	0	2010-08-07T13:41:47Z	6.926197	20.732729	14	1500	12	20	200	Garmin GPSmap720S	0

Record: 1 Show: All Selected Records (0 out of 19320 Selected) Options

Figure 6.4 The attribute data for a GPX file

6.8 The nominal vertical accuracy in two consumer units

With the GPX parser, the raw depth readings can be extracted. On problem when assessing the quality of these, is the nominal accuracy. The reading on the echo sounder is in 0.1 meter or feet, but the internal one is unknown. As the parser extracts depth with all decimals, a simple experiment was set up using a large 120 litres water container. The depth was fixed (at approx 75 cm) and data tracks recorded. Two “combi” instruments were used: A Garmin GPSmap178c from 2004, and a Garmin GPSmap 720s from 2010. Both operate with dual frequency transducer. Both were set to record the depth at 200 kHz. A part of the track log was parsed, and the recorded depths investigated. As the depth was fixed, only errors in echoes, small deviations in water temperature and random errors would influence on the result. Therefore it would be possible to se alterations in the recorded depth by its smallest measure, and therefore show the internal nominal accuracy. The parsed depth recordings were analyzed in frequency tables. The data is presented in Appendix H. The smallest deviation was a constant and was:

Garmin GPSmap 178c: 0.976753235 cm

Garmin GPSmap 720s: 2.371978760 cm

The theoretical accuracy of a 200 kHz sound pulse is approx 1 cm (varies with sound velocity) (Lurton 2002). It seems that the elder GPSmap178c is constructed with this in mind.

Some further testing was also done to see the influence of different water temperature hence the sound velocity, but results were inclusive, properly due to back scatter error in data, and the fact that the internal accuracy is very large in comparison with the theoretical influence on the recorded depth. At best approx 5% deviation could be expected which is 3.5 cm of the fixed depth of 75 cm.

6.9 Vertical accuracy and sound velocity in two consumer units

A test to ascertain the actual vertical accuracy, was conducted using the bar check principle. The test included a physical test in a stable boat and echo sounders.

6.9.1 Test hypothesis

The hypotheses is that the consumer instruments used one or two constants for sound velocity in water for their calculations, and that the difference in actual depth and the measured depth by the echo sounder can be zeroed, when corrected with an estimate for the actual sound velocity given the temperature and the offset between the transducer and surface water level.

Depth corrected to referenced water surface: **d** = **1/2** x V x **t** + **k** + **dr** **(USACE)**

Where: d = corrected depth from reference water surface
v = average velocity of sound ("c" is used elsewhere) in the water column
t = measured elapsed time from transducer to bottom and back
k = system index constant
dr = distance from reference water surface to transducer

In this experiment "dr" is set to the distance from transducer to actual water surface, as the purpose is to control the echo sounder not to produce a referenced depth value. The value "d" is known by measure. K is set to nil. The depth logged in the echo sounder is "**1/2** x V x **t".** It follows that the difference between the actual depth and the recorded depth can be explained by the difference in used sound velocity in calculations versus the real value given that the transducer works correctly ("t" is correct). This implies that the difference in measured depth reflects the actual average sound velocity given the one used in calculations is known, or that an estimate of the actual average sound velocity based on temperature readings, can be used to correct the data given a hypothesis about the sound velocity used in calculations.

6.9.2 Control against IHO vertical standards

If the result seems to be within IHO specifications for vertical accuracy (IHO S-44), the data from consumer echo sounders will in theory be useable in surveys to IHO specifications. To calculate the allowable errors the formula [o

Order	Special	1a	1b
Description of areas.	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.
Maximum allowable TVU 95% *Confidence level*	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013

Table 6.2 IHO S-44 (IHO [2] 2008)

6.9.3 Test setup

In order to establish the constant for sound velocity used in the echo sounder, four test areas were selected. The areas were known beforehand to have a relatively flat lakebed, so sideways movement due to current and wind would only marginally influence the position of the anchored boat. Given the exact depth can be measured with a measuring tape and a flat bottom weight, corresponding depth measurements done by echo sounder must show the same values when corrected for transducer offset, unless the sound velocity used in the calculations differ from the actual one. A 2.8 kilo gram 24 cm diameter flat disc was molded in concrete. The disc shape was chosen to prevent penetrating into the mud. Two echo sounders (with GPS) and two transducers were used. Both transducers are double 50/200 kHz frequency with temperature sensor. Both were only used at 200 kHz.

UTM 32N ETRS 89 centroids	Lon	Lat	Foot print diameter Garmin (10°)	Foot print diameter Airmar (11°)
Area 1 - 11 meters depth	714169	6190067	1,9 meters	2,1 meters
Area 2 – 11 meters depth	714444	6189995	1,9 meters	2,1 meters
Area 3 – 15 meters depth	714265	6189772	2,6 meters	2,9 meters
Area 4 – 19 meters depth	714582	6189533	3,3 meters	3,7 meters

Table 6.3 Test areas and coverage on lake bed

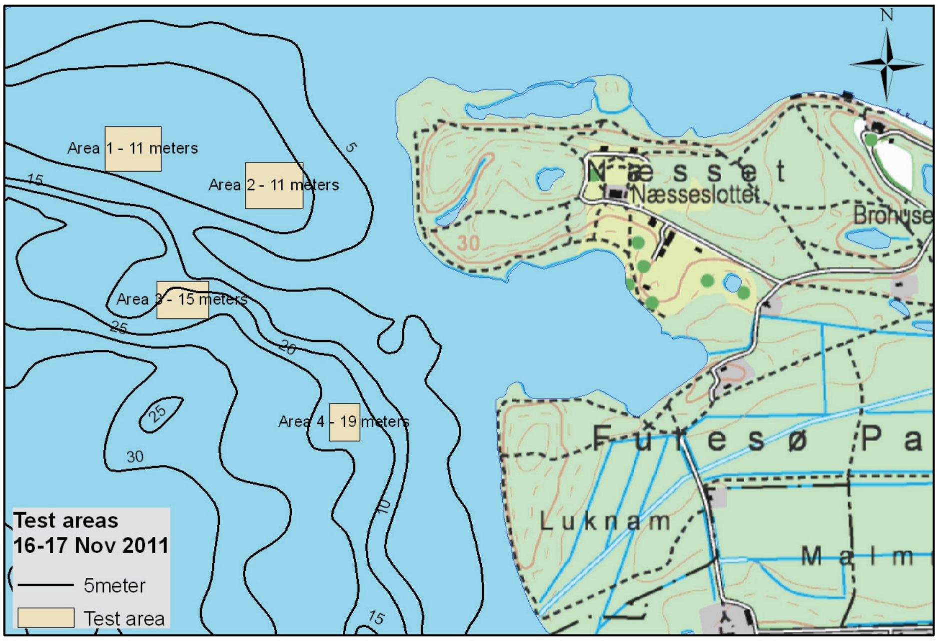


Figure 6.5 Test areas Lake Furesoe (KMS Kort25 & depth data from Thomas Vedel)

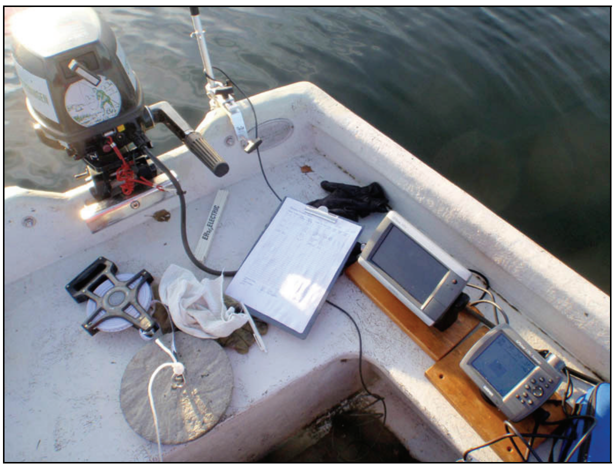


Figure 6.6 The setup in the boat with the GPS/Echo sounder and a transom mounted transducer (Vedel 2011).

The concrete disc would be lowered down just inside the cone, controlled by a solid rope, and the measuring tape would be used when the disc had settled on the bottom. Depth measurements were taken at the start and the end of each data logging. The distance from the center of foot print to the disc, was between 1 and 1.5 meters. The boat however did not remain at the exact same spot, due to light wind and current. The depth was recorded during the whole test and an average depth value used.

The temperature was recorded automatically in the data. In some cases the transducer was lowered down as far as the wire would go (approx 9 meters), and the local temperature was recorded.

6.9.4 Specification of corrections

Concrete disc: The distance from the inside of the loop eye on the disc underside is 7.5 cm. If the disc settles it self 1.5 cm into the lake bed, 6 cm has to be added to the tape measured depth. There was no indication that the disc settled very low in the mud, as no traces of mud were found on the topside of the disc. The top side being very rough would have retained mud if it were so. During test small waves influenced the reading by +/- 1 cm.

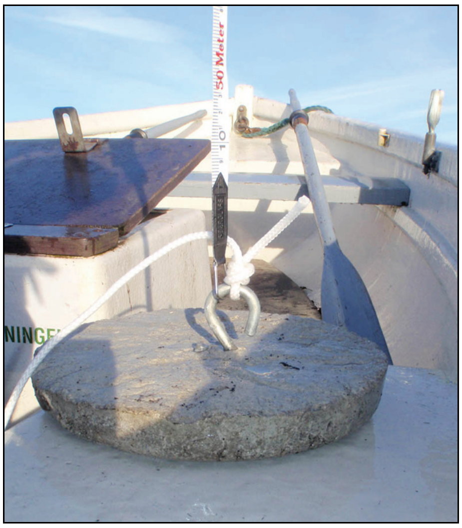


Figure 6.7 The concrete disc (Vedel)

The measuring tape: The tape it self is non elastic. The tape was checked against other yardsticks. The inside of the end ring is nil cm.

The boat: The boat was a 14 feet “Eivind” dingy. Made as a life boat it is very stable. Displacement due to a person working over the side was negligible as it did not influence the tape measuring, and only shortly could influence the echo reading.

Transducer transom mount: Two transducers were used, each mounted on a stick and placed abaft (transom). Garmin Airmar P66 transducer had 28 cm from the top to the surface and is 4.7 cm high. It is assumed that that the average transducer sends and receives position from approx inside center, and the correction was therefore set at 30 cm from the water surface. The standard Garmin transducer was like wise set to have a 22 cm correction.

6.9.5 Test

Tests were conducted in the 4 areas as the table shows. As it happens the Garmin GPSmap178c has two settings in the sonar setup (Fresh/Salt), and tests were done with both settings. The Garmin GPSmap720s has no such option. The tests were performed during two days and comprised of 19 tests and a number of temperature checks. Track log interval was set at 1 second, and approx 3300 depth readings were recorded. The numbers of tests in each area were determined by the conditions during 16th -17th November 2011. The plan was to coverage at least the 10 and 20 metre area with all combinations of echo sounder and transducer.

Echo sounder	Transducer (200 kHz)	Cone angle 3 db	Fresh/Salt	Area 1	Area 2	Area 3	Area 4	Tests
Garmin GPSMap178C	Garmin	10	Fresh	1	-	-	1	2
Garmin GPSMap178C	Garmin	10	Salt	1	-	-	1	2
Garmin GPSMap178C	Airmar P66	11	Fresh	1	1	1	2	5
Garmin GPSMap178C	Airmar P66	11	Salt	1	2	1	2	6
Garmin GPSmap720s	Garmin	10	n.a.	1	-	-	-	1
Garmin GPSmap720s	Airmar P66	11	n.a	1	-	1	1	3

Table 6.4 Test combinations of echo sounder, transducers and areas.

Each test track was identified and cleaned in Garmin MapSource application. Then saved in GPX format, and parsed in ArcGis with GPS2Layer toolbox. Mean and standard deviation for depth data was calculated for each data set.

6.9.6 Test results

Air temperature was near zero both days. This resulted in a long “warming” period for the temperature sensors inside the transducers, which made some temperature data doubtful. Lake Furesoe is very large and deep, and tests were conducted in different areas. The water temperature can not be expected to be homogeneous in all parts of such a big lake. However average values of sensor data from submerged transducers gave following average results:

Garmin GPSmap178c sensor data: 8.72°C
Garmin GPSmap720s sensor data: 7.59°C.
The average (both transducers) is 8.16°C

An alternative instrument, a Lowrance HDS sounder was used as control, and it produced a temperature of 7.94°C. The Lowrance transducer is much thinner in material and seemed to react quickly to temperature changes.

The test settles for an average water temp of 8.1°C which corresponds to a sound velocity of approx 1440 m/s in clean water. The figure showing water temperature in Lake Furesoe on (Figure 2.10) also supports a average temperature approx 8 °C in mid November.

The test of hypothesized internal sound velocity constant was based on different sources mentioned above. During the test it quickly became obvious that Garmin GPSmap 720S used the same constant as Garmin GPSmap178C use for salt water, so only this values were included in the test.

The standard deviations all indicates stable results, and close to internal yard stick for each echo sounder.

Dataset	Unit	Setting	Area	Transducer	Average logged depth (m)	observations	Standard deviation	Transducer offset (m)	Tape measured depth (m)	Tape correction (m)
01	GPSmap720s	Standard	1	Garmin	11.868289	462	0.054012	0.22	11,36	0.06
02	GPSmap720s	Standard	1	Airmar P66	11.852702	92	0.046231	0.30	11,38	0.06
03	GPSmap720s	Standard	4	Airmar P66	19.606877	347	0.065192	0.30	18,79	0.06
04	GPSmap720s	Standard	3	Airmar P66	16.250539	349	0.066804	0.30	15,61	0.06
05	GPSmap178c	Fresh	1	Garmin	11.400504	237	0.025761	0.22	11,35	0.06
06	GPSmap178c	Fresh	4	Garmin	18.949368	112	0.03345	0.22	18,79	0.06
07	GPSmap178c	fresh	1	Airmar P66	11.372513	322	0.038411	0.30	11,38	0.06
08	GPSmap178c	fresh	4	Airmar P66	18.806706	327	0.053772	0.30	18,79	0.06
09	GPSmap178c	fresh	3	Airmar P66	15.565306	209	0.070964	0.30	15,56	0.06
10	GPSmap178c	Salt	1	Garmin	11.721894	136	0.020679	0.22	11,35	0.06
11	GPSmap178c	Salt	4	Garmin	19.480422	170	0.027277	0.22	18,79	0.06
12	GPSmap178c	Salt	1	Airmar P66	11.685909	251	0.033583	0.30	11,35	0.06
13	GPSmap178c	Salt	4	Airmar P66	19.333927	104	0.037711	0.30	18,79	0.06
14	GPSmap178c	Salt	3	Airmar P66	16.0901	64	0.022186	0.30	15,56	0.06
15	GPSmap178c	Fresh	2	Airmar P66	11.192039	144	0.021657	0.30	11,28	0.06
16	GPSmap178c	Fresh	4	Airmar P66	18.930844	608	0.041697	0.30	18,88	0.06
17	GPSmap178c	Salt	2	Airmar P66	11.52833	121	0.032182	0.30	11,28	0.06
18	GPSmap178c	Salt	2	Airmar P66	11.429613	104	0.027117	0.30	11,28	0.06
19	GPSmap178c	Salt	4	Airmar P66	19.464486	87	0.010308	0.30	18,89	0.06

Table 6.5 Test results

Unit	SVC Fresh	SVC Salt	SVC Standard	Internal vertical unit	Transducer freq	Theoretical resolution
Garmin GPSmap178C	1463 m/s	1500 m/s	n.a.	0,9 cm	200 kHz	1 cm
Garmin GPSmap720S	n.a.	n.a.	1500 m/s	2,3 cm	200 kHz	1 cm

Table 6.6 Assumed sound velocity constants

When calculating the corrected depth, the depth was corrected with 1440 m/s divided with 1463 m/s or 1440m/s divided with 1500m/s, before adding constants, thus correcting for the actual longer return period per echo.

Total uncorrected depth = Logged depth + transducer offset

Total corrected depth = [Logged depth * 1440 m/s / SVC] + transducer offset

Tape actual depth = Tape measured depth + 0.06 m

Raw error = Total uncorrected depth - Tape actual depth

Error corrected = Total corrected depth - Tape actual depth

For comparison the Maximum allowable TVU 95% confidence level in IHO S-44 were calculated. To compare the errors in the data with IHO standard, it must be assumed that the errors are normal distributed. In appendix D histograms for all 19 data set are displayed. The histograms show the depth distributions. As the actual depth is known for each dataset, the distribution pattern of the depth recordings will be the same as the errors. From the histograms it is clear that data is not normal distributed, however not scattered. Some skew ness is observed. This might be due to boat movements.

Dataset	Total uncorrected depth (m)	SVC (m/s)	Total corrected depth (m)	Tape actual depth (m)	Raw error (m)	Error corrected (m)	Relative corrected error (%)	IHO error 1a&1b (+/- m)	IHO Special (+/- m)
01	12.09	1500	11.61	11,42	0.67	0.19	1.66	0.52	0.26
02	12.15	1500	11.68	11,44	0.71	0.24	2.10	0.52	0.26
03	19.91	1500	19.12	18,85	1.06	0.27	1.43	0.56	0.29
04	16.55	1500	15.90	15,67	0.88	0.23	1.47	0.54	0.28
05	11.62	1463	11.44	11,41	0.21	0.03	0.26	0.52	0.26
06	19.17	1463	18.87	18,85	0.32	0.02	0.11	0.56	0.29
07	11.67	1463	11.49	11,44	0.23	0.05	0.44	0.52	0.26
08	19.11	1463	18.81	18,85	0.26	0.04	0.21	0.56	0.29
09	15.96	1463	15.62	15.61	0.35	0.01	0.06	0.54	0.28
10	11.94	1500	11.47	11.41	0.53	0.06	0.53	0.52	0.26
11	19.70	1500	18.92	18.85	0.85	0.07	0.37	0.56	0.29
12	11.99	1500	11.52	11.41	0.58	0.11	0.96	0.52	0.26
13	19.63	1500	18.86	18.85	0.78	0.01	0.05	0.56	0.29
14	16.39	1500	15.75	15.61	0.78	0.14	0.90	0.54	0.28
15	11.49	1463	11.32	11.34	0.15	0.02	0.18	0.52	0.26
16	19.23	1463	18.93	18.94	0.29	0.01	0.05	0.56	0.29
17	11.83	1500	11.37	11.34	0.49	0.03	0.26	0.52	0.26
18	11.73	1500	11.27	11.34	0.39	0.07	0.62	0.52	0.26
19	19.76	1500	18.99	18.95	0.81	0.04	0.21	0.56	0.29

Table 6.7 Test results with corrections

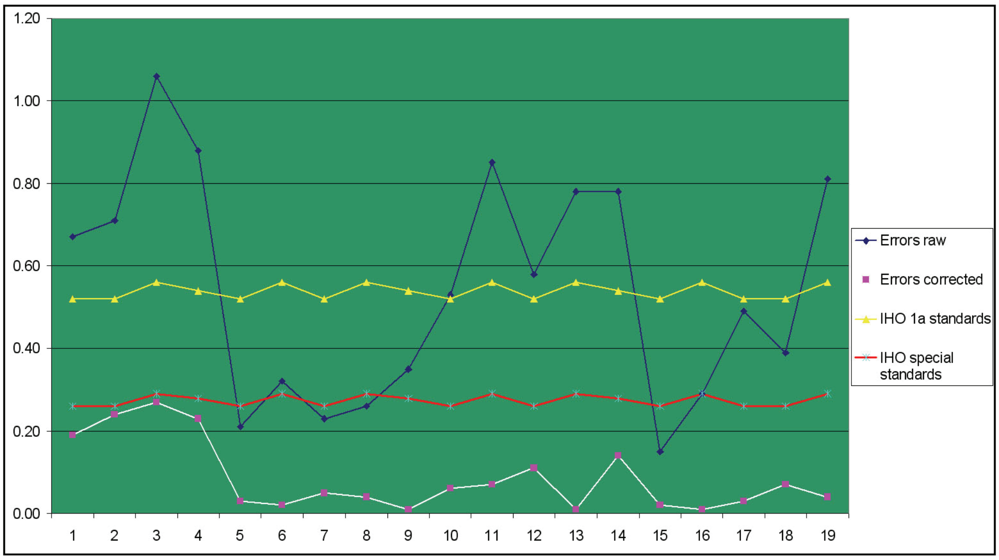


Figure 6.8 Data compared to IHO S-44 (total error per dataset)

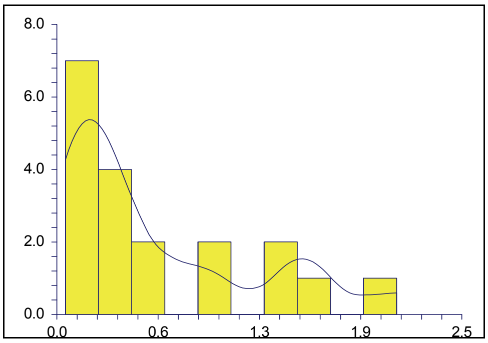


Figure 6.9 Relative corrected errors

The plot over relative corrected errors displays a distribution centred on zero thus confirming that the correction seems based on the correct hypothesis. The average relative error is 0.6%. A quality guideline states that measured depth must be with in 1% (Lurton 2002). This supports the hypothesis that the tested units use a constant for sound velocity, and that the constant is 1463 m/s or 1500 m/s depending on instrument and setting.

When comparing the two instruments used, it is clear that the Garmin GPSmap178c has a lower relative error than the Garmin GPSmap720S. Some of this difference might be explained by the higher nominal measure in the 720S. As the numbers of test with the 178c is quite larger than the number of tests with the 720S it would not be fair to exclude the 720S yet from being able to measure depth within a 1% limit.

6.10 Summary

The difference between professional and consumer echo sounders may not seem that big, but the lack of compliance to standards and the lack of documentation on the consumer parts, makes these instruments in "magical black boxes" the user either trust or don't. Any surveyor must have clear and reliable data about the instruments.

However the technology employed into consumer echo sounders is getting far more advanced than seen before and these instruments are used for scientific work (Childs et al 2003). If depth data from consumer echo sounders is to be used, the data must be extracted first.

The depth data has to be accompanied by a position. In this case a standard consumer combined echo sounder with GPS was assumed. Only the depth data was used in the test, as GPS can originate from other and better sources. The logged data in the vendor proprietary format is transferred raw i.e. with out generalization, to the vendor software. Here it is cleansed for dataset missing attribute values and exported in GPX format. In ArcGis the file is parsed into shape format, using a Python parser incorporated into a ArcGis toolbox. The WGS84 datum and geographical coordinates from the GPS system is unaltered in the process. From here data extraction into xyz points is easy.

The extracted data was used to establish that the echo sunders tested uses different an internal yardstick for nominal measure of depth.

A test was conducted to measure how accurate the echo sounders are in real life measuring the depth at four locations in Lake Furesoe trough measurement of all corrections associated with at depth recording. The hypotheses was that the echo sounder use one or two fixed values for sound velocity in their calculations, and that post processing data correcting for this would bring the measured depth close to the real depth. This was established trough test showing that the consumer echo sounder measures the depth within or close to 1 % of the actual depth.

7 – Lake map WebGis prototype

To demonstrate how crowd sourcing for updating inland lake maps, using Web 2.0 principles such as user interaction, a prototype WebGis prototype with web mapping displaying a Mash Up of relevant existing maps and info, including user generated and uploaded data, will be developed. The design and components will reflect the different aspects and problems in crowd sourcing.

7.1 Problems in crowd sourcing VGI

The summary conclusions about VGI data from chapter 3:

- How to handle skills among VGI contributors?
- How to handle lack in completeness in data?
- How to handle uncertainties in VGI data?
- How can visualization assist the VGI process?
- How to ensure metadata?
- How to recognize the efforts from contributors?
- Who owns VGI data?

The Webgis prototype does not attempt to solve all the different kinds of problems associated with VGI. Especially lack of completeness in data cannot be solved but only helped. The web prototype will attempt to help in following ways:

Problem	**Action**
How to handle skills among VGI contributors?	Education through web page
How to handle lack in completeness in data?	Visualization of existing data and encouragements to contribute.
How can visualization assist the VGI process?	Existing data and VGI data displayed on map client
How to ensure metadata?	Introduce elaborate metadata form
How to recognize the efforts from contributors?	Add contributors name to displayed VGI data

7.2 Stakeholders and potential contributors

The stakeholders concerning lake maps are a mix of producers and users. It is not easy to include or exclude groups as many will and can have a interest in a lake map. Leisure users, environmental users and cartographers all have natural interest in these. The figure 7.1 outlines the stakeholders known to or expected to exist.

All these stakeholders can in principle participate with data, although only private non commercial parties are expected to contribute with actual map data, whereas commercial or government parties can contribute with metadata.

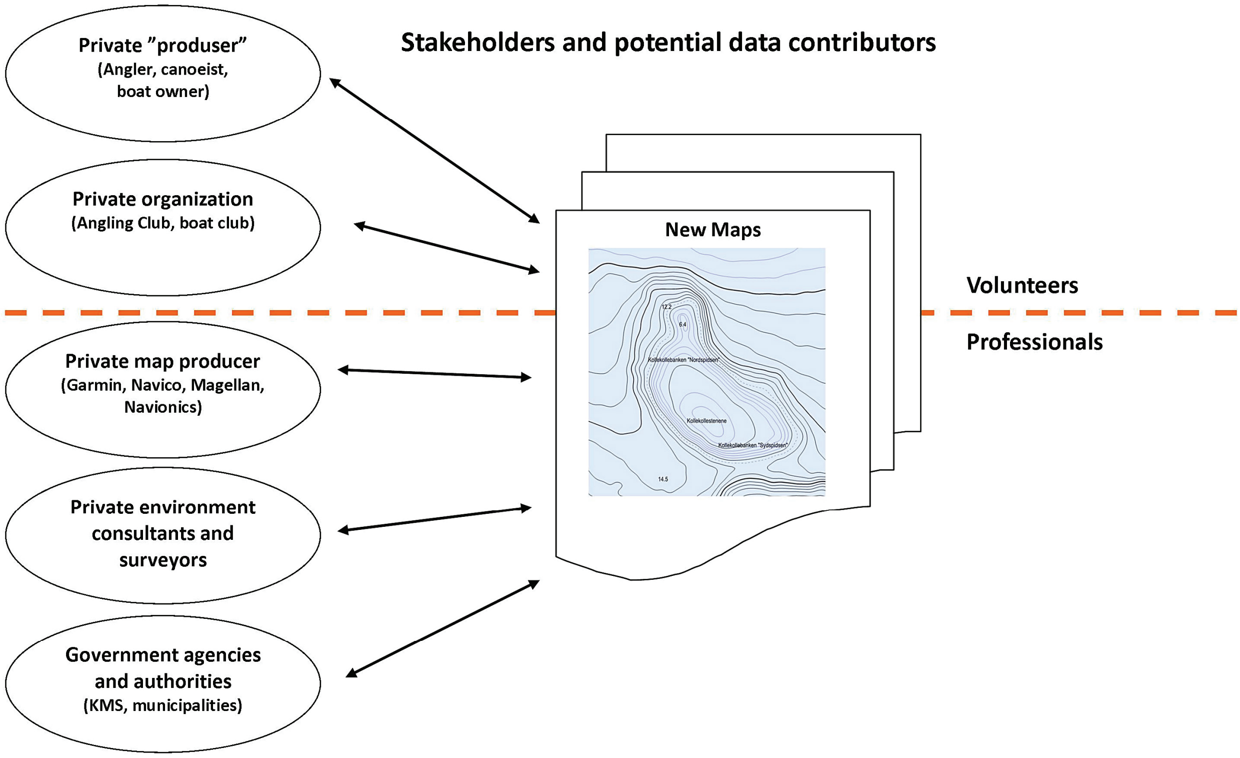


Figure 7.1 Stakeholders in lake maps (Vedel)

7.3 Main concepts

The prototype will focus on browsing spatial contents, submitting data functions and support of the user through introduction to relevant concepts and methods, addressing problems with VGI data and data considerations in bathymetric surveying. It is not the purpose of the prototype, to present the user with tools to generate maps based on data, to retrieve data or to enable data manipulation.

- To present the user with lake data and relevant map layers through a map browser.
- To induce the user to contribute with data or other kinds of relevant data.
- To clarify metadata issues.

7.3.1 Browsing spatial content

The map browsing part is a “slippery map” client with a MashUp of relevant maps.

Base layers:

- Topographic maps
- Historic topographic maps
- Ortho photo layer
- Google Earth
- Openstreetmap
- DTM data (hill shade)
- No map (neutral)

The base map layers will have Danish topographic maps from and the latest ortho photo from KMS. An important aspect of the Danish lake maps is their age. The old series from 1929-34, used “Lave Kort” 1:20.000 topographic maps as a reference when printed, while Thorkild Høy used the modern “map manuscript” 1:10.000 that were published in 1.25.000 as “4 cm maps”. The topographic maps will include historic maps so the user can view a lake map in its original reference map.

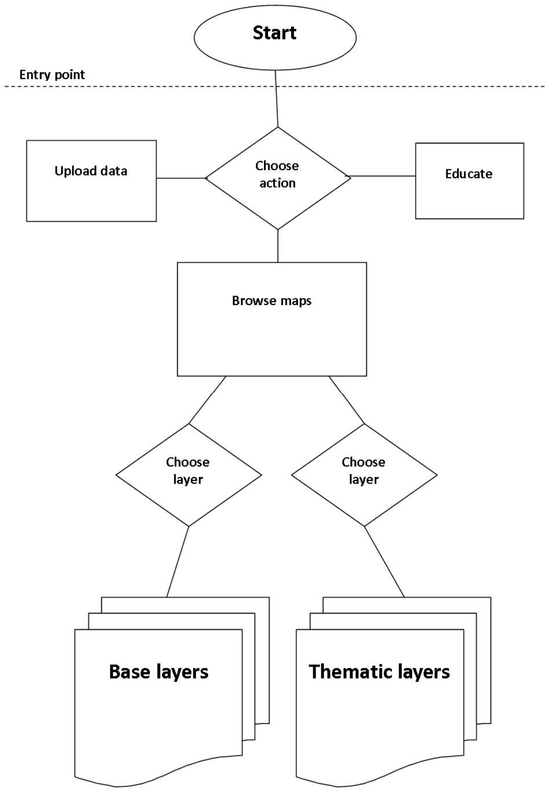


Figure 7.2 Structure of prototype

The user must be able to ascertain the mapping status of data for a given lake if data exist. The overlays are the thematic map layers specific about hydrology (surface water), original maps, vector data showing depth contours etc., and basic info about when the lake were surveyed and the method used.

Thematic layers:
- Water (vector)
- Original map (transparent overlay)
- Surveyed lakes (metadata)
- Vector data (depth data)
- Lake names
- VGI data

The user generated content can be displayed as lines (tracks) or points (text input, metadata etc).

7.3.2 Uploading data

Web 2.0 is characterized by user generated content in web pages. Users can upload different kind of data, and at some point the content will be a part of the web page. It may be GPS data from a GPS device. It might be notes about features, or it might be something else but still relevant. The uploading functionality must therefore embrace all sorts of data.

The quality including accuracy of the user generated content does not as such influence the Web prototype functionalities, as problems related to accuracy both spatial and otherwise, will be dealt with in the post processing process. However the user must be encouraged to deliver the best data available, i.e. to deliver the raw track log from a GPS instead of a generalized track, and to describe the data.

7.3.3 Metadata

The standard method to asses the quality involves metadata generated by the data producer which in this case is the VGI producer. A metadata submitting function is therefore relevant to include. The perception of metadata among the standard user is probably very low (Grira, Bédard & Roch, 2009), and even a professional or trained contributor might have difficulties when deciding what to include in metadata. After all metadata specifications are often the result of negotiated standards.

A VGI contributor cannot be expected to produce metadata of this kind, nor is it useful. Instead metadata must tell about equipment, conditions, user rights, name, contacts, area, maybe data history, and spatial references (even though raw GPS data always is geographical WGS84), and something about the contributors motives and education.

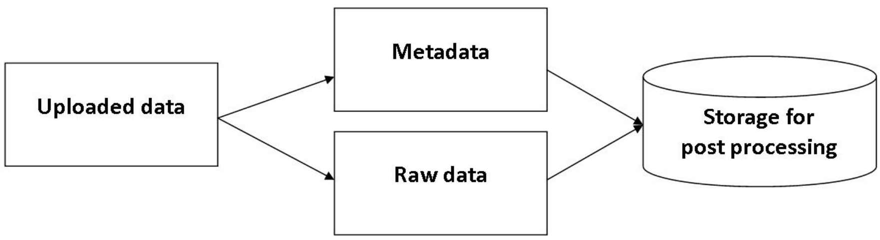


Figure 7.4 Metadata follows data

VGI metadata or "metadata 2.0" might be compared to the authoritive data they are intended to supplement. This is tempting to present a formula based on i.e. IHO metadata for surveys, or a general form based on ISO metadata standards. However VGI metadata must reflect the source of data, and it will be more prudent for the professional in the post processing to process metadata for later use.

7.4 Mapping client architecture

The web design consists of a client, a WebServer & Map server setup, and a PostGis database. Extern data sources are used as well.

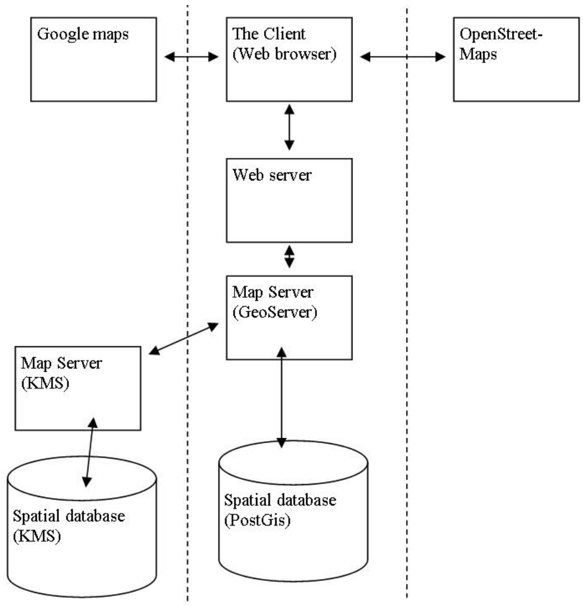


Figure 7.3 Mapping client architecture

7.5 Data upload architecture

The upload architecture runs separately from the main web page and has its own architecture.

In order to use the uploaded data for mapping, a post processing process is necessary. This process will be manually outside the functionalities of the webpage. The uploaded data will not have coordinates or some other kind of spatial tagging, so in order to depict the presence of VGI data on the map, an extra set of spatial data will have to be produced. This dataset will show VGI on the map as lines if the data is track logs or points if VGI data is metadata, old scanned maps or otherwise data.

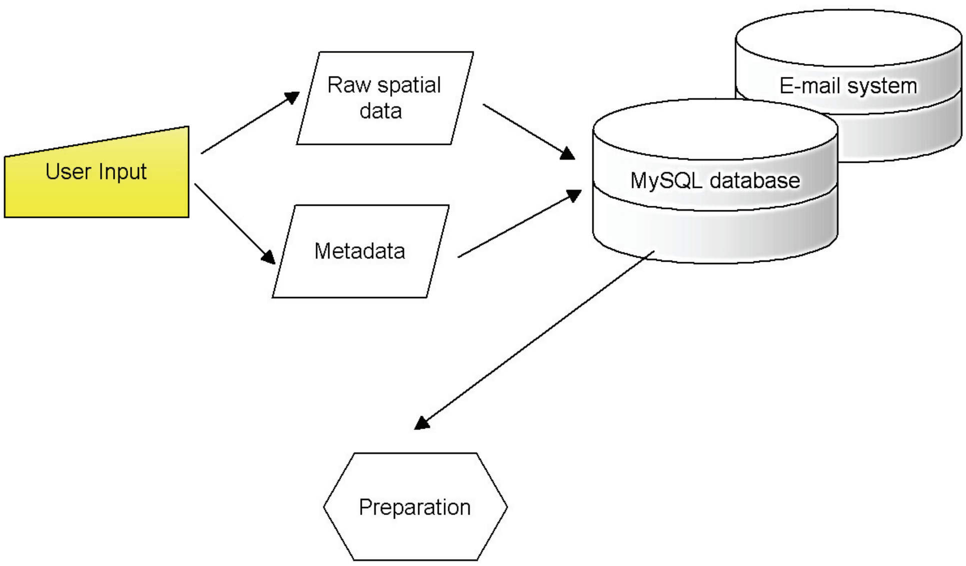


Figure 5.1 The VGI upload structure and initial post processing

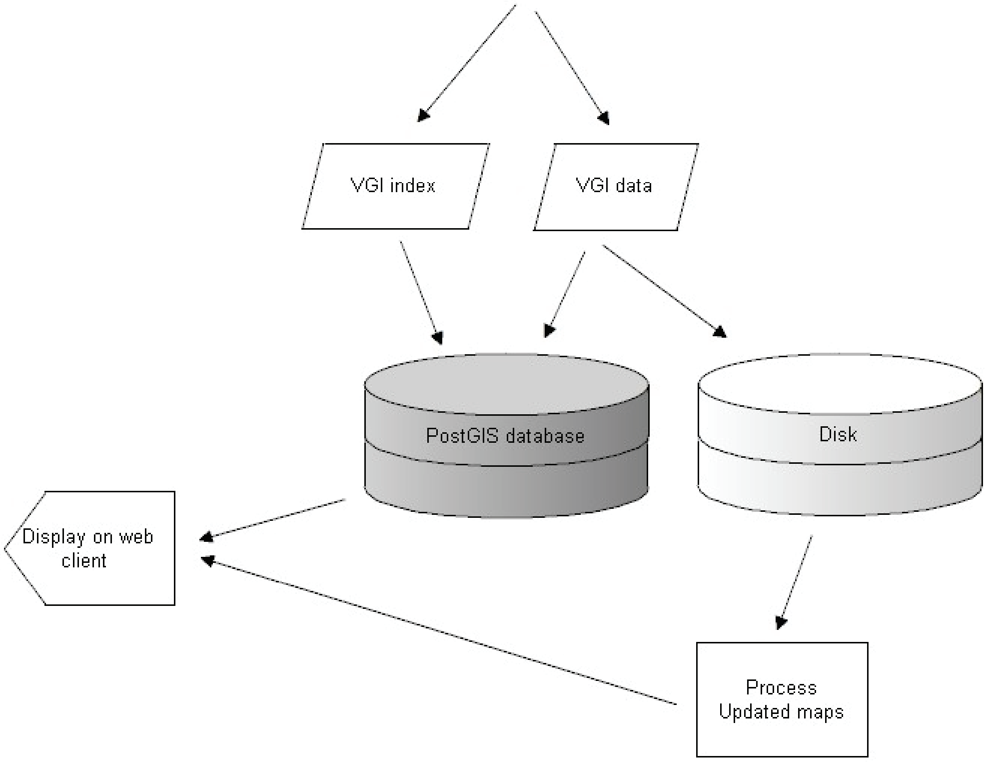


Figure 7.5 (continued) The VGI upload structure and initial post processing

The raw data can be saved in a file based storing system or as a binary file in the data base with a spatial tag. For display on the map client a vector layer representing VGI data will be a point or a line feature class, and will have only the basic attributes:

7.5.1Possible data types

The possible kinds of data are numerous. For the purpose of harvesting new depth data, which is the primary scope, it will of course be best if users upload GPS data with attribute depth data. Every kind of data can be submitted as long as it is in digital form. In the table some well known data types are listed. One alternative can be local scanned maps unknown hitherto.

While the focus so far has been on the VGI producer as the data supplier, this portal could also serve as a collecting platform for professional data. This includes vector data, grid data or only metadata if data is under distribution restrictions.

Data type	**Data format**	**Geometry**
GPS tracks with attribute data	GPX or proprietary	Polyline + point
GPS tracks without attribute data	GPX or proprietary	Polyline
GPS waypoints	GPX or proprietary	Point
Comments	Text	-
Metadata	Xml or text	-
Grid data	various	grid
Vector	various	various
Scanned maps (could be georeferenced)	Jpeg, Tiff, geotiff, png etc.	Raster
Photos (could be geotagged)	Jpeg, Tiff etc.	-
Sonar data files	proprietary	Point

Table 7.1 Possible VGI data types

Attribute	Description
shape	Geometry (point or line)
VGI Id	Database Id
Description	Contents
Depth	"Yes" or "No" marked by color
VGI_user	Name

Table 7.2 VGI layer on map client

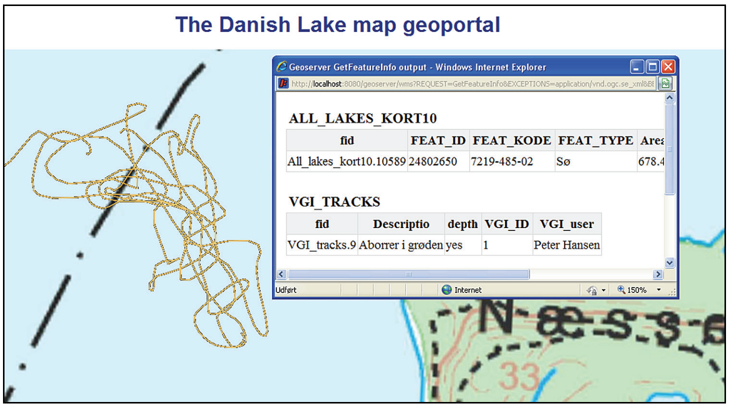


Figure 7.6 Presenting VGI data on map client (KMS)

7.6 Legal aspects of user data

The ownership and distributions rights to a given set of raw data can put some restraints on VGI. There are two scenarios for data ownership in a legal sense:

1. Data is owned by the contributor (true producer).
2. Data belong to someone else.

Although the submitted metadata should provide information about ownership, it might not be so, if this information isn't passed on, or indeed is incorrect if it is. This poses a dilemma. The standard way to handle this is to make the contributor sign to an agreement promising users right to the data receiver, and promising that the contributor do have the owners rights to the data. But this will not be a safe guard against deliberate copyright infringement. This problem can not be solved in this context, but the use of metadata with positive identification of data owner might help to avoid deliberate data theft.

The future use of submitted data is also an issue. When users contribute with data, whether being for altruistic reasons or personal gain, they must have some idea about how the data is going to be used. Data might end up in national databases or in commercial map products.

7.7 Limitations

A design of a WebGis system involves some choices in functionality. It is obvious when comparing with other systems offering upload functions to users, that a simple file or text upload is limited in use, although it will serve its purpose. In this case only a basic functionality is used, as to describe the basis principles of uploading user generated data.

The upload function will only be discriminate towards size. A limit of approx 8 MB will be sufficient. Remember that although size limits for binary data can be set very high, it will not be practical to have big file uploads via the Internet. Even large pictures or data log can be compressed to a high degree before upload. Therefore it might be considered best to allow users simply to upload the raw data extracted from the GPS instruments using internal file saving functions or supporting software exporting functions.

This prototype will not be able to perform all functions suitable for this kind of webpage, as it is constructed to show the basic principles in designing a web site for VGI data collection.

7.8 Constructing the prototype

Open source software was chosen for all coding. This may not result in the best optimized solutions, but it is free and less restricted in use.

7.8.1 Choice of programming languages

The client is loaded onto the user's computer from the web server. It is written using three programming languages HTML, PHP and JavaScript.

The standard html (Hyper Text) code is a static code that runs in the web browser. It binds the web page together and presents the client with its contents.

Personal Home Page (PHP is designed with web pages in mind) also called *Hypertext Preprocessor* is a server side based code, that can be run from within the html code client side, thus making an interacting between the client and web server possible. To interact with the web server and data base PHP is used. The upload of files to a database requires a script language which is able to communicate with a server. While html delivers the interface and a form, a PHP script will take the uploaded data to the server (server side) and process it, i.e. store the data in the database. PHP code does not require PHP to be installed on the client's computer as it is run server side. The code tells the browser to run PHP code either on the client or on the web server (Gilmore 2006).

A second scripting language is JavaScript (not to be confused with Java) widely used for may web applications. JavaScript is object oriented and is used for making dynamic websites. The advantages is that most if not all web browsers supports it, and that it is fairly secure to use. It is a very handy language is used for many web applications. OpenLayers and Google Maps are using JavaScript in their API's. For security reasons JavaScript's running on a client, can't access files on the server where it is fetched.

For writing the code any text editor can be used, but the choice was Komodo (freeware version used) and Adobe Dreamweaver CS3 due to their editing functions. The Dreamweaver has a very good interface combined with both local and remote server update functions, which make code editing and testing fast.

7.8.2 Choice of Web Server

The web server software is Wampserver. This is free open source software under GNU (www.wampserver.com). It is easy to install, and consist of the Apache server, the PHP script language and the MySQL database system.

When choosing a web server some considerations have to be made. In case the website will be published and run from and extern ISP, this ISP must have the adequate services to run the web page i.e. supporting the same web server setup, scripting languages and databases.

7.8.3 Choice of Map Client

A map client is necessary to present the spatial data in the browsing section. There are several map clients available. Among the free ones Google Maps API, OpenLayers and Yahoo are well known. When choosing a map client browser compatibility, cost, personal experience and functionality are important. Both Google and OpenLayers are free to use. They both use JavaScript and have good support from user communities. OpenLayers has been chosen as it is open source in all aspects, and free to use. The key functionality in OpenLayers in this context is the support of OGC web services and the good ability to work with GeoServer in general.

7.8.4 Choice of Database Client

The choice of database client is PostGis and MySQL. PostGis is the spatial extension to PostgreSQL. PostGis is the obvious choice for handling spatial data and it is free. MySQL is chosen as database for the initial upload of data as it is included in the WampServer package.

7.8.5 Choice of Map server

GeoServer is chosen as a map server. GeoServer is a well established open source product written in Java. It is very easy to setup, and supports OGC standards as WMS services, and has a PostGis and MySQL interface. It handles both raster (including grid) and vector data. GeoServer is built on an open source java toolkit incorporating another java coded toolkit GeoTools. GeoServer can work with APIs from Google, Yahoo a.o. and works very well with OpenLayers (Obe & Hsu 2011).

7.8.6 The code of the front page

The index page or the front page of the Geoportal is written in html only. It is a simple center table containing an introduction and 3 links to the other elements of the Geoportal. The background image is a map of Lake Glenstrup from 1934. The code is presented in Appendix E.

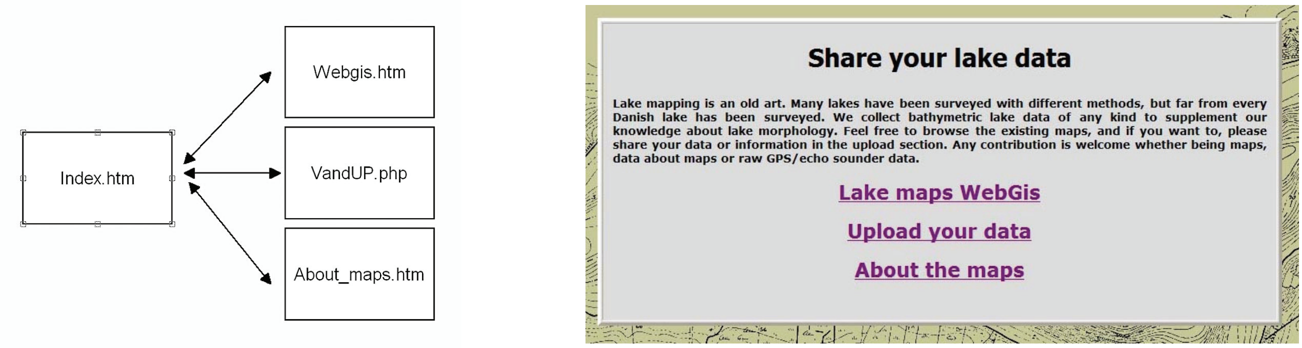


Figure 7.7 Front of web page

7.8.7 The code of the WebGis page

The webgis page is a mapping client and is the key element of the Geoportal as it present spatial data to the user. To present map client html code is used to create a frame for display and address the JavaScript's necessary to generate the data, and to inform about data suppliers etc. The code is presented in Appendix E.

The html code to call the JavaScript's:

```
<script src="http://maps.google.com/maps/api/js?sensor=false&v=3.2"></script>
<script src="http://www.openlayers.org/api/OpenLayers.js"></script>
<script src="http://www.openstreetmap.org/openlayers/OpenStreetMap.js"></script>
<script src="proj4js-compressed.js"></script>
<script src="webgis.js"></script>
```

The JavaScript's works client side. Among these only "webgis.js" is native. The rest is imported. Both OpenLayers and Openstreetmap scripts could reside locally on the WebServer, but fetching these scripts directly from their source, ensures that the latest version is used. Google Maps or Openstreetmap are included as optional free data sources. OpenLayers.js and proj4.js support webgis.js.

The html code that generate the frame to contain the map:

```
<div class="kolonner" id="map" style="width:100%; height:90%"></div>
<body text="#F4F3EE" link="#FFFFFF" vlink="#FFFFFF" alink="#FFFFFF" onLoad="init();">
<table width="84%" border="0">
```

The "ID" reference is to the element inside the frame, in this "map" which is the name for map defined and generated in the JavaScript "webgis.js". "onLoad" tells the browser to initiate and load the map.

7.8.8 The code of the map client

The first four lines of the code, defines where to center the map once loaded. It is lat/lon combined with a zoom level, and the variable "map" as referred to in frame html code is defined. The code is presented in Appendix E.

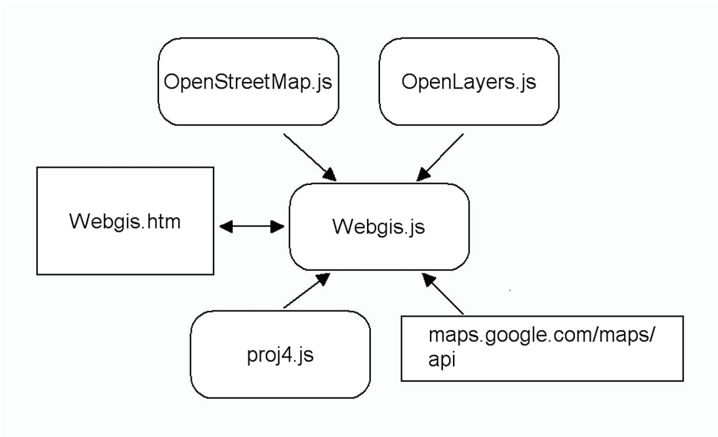


Figure 7.8 Webgis and map client

OpenLayers native projection is a Mercator variant called 900913. If the map client is to show positions in geographic coordinates, a geographic projection like WGS84 is called for. OpenLayers supports this projection and it is set in the code. However if the projection instead should be UTM ETRS 32N ((EPSG: 25832) OpenLayers fall short. To compensate for this, the script proj4.js is brought into the code. Proj4 is a JavaScript library that provides coordinate transformations between map projections and longitude/latitude, including datum transformations, for implementation in a web client (Proj4.js web). Proj4 is an open source project constantly revised in code and supported projections. It support both EPSG 25832 and EPSG 7416 i.e. ETRS89 UTM zone 32N + DVR90 height.

```
var map;
function init() {
Proj4js.defs["EPSG:25832"] = "+proj=utm +zone=32 +ellps=WGS84 +datum=WGS84 +units=m +no_defs";
		map = new OpenLayers.Map ("map", {
				controls: [
				new OpenLayers.Control.Navigation(),
				new OpenLayers.Control.PanZoomBar(),
				new OpenLayers.Control.LayerSwitcher(),
				new OpenLayers.Control.MousePosition()
		],
				maxExtent: new OpenLayers.Bounds(-2500000.0,3500000.0,3045984.0,9045984.0),
				maxResolution: 2708.0,
				minExtent: new OpenLayers.Bounds(-1,-1, 1, 1),
				numZoomLevels: 18,
				units: 'm',
				projection: new OpenLayers.Projection("EPSG:900913"),
				displayProjection: new OpenLayers.Projection("EPSG:25832")
		} );
		map.addControl(new OpenLayers.Control.LayerSwitcher());
		map.addControl(new OpenLayers.Control.ScaleLine());
		map.addControl(new OpenLayers.Control.MousePosition());
		map.addControl(new OpenLayers.Control.KeyboardDefaults());
```

The remaining code builds the map structure before the layers are added. Control panel, zoom levels and map bounds etc are defined, and finally added to the map display. Zoom levels and resolution has to be matched to suit the map data and usage. Third party map layers like data retrieved from a mapserver will have their own default zoom levels. They can be altered but were left as they were.

Before adding the map layer a simple functionality was added to the map. When viewing objects or marking symbolizing data, it is very prudent to be able to see metadata about his object. A click on map function was added. A little box with the data about the object will appear on top of the map client as an independent frame. The click function collects data from the source of the given data; in this case the mapserver GeoServer (se below).

```
var wmsurl = "http://localhost:8080/geoserver/wms";
map.events.register('click', map, function (e) {
  var url = wmsurl
    + "?REQUEST=GetFeatureInfo"
    + "&EXCEPTIONS=application/vnd.ogc.se_xml"
    + "&BBOX=" + map.getExtent().toBBOX()
    + "&X=" + e.xy.x
    + "&Y=" + e.xy.y
    + "&INFO_FORMAT=text/plain"
    + "&QUERY_LAYERS=Database,VGI_data"
    + "&LAYERS=Database,VGI_data"
    + "&FEATURE_COUNT=3"
    + "&SRS=EPSG:900913"
    + "&STYLES="
    + "&WIDTH=" + map.size.w
    + "&HEIGHT=" + map.size.h;
  window.open(url,
   "getfeatureinfo",
   "location=0,status=0,scrollbars=1,resizable=1,width=800,height=300"
```

The click function use OpenLayers “map.events.register” function. The GetFeatureInfo is a OGC web standard function supported by GeoServer. I this case the default setting was used only altered to show standard text in the info box instead of a table. This makes metadata harvesting using copy/paste easy. In the layers selection only the relevant layers for metadata were included. On the server side the same layers in the server (GeoServer) has to be queryable. The SRS has to be OpenLayers native EPSG: 900913 in order to display the objects inside the visible map.

The bulk of the map client code concerns the map layers. OpenLayers has support for both Google Maps and Openstreetmap, so it is straight forward to use these. OpenLayers also supports OGC web standards such as WMS. This is use full as it enables maps to be delivered by a mapserver like GeoServer. The map display distinguishes between “base layer” and “overlay”. Base layers can only be shown one at a time while overlays can be activated independently.

```
var osm_layer = new OpenLayers.Layer.OSM.Mapnik("OpenStreetMap Layer",{isBaseLayer: true});
var google_satellite = new OpenLayers.Layer.Google("Google Satellite",{type: google.maps.MapTypeId.SATELLITE});

var wms_1 = new OpenLayers.Layer.WMS("DTK/SKÆRMKORT","http://localhost:8080/geoserver/wms",
                    {layers: "dtk_skaermkort",tiled: true,visibility: true,transparent: false},{opacity:1});

map.addLayers([wms_1,wms_2,wms_3,wms_4,wms_5,wms_6,osm_layer,google_satellite,wms_9,wms_7]);

var wms_12 = new OpenLayers.Layer.WMS("Water","http://localhost:8080/geoserver/wms",
{layers: "Water",transparent: true},{visibility: false,opacity:1, minScale: 151648.0});

map.addLayers([wms_12,wms_10,wms_17,wms_16,wms_11,wms_15,wms_8]);
```

These lines are just a little extract from the code (Appendix E). The standard OSM layer and the Google layer (with three possible versions to display). Note the setting for Base layer in the OSM layer. Actually all WMS layers are “Base layers” by default (Hazzard 2011). In the WMS code line the relevant line is “transparent”. If this is to “true” the map layer will be available among overlays on the map. If the setting is “False” the layer will be a base layer.
The “visibility” setting determines if the map is visible at start up. The opacity values controls the transparency. Map layers are added to the map display in the order they appear in “map.addLayers”. As seen in “var wms_12” layer, which is the layer containing the water theme from Kort10, a setting for “minScale” is added. This setting is important to control at which zoom level the overlay data appears in order to avoid cluttering of the map.

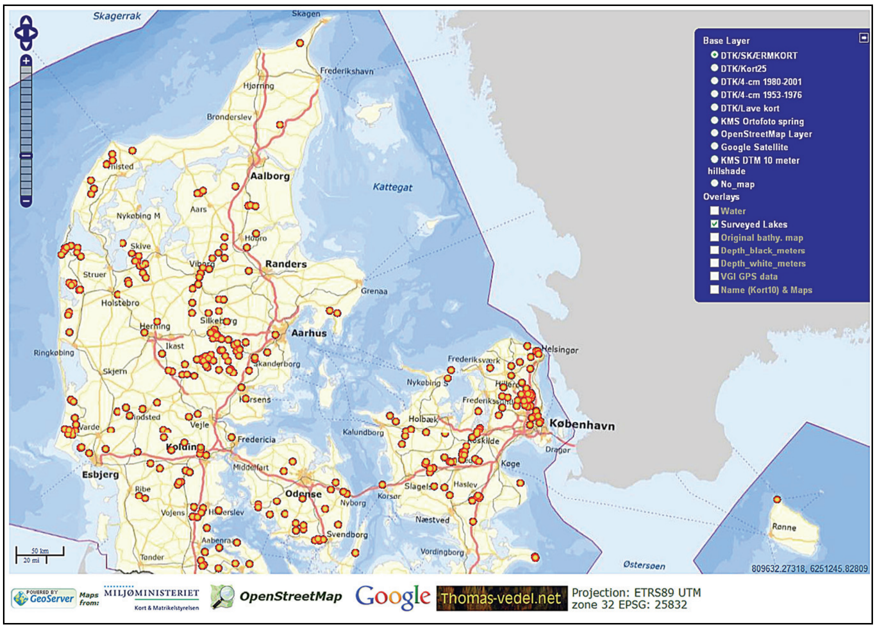


Figure 7.9 The final map client display (KMS)

Finally a map center is defined and the loaded map adjusted according:

```
var lat=55.50
var lon=11.51
var zoom=6;

if( ! map.getCenter() )
{var lonLat = new OpenLayers.LonLat(lon, lat).transform(new OpenLayers.Projection("EPSG:4326"),
map.getProjectionObject());
map.setCenter (lonLat, zoom);
```

7.8.9 The code of the upload page

The upload page is the central crowd sourcing component as it offers the means to contribute with data. It also addresses issues with education, metadata and perception of data. The code is included in Appendix E.

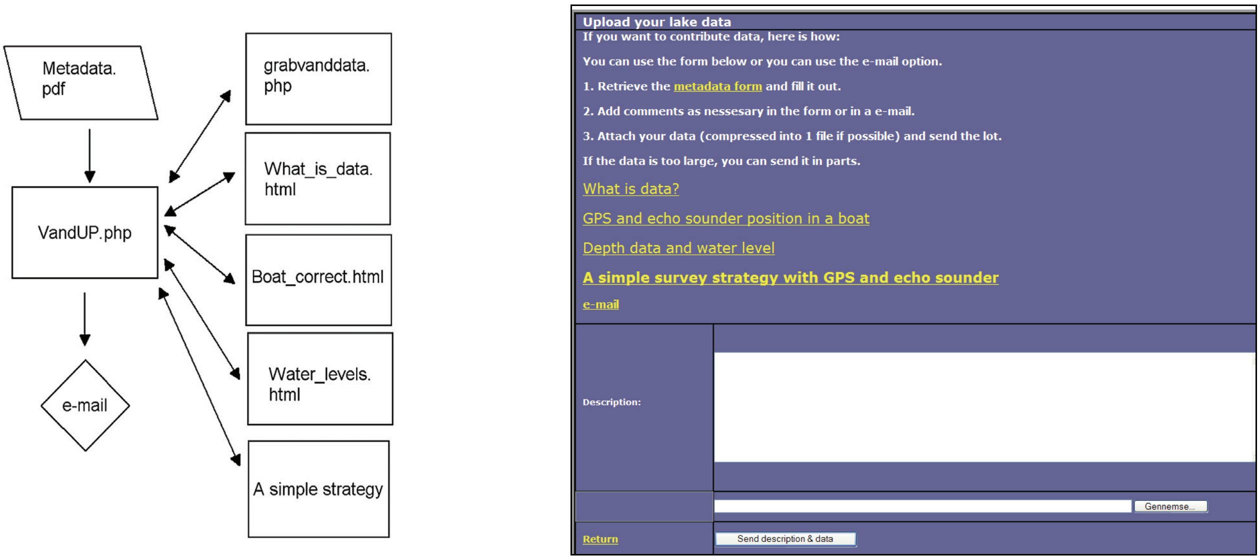


Figure 7.10 The Upload page with support functions

This section of pages is written in html code and php. The code is centred a design for a upload form incorporating a php script:

```
<form enctype="multipart/form-data" name="frmUploadFile" action="grabvanddata.php" method="post">
```

The form contains a text area for comments and a file browse file function and a upload botton. There is a text limit and a file size limit attached:

```
<span class="Fed">Description:</span></font>
<p style="margin-left: 10; font-family: Arial, Helvetica, sans-serif; font-size: 12px;"></td>
<td width="85%" bgcolor="#666699"><textarea name="strDesc" cols="100" rows="10"></textarea></td>

<input type="hidden" name="MAX_FILE_SIZE" value="10000000" />
  <input type="file" name="fileUpload" size="60">
```

This code is straight forward as used in many applications. The text and file are processed in a php script inserting this into a database as text and binary file. There are some limits to the size of the files uploaded. These are set within the PHP ini code on the server and reflected in the html code in the upload form. The metadata form in pdf format (Appendix F) is easy to retrieve and fill out with relevant metadata. The pdf file is the attached as a file upload. From the form raw data can also be attached for convenience to avoid further file handling by the user. A direct email or upload functionality in the form has been considered, but it proved difficult to ensure attached files in this process.

7.8.10 Upload data to a database

The upload function triggers a php code that contacts the database and inserts the data. As the data is not spatial an ordinary data base is sufficient. The database is made with MySQL. PostGreSQL ia a alternative, but the WebServer package used includes MySQL. The php code is presented in the appendix E (Grabvanddata.php) and resides on the WebServer. If data insertion is impossible an error message shows. If the upload is successful and option for more uploads is presented. The php code makes contact to the database (in this cae on the same server) and adds data to the chosen table. Retrieving data from the database is done by web interface or a standard set of php code.

7.8.10.1 The database

The database for storing the uploaded data is constructed in MySQL.

```
CREATE TABLE IF NOT EXISTS `wet_data` (
  `Id` int(11) NOT NULL AUTO_INCREMENT,
  `Title` varchar(1000) COLLATE utf8_danish_ci DEFAULT NULL,
  `Data` longblob,
  `Type` varchar(50) COLLATE utf8_danish_ci DEFAULT NULL,
  UNIQUE KEY `id` (`blobId`)
) ENGINE=MyISAM  DEFAULT CHARSET=utf8 COLLATE=utf8_danish_ci AUTO_INCREMENT=35 ;
```

The database is setup with four columns:

The ID: The Id is generated automatic and is used for cataloguing.
The Title: The description of data is very important. For this reason plenty of room (1000 char) is given.
The data: The can be anything. Some will upload gpx files; others zipped ones or other kind of GPS data.
The type: This describes the uploaded data as the server sees it.

The PostGis database is somewhat different in it's setup in this case. It is used for storing data about VGI data for display on the map client and to present the metadata about the presently surveyed lakes. It may also be used for storage of the processed VGI data.

The data for display on the map client is loaded into PostGis as shape files using the "loader", which constructs a table according to the attributes with the shape files geometry. Trough GeoServer the data can be called upon and displayed on the map.

7.8.10.2 Alternatives to the database

If, for some reason the database upload does not function, a email alternative is included. The email solution is strictly a option to use any ISP email services instead of setting up data services.

7.8.11 User perception of data

One major issue concerning VGI data is the contributors understanding of data and data concepts like metadata. To guide the uploading user to include the correct metadata, a form in pdf format with editable fields is included. Furthermore three pages illustrating and explaining data are included. It is important that the basic data issues are explained. The instructional pages are written in simple html with images added. These pages are a support to the metadata form.

Web sub page	**Function**
What is data?	Describes different kind of data.
GPS and echo sounder position in a boat?	Shows what is understood as the distance and positions of the GPS and echo sounder. This is important to asses the error due to displacement.
Depth data and water level?	Gives an overview over different kind of water level data. Very important for post processing.
A simple survey strategy with GPS and echo sounder	Describes the basic in collecting depth values, and present a simple survey plan.

These pages do not attempt to explain all the complex error sources in hydrographic surveying like speed of sound in water, latency etc. The metadata form sums up on all these issues and includes standard metadata components like name, ownership, contacts etc.

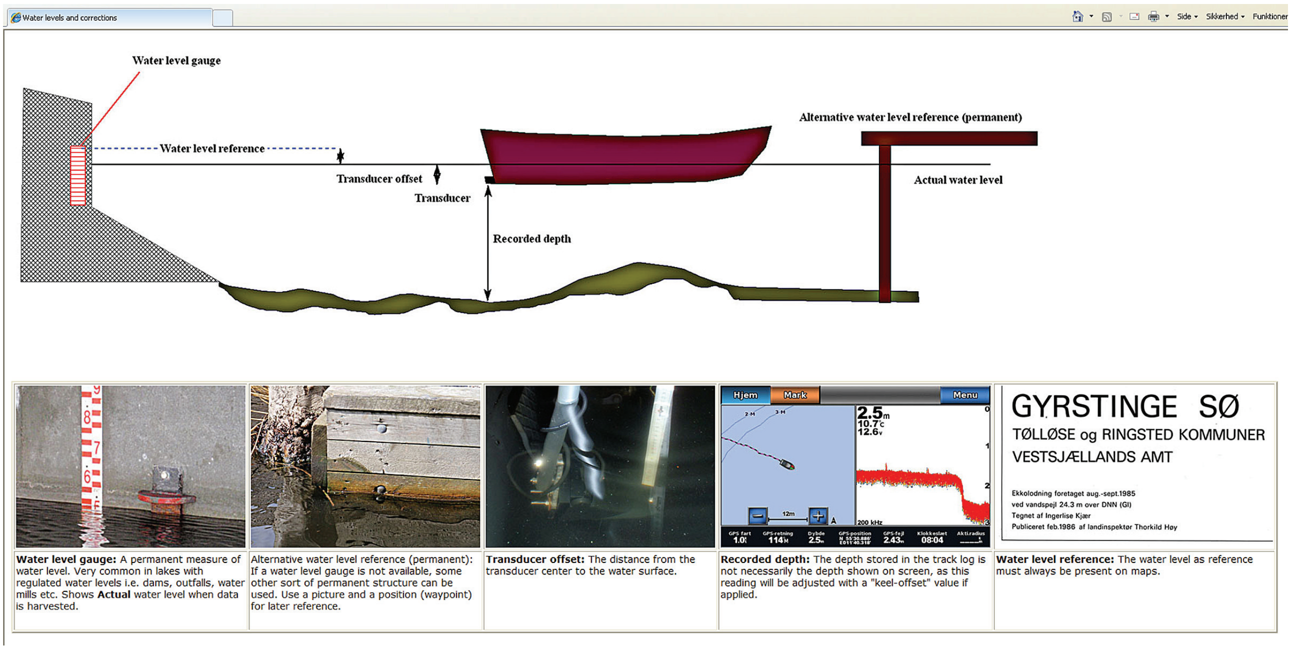
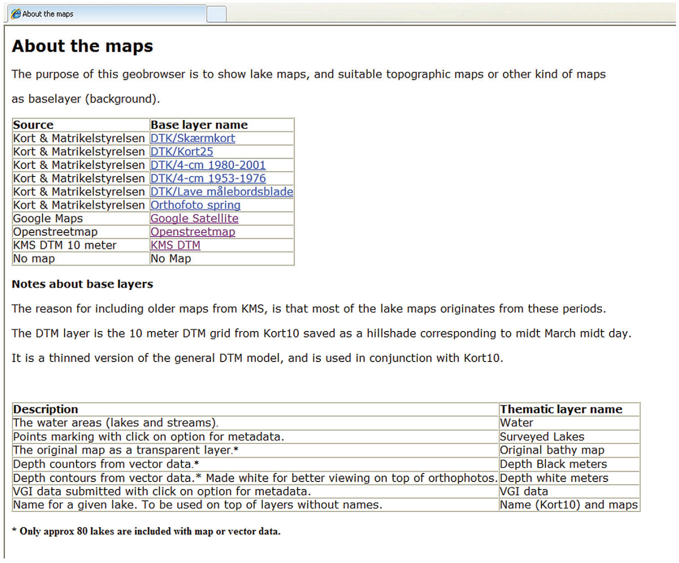


Figure 7.11 Illustration of concepts in depth and water level (Vedel)

7.9 Map data guide

The last supporting page "About the maps" is an html page with description of each map layer in the map client. The base layers are supported with links to their source, and the thematic layers are supported with a brief description and advice for their use.


About the maps

About the maps

The purpose of this geobrowser is to show lake maps, and suitable topographic maps or other kind of maps

as baselayer (background).

Source	Base layer name
Kort & Matrikelstyrelsen	DTK/Skærmkort
Kort & Matrikelstyrelsen	DTK/Kort25
Kort & Matrikelstyrelsen	DTK/4-cm 1980-2001
Kort & Matrikelstyrelsen	DTK/4-cm 1953-1976
Kort & Matrikelstyrelsen	DTK/Lave målebordsblade
Kort & Matrikelstyrelsen	Orthofoto spring
Google Maps	Google Satellite
Openstreetmap	Openstreetmap
KMS DTM 10 meter	KMS DTM
No map	No Map

Notes about base layers

The reason for including older maps from KMS, is that most of the lake maps originates from these periods.

The DTM layer is the 10 meter DTM grid from Kort10 saved as a hillshade corresponding to midt March midt day.

It is a thinned version of the general DTM model, and is used in conjunction with Kort10.

Description	Thematic layer name
The water areas (lakes and streams).	Water
Points marking with click on option for metadata.	Surveyed Lakes
The original map as a transparent layer.*	Original bathy map
Depth countors from vector data.*	Depth Black meters
Depth contours from vector data.* Made white for better viewing on top of orthophotos.	Depth white meters
VGI data submitted with click on option for metadata.	VGI data
Name for a given lake. To be used on top of layers without names.	Name (Kort10) and maps

*** Only approx 80 lakes are included with map or vector data.**

Figure 7.12 A short map description with reference links

7.10 Setting up GeoServer and data layers

The map client use GeoServer as primary mapserver. GeoServer is Java based server application (http://geoserver.org). It is Open Source and free. Once installed, it is maintained through a web interface. GeoServer supports both vector and raster data and OGC (WMS WFS etc) layers based externally. GeoServer organizes data in Workspaces, Stores and Layers. Layers can be assembled into "layer groups". The layers are accessible using OGC standards. In this case only WMS calls were used. GeoServer also supports styling using SLD definitions (xml), and raster pyramid building for optimized viewing using GeoWebCache.

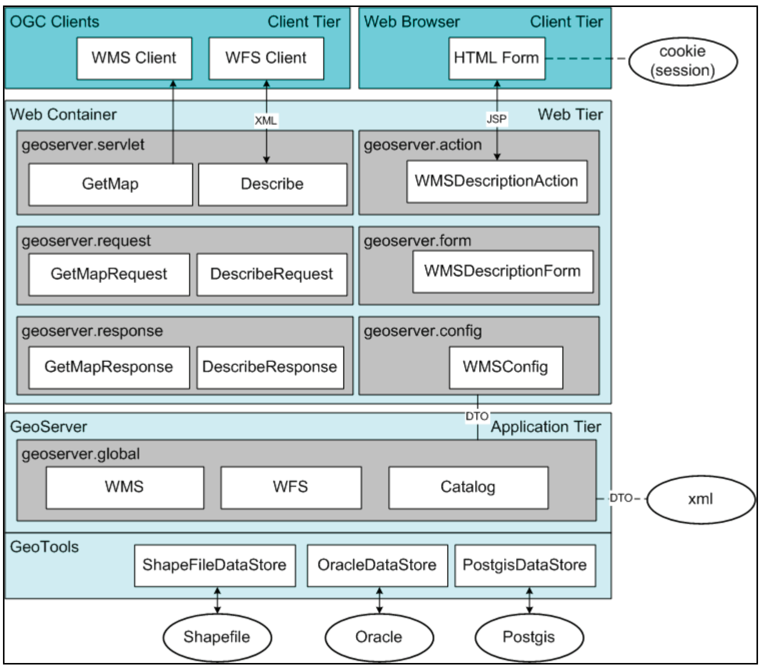


Figure 7.13 The tiers in a GeoServer setup

GeoServer can recognize and transform many projections. However to save computing time, it is best to use the same or very few spatial references for data. GeoServer will reproject data into OpenLayers EPSG: 900913 upon WMS calls.

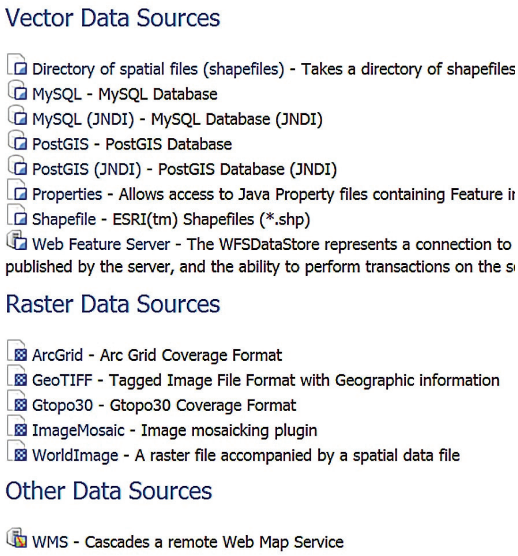


Figure 7.14 GeoServer create Store (data store)

7.10.1 Base data layers

The base data layers are raster layers. Their function is to enable the user in a fast way to focus on a special area. They come from several sources. Both free sources which already are implemented into OpenLayers as Google and Openstreetmap, and proprietary maps from Kort & Matrikelstyrelsen which forms the bulk. The Openstreetmap and Google maps loads very fast due to their tiling structure directly from the OpenLayers JavaScript, while the layers from KMS loads via GeoServer using WMS calls, and are therefore somewhat slower.

Source	Service	Base layer name	Scale	Raster layer data source	Age
Kort & Matrikelstyrelsen	WMS	DTK/Skærmkort	1:4000 – 1:8 mill	Vector based web optimized	Contemporary
Kort & Matrikelstyrelsen	WMS	DTK/Kort25	1:25.000	Vector based	Contemporary
Kort & Matrikelstyrelsen	WMS	DTK/Lave kort	1:20.000	Scanned raster	1928-1945
Kort & Matrikelstyrelsen	WMS	DTK/4-cm 1953-1976	1:25.000	Scanned raster	1953-1976
Kort & Matrikelstyrelsen	WMS	DTK/4-cm 1980-2001	1:25.000	Scanned raster	1980-2001
Kort & Matrikelstyrelsen	WMS	Ortofoto forår	10 cm pixels	Ortho photo	Contemporary
Google Maps	API	Google Satellite		Arial photo	2006
Openstreetmap	API	Openstreetmap		Vector based	Contemporary
KMS Kort10 DTM	WMS	KMS DTM 10 meter	1:10.000	Raster based	2009
Blank map	n.a.	No Map	-	-	-

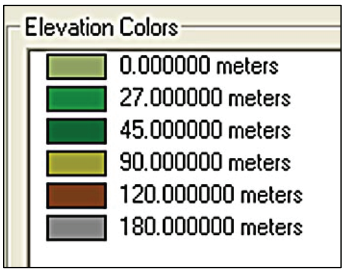
Table 7.3 Base data layers

The choice of base layers reflects the thematic layers. As mentioned above bathymetric maps from different periods in time, were drawn on map manuscripts of that age. If these maps were placed on a modern map, it will almost certainly not fit, due to changes in landscape, techniques and map quality. Most of the Danish bathymetric lake maps are made by Thorkild Høy in the period mid 50'es to mid 90'es. The equaling maps for this period must therefore also be available.One base layer is not a map but a relief of the terrain. Combined with a thematic vector layer with lakes and stream, it is possible to show how the surface water is located, and present a clear view of the water systems.

The blank or empty map is included when a thematic layer is best shown alone or with other thematic layers only.

The final base layers serves to place the user's data aiding with providing location. In some cases the ortho photo can supply further relevant data.

7.10.2 KMS DTM 10 meter base layer



This layer is a hill shade image of Denmark made from the DTM model attached to Kort10 vector data set. The basic DTM data is in ACSII format. The coastline is the coast line as in the vector data set. The hill shade was set a solar position equalling to middle March mid day. As the DTM delivers data a 10 meter grid the edges would be jagged around the cost line unless a mask is used. The mask is a blue background with the land area cut out using the coastline to produce a land polygon. To complete the DTM image, rivers, and lakes larger than 1 ha data from the Kort10 Hydro polygon data set were included. The layer "kanalen" is a missing data object in Kort10 but added for completeness. It was made manually based on ortho photo. Not all canals etc. were checked, but in this case it was very obvious as it is an area often visited. The end result of this layer is used on the thesis front page.

Position	Layer	Default Style	Style	Remove
↓	Lakemaps:Land	☐	Land	⊖
↑ ↓	Rasters:DK_DTM_10m	☐	raster	⊖
↑ ↓	Lakemaps:Hav_u_land	☐	Sea	⊖
↑ ↓	Lakemaps:Soer_1ha	☐	Lake	⊖
↑ ↓	Lakemaps:Kanalen	☐	Lake	⊖
↑	Lakemaps:VANDL_BR	☐	Lake	⊖

Figure 7.15 Layers forming the layer group

7.11 Thematic layers (overlays)

The thematic layers are either based on scanned maps or vector data. They represent existing relevant data. The scanned maps are the original bathymetric maps. EPSG 25832 were used as projection (UTM 32N ETRS89). Of the 322 lakes surveyed only approx 80 of the most important lakes are included due to the large work involved (Appendix G).

7.11.1 Water

This layer is based on the hydro theme in Kort10. The purpose of is to present a clear blue indication of water and to serve as a background for the transparent original map display. When used in conjunction with the DTM hill shade a clear hydrologic picture of the landscape emerges. When clicked on a lake polygon data from Kort10 about his feature is shown.

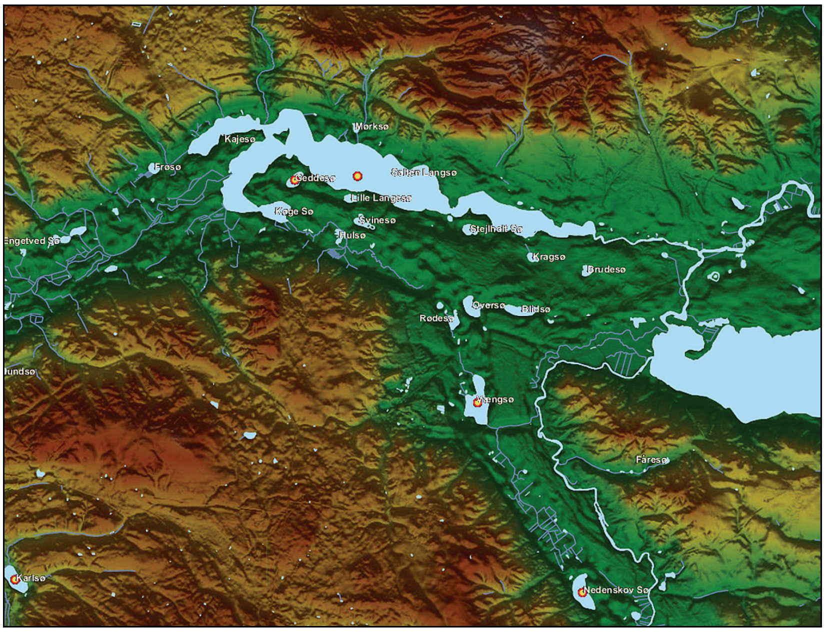


Figure 7.16 Hill shade with water and name layer (KMS)

7.11.2 Surveyed lakes & names

This layer marks which lake is surveyed by a red dot. On click on the feature a html popup appears showing the metadata for the lakes. This is the database or inventory over surveyed lakes (Appendix B). An extra name layer from the name theme in Kort10 is also an option. This layer also has names from surveyed lakes as not all is included in the name theme.

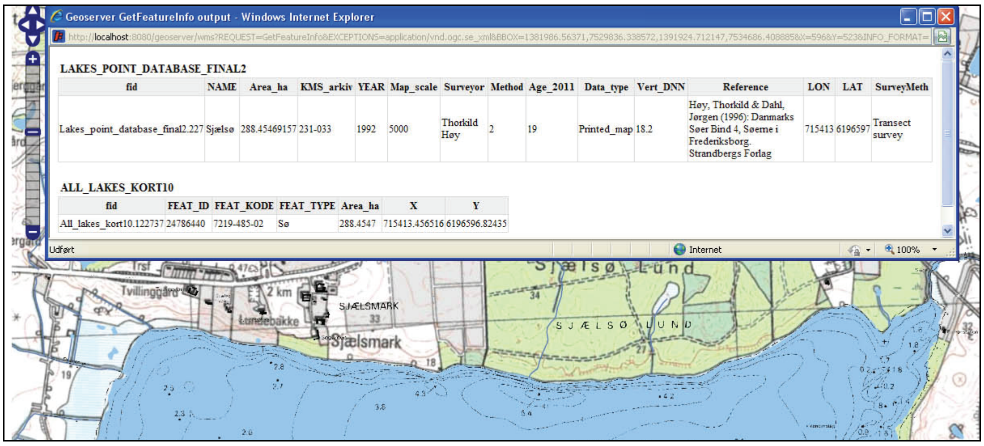


Figure 7.17 Surveyed lakes database on click (KMS)

7.11.3 Original map overlay

To present the original map as a transparent map, the original printed map has to be georeferenced and saved in raster png format enabling transparent pixels. This process is accepting a large degree of uncertainty both from the original method used to make the map, but also from the inherent error in a printed map. Furthermore a transparent overlay most likely will fail to fit all base maps.

7.11.3.1 Georeferencing scanned maps

A map from 1929-1934 series from Geodætisk Institut was drawn on a 1.20.000 scale map, known today as “Lave målebordsblade”. An example of this is the map of Lake Mossø (Figure 7.13). Note the clear reference to the contemporary map. Although the reference map were updated during the period, and the map tiles drawn from KMS map server may not always be exactly, the same as used in the bathymetric map, is it still the same map manuscript. The local fix points and spot heights are reused on the bathymetric maps, so the process is relatively easy. When added to the original base map, the original bathymetric map looks better and is presented in a fair context.

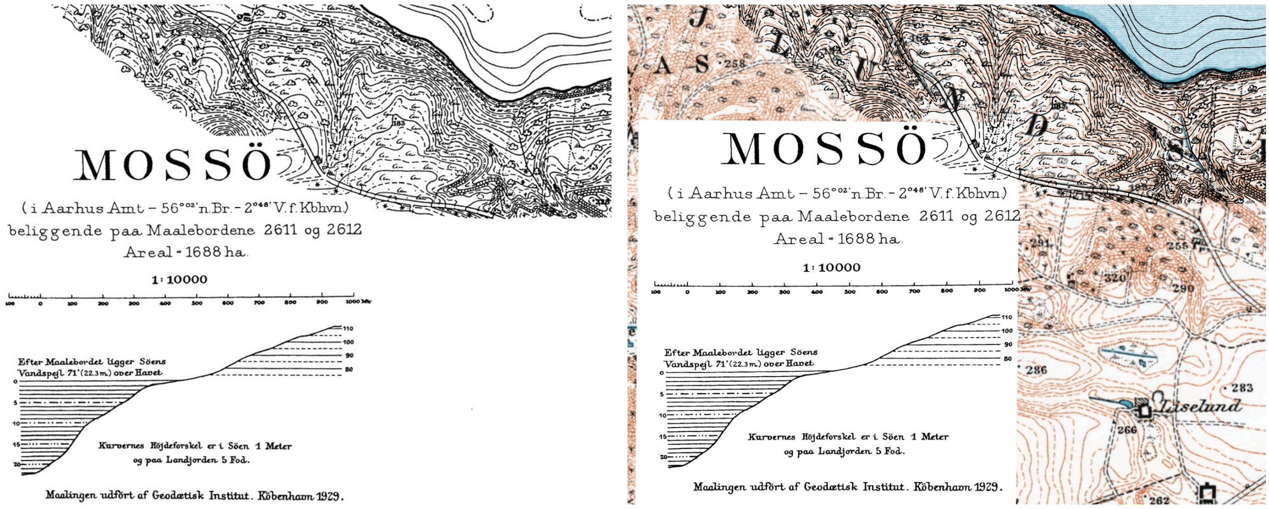


Figure 7.18 Positioning old bathymetric map on contemporary topographic map. (KMS)

The same applies with maps from Thorkild Høy (1957-1997). One big advantage with Thorkild Høy’s choice of 1:10.000 map manuscript as reference map, is that outline of houses are present. Of course this is a reflection of the method using fix points of various kinds for positioning, and in this case it is possible to georeference his maps using houses. There will be a likely source of error in this method, as the house may not have been positioned correctly on the map, but ortho photos can be used to control this, provided the buildings used still exist on these photos. To illustrate this problem, the bathymetric map over Lake Bagsværd is a very good example.

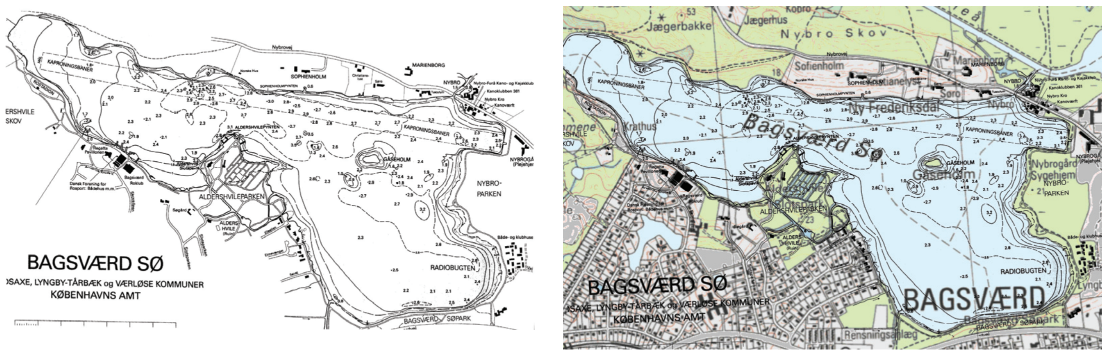


Figure 7.19 Lake Bagsværd positioned on its contemporary map (KMS)

The lake surroundings have no lack of buildings. In fact there so much old and new to use as fix points, it seems very unlikely that this will present a problem. However it does. When controlled against ortho photos it was clear that the positions of some smaller houses on the east bank were wrong. This caused the whole georeference process to go askew and halted until the misplaced objects were identified and omitted from the process. Due to the large difference in scale from the 4-cm map (1.25.000) and Thorkild Høys map (1:5.000) vector data in scale 1:10.000 (Kort10) were used to supplement georeferencing the map along with ortho photos (10 cm). Note that when georeferencing bathymetric maps, it is the depth data that is georeferenced by reversing the surveying technique. All maps shows data collected with reference to points on land, not to the shore line. Shorelines may therefore not match the base layers.

The data sources are in all cases printed maps. The data capture process is a scanning process to a PC, where the image is cleaned and saved in bitmap (black & white). Before scanned, the printed map was studied very closely to ascertain the DPI value in the print. The standard print (laser copy or offset black and white print) has a dpi around 600, so in this case a scanning of 720 dpi were used to capture even small faults in the print. This is useful when restoring the image later. Some maps were printed in high quality offset print in two colors – black and blue. In these cases a 1200 dpi scan were used, so the blue dots in the print could be identified and removed later in the process.

The scanned and cleaned map was reprojected into UTM ETRS89. The reference data were Kort10 vector data combined with Kort25 raster data for Thorkild Høys maps, or "Lave målebordskort" from KMS for the elder maps. Ortho photos were used to control the results, and if morphological changes were evident the maps were corrected. This method is very crude, and only the fact that all these maps has an inherit uncertainty make this action justified. Bathymetric are always as a rule, just and aid to the navigator and not the truth.

Lastly the depth data on the maps were controlled against the lake theme (polygon) in Kort10 to ensure the topology. Some errors can not be corrected when trying to make old maps fit into updated maps. Shorelines change by nature or by man, and underwater features then unknown to the surveyor, might be visible to today on ortho photos. One problem related to the shorelines, is the fact that many shorelines in the Kort10 database lake theme (polygon), are identified from ortho photos. Trees can obscure the shoreline, and the polygon may reflect this. However the surveyor can collect depth data beneath the trees. This present a possible topology problem as depth line always must be inside the polygon. The final bitmap image of the scanned map, was saved in png format allowing transparent pixels.

The bitmaps were imported into GeoServer as a file directory using the ImageMosaic Store import option.

7.11.4 Depth contours

The vector layers are presented by GeoServer as raster due to the nature of WMS. The theme "depth", is the vectorized depth lines from the bathymetric maps mentioned above. These vector layers have several purposes, but mainly they must show what kind of vector data that's already on hand. There are a black and a white version of the same dataset, to allowing for better viewing on various base layers.

7.11.4.1 Vectorizing scanned maps

The purpose of this vectorization was to extract depth contours and soundings. Before the georeferenced images were vectorized, further cleaning of labels from the printed map were done, and in some cases the empty space left, were filled manually by photo editing. The vectorization process involved a semi automatic process instead of the manual way of creating the polyline in an overlay. There are several software products capable of doing this. The freeware Wintopo was used in this case.

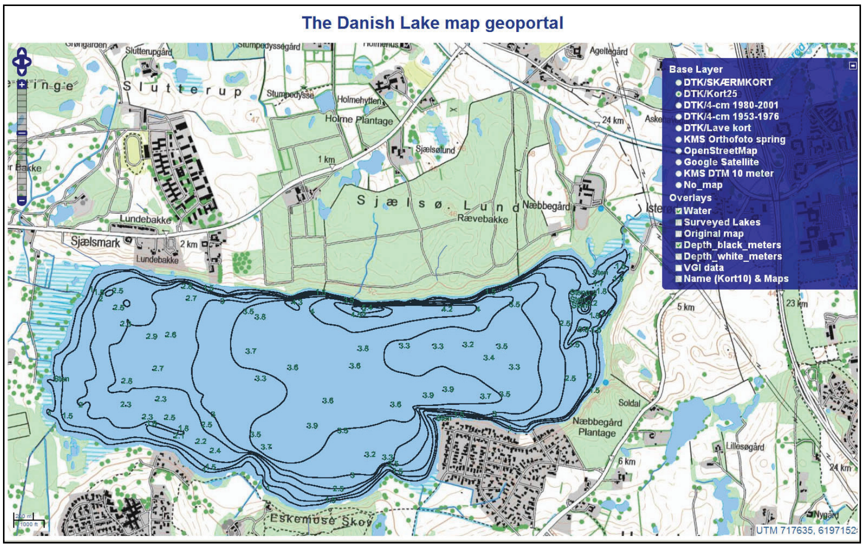


Figure 7.20 Lake Sjælsø with black contours viewed on Kort25 and Water layer (KMS)

The raw vectors were then imported into ArcGis for manual cleaning and combining with the scanned map as reference. The end result were polylines for depth lines and points for spot depths, and other relevant objects including name labels. In some cases further control were necessary. Using an ortho photo (preferably from a year with no wind and clear water), the vector data were controlled against clearly visible faults such as low water areas, rocks, etc. Finally the polylines were given extra nodes to improve smooth fullness and making later generalizations better funded, and controlled once again for topology issues with the Kort10 vector data set.

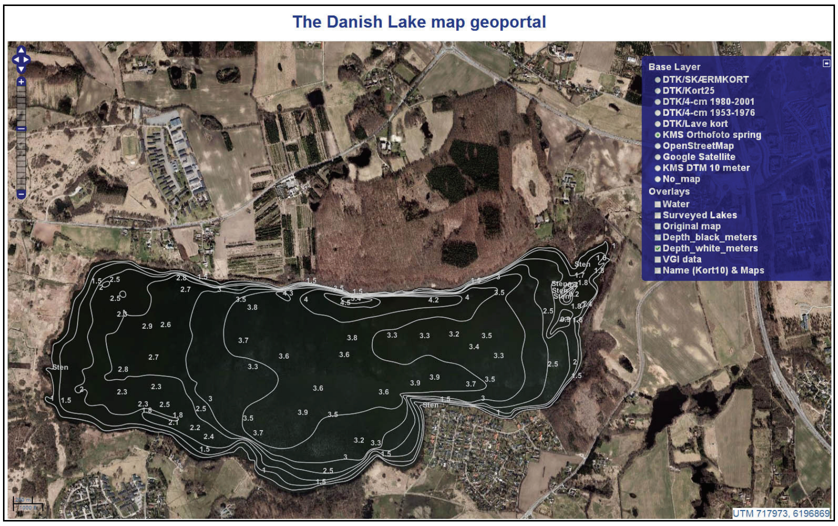


Figure 7.21 Lake Sjælsø with white contours viewed on ortho photo (KMS spring)

7.12 VGI data layers

These layers are vector based. The vector data resides in PostGis database. Vector data is either lines or points. The line features represents tracks with or with out depth attributes, and point features represent any kind of data specific position (could be observation of a dangerous object).

The VGI data layers will not update continuously or automatic upon upload. This could be done in theory, but data validation has to be done for each contribution before displaying on the map. VGI data will be shown in form of a post processed vector layer showing the kind of submitted and validated data.

Yellow line depicts GPS tracks depth and purple line without depth. Points marks VGI of any kind including metadata about new maps, old maps, hazards etc. Click on a object reviels metadata.

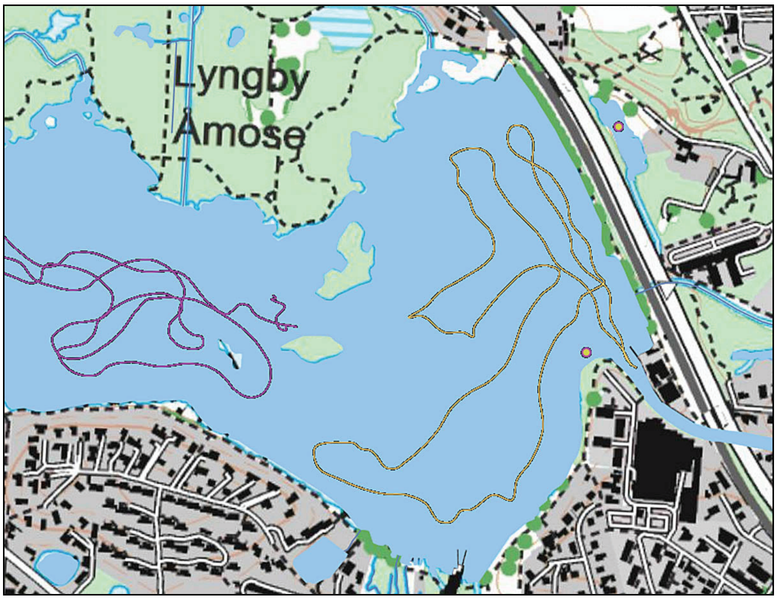


Figure 7.22 VGI data lines and points (KMS)

7.13 Summary

A Webgis portal was constructed depicting existing data and metadata, and allowing user to view data and to upload data. Several aspects of Web 2.0, VGI and presenting lake maps were considered.

Some identified problems in crowd sourcing VGI were addressed and the stakeholders identified. The main concepts of the WebGis prototype are:

- To present the user with lake data and relevant map layers through a map browser.
- To induce the user to contribute with data or other kinds of relevant data.
- To clarify metadata issues.

The first part was done by construction a map client with browsing capacities showing a large portion of the existing lake maps, and a base layer choice corresponding to the age of the lake map. The base layers included map form KMS and maps from Google and Openstreetmap, a blank map and a DTM hill shade based on the DTM data in Kort10 and elements of the vector data theme Hydro in same. The thematic layers included a detailed water layer, a point layer marking surveyed lakes (metadata presented when clicked on), the original lake map in transparent version for over lay, the depth contours in both black and white and finally the names of lakes.

Added to thematic layer is a VGI data layers showing where and what VGI data is uploaded. Polyline in two colours were used to depict data with or without depth data, and points were used to mark other kind of VGI data. When clicked on basic metadata is shown including a reference by ID to raw data.

To induce the user to contribute with data the map client was made as detailed as possible, and the other parts of the web page supplied the user with helping information and guidance. The metadata issue was solved using a form reading to fill out and email or upload option along with raw data.

As software only open source products was chosen. OpenLayers for map client and GeoServer for map server, Wamp (Apache, php & MySQL) for web server and PostGis for VGI database.

The thematic data layers in the map client, consists to a large part of bathymetrical data georeferenced (registered) and vectorized for the first time. The time involved is this process is quite large. They are however necessary to present lake mapping.

8 - Conclusion

The following research questions were put forward.

"What are the relevant standards?"

The answer to question is not clear, as bathymetric data for inland waters still need to be implemented in national databases, and neither ISO, nor OGC has specific standards. The INSPIRE draft for Elevation suggests implementing IHO standards including a sub dividing process by national hydrographic offices of lakes in areas according to surveying orders as in IHO S-44. The practice in this area is to apply IHO standards where charts for navigation are made. In Denmark the situation is somewhat different as the hydrographic office only operates in marine areas. This can change by implementing the INSPIRE elevation theme.

Compared to published and used inland lake maps from countries like Sweden and USA, it is clear that anything resembling a lake map is accepted, unless IHO standards are enforced. Printed maps, hand drawn map and maps based on hydrographic surveys are used indiscriminately. This would imply that a policy of "any map is better that no map" is acceptable unless a specific standard or data quality measure is enforced.

An answer could be to apply IHO standards to the whole Danish area and in the process assign all lakes to IHO order 1b, unless the hydrographic office decides that given lakes or water areas, has to be surveyed with hydrographic considerations in mind according to IHO Order Special or 1a. This approach will embrace the INSPIRE elevation draft.

"How is lake charts made?"

The surveying methods employed is the same used for surveying in marine areas with some considerations to cost, relevance and physical environment. Historically methods include soundings, acoustics and electro magnetic radiation like light and laser. Lake surveys have evolved from grid surveys, on to transect surveys, and to XYZ point surveys comparable to standard marine surveys.

Multi beam surveying is reserved to marine surveys following IHO standards despite smaller multibeam surveying vessels do exist. The cost is however prohibitive thus reserving lake mapping to cheaper single beam surveys.

The measured depth is combined with a coherent position obtained through GPS. The data is transformed into a DTM model. Single objects identified and deemed important for navigation are included in the map.

Data density varies given method and strategy. Multi beam surveys results in a "full seafloor search". Single beam surveys results in XYZ surveys with a line spacing given the chosen data density and a positional accuracy given the standard used.

"What issues in crowd sourcing VGI data are important?"

Crowd sourcing VGI is a subject for intense research. Both data and ontology related matters are investigated. The overall interest lies in the possibilities for supporting authoritive databases with VGI.

- *How to handle skills among VGI contributors?*
- *How to handle lack in completeness in data?*
- *How to handle uncertainties in VGI data?*
- *How can visualization assist the VGI process?*
- *How to ensure metadata?*
- *How to recognize the efforts from contributors?*
- *Who owns VGI data?*

Crowd sourced VGI data has several issues in comparison with professional data such as spatial accuracy, quality, completeness and credibility. All these potential errors in data, suggests a validation and control/filtering of data before use. Any system collecting data from the Internet will be vulnerable to erroneous or fake data. Added contributors motives to this, and we have some issues to tackle before using VGI data. At the receiving end, issues about data quality, given the planned use, are a main concern. This issue also applies to inclusion of VGI data into SDI. To some part it is assumed that the very use of VGI in authoritative databases also implies use in SDI.

"What is the present survey status for the Danish lakes?"

From an inventory only including the latest mapping effort for each lake, 322 lakes have a map. Nearly all data is published as a printed map. These lakes have a surface area of 50% of the total lake surface area given the Kort10 definition for lakes. Of lakes with a surface area of 10 hectares and larger, 75% of the area is mapped. This is a relatively large proportion. However if the age of the maps is considered, the results shows that the average age per surveyed hectare is 36 years, and that 97% were surveyed before 1997. The largest issue with the maps is the surveying method used. 93 have no description of method. 50 were made using "soundings". 175 were made using transects and only 4 were surveyed using modern xyz method. Furthermore only very little data about data density is available. It is therefore nearly impossible to asses the true quality of these maps.

"How good is the vertical accuracy of consumer echo sounders?"

The difference in professional and consumer electronics is significant, but if consumer electronics yields within a set of data standards, then data is useable. The vertical accuracy was tested. The main flaw of consumer echo sounders is the lack of sound velocity corrections. Instruments to measure sound velocity profiles are not common among non-professionals, so any echo sounder data from consumer products would be useless unless the factor is considered. To asses the vertical quality of consumer echo sounders, two echo sounders were subjected to a test to determine the vertical accuracy. It was assumed that the echo sounders use a fixed value for sound velocity. By measuring the water temperature a sound velocity was estimated. 4 areas were selected and a static test using more than 3000 depth readings were collected. The actual depth was measured. The test showed that a the echo sounder most likely use a constant sound velocity of 1463 and 1500 m/s, and that a correction with an estimated sounds velocity bring the relative error of depth measurement down to 0.6% or within accepted error margins. So the answer is that consumer echo sounders vertically are fit to harvest bathymetric data.

With respect to implementation of IHO standards, it would imply that VGI data would be restricted to "Orders 1b" allowing single beam data. As it happens the horizontal specification for this order is 5 meters, which in general should comply with most consumer echo sounder and GPS setups, given that systematic errors are compensated for or are negligible.

"Can a web based system be constructed to collect data using crowdsourcing, and can the data collected, form the basis for bathymetric data for inland lake charts according to relevant standards?"

The main research question is solved. A web based system to collect VGI data was constructed. It present the status and to some extent the data in question. And so it invites the potential contributors to fill out the gaps. As discovered any data is acceptable as no standards is enforced, and if a user were to contribute, they are asked to submit all relevant metadata to asses the quality of the data.

The visualization is very detailed and presents a robust view of the present lake map status in Denmark.

The upload functions did not proved as easy to solve. In fact the conclusion is that a very crude file upload system to contain all sorts of data is needed. The difficult part is not to collect data, but to post process data and making it available for later use.

Some software issues did pose a problem. In some parts the system design had to very crude. This was a pleasing in disguise, as it turned out that VGI data might be anything, and that the crucial part of the system is to collect metadata.

As crude the upload part might be, the post processing part is otherwise complicated. It will involve manual labour even before a VGI data on the map client can be updated. With respect to the data issues described, it is clear that a automated easy post processing is unrealistic.

9 - Perspectives

The initiating interest behind this thesis is surveying of lakes. The fascination of mapping the lakebed and mapping features are the driving forces. Denmark has well over 140.000 lakes covering over 60.000 hectares, but the lakes is among the least surveyed areas in Denmark. Only half the areas are surveyed at some time and with flimsy quality. They contain the last unknown areas, or even genuine white areas on the map.

Lake mapping have been conducted for many years, and there are several reasons for doing that. Besides exploring the unknown, lakes are important as resources. Studies into water capacity, fishing, scientific studies, recreational boating and unfortunately local waste deposit areas in several senses, all add to reasons for surveying and monitoring lakes. Data about lake morphology is essential for environmental monitoring. Any biologist will testify to that.

9.1 Data in national databases

Traditionally topographic mapping is restricted to visual areas from the air. I. e. tunnels are not mapped in national surveys. Lakes are neither. And charts made for navigation are just and aid to safe traffic. Some small areas are surveyed very accurately in conjunction with construction works, but these are exceptions. As the status is for Danish lake surveying, and in principle for European lake surveying, lake maps or data about lake morphology are not part of national topographic data sets. Charts made for navigation are handled separately. The draft for the new INSPIRE elevation theme includes lake bathymetry, so lake maps may be included in national data sets after all. Data standards for this kind of data are also in the dark, as neither ISO nor OGC has decided yet. Drafts are on the table. Time will show when and how.

9.2 Lakebed definition

The definition of the lakebed is dependent on the “eyes” that see. The depth at a point in a lake can be measured in different ways that all will generate different results. The variance might not be large, but a soft or weedy lake bed will yield significant different result when comparing methods. There is a set of definitions in DTM modelling of the earth’s surface. The same is not the case for lakes. The INSPIRE draft refers to standards set by IHO. This implies an adoption of IHO guidelines for surveying and points towards a depth definition, as a depth reading from the echo of a 200 kHz transducer, much like the American USACE employs. This definition is handy as most standard echo sounders both professional and consumer, and multi beam and single beam alike, can operate at this frequency. It is also handy on a sandy (sea) floor. Sonar waves will penetrate as deep as their energy allows. Low frequencies beneath 32 kHz will go deep in the sediment passing the surface. Frequencies between 32 and 100 kHz will penetrate plants and mud, while frequencies above this will show the visual surface depending on its density. High frequencies above 800 kHz to 1 MHz are not use full. There is however more to consider.

The new method bathymetric Lidar is employed more and more for shallow water surveying. Compared to standard multi beam surveying from large vessels, or detailed surveying in general, it is a cheap method. The principle in this method is light penetration in water, while echo sounders use sound propagation. The depth is in both cases determined by the time elapse before the echo/reflection return. But there is no guarantee that the two methods yield same results. This presents the problem of a definition: Where is the lakebed?

9.3 Bathymetric Lidar

As the Lidar method assumes clear water to the lake bed (and only operate until three times the clarity in water), the scope for this method in Danish lakes is limited to a very few. The overall tendency for Danish lakes is a development from unclear algae water into clear water lakes with water plants, which themselves will reflect light. But Bathymetric Lidar has to be investigated further for at least local deployment in Denmark. Some very clear lakes lack new data, and in some cases Lidar might be a good choice. There are two such candidates: Lake Vandet and lake Maribo Søndersø. Lake Vandet was surveyed in 1932 using soundings. It has very clear water. In fact so clear, that during georeferencing the original map, it was clear that the map was wrong. In this case bathymetric Lidar seems a good option. Lake Maribo Søndersø is another example of a difficult surveying. This is a big shallow lake. It was surveyed using transects during 1971-1976. The surveyor Thorkild Høy clearly writes on his map, that caution is advised when using his map, as many small unknown shallows might appear. In other word the morphology is so complex that his method did not reveal all potential hazards. This problem calls for a multi beam surveying, but this is unrealistic. When Thorkild Høy surveyed the lake, it was filled with green algae. Due to restoration the water is now clear and aerial photos clearly shows what the old map missed. Bathymetric Lidar performed in early spring just when water clears, and before brown algae and plants emerge, would provide a good map.

9.4 A new kind of mapping?

Published lake maps and charts depict the typical objects found on topographic maps and navigation charts, i.e. depth contours, soundings, hazards, marine structures etc. But a lake map showing the lakebeds composition is very rarely seen. With echo sounder and Lidar methods plants, mud and bedrock can be identified. Maybe it is time to reconsider that bathymetric maps solely must depict one (1) understanding of the lakebed. Like a DEM model showing the surface (DTM) and objects (DSM), and the topographic map showing both contours and the composition of the surface as well. One way could be to introduce specific layers reflecting the use of the map:

- Basic morphologic layer
- Environmental layer (sediment deposits etc)
- Aquatic layer (vegetation etc.)
- Hydrographic layer (IHO S-57 ENC)

9.5 Bathymetry in the Danish DTM?

The inclusion of a lake DTM into a general DTM sphere is perhaps closer than the relevance of lake mapping suggests. After all a lake is just by definition, a cavity in the surface filled with water (a puddle!). Every lake surveying is made with a reference to a water level relative to a vertical datum, and every lake polygon in our national datasets (Kort10 and FOT) is defined with a water level. In the Danish DTM model lake surfaces are flatten by enforcing a polygon into the model. It is usually done by setting a high water mark and defining a breakline. In the Danish case each lake were identified in the dataset and flatten (Lakefix method). Contrary to terrain surface the height of the water surface is ever changing, thus making any reference to a water level unreliable, whereas the inclusion of a lake DTM model would be comparably stable, and supported by a high water mark, a very good foundation for bathymetric lake charts.

9.6 How good are our maps?

The inventory for surveyed Danish lakes showed that the mapping quality is difficult to asses. It is properly not bad, as most surveying were done by professionals using techniques adequate at the time. But in reality no ones know. The maps show a generalized morphology sufficient for hydrologic calculations and ordinary navigation. Compared to the relevant IHO standard S-44 Order 1b, metadata is too scarce. It would be prudent to undertake further investigations into raw data of every surveying, to see if archived data could assist. In some cases it is evident that new surveying is needed, especially when the data is very old.

9.7 Do we need new data?

With so many uncharted lakes, and so much old lake surveying, the question is not if but when we need new data. There are economic, cartographic and political issues to consider. It is not realistic to hope for a complete lake survey effort in Denmark, nor that lake DTM's, in general will be established. However the need for new or better maps among environmental authorities and recreational stakeholders does support new mapping.

9.8 Alternative ways for harvesting new data

If the resources for new mapping are missing then crowd sourcing might be an option. There are much hype and buzzing about crowd sourcing. The spatial variant of crowd sourcing is centered on voluntary geographic information or VGI. VGI is tempting to use. This thesis describes the most important issues with VGI data. When VGI is discussed it seems to end up in a professional versus amateur data standoff. It is not that simple. Considering Goodchilds early work and others, describing the citizens as sensors and neogeographers qualities, data can be divided into its origin (source), use and quality.

Its origin might be the neophyte or the keen amateur, but it might as well be the well educated non-cartographer who want to help out (all motives included), or simply another qualified institution or person outside the professional cartographer sphere. In essence VGI represents both a challenge to authorities in specific areas, and new possibilities.

Use of VGI is very fragmented. Some data are just a geotagged notes about invasive plants etc. for use in municipalities. This is a very simple but effective way of sensor behaviour. Other kind of VGI data like tracks from GPS can be used to place roads or tracks like Openstreetmap collects data. And then there is VGI aimed at use alongside or within professional data.

The quality of data must be seen in conjunction with its use. VGI data is by nature uncertain. Geotagged messages from citizens acting as sensors may not have a very good horizontal accuracy. The attribute data is more important. GPS data from consumer units is a data type in its own right, as it tells us about the whereabouts of the citizens. In some cases data is used in Openstreetmap (and verified). In other instances the track numbers and density show the preferred routes being on land or on water. Again the horizontal position accuracy is not that important. The most demanding use of VGI data is along professional data, and so the quality in this case has to be sufficiently high including presence of metadata.

Data rights management or just intellectual rights also apply to VGI data. To secure use of VGI data, contributors are asked to hand over right s or attest to their ownership. But the problem will demand some legal considerations and maybe legislation, to both ensure that VGI data is useable and that VGI is not misused.

9.9 Quality of consumer echo sounders/GPS

This thesis confronts consumer echo sounder data with the standards data meets for professional use. And it shows that at least one element of data, the vertical accuracy, lives up to standards.

There are two other elements not investigated. That's horizontal accuracy and latency. The horizontal accuracy was tested using standard methods, and it showed that they perform very well in a kinematic test with accuracies below 1.5 meters from a control line. But the test was omitted simply because the method used was designed to ascertain the accuracy of a line, not a set of positions with attribute data. We lack a good method to test kinematic GPS data with attributes. Apart from the attribute test systematic errors in GPS data were persistent, and it would involve too much new testing to get a better grip of the problem. The way consumer GPS develops indicates that we can expect accuracies well below 5 meters, and thus testing this may be redundant, as the only surveys single beam echo sounders are permitted to do, have 5 meters as standard for horizontal accuracy.

The latency problem might not be such a problem. Some test with tracks and attributes moving in opposite directions, indicates latency around 1 second or less. It is not clear if this latency is a constant or is dependent of the echo sounder and GPS internal cpu load. It is however clear that Garmin units pick up a depth before calculating the position (using Kalman filtering) and a strategy to compensate for this error, is to sail crisscross.

9.10 Sound velocity in data and control of data

It is not possible to use echo sounders for depth data harvesting whit out knowing the speed of sound in water at the given time. In case of single beam echo sounder it is the (vertical) average of the sound velocity. A VGI system that collects these data must have some data about this. Unfortunately sound velocity profilers are not common equipment. Thermometers are, and most consumer "combi" units do record the surface temperature alongside the depth. The surface temperature might be a false lead. I.e. a calm day in spring will warm up only the surface layer of the water. The transverse happens in autumn as in the test conducted showed where air temperature falls significantly below water temperature and cools down the surface layer and the equipment. The VGI contributor cannot be expected to correct for this or to remember to check this. Added to this, are problems with thermoclines.

The presence of a thermo cline makes sound velocity monitoring crucial, and guide lines from professionals advices numerous test during surveys. In a relative small, but deep Danish lake, new sound velocity profiles would be necessary very often. One way to compensate for this is to use the temperature plots made as part of environmental monitoring as the one depicted in chapter 2 (Figure 2.8). Large water bodies react slowly to temperature changes and a yearly comparison from Lake Furesoe, indicates that the average temperature over deeper water is the same given the week year for year. In theory, these temperature data could be used to generate a matrix containing average temperature for a given depth for a given week. The temperature can be used to estimate the sound velocity using standard formulas.

One method to control depth data is the use of control areas. This method employed by Farvandsvæsenet when guiding extern data harvest, is simple. Certain areas with a known depth, has to be visited, and the depth collected can then be compared. This method has some potential in a VGI collecting system for lakes. However given the number of lake, the total control areas would be very large.

9.11 Sound velocity in echo sounders calculations

Every consumer echo sounder use one or two fixed values for sound velocity when calculating the depth from the time span of the returning echo. Professional echo sounders do the same or leave an option for later of active correction with this factor. This thesis presents a test which support that the constants used are 1463 (4800 feet/sec) & 1500 m/s. This would properly apply to most consumer sounders, but in order to collect data from echo sounders at large, a database with the constant for each unit must be established, or the contributor has to test the unit themselves. Only a handful vendors presently supply echo sounders with depth recording capabilities (GPS or via NMEA). The internal sound velocity constant might be the same for each vendor and product range, or it might not. In principle every echo sounder must undergo a test to determined the constant used. It would be strange if algorithms would differ from unit to unit, so it is properly a fair guess, that each model range uses the same. Maybe an understanding between the public or clients and vendors, would help to disclose this information.

9.12 Open source software and security issues

There were some technical issues due to the nature of Open Source software. Open source software has its advantages besides from being free, as they allow users to moderate or correct the code. There are however some problems with compatibility. In this case the whole client and setup was located on the same PC. This is the condition when designing such a system. However it turned out, that the two databases use the same server software, thus conflicting. For this reason some functionalities had to be let untried. Another problem arouse when a software update was applied to GeoServer. GeoServer is maintained with a new updated version relative often, and as it is software under constant development, it was presumed that an update would benefit the system. It was not so. In fact the whole installation process of data layers had to be repeated. In case a GeoServer setup is available at an ISP, this will present a large problem. GeoServer as a free packet is very easy to use, and its xml based SLD functionalities is very handy. But it is clear that GeoServer still is a beta product aimed at OpenLayer users well founded in JavaScript, Java and xml (including Ajax).

Another issue is security. The Internet pose some serious threats to data owners who wish to display their data, but not necessarily distribute it out of control. This system did not implement security issues, as it not designed for the public but a prototype. The code used may also not reflect the latest experience with secure coding. Therefore the email setup is tempting to use instead of an upload to database system, as the email functionality is found within all ISP's incorporating updated security measures.

9.13 The big picture for future Danish lake mapping

If VGI data is considered as a data alternative to professional data harvesting, and if data from consumer products can meet relevant standards, then data harvesting to these standards, regardless of source is relevant to consider. If the local authorities (municipalities) wish to update local lake maps, then a public VGI system and data harvesting by own staff with consumer electronic is a possibility. A joint venture between stakeholders could provide the raw data, and post processing and deliveries would be the job of the municipality or equal. The trend in data harvesting for national databases is moving towards local tasks, and perhaps the only way to get new data for lake mapping would be this way.

If one takes professional qualifications as the distinguishing characteristic of the professional, Darwin was by modern standards an amateur ornithologist, Banks was an amateur taxonomist and Galileo an amateur astronomer (Goodchild [1] 2009).

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Appendices:

A. Lake maps for sale. Inventory

B. Inventory over surveyed lakes

C. Python GPX parser

D. Error distribution for depth test

E. Code of Webgis
  1. Code of front page
  2. Map client
  3. The upload page
  4. About the maps
  5. What is data?
  6. GPS & echo sounder in a boat
  7. Water levels and corrections
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F. Metadata form

G. Vectorized lakes

H. Tanktest data

Appendix A

Lake maps for sale.
Inventory
Kort- & Matrikelstyrelsen

Nr.	Beskrivelse	pris m. moms
231-001 Agesø, Sjælland	Indsøkort 1:2.000	52,25
231-002 Arresø	Indsøkort 1:20.000	156,75
231-003 Avnsø	Indsøkort 1:4.000	52,25
231-004 Bagsværd Sø	Indsøkort 1:5.000	104,50
231-005 Bagsværd Sø	Indsøkort 1:9.080	52,25
231-006 Bastrup Sø	Indsøkort 1:5.000	104,50
231-007 Borup Sø	Indsøkort 1:5.000	52,25
231-008 Buesø	Indsøkort 1:4.000	52,25
231-009 Buresø	Indsøkort 1:5.000	104,50
231-010 Bøgeholm Sø og Bondedammen	Indsøkort 1:5.000	104,50
231-011 Dalby Sø	Indsøkort 1:5.000	52,25
231-012 Damhussøen	Indsøkort 1:4.000	104,50
231-013 Donse Storedam	Indsøkort 1:4.000	52,25
231-014 Emdrup Sø	Indsøkort 1:2.000	52,25
231-015 Esrum Sø	Indsøkort 1:10.000	156,75
231-016 Esrum Sø med farveaftrapning	Indsøkort 1:20.000	104,50
231-017 Farum Sø	Indsøkort 1:5.000	104,50
231-018 Gentofte Sø	Indsøkort 1:4.000	52,25
231-019 Gentofte Sø	Indsøkort ca. 1:5.700	52,25
231-020 Gundsømagle Sø	Indsøkort 1:5.000	104,50
231-021 Gurre Sø	Indsøkort 1:5.000	156,75
231-022 Hornbæk Sø	Indsøkort 1:5.000	52,25
231-023 Julmose	Indsøkort 1:4.000	52,25
231-024 Kattinge-Søerne	Indsøkort 1:5.000	156,75
231-025 Kimmerslev Sø	Indsøkort 1:5.000	104,50
231-026 Klaresø	Indsøkort 1:2.000	52,25
231-027 Knapsø	Indsøkort 1:5.000	52,25
231-028 Kornerup Sø	Indsøkort 1:5.000	52,25
231-029 Lyngby Sø	Indsøkort 1:4.000	104,50
231-030 Lyngby Sø med fotomosaik	Indsøkort ca. 1:4.000	104,50
231-031 Rude Skov Søerne (Agersø,	Løgsø og Skovrød Sø)	104,50
231-031 Rude Skov Søerne (Agersø,	Indsøkort 1:4.000	104,50
231-032 Selsø Sø	Indsøkort 1:5.000	104,50
231-033 Sjælsø Sø	Indsøkort 1:5.000	156,75
231-034 Sortesø	Indsøkort 1:2.000	52,25
231-035 Store Hulsø	Indsøkort 1:4.000	52,25
231-036 Svogerslev Sø	Indsøkort 1:5.000	52,25
231-037 Søndersø	Indsøkort 1:5.000	156,75
231-038 Vejlesø	Indsøkort 1:4.000	52,25
231-039 Avnsø	Indsøkort 1:4.000	52,25
231-040 Bromme Lillesø	Indsøkort 1:5.000	52,25
231-041 Bromme Maglesø	Indsøkort 1:5.000	104,50
231-042 Dybesø	Indsøkort 1:5.000	52,25

231-043 Ejlemade Sø	Indsøkort 1:5.000	52,25
231-044 Grevens Sø	Indsøkort 1:5.000	52,25
231-045 Gyrstinge Sø	Indsøkort 1:5.000	156,75
231-046 Gørlev Sø	Indsøkort 1:4.000	52,25
231-047 Haraldsted Langesø	Indsøkort 1:5.000	156,75
231-048 Holsteinborg Nor	Indsøkort 1:10.000	156,75
231-049 Hovvig	Indsøkort 1:5.000	156,75
231-050 Hvidsø	Indsøkort 1:5.000	52,25
231-051 Jystrup Sø	Indsøkort 1:5.000	52,25
231-052 Klarsø	Indsøkort 1:4.000	52,25
231-053 Korsør Nor	Indsøkort 1:10.000	156,75
231-054 Langedam/Sivdamsø/Skatkammersø	Indsøkort 1:4.000	104,50
231-055 Lejsø	Indsøkort 1:5.000	52,25
231-056 Madesø	Indsøkort 1:5.000	52,25
231-057 Maglesø	Indsøkort 1:4.000	52,25
231-058 Mortenstrup Sø	Indsøkort 1:5.000	52,25
231-059 Pedersborg Sø	Indsøkort 1:5.000	52,25
231-060 Saltbæk Vig	Indsøkort 1:10.000	156,75
231-061 Skarresø	Indsøkort 1:5.000	156,75
231-062 Skjoldenæsholm Gårdsø	Indsøkort 1:5.000	52,25
231-063 Skælskør Nor	Indsøkort 1:5.000	156,75
231-064 Sorø Sø	Indsøkort 1:5.000	156,75
231-065 Søtorup Sø	Indsøkort 1:5.000	104,50
231-066 Tissø	Indsøkort 1:8.000	156,75
231-067 Tissø	Indsøkort 1:10.000	156,75
231-068 Torbenfeld Sø	Indsøkort 1:5.000	52,25
231-069 Tuel Sø	Indsøkort 1:5.000	156,75
231-070 Tystrup og Bavelse Søer	Indsøkort 1:5.000	156,75
231-071 Tystrup og Bavelse Søer	Indsøkort 1:10.000	156,75
231-072 Ulse Sø	Indsøkort 1:5.000	52,25
231-073 Valsølille Sø	Indsøkort 1:5.000	104,50
231-074 Gjorslev Møllesø	Indsøkort 1:5.000	52,25
231-075 Glumsø Sø	Indsøkort 1:5.000	52,25
231-076 Hejrede Sø	Indsøkort 1:5.000	104,50
231-077 Maribo Nørresø	Indsøkort 1:5.000	104,50
231-078 Maribo Søndersø	Indsøkort 1:5.000	156,75
231-079 Maribo Søndersø	Indsøkort 1:10.000	156,75
231-080 Nakskov Indrefjord	Indsøkort 1:5.000	156,75
231-081 Nielstrup Sø	Indsøkort 1:5.000	52,25
231-082 Røgbølle Sø	Indsøkort 1:5.000	156,75
231-083 Snesere Sø	Indsøkort 1:4.000	52,25
231-084 Stege Nor	Indsøkort 1:10.000	156,75
231-085 Søerne på Høje Møn (Hund Sø,	Aborresø og Store Geddesø)	104,50
231-085 Søerne på Høje Møn (Hund Sø,	Indsøkort 1:4.000	104,50
231-086 Søerne ved Virket (Hulsø,	Møllesø og Virket Sø)	104,50
231-086 Søerne ved Virket (Hulsø,	Indsøkort 1:5.000	104,50
231-087 Søgård Sø	Indsøkort 1:5.000	52,25
231-088 Vesterborg Sø	Indsøkort 1:5.000	52,25
231-089 Hammer Sø	Indsøkort 1:4.000	52,25
231-090 Arreskov Sø	Indsøkort 1:5.000	156,75
231-091 Brahetrolleborg Nørresø	Indsøkort 1:5.000	104,50

231-092 Gudme Sø	Indsøkort 1:4.000	52,25
231-093 Hjulby Sø	Indsøkort 1:4.000	104,50
231-094 Ladegård Sø	Indsøkort 1:2.000	52,25
231-095 Langesø	Indsøkort 1:4.000	104,50
231-096 Nordby Sø	Indsøkort 1:4.000	52,25
231-097 Ollerup Sø	Indsøkort 1:5.000	104,50
231-098 Sortesø	Indsøkort 1:2.000	52,25
231-099 Søbo Sø	Indsøkort 1:4.000	52,25
231-100 Søby Sø	Indsøkort 1:4.000	52,25
231-101 Søholm Sø	Indsøkort 1:5.000	104,50
231-102 Sørup Sø	Indsøkort 1:5.000	52,25
231-103 Engelsholm Sø	Indsøkort 1:5.000	104,50
231-104 Fårup Sø	Indsøkort 1:5.000	104,50
231-105 Hallesø	Indsøkort 1:5.000	104,50
231-106 Hastrup Sø	Indsøkort 1:5.000	52,25
231-107 Ring Sø	Indsøkort 1:5.000	52,25
231-108 Stallerup Sø	Indsøkort 1:5.000	104,50
231-109 Stigsholm Sø	Indsøkort 1:5.000	52,25
231-110 Torup Sø	Indsøkort 1:5.000	52,25
231-111 Vestbirk-Søerne	(Bredvad Sø, Naldal Sø)	156,75
231-111 Vestbirk-Søerne	Indsøkort 1:5.000	156,75
231-112 Vængsø	Indsøkort 1:5.000	52,25
231-113 Alling Sø	Indsøkort 1:5.000	104,50
231-114 Avnsø (Aunsø)	Indsøkort 1:5.000	52,25
231-115 Birksø-Lillesø	Indsøkort 1:5.000	104,50
231-116 Brabrand Sø	Indsøkort 1:5.000	156,75
231-117 Bryrup Langsø og Karlsø	Indsøkort 1:5.000	104,50
231-118 Ellesø	Indsøkort 1:5.000	52,25
231-119 Fussing Sø	Indsøkort 1:5.000	156,75
231-120 Gudensø og Rye Møllesø	Indsøkort 1:5.000	156,75
231-121 Gudensø-Rye	Møllesø-Birksø-Lillesø	104,50
231-121 Gudensø-Rye	Indsøkort 1:10.000	104,50
231-122 Kalgård Sø og Kongsø	Indsøkort 1:5.000	52,25
231-123 Kvindsø, Kulsø og Snabe Igelsø	Indsøkort 1:5.000	104,50
231-124 Lyngsø	Indsøkort 1:5.000	52,25
231-125 Rævsø	Indsøkort 1:5.000	52,25
231-126 Sminge Sø	Indsøkort 1:5.000	104,50
231-127 Stilling-Solbjerg Sø	Indsøkort 1:5.000	156,75
231-128 Stilling-Solbjerg Sø	Indsøkort 1:10.000	104,50
231-129 Stubbe Sø	Indsøkort 1:5.000	156,75
231-130 Thorsø	Indsøkort 1:5.000	104,50
231-131 Velling Igelsø	Indsøkort 1:5.000	52,25
231-132 Vessø	Indsøkort 1:5.000	104,50
231-133 Hornum Sø	Indsøkort 1:5.000	52,25
231-134 Kielstrup Sø	Indsøkort 1:5.000	104,50
231-135 Mossø, Rold Skov	Indsøkort 1:4.000	52,25
231-136 Navnsø	Indsøkort 1:5.000	104,50
231-137 Sjørup Sø og Øjesø	Indsøkort 1:5.000	104,50
231-138 Snæbum Sø	Indsøkort 1:5.000	52,25
231-139 Flyndersø/Skallesø med Mørkesø	Indsøkort 1:5.000	156,75
231-140 Flyndersø/Skallesø med Mørkesø	Indsøkort 1:10.000	156,75

231-141 Hald Sø	Indsøkort 1:5.000	156,75
231-142 Hauge (Have) Sø	Indsøkort 1:5.000	52,25
231-143 Kås Sø	Indsøkort 1:5.000	104,50
231-144 Loldrup Sø	Indsøkort 1:5.000	52,25
231-145 Nørhå (Gyrup) Sø	Indsøkort 1:5.000	52,25
231-146 Ovesø	Indsøkort 1:10.000	156,75
231-147 Vansø	Indsøkort 1:5.000	104,50
231-148 Vedsø	Indsøkort 1:5.000	156,75
231-149 Viborg Nørre- og Søndersø	Indsøkort 1:5.000	156,75
231-150 Vorup (Førby) Sø	Indsøkort 1:5.000	52,25
231-151 Vullum (Voldum) Sø	Indsøkort 1:5.000	52,25
231-152 Elværk Sø	Indsøkort 1:5.000	52,25
231-153 Elværk Sø med fotomosaik	Indsøkort	52,25
231-154 Gødstrup Sø	Indsøkort 1:5.000	52,25
231-155 Hellesø	Indsøkort 1:5.000	52,25
231-156 Husby Sø/Nørresø (Åbjerg Sø)	Indsøkort 1:5.000	156,75
231-157 Kilen	Indsøkort 1:5.000	156,75
231-158 Kilen med fotomosaik	Indsøkort 1:7.560	104,50
231-159 Lemvig Sø med fotomosaik	Indsøkort 1:4.000	52,25
231-160 M.E.S. Sø	Indsøkort 1:5.000	52,25
231-161 M.E.S. Sø med fotomosaik	Indsøkort ca. 1:4.800	52,25
231-162 Stubbergård Sø	Indsøkort 1:5.000	156,75
231-163 Sunds Sø	Indsøkort 1:5.000	104,50
231-164 Søby Sø	Indsøkort 1:5.000	104,50
231-165 Søby Sø med fotomosaik	Indsøkort 1:6.400	52,25
231-166 Tranemose	Indsøkort 1:4.000	52,25
231-167 Tranemose med fotomosaik	Indsøkort ca. 1:3.300	52,25
231-168 Agsø	Indsøkort 1:4.000	52,25
231-169 Bankel Sø	Indsøkort 1:5.000	156,75
231-170 Grarup Sø	Indsøkort 1:4.000	52,25
231-171 Gråsten Slotssø	Indsøkort 1:5.000	52,25
231-172 Haderslev Dam med koor.system	Indsøkort 1:4.000	156,75
231-173 Haderslev Dam med koor.system	Indsøkort 1:5.000	156,75
231-174 Hejls Nor	Indsøkort 1:5.000	156,75
231-175 Hopsø	Indsøkort 1:4.000	52,25
231-176 Hostrup Sø	Indsøkort 1:5.000	156,75
231-177 Jels-Søerne	Indsøkort 1:5.000	52,25
231-178 Jels-Søerne, minoreret udgave	Indsøkort ca. 1:20.400	52,25
231-179 Ketting Nor	Indsøkort 1:5.000	104,50
231-180 Kruså Møllesø	Indsøkort 1:4.000	52,25
231-181 Lillehav	Indsøkort 1:5.000	52,25
231-182 Nordborg Sø	Indsøkort 1:5.000	104,50
231-183 Pamhule Sø	Indsøkort 1:4.000	52,25
231-184 Rygbjerg Sø	Indsøkort 1:4.000	52,25
231-185 Sandbjerg Mølledam	Indsøkort 1:5.000	52,25
231-186 Stevning Dam-Tørning Mølledam	Indsøkort 1:5.000	104,50
231-187 Søgård-Søerne	Indsøkort 1:5.000	104,50
231-188 Varnæs Skovsø	Indsøkort 1:5.000	52,25
231-189 Vedbøl Sø	Indsøkort 1:4.000	52,25
231-190 Vedsted Sø	Indsøkort 1:4.000	52,25
231-191 Hampen Sø/Geddesø, 1929/1931	Indsøkort 1:5.000	52,25

231-192 Almind Sø og Slaaensø, 1931	Indsøkort 1:5.000	104,50
231-193 Blegsø/Nors Sø/Vandet Sø, 1932	Indsøkort 1:10.000	156,75
231-194 St. Økssø og Madum Sø, 1932	Indsøkort 1:10.000	104,50
231-195 Glenstrup Sø, 1932	Indsøkort 1:10.000	156,75
231-196 Tjele Langsø, 1934	Indsøkort 1:10.000	156,75
231-197 Klejtrup Sø/HærupSø/Rødsø,1932	Indsøkort 1:10.000	156,75
231-198 Hald Sø og Hinge Sø. 1932	Indsøkort 1:10.000	156,75
231-199 Viborg Nørre- og Søndersø,1934	Indsøkort 1:10.000	156,75
231-200 Silkeborg Langsø/SmingeSø,1932	Indsøkort 1:10.000	156,75
231-201 Ørnsø/Brassø/Borres Sø, 1929	Indsøkort 1:10.000	156,75
231-202 Julsø, 1929	Indsøkort 1:10.000	156,75
231-203 Knudsø og Ravnsø, 1932	Indsøkort 1:10.000	156,75
231-204 Salten Langsø, 1929	Indsøkort 1:10.000	156,75
231-205 Mossø, 1929	Indsøkort 1:10.000	156,75
231-206 Skanderborg Søerne, 1932	Indsøkort 1:10.000	156,75
231-207 Rørbæk Søerne, 1932	Indsøkort 1:10.000	156,75
231-209 Pedersborg Sø, Tuel Sø og	Søtorup Sø, 1932	156,75
231-209 Pedersborg Sø, Tuel Sø og	Indsøkort 1:10.000	156,75
231-210 Farum Sø, 1917	Indsøkort 1:5.000	156,75
231-211 Furesø, 1917	Indsøkort 1:10.000	156,75
231-212 Bagsværd Sø	Indsøkort 1:5.000	156,75
231-213 Bastrup Sø, 1917	Indsøkort 1:5.000	104,50
231-214 Lyngby Sø, 1917	Indsøkort	52,25
231-215 Frederiksborg Slotssø	Indsøkort 1:4.000	52,25

Appendix B.

Inventory

Surveyed Danish lakes

NAME	Area_ha	Data_type	Map_scale	Vert_DNN	SurveyMeth	Surveyor	YEAR	KMS_arkiv	Reference
Aborresø	2.4	Printed_map	4000	92.5	Transect survey	Thorkild Høy	1981	231-085	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Agersø	3.5	Printed_map	4000	53	Grid Survey (Soundings)	Thorkild Høy	1996	231-031	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Agesø	2.4	Printed_map	2000	0	Grid Survey (Soundings)	Thorkild Høy	1964	231-001	Høy, Thorkild (1964): Agesø, Frederiksborg Amt
Agsø	11.3	Printed_map	4000	27	Transect survey	Thorkild Høy	1984	231-168	Høy, Thorkild (1984): Agsø, Åbenrå Kommune, Sønderjyllands Amt
Alling Sø	40.9	Printed_map	5000	22.7	Transect survey	Thorkild Høy	1975	231-113	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Ålling Sø	2.7	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Ålling Sø, Ølgod Kommune, Ribe Amt
Almind Sø	53.2	Printed_map	5000	21	Grid Survey (Soundings)	Geodætisk Institut	1931	231-192	Kort & Matrikelstyrelsen (1997): Almind Sø & Slaaensø
Amstrup Søer	2.2	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Amstrup Søer, Lemvig Kommune, Ringkøbing Amt
Amstrup Søer1	1.7	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Amstrup Søer, Lemvig Kommune, Ringkøbing Amt
Amstrup Søer2	1.4	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Amstrup Søer, Lemvig Kommune, Ringkøbing Amt
Amstrup Søer3	1.4	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Amstrup Søer, Lemvig Kommune, Ringkøbing Amt
Arreskov Sø	315.2	Printed_map	5000	32.7	Transect survey	Thorkild Høy	1989	231-090	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Arresø	3955.7	Printed_map	20000	3.97	Transect survey	Thorkild Høy	1994	231-002	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Avnsø	6.6	Printed_map	4000	9	Transect survey	Thorkild Høy	1988	231-039	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Avnsø	4.9	Printed_map	4000	69.2	Transect survey	Thorkild Høy	1981	231-003	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Avnsø	10.5	Printed_map	5000	21	Transect survey	Thorkild Høy	1982	231-114	Høy, Thorkild (1982): Avnsø, Silkeborg Kommune, Århus Amt
Bagsværd Sø	116.8	Printed_map	5000	18.5	Transect survey	Thorkild Høy	1993	231-004	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Barnsø	21.8	Printed_map	1500	0	Unknown method	BioConsult	1986		BioConsult (1986): Barn Sø, Blåvandshuk Kommune, Ribe Amt
Bastrup Sø	30.3	Printed_map	4000	28.7	Transect survey	Thorkild Høy	1976	231-006	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Birkerød Sø	8.6	Printed_map	2500	46.8	Grid Survey (Soundings)	Birkerød Kommune	1996		Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Birksø	69	Printed_map	5000	21	Transect survey	Thorkild Høy	1975	231-115	Høy, Thorkild (1987): Birksø, Lillesø, Gudensø og Rye Mølle Sø, Ry Kommune, Århus Amt
Blegsø	39.3	Printed_map	10000	16.09	Grid Survey (Soundings)	Geodætisk Institut	1932	231-193	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Bøgeholm Sø	28.4	Printed_map	5000	25.3	Transect survey	Thorkild Høy	1982	231-010	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Bondedammen	13.5	Printed_map	5000	21	Transect survey	Thorkild Høy	1982	231-010	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Bønstrup Sø	9.8	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Bønstrup Sø, Vamdrup Kommune, Vejle Amt
Borgbjerg Møllesø	12.6	Printed_map	0	15.08	Unknown method	BioConsult	1990		BioConsult (1990): Borbjerg Møllesø, Holstebro Kommune, Ringkøbing Amt
Borgsø	12.7	Printed_map	0	5.4	Transect survey	Thorkild Høy	1998		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Borresø	198.3	Printed_map	10000	20.7	Grid Survey (Soundings)	Geodætisk Institut	1929	231-201	Kort & Matrikelstyrelsen (1997): Ørnsø, Brassø & Borresø
Borup Sø	9	Printed_map	5000	40	Transect survey	Thorkild Høy	1991	231-007	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Brabrand Sø	145.8	Printed_map	5000	0.7	Transect survey	Thorkild Høy	1979	231-116	Høy, Thorkild (1979): Brabrand Sø. Århus Kommune, Århus Amt
Brændegård Sø	105.6	Printed_map	2000	40.31	Unknown method	Fyns Amt	1974		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Brahetrolleborg Nørresø	69.3	Printed_map	5000	40.8	Transect survey	Thorkild Høy	1988	231-091	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Brassø	121.7	Printed_map	10000	20.7	Grid Survey (Soundings)	Geodætisk Institut	1929	231-201	Kort & Matrikelstyrelsen (1997): Brassø & Borresø
Bredvad Sø	12.8	Printed_Map	0	42.3	Transect survey	Thorkild Høy	1974	231-111	Høy, Thorkild (1974): Vestbirk Søerne (Vestbirk Sø, Naldal Sø & Bredvad Sø), Brædstrup og Gedved kommuner, Vejle Amt
Bromme Lillesø	12.7	Printed_map	5000	30.4	Transect survey	Thorkild Høy	1985	231-040	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Bromme Maglesø	70.6	Printed_map	5000	30	Transect survey	Thorkild Høy	1985	231-041	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Buesø	5.5	Printed_map	4000	2.6	Transect survey	Thorkild Høy	1990	231-008	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Buresø	75.4	Printed_map	5000	26.5	Transect survey	Thorkild Høy	1981	231-009	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Bygholm Sø	50.8	Printed_map	11000	0	Unknown method	BioConsult	1988		BioConsult (1988): Bygholm Sø, Horsens Kommune, Vejle Amt
Dalby Sø	13.7	Printed_map	5000	31.5	Transect survey	Thorkild Høy	1991	231-011	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Dallerup Sø	8.3	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Dallerup Sø, Horsens Kommune, Vejle Amt
Dallund Sø	15	Printed_map	0	12.07	Unknown method	BioConsult	1991		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Damhus Sø	46.2	Printed_map	4000	8.5	Transect survey	Thorkild Høy	1994	231-012	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Dybesø	17.1	Printed_map	5000	2.3	Transect survey	Thorkild Høy	1987	231-042	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Ejlemade Sø	21.3	Printed_map	5000	50.5	Transect survey	Thorkild Høy	1984	231-043	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Ejstrup Sø	39.3	Printed_map	0	0	Unknown method	BioConsult	1989		BioConsult (1989): Ejstrup Sø, Nørre-Snede Kommune, Vejle Amt
Ellesø	7.2	Printed_map	5000	21	Transect survey	Thorkild Høy	1982	231-118	Høy, Thorkild (1982): Ellesø, Silkeborg Kommune, Århus Amt
Elværk Sø	10.9	Printed_map	5000	41.1	Transect survey	Thorkild Høy	1990	231-152	Høy, Thorkild (1990): Elværk Sø, Brande Kommune, Ringkøbing Amt
Emdrup Sø	5.9	Printed_map	2000	14.7	Transect survey	Thorkild Høy	1994	231-014	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Engelsholm Sø	43.2	Printed_map	5000	55	Transect survey	Thorkild Høy	1981	231-103	Høy, Thorkild (1981): Engelsholm Sø, Egtved Kommune, Vejle Amt
Engsøen	28.2	Printed_map	0	0	Unknown method	?	1986		Billund Kommune (2008): Grindsted Engsø – Miljøtilstand og fremtidsmuligheder
Ensø	10.5	Printed_map	0	0.48	Unknown method	BioConsult	1991		BioConsult (1991): Ensø, Nørresnede Kommune, Vejle Amt
Esrum Sø	1738.5	Printed_map	10000	9.4	XYZ Point Survey	Thorkild Høy	1983	231-015	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Fåresø	9	Printed_map	1500	0	Unknown method	BioConsult	1986		BioConsult (1986): Fåresø, Blåvandshuk Kommune, Ribe Amt
Farum Sø	117.4	Printed_map	5000	20.5	Transect survey	Thorkild Høy	1976	231-017	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Fårup Sø	94.9	Printed_map	5000	48.1	Transect survey	Thorkild Høy	1981	231-104	Høy, Thorkild (1981): Fårup Sø, Egtved og Jelling Kommuner, Vejle Amt
Ferring Sø	315	Printed_map	0	0.21	Unknown method	BioConsult	1989		BioConsult (1989): Ferring Sø, Lemvig/Thyborøn-Harboøre Kommune, Ringkøbing Amt
Filsø	65.9	Printed_map	3000	0	Unknown method	BioConsult	1986		BioConsult (1986): Filsø, Blåbjerg Kommune, Ribe Amt
Fjellerup Sø	5.9	Printed_map	2535	73.15	Unknown method	BioConsult	1992		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Flødstrup Sø	4.3	Printed_map	2000	12.2	Unknown method	BioConsult	1997		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Flyndersø	418.5	Printed_map	5000	3	Transect survey	Thorkild Høy	1986	231-139	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Førby Sø	50.5	Printed_map	5000	16.9	Transect survey	Thorkild Høy	1984	231-150	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Fuglesø	4.9	Printed_map	5000	6.02	Unknown method	Geoscandio	1990		Frederiksborg Amt (2002): Internt notat, Fuglesø 2000
Furesø	935.9	Digital_data	5000	20.5	XYZ Point Survey	Thomas Vedel	2010		Vedel, Thomas (2011): Personal archive
Fussing Sø	219.4	Printed_map	5000	16.9	Transect survey	Thorkild Høy	1979	231-119	Høy, Thorkild (1979): Fussing Sø, Purhus Kommune, Århus Amt
Gårdsø	10.3	Printed_map	5000	64.8	Transect survey	Thorkild Høy	1986	231-062	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Geddesø	3.3	Printed_map	5000	0	Grid Survey (Soundings)	Geodætisk Institut	1931	231-191	Kort & Matrikelstyrelsen (1997): Hampen Sø & Geddesø
Gentofte Sø	22.5	Printed_map	4000	16.8	Transect survey	Thorkild Høy	1994	231-018	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Gjeller Sø	55.5	Printed_map	0	0.05	Unknown method	BioConsult	1989		BioConsult (1989): Gjeller Sø, Lemvig Kommune, Ringkøbing Amt
Gjorslev Møllesø	21.7	Printed_map	5000	9.3	Transect survey	Thorkild Høy	1984	231-074	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Glenstrup Sø	349.1	Printed_map	10000	14.08	Grid Survey (Soundings)	Geodætisk Institut	1932	231-195	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Glumsø Sø	23.3	Printed_map	5000	10.5	Transect survey	Thorkild Høy	1978	231-075	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Gødstrup Sø	44.9	Printed_map	5000	37.4	Transect survey	Thorkild Høy	1988	231-154	Høy, Thorkild (1988): Gødstrup Sø, Herning Kommune, Ringkøbing Amt
Gørlev Sø	7.9	Printed_map	4000	21.8	Transect survey	Thorkild Høy	1990	231-046	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Grarup Sø	8.3	Printed_map	4000	16.5	Transect survey	Thorkild Høy	1984	231-170	Høy, Thorkild (1984): Grarup Sø, Haderslev Kommune, Sønderjyllands Amt
Grevens Sø	10	Printed_map	5000	0	Grid Survey (Soundings)	Thorkild Høy	1990	231-044	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Grovsø	4.8	Printed_map	1000	0	Unknown method	BioConsult	1986		BioConsult (1986): Grovsø, Blåvandshuk Kommune, Ribe Amt
Gudensø	130.9	Printed_map	5000	2.23	Transect survey	Thorkild Høy	1975	231-120	Høy, Thorkild (1975): Gudensø og Rye Mølle Sø, Ry Kommune, Århus Amt
Gudme Sø	9.1	Printed_map	4000	49.3	Transect survey	Thorkild Høy	1987	231-092	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Guldager Mølledam	2.2	Printed_map	0	0	Unknown method	BioConsult	1986		BioConsult (1986): Guldager Mølledam, Esbjerg Kommune, Ribe Amt
Gundsømagle Sø	28.7	Printed_map	5000	3.9	Transect survey	Thorkild Høy	1981	231-020	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Gurre Sø	190.9	Printed_map	5000	26.4	Transect survey	Thorkild Høy	1962	231-021	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Gyrstinge Sø	261.9	Printed_map	5000	24.3	Transect survey	Thorkild Høy	1985	231-045	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Haderslev Dam	268	Printed_map	5000	2.1	Transect survey	Thorkild Høy	1985	231-173	Høy, Thorkild (1985): Haderslev Dam, Haderslev Kommune, Sønderjyllands Amt
Hærup Sø	60.2	Printed_map	10000	3.1	Grid Survey (Soundings)	Geodætisk Institut	1932	231-197	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Hald Sø	342.8	Printed_map	5000	9.1	Transect survey	Thorkild Høy	1988	231-141	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Halle Sø	31.2	Printed_map	5000	68	Transect survey	Thorkild Høy	1976	231-105	Høy, Thorkild (1976): Halle Sø, Nr. Snede og Brændstrup Kommuner, Vejle Amt
Hammer Sø	10.3	Printed_map	4000	8.5	Transect survey	Thorkild Høy	1984	231-089	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Hampen Sø	72.3	Printed_map	5000	0	Grid Survey (Soundings)	Geodætisk Institut	1929	231-191	Kort & Matrikelstyrelsen (1997): Hampen Sø & Geddesø
Haraldsted Sø	197.4	Printed_map	5000	22	Transect survey	Thorkild Høy	1981	231-047	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Hastrup Sø	13.7	Printed_map	5000	51.9	Transect survey	Thorkild Høy	1982	231-106	Høy, Thorkild (1982): Hastrup Sø, Give Kommune, Vejle Amt

NAME	Area_ha	Data_type	Map_scale	Vert_DNN	SurveyMeth	Surveyor	YEAR	KMS_arkiv	Reference
Hauge Sø	15.2	Printed_map	5000	65.8	Transect survey	Thorkild Høy	1988	231-142	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Hejrede Sø	54.9	Printed_map	5000	7	Transect survey	Thorkild Høy	1977	231-076	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Hellesø	25.2	Printed_map	5000	3.5	Transect survey	Thorkild Høy	1985	231-155	Høy, Thorkild (1985): Hellesø, Vinderup Kommune, Ringkøbing Amt
Hellesø	2.9	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Helle Sø, Blåvandshuk Kommune, Ribe Amt
Hinge Sø	91.8	Printed_map	0	25.37	Unknown method	BioConsult	1992		Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Hjortlund Sø	2.4	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Hjortlund Sø, Grindsted Kommune, Ribe Amt
Hjulby Sø	14.8	Printed_map	4000	3.95	Transect survey	Thorkild Høy	1985	231-093	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Højbjergsø	0.4	Printed_map	1000	0	Transect survey	Thomas Vedel	2002		Vedel, Thomas (2011): Personal archive
Holmgård Sø	13.4	Printed_map	0	10.28	Unknown method	BioConsult	1990		BioConsult (1990): Holmgård Sø, Holstebro Kommune, Ringkøbing Amt
Holmsø	11.7	Printed_map	1500	0	Unknown method	BioConsult	1986		BioConsult (1986): Holmsø, Blåvandshuk Kommune, Ribe Amt
Hopsø	9.5	Printed_map	4000	0.3	Transect survey	Thorkild Høy	1986	231-175	Høy, Thorkild (1986): Hopsø, Haderslev Kommune, Sønderjyllands Amt
Hornbæk Sø	11.8	Printed_map	5000	4.3	Transect survey	Thorkild Høy	1981	231-022	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Hornsø	28.7	Printed_map	0	0.34	Unknown method	BioConsult	1989		BioConsult (1989): Hornsø, Lemvig Kommune, Ringkøbing Amt
Hornum Sø	11.5	Printed_map	5000	46.5	Transect survey	Thorkild Høy	1981	231-133	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Hostrup Sø	203.4	Printed_map	5000	35.3	Transect survey	Thorkild Høy	1983	231-176	Høy, Thorkild (1983): Hostrup Sø, Lundtoft Kommune, Sønderjyllands Amt
Hovvig	4.9	Printed_map	5000	0.1	Transect survey	Thorkild Høy	1988	231-049	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Hulsø	3	Printed_map	5000	11	Grid Survey (Soundings)	Thorkild Høy	1978	231-086	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Hunesø	5.9	Printed_map	4000	88.3	Transect survey	Thorkild Høy	1981	231-085	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Husby Sø	132.7	Printed_map	5000	0.3	Transect survey	Thorkild Høy	1988	231-156	Høy, Thorkild (1988): Husby Sø og Nørresø (Åbjerg Sø), Ulfborg-Vemb og Ringkøbing Kommuner, Ringkøbing Amt
Hvidkilde Sø	59.7	Printed_map	6000	19.43	Unknown method	BioConsult	1995		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Hvidsø	5.7	Printed_map	5000	59.9	Transect survey	Thorkild Høy	1961	231-050	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Hygum Nor	27.7	Printed_map	0	0.05	Unknown method	BioConsult	1989		BioConsult (1989): Hygum Nor, Lemvig Kommune, Ringkøbing Amt
Igelsø	7.6	Printed_map	5000	0	Transect survey	Thorkild Høy	1976	231-131	Høy, Thorkild (1976): Velling Igelsø, Them Kommune, Århus Amt
Indfjorden	206.8	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Indfjorden, Lemvig Kommune, Ringkøbing Amt
Indrefjord	67.2	Printed_map	5000	-0.1	Transect survey	Thorkild Høy	1978	231-080	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Julmose	2.7	Printed_map	4000	34.8	Grid Survey (Soundings)	Thorkild Høy	1996	231-023	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Julsø	557.5	Printed_map	10000	20.7	Grid Survey (Soundings)	Geodætisk Institut	1929	231-202	Kort & Matrikelstyrelsen (1997): Julsø
Jystrup Sø	5.8	Printed_map	5000	62.9	Transect survey	Thorkild Høy	1986	231-051	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Kalgård Sø	9.6	Printed_map	5000	74.7	Transect survey	Thorkild Høy	1974	231-122	Høy, Thorkild (1993): Kalgård Sø og Kongsø, Them Kommune, Århus Amt
Karlsgårde Sø	82.5	Printed_map	0	12.8	Unknown method	BioConsult	1987		BioConsult (1987): Karlsgårde Sø, Helle Kommune, Ribe Amt
Karlsø	7.3	Printed_map	5000	58.2	Transect survey	Thorkild Høy	1972	231-117	Høy, Thorkild (1972): Bryrup Langsø og Karlsø, Bryrup, Vinding og Grædstrup sogne, Århus og Vejle Amter
Kås Sø	60.6	Printed_map	5000	0.4	Transect survey	Thorkild Høy	1984	231-143	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Keldsnor	70.2	Printed_map	4000	0	Unknown method	BioConsult	1994		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Kielstrup Sø	35.1	Printed_map	5000	0.01	Transect survey	Thorkild Høy	1981	231-134	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Kimmerslev Sø	37.5	Printed_map	5000	30.8	Transect survey	Thorkild Høy	1991	231-025	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Klaresø	3.7	Printed_map	2000	27	Grid Survey (Soundings)	Thorkild Høy	1961	231-026	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Klarsø	2.7	Printed_map	4000	47.8	Transect survey	Thorkild Høy	1989	231-052	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Klejtrup Sø	128.4	Printed_map	10000	6.15	Grid Survey (Soundings)	Geodætisk Institut	1932	231-197	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Klokkerholm Møllesø	7.3	Printed_map	0	0	Unknown method	Nordjyllands amt	2007		Liboriussen, L., Søndergaard, M. & Jeppesen, E. (red.) 2007: Sørestaurering i Danmark. Del II: Faglig rapport fra DMU nr. 636
Knapsø	5.2	Printed_map	5000	51.2	Grid Survey (Soundings)	Thorkild Høy	1993	231-027	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Knoldsø	3.5	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Knoldsø, Billund Kommune, Ribe Amt
Knudsø	194.1	Printed_map	10000	20.9	Grid Survey (Soundings)	Geodætisk Institut	1932	231-203	Kort & Matrikelstyrelsen (1997): Knudsø & Ravnsø
Kongsø	3.3	Printed_map	5000	74.2	Transect survey	Thorkild Høy	1974	231-122	Høy, Thorkild (1993): Kalgård Sø og Kongsø, Them Kommune, Århus Amt
Komerup Sø	7.2	Printed_map	5000	4	Transect survey	Thorkild Høy	1989	231-028	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Kulsø	16.4	Printed_map	5000	55.15	Transect survey	Thorkild Høy	1972	231-123	Høy, Thorkild (1993): Kvindsø, Kulsø og Snabe Igelsø, Bryrup og Vrads Sogne, Århus Amt
Kvie Sø	31.3	Printed_map	2000	0	Unknown method	BioConsult	1986		BioConsult (1986): Kvie Sø, Ølgod Kommune, Ribe Amt
Kvindsø	15.7	Printed_map	5000	55.2	Transect survey	Thorkild Høy	1972	231-123	Høy, Thorkild (1993): Kvindsø, Kulsø og Snabe Igelsø, Bryrup og Vrads Sogne, Århus Amt
Ladegård Sø	2.1	Printed_map	2000	3.75	Transect survey	Thorkild Høy	1985	231-094	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Landsø	5	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Landsø, Blåbjerg Kommune, Ribe Amt
Langebjerg Gravsø	4.8	Printed_map	0	0	Unknown method	Frederiksborg Amt	2006		Frederiksborg Amt (2007): Langebjerg Gravsø, Bunddyrsundersøgelse
Langedam	5.4	Printed_map	4000	49.9	Transect survey	Thorkild Høy	1989	231-054	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Langesø	17.1	Printed_map	4000	25.3	Transect survey	Thorkild Høy	1986	231-095	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Langsø	37.4	Printed_map	5000	57.6	Transect survey	Thorkild Høy	1972	231-117	Høy, Thorkild (1972): Bryrup Langsø og Karlsø, Bryrup, Vinding og Grædstrup sogne, Århus og Vejle Amter
Langsø	30.9	Printed_map	2000	0	Unknown method	BioConsult	1986		BioConsult (1986): Grærup Langsø, Blåvandshuk Kommune, Ribe Amt
Langsø	38.1	Printed_map	10000	14	Unknown method	Århus Amt	1981		BioConsult (2005): NOVANA 2004, Vegetationen i Ulstrup Langsø
Lejsø	18.3	Printed_map	5000	0.5	Grid Survey (Soundings)	Thorkild Høy	1990	231-055	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Lemvig Sø	14.4	Printed_map	4000	0.3	Transect survey	Thorkild Høy	1989	231-159	Høy, Thorkild (1989): Lemvig Sø, Lemvig Kommune, Ringkøbing Amt
Lille Kattinge Sø	4.2	Printed_map	5000	2.5	Transect survey	Thorkild Høy	1990	231-024	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Lille Østerlide Sø	0.4	Printed_map	2000	0	Grid Survey (Soundings)	Thomas Vedel	1990		Vedel, Thomas (2011): Personal archive
Lille Søgård Sø	6.8	Printed_map	5000	34.4	Transect survey	Thorkild Høy	1983	231-187	Høy, Thorkild (1983): Søgård-Søerne, Lundtoft Kommune, Sønderjyllands Amt
Lilleflo	1.7	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Lønne Kirkeflod, Nørre Nebel (Blåbjerg) Kommune, Ribe Amt
Lillehav	15.9	Printed_map	5000	0.1	Transect survey	Thorkild Høy	1987	231-181	Høy, Thorkild (1987): Lillehav, Augustenborg Kommune, Sønderjyllands Amt
Lillesø	21.2	Printed_map	10000	23.46	Grid Survey (Soundings)	Geodætisk Institut	1932	231-206	Kort & Matrikelstyrelsen (1997): Skanderborg-Søerne
Løjesø	6.4	Printed_map	4000	49.9	Grid Survey (Soundings)	Thorkild Høy	1996	231-031	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Loldrup Sø	38.2	Printed_map	5000	11.6	Transect survey	Thorkild Høy	1987	231-144	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Lyngby Sø	56.7	Printed_map	4000	18.5	Transect survey	Thorkild Høy	1989	231-029	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Lyngsø	9.3	Printed_map	5000	20.8	Transect survey	Thorkild Høy	1982	231-124	Høy, Thorkild (1982): Lyngsø, Silkeborg Kommune, Århus Amt
M.E.S. Sø	13.6	Printed_map	5000	46.8	Transect survey	Thorkild Høy	1990	231-160	Høy, Thorkild (1990): M.E.S. Sø, Brande Kommune, Ringkøbing Amt
Madesø	28.5	Printed_map	5000	1.7	Transect survey	Thorkild Høy	1979	231-056	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Madum Sø	203	Printed_map	10000	37.1	Grid Survey (Soundings)	Geodætisk Institut	1932	231-194	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Maglesø	14.1	Printed_map	4000	50.8	Transect survey	Thorkild Høy	1990	231-057	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Marbæksøerne	4.5	Printed_map	2000	0	Unknown method	BioConsult	1986		BioConsult (1986): Marebæk Sø, Esbjerg Kommune, Ribe Amt
Marbæksøerne	13.4	Printed_map	2000	0	Unknown method	BioConsult	1986		BioConsult (1986): Marebæk Sø, Esbjerg Kommune, Ribe Amt
Marbæksøerne	2.5	Printed_map	2000	0	Unknown method	BioConsult	1986		BioConsult (1986): Marebæk Sø, Esbjerg Kommune, Ribe Amt
Maribo Nørresø	38.1	Printed_map	5000	8.6	Transect survey	Thorkild Høy	1976	231-077	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Maribo Søndersø	802	Printed_map	10000	8.6	Transect survey	Thorkild Høy	1977	231-079	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Marielundsøen	1.6	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Marielund Sø, Kolding Kommune, Vejle Amt
Mellemvese	12.2	Printed_map	0	0.11	Unknown method	BioConsult	1989		BioConsult (1989): Mellemvese, Thyborøn-Harboøre Kommune, Ringkøbing Amt
Midtsø	24.1	Printed_map	5000	36	Transect survey	Thorkild Høy	1982	231-177	Høy, Thorkild (1982): Jels-Søerne, Rødding Kommune, Sønderjyllands Amt
Møllesø	10.2	Printed_map	5000	12.5	Transect survey	Thorkild Høy	1978	231-086	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Møllesøen	11.7	Printed_map	4000	0	Transect survey	Thorkild Høy	1982	231-180	Høy, Thorkild (1982): Kruså Møllesø, Bov Kommune, Sønderjyllands Amt
Mørkesø	3.8	Printed_map	5000	4.1	Transect survey	Thorkild Høy	1986	231-139	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Mortenstrup Sø	8	Printed_map	5000	64.9	Transect survey	Thorkild Høy	1986	231-058	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Mossø	1657	Printed_map	10000	22.3	Grid Survey (Soundings)	Geodætisk Institut	1929	231-205	Kort & Matrikelstyrelsen (1997): Mossø
Mossø	3.5	Printed_map	4000	55.7	Transect survey	Thorkild Høy	1981	231-135	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Munkesø	21.2	Printed_map	2000	0	Unknown method	BioConsult	1986		BioConsult (1986): Munke Sø, Ribe Kommune, Ribe Amt
Naldal Sø	13.6	Printed_map	5000	42.3	Transect survey	Thorkild Høy	1974	231-111	Høy, Thorkild (1974): Vestbirk Søerne (Vestbirk Sø, Naldal Sø & Bredvad Sø), Brædstrup og Gedved kommuner, Vejle Amt
Navnsø	18.2	Printed_map	5000	27.5	Transect survey	Thorkild Høy	1981	231-136	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Nebel Sø	2.1	Printed_map	1000	0	Unknown method	BioConsult	1986		BioConsult (1986): Vester Nebel Sø, Esbjerg Kommune, Ribe Amt
Nedenskov Sø	9.5	Printed_map	0	0.6	Unknown method	BioConsult	1991		BioConsult (1991): Nedenskov Sø, Brædstrup Kommune, Vejle Amt
Nedersø	53.4	Printed_map	5000	36	Transect survey	Thorkild Høy	1982	231-177	Høy, Thorkild (1982): Jels-Søerne, Rødding Kommune, Sønderjyllands Amt

NAME	Area_ha	Data_type	Map_scale	Vert_DNN	SurveyMeth	Surveyor	YEAR	KMS_arkiv	Reference
Nielstrup Sø	15.2	Printed_map	5000	48.7	Grid Survey (Soundings)	Thorkild Høy	1979	231-081	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Nielstrup Sø	4	Printed_map	2850	12.76	Grid Survey (Soundings)	Fyns Amt	1974		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Nipgård Sø	33	Printed_map	9000	58.8	Grid Survey (Soundings)	Korkman	1976		Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Nordborg Sø	54.6	Printed_map	5000	4.2	Transect survey	Thorkild Høy	1985	231-182	Høy, Thorkild (1985): Nordborg Sø, Nordborg Kommune, Sønderjyllands Amt
Nordby Sø	5.6	Printed_map	4000	18	Transect survey	Thorkild Høy	1988	231-096	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Noret	17.8	Printed_map	0	1.18	Unknown method	BioConsult	1989		BioConsult (1989): Noret, Thyborøn-Harboøre Kommune, Ringkøbing Amt
Nørhå Sø	21.4	Printed_map	5000	1.1	Grid Survey (Soundings)	Thorkild Høy	1992	231-145	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Nørresø	122.9	Printed_map	5000	11.1	Transect survey	Thorkild Høy	1987	231-149	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Nørresø	105.9	Printed_map	5000	0.3	Transect survey	Thorkild Høy	1988	231-156	Høy, Thorkild (1988): Husby Sø og Nørresø (Åbjerg Sø), Ulfborg-Vemb og Ringkøbing Kommuner, Ringkøbing Amt
Nørresø	4.9	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Nørresø, Billund Kommune, Ribe Amt
Nørresø	32.7	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Nørresø, Egtved og Kolding Kommune, Vejle Amt
Nørrevese	16.2	Printed_map	0	0.16	Unknown method	BioConsult	1989		BioConsult (1989): Nørrevese, Thyborøn-Harboøre Kommune, Ringkøbing Amt
Nors Sø	353.8	Printed_map	12820	13.67	Unknown method	BioConsult	1992	231-193	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Øjesø	2.5	Printed_map	5000	24.5	Grid Survey (Soundings)	Thorkild Høy	1966	231-137	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Ollerup Sø	21.5	Printed_map	5000	12.2	Transect survey	Thorkild Høy	1985	231-097	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Ormstrup Sø	12.2	Printed_map	4000	0	Transect survey	Viborg Amt	1977		Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Ørnsø	39.9	Printed_map	10000	19.1	Grid Survey (Soundings)	Geodætisk Institut	1929	231-201	Kort & Matrikelstyrelsen (1997): Ørnsø, Brassø & Borresø
Østerlide Sø	1.9	Printed_map	2000	0	Grid Survey (Soundings)	Thomas Vedel	1990		Vedel, Thomas (2011): Personal archive
Oversø	8.7	Printed_map	5000	36	Transect survey	Thorkild Høy	1982	231-177	Høy, Thorkild (1982): Jels-Søerne, Rødding Kommune, Sønderjyllands Amt
Ovesø	354.5	Printed_map	10000	0.9	Transect survey	Thorkild Høy	1984	231-146	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Pamhule Sø	10.6	Printed_map	4000	17.4	Transect survey	Thorkild Høy	1982	231-183	Høy, Thorkild (1982): Pamhule Sø, Haderslev Kommune, Sønderjyllands Amt
Peblingesø	21.6	Printed_map	2000	0	Grid Survey (Soundings)	Københavns Kommune	1933		Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Pedersborg Sø	14.6	Printed_map	5000	33.7	Transect survey	Thorkild Høy	1985	231-059	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Præstesø	4.3	Printed_map	1500	0	Unknown method	BioConsult	1986		BioConsult (1986): Præstesø, Blåvandshuk Kommune, Ribe Amt
Rævsø	4.9	Printed_map	5000	72.9	Transect survey	Thorkild Høy	1976	231-125	Høy, Thorkild (1976): Rævsø, Them Kommune, Århus Amt
Råkær	3.5	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Råkjær Sø, Holsted Kommune, Ribe Amt
Rands Fjord	143.9	Printed_map	0	0.22	Unknown method	BioConsult	1990		BioConsult (1990): Rands Fjord, Børkop/Fredericia Kommune, Vejle Amt
Raskenborg Sø	1.3	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Raskenborg Sø, Holsted Kommune, Ribe Amt
Ravnsø	176.6	Printed_map	10000	21.96	Unknown method	BioConsult	1999	231-203	Århus Amt (2005a): NOVANA 2004 Vegetationen i Ravn Sø. Teknisk rapport, Natur & Miljø, Århus Amt.
Ring Sø	21.3	Printed_map	5000	78.6	Transect survey	Thorkild Høy	1983	231-107	Høy, Thorkild (1983): Ring Sø, Brædstrup Kommune, Vejle Amt
Rødsø	75.8	Printed_map	10000	3.15	Grid Survey (Soundings)	Geodætisk Institut	1932	231-197	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Røgbølle Sø	190.7	Printed_map	5000	10.5	Transect survey	Thorkild Høy	1977	231-082	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Rørbæk Sø	83.8	Printed_map	10000	55.84	Unknown method	BioConsult	1991		BioConsult (1991): Rørbæk Sø, Nørresnede/Give Kommune, Vejle Amt
Rye Mølle Sø	39.1	Printed_map	5000	2.23	Transect survey	Thorkild Høy	1975	231-120	Høy, Thorkild (1975): Gudensø og Rye Mølle Sø, Ry Kommune, Århus Amt
Rygbjerg Sø	9.9	Printed_map	4000	0	Transect survey	Thorkild Høy	1982	231-184	Høy, Thorkild (1982): Rygbjerg Sø, Vojens Kommune, Sønderjyllands Amt
Salmenor	6.5	Printed_map	4000	0	Unknown method	BioConsult	1994		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Saltbæk Vig	1593	Printed_map	10000	-1.2	Transect survey	Thorkild Høy	1987	231-060	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Salten Langsø	300.4	Printed_map	10000	22.6	Grid Survey (Soundings)	Geodætisk Institut	1929	231-204	Kort & Matrikelstyrelsen (1997): Salten Langsø
Sandbjerg Mølledam	10.6	Printed_map	5000	3.2	Transect survey	Thorkild Høy	1986	231-185	Høy, Thorkild (1986): Sandbjerg Mølledam, Sundeved Kommune, Sønderjyllands Amt
Sarup Sø	3.1	Printed_map	2020	12.41	Unknown method	BioConsult	1990		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Selsø Sø	86.5	Printed_map	5000	0.1	Transect survey	Thorkild Høy	1981	231-032	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Silkeborg Langsø	228.7	Printed_map	10000	18.71	Grid Survey (Soundings)	Geodætisk Institut	1932	231-200	Kort & Matrikelstyrelsen (1997): Silkeborg Langsø
Sivdam & Skatkammer Sø	4.6	Printed_map	4000	52.4	Transect survey	Thorkild Høy	1989	231-054	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Sjælsø	288.5	Printed_map	5000	18.2	Transect survey	Thorkild Høy	1992	231-033	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Sjapmose	5	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Sjapmose, Ribe Kommune, Ribe Amt
Sjørup Sø	37.4	Printed_map	5000	18.1	Transect survey	Thorkild Høy	1966	231-137	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Skærsø	16.2	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Skærsø, Vejen Kommune, Ribe Amt
Skallesø	70.3	Printed_map	5000	3	Transect survey	Thorkild Høy	1986	231-139	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Skanderborg Sø	843.1	Printed_map	10000	23.46	Grid Survey (Soundings)	Geodætisk Institut	1932	231-206	Kort & Matrikelstyrelsen (1997): Skanderborg-Søerne
Skånsø	9.4	Printed_map	0	7.63	Unknown method	BioConsult	1990		BioConsult (1990): Skånsø, Vinderup Kommune, Ringkøbing Amt
Skarresø	189.4	Printed_map	5000	18.5	Transect survey	Thorkild Høy	1984	231-061	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Skørsø	8.2	Printed_map	0	3.79	Unknown method	BioConsult	1990		Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Skovrød Sø	4.3	Printed_map	4000	35.7	Grid Survey (Soundings)	Thorkild Høy	1996	231-031	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Skovsø	8.8	Printed_map	5000	0.5	Transect survey	Thorkild Høy	1983	231-188	Høy, Thorkild (1983): Varnæs Skovsø, Lundtoft Kommune, Sønderjyllands Amt
Slåensø	21.1	Printed_map	5000	24.2	Grid Survey (Soundings)	Geodætisk Institut	1931	231-192	Kort & Matrikelstyrelsen (1997): Almind Sø & Slåen Sø
Slotssø	24.1	Printed_map	4000	26.55	Transect survey	Thorkild Høy	1996	231-215	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Slotssøen	16.8	Printed_map	5000	0.1	Transect survey	Thorkild Høy	1983	231-171	Høy, Thorkild (1983): Gråsten Slotssø, Gråsten Kommune, Sønderjyllands Amt
Smedshavevese	5.7	Printed_map	0	0.21	Unknown method	BioConsult	1989		BioConsult (1989): Smedshavevese, Thyborøn-Harboøre Kommune, Ringkøbing Amt
Sminge Sø	21.5	Printed_map	5000	17.7	Transect survey	Thorkild Høy	1974	231-126	Høy, Thorkild (1974): Sminge Sø. Gjern Kommune, Århus Amt
Snabe Igelsø	3	Printed_map	5000	60.5	Transect survey	Thorkild Høy	1972	231-123	Høy, Thorkild (1993): Kvindsø, Kulsø og Snabe Igelsø, Bryrup og Vrads Sogne, Århus Amt
Snæbum Sø	8.1	Printed_map	5000	35.2	Transect survey	Thorkild Høy	1986	231-138	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Snesere Sø	6.7	Printed_map	4000	36.6	Transect survey	Thorkild Høy	1981	231-083	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Sø ved Galtho	3.6	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Søer ved Galtho, Ølgod Kommune, Ribe Amt
Sø ved Galtho	3.3	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Søer ved Galtho, Ølgod Kommune, Ribe Amt
Søbo Sø	20.7	Printed_map	4000	38.8	Transect survey	Thorkild Høy	1988	231-099	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Søby Sø	16.2	Printed_map	4000	34.7	Transect survey	Thorkild Høy	1987	231-100	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Søby Sø	72.2	Printed_map	5000	39.4	Transect survey	Thorkild Høy	1989	231-165	Høy, Thorkild (1989): Søby Sø, Herning Kommune, Ringkøbing Amt
Søgård Sø	6.8	Printed_map	5000	8.2	Grid Survey (Soundings)	Thorkild Høy	1978	231-087	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Søgård Sø	24.1	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Søgård Sø, Vamdrup Kommune, Vejle Amt
Søholm Sø	25.5	Printed_map	5000	49.8	Transect survey	Thorkild Høy	1985	231-101	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Sølager Sø	7.5	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Sølager Sø, Blåvandshuk Kommune, Ribe Amt
Søllerød Sø	13.3	Printed_map	2000	21.6	Transect survey	Søllerød Kommune	1975		Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Sønder Lem Vig	220.7	Printed_map	14000	0.02	Unknown method	BioConsult	1992		Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Sønderby Sø	7.7	Printed_map	0	21.12	Unknown method	BioConsult	1991		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Sønderskov Mølledam	2.7	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Sønderskov Mølledam, Brørup Kommune, Ribe Amt
Søndersø	145.3	Printed_map	5000	11.1	Transect survey	Thorkild Høy	1987	231-149	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Søndersø	118.2	Printed_map	5000	12.45	Transect survey	Thorkild Høy	1982	231-037	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Søndersø	26.8	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Søndersø, Kolding Kommune, Vejle Amt
Søndersø	1	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Søndersø, Billund Kommune, Ribe Amt
Søndersund	3.6	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Søndersund og Byn, Lemvig Kommune, Ringkøbing Amt
Søndervese	34.5	Printed_map	0	0.16	Unknown method	BioConsult	1989		BioConsult (1989): Søndervese, Thyborøn-Harboøre Kommune, Ringkøbing Amt
Sorø Sø	208.1	Printed_map	5000	34.7	Transect survey	Thorkild Høy	1984	231-064	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Sortedams Sø	13.7	Printed_map	2000	0	Grid Survey (Soundings)	Københavns Kommune	1933		Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Sortesø	1.2	Printed_map	2000	65.9	Transect survey	Thorkild Høy	1986	231-098	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Sortesø	2.4	Printed_map	1000	0	Unknown method	BioConsult	1986		BioConsult (1986): Sortesø, Blåvandshuk Kommune, Ribe Amt
Sortesø	3.1	Printed_map	2000	29	Grid Survey (Soundings)	Thorkild Høy	1962	231-034	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Sørup Sø	11.2	Printed_map	5000	55.9	Transect survey	Thorkild Høy	1986	231-102	Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Søtorup Sø	67.7	Printed_map	5000	56.2	Transect survey	Thorkild Høy	1985	231-065	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Søvig Sund	27.7	Printed_map	4000	0	Unknown method	BioConsult	1986		BioConsult (1986): Søvigsund Sø, Blåvandshuk Kommune, Ribe Amt
Stadil Fjord	1616.1	Printed_map	0	0.22	Unknown method	BioConsult	1990		BioConsult (1990): Stadil Fjord, Ringkøbing og Holmsland Kommune, Ringkøbing Amt
Stallerup Sø	23.7	Printed_map	5000	25.4	Transect survey	Thorkild Høy	1986	231-108	Høy, Thorkild (1986): Stallerup Sø, Kolding Kommune, Vejle Am

NAME	Area_ha	Data_type	Map_scale	Vert_DNN	SurveyMeth	Surveyor	YEAR	KMS_arkiv	Reference
Stavshede Sø	4	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Stavshede Sø, Vejen Kommune, Ribe Amt
Stevning Dam	29.9	Printed_map	5000	18.7	Transect survey	Thorkild Høy	1989	231-186	Høy, Thorkild (1989): Stevning Dam, Tørning Mølledam, Vojens Kommune, Sønderjyllands Amt
Stigsholm Sø	18.5	Printed_map	5000	67.9	Transect survey	Thorkild Høy	1983	231-109	Høy, Thorkild (1983): Stigsholm Sø, Brædstrup og Nr. Snede Kommuner, Vejle Amt
Stilling-Solbjerg Sø	371.9	Printed_map	10000	49.9	Transect survey	Thorkild Høy	1990	231-128	Høy, Thorkild (1991): Stilling-Solbjerg Sø, Hørning, Skanderborg og Århus Kommuner, Århus Amt
Store Geddesø	2.8	Printed_map	4000	99.5	Transect survey	Thorkild Høy	1981	231-085	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Store Gribsø	10.2	Printed_map	2000	49.5	Grid Survey (Soundings)	Hillerød Kommune	1955		Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Store Hulsø	2.6	Printed_map	4000	18.8	Grid Survey (Soundings)	Thorkild Høy	1994	231-035	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Store Kattinge Sø	66.4	Printed_map	5000	2.5	Transect survey	Thorkild Høy	1990	231-024	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Store Økssø	32.3	Printed_map	10000	63.9	Grid Survey (Soundings)	Geodætisk Institut	1932	231-194	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Store Søgård Sø	61.4	Printed_map	5000	34.4	Transect survey	Thorkild Høy	1983	231-187	Høy, Thorkild (1983): Søgård-Søerne, Lundtoft Kommune, Sønderjyllands Amt
Storedam	17.6	Printed_map	4000	40.4	Transect survey	Thorkild Høy	1993	231-013	Høy, Thorkild & Dahl, Jørgen (1996): Danmarks Søer Bind 4, Søerne i Frederiksborg. Strandbergs Forlag
Stubbe Sø	376.4	Printed_map	5000	1.3	Transect survey	Thorkild Høy	1983	231-129	Høy, Thorkild (1983): Stubbe Sø, Ebeltoft Kommune, Århus Am
Stubbergård Sø	150.8	Printed_map	5000	3.9	Transect survey	Thorkild Høy	1986	231-162	Høy, Thorkild (1986): Stubbergård Sø, Vinderup Kommune, Ringkøbing Amt
Sunds Sø	123.9	Printed_map	5000	41.8	Transect survey	Thorkild Høy	1988	231-163	Høy, Thorkild (1988): Sunds Sø, Herning Kommune, Ringkøbing Amt
Svogerslev Sø	24.2	Printed_map	5000	2.5	Transect survey	Thorkild Høy	1990	231-036	Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Tange Sø	544.7	Digital_data	10000	13.6	XYZ Point Survey	Viborg Landinspektørko...	2001		Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Tangsø	21.5	Printed_map	0	0	Unknown method	BioConsult	1988		BioConsult (1988): Tangsø, Lemvig Kommune, Ringkøbing Amt
Tebstrup Sø	28.2	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Tebstrup Sø, Gedved Kommune, Vejle Amt
Thorsø	69.9	Printed_map	5000	22.6	Transect survey	Thorkild Høy	1964	231-130	Høy, Thorkild (1964): Thorsø, Skanderborg Amt
Tissø	1246	Printed_map	8000	1	Transect survey	Thorkild Høy	1987	231-066	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Tivolisøen	27	Printed_map	5000	21.2	Transect survey	Thorkild Høy	1981	231-047	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Tjele Langsø	398.4	Printed_map	10000	9.9	Grid Survey (Soundings)	Geodætisk Institut	1934	231-196	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Torbenfeld Sø	14.3	Printed_map	5000	39.3	Transect survey	Thorkild Høy	1987	231-068	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Torp Sø	6.4	Printed_map	0	0	Unknown method	BioConsult	1986		BioConsult (1986): Torp Sø, Brædstrup Kommune, Vejle Amt
Torup Sø	19.7	Printed_map	5000	75.82	Transect survey	BioConsult	2001		Liboriussen, L., Søndergaard, M. & Jeppesen, E. (red.) 2007: Sørestaurering i Danmark. Del II: Faglig rapport fra DMU nr. 636
Tranekær sø	0.8	Printed_map	0	0	Unknown method	BioConsult	1987		BioConsult (1987): Tranekær Sø, Vejen Kommune, Ribe Amt
Tranemose	6.1	Printed_map	5000	7.9	Transect survey	Thorkild Høy	1990	231-166	Høy, Thorkild (1990): Tranemose, Vinderup Kommune, Ringkøbing Amt
Tryggelev Nor	0.4	Printed_map	4000	0	Unknown method	BioConsult	1994		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Tuelsø	189.4	Printed_map	5000	32.1	Transect survey	Thorkild Høy	1985	231-069	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Tværmose	14.9	Printed_map	0	3.05	Unknown method	BioConsult	1990		BioConsult (1990): Tværmose, Vinderup Kommune, Ringkøbing Amt
Tystrup_Bavelse Søer	751.9	Printed_map	5000	6.8	Transect survey	Thorkild Høy	1984	231-070	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Ulse Sø	50.3	Printed_map	5000	52.9	Transect survey	Thorkild Høy	1978	231-072	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Utterslev Mose - øst bassin	29.9	Printed_map	4000	16.8	Unknown method	COWI	1989		Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Utterslev Mose - vest bassin	30.5	Printed_map	4000	16.8	Unknown method	COWI	1989		Høy, Thorkild & Dahl, Jørgen (1995): Danmarks Søer Bind 3, Søerne i Roskilde Amt, Københavns Kommune og Københavns Amt. Strandbe...
Vængsø	16	Printed_map	5000	26.3	Transect survey	Thorkild Høy	1983	231-112	Høy, Thorkild (1983): Vængsø, Brændstrup Kommune, Vejle Amt
Valsølille Sø	69.9	Printed_map	5000	58	Transect survey	Thorkild Høy	1992	231-073	Høy, Thorkild & Dahl, Jørgen (1993): Danmarks Søer Bind 2, Søerne i Vestsjællands Amt. Strandbergs Forlag
Vandet Sø	474.8	Printed_map	10000	12.4	Grid Survey (Soundings)	Geodætisk Institut	1932	231-193	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Vandkraftsøen	50.7	Printed_map	0	13.7	Unknown method	BioConsult	1991		BioConsult (1991): Vandkraftsøen, Holstebro Kommune, Ringkøbing Amt
Vansø	15.6	Printed_map	5000	20.1	Grid Survey (Soundings)	Thorkild Høy	1982	231-147	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Vedbøl Sø	15.6	Printed_map	4000	25.7	Transect survey	Thorkild Høy	1984	231-189	Høy, Thorkild (1984): Vedbøl Sø, Vojens Kommune, Sønderjyllands Amt
Vedsø	149.8	Printed_map	5000	6.9	Transect survey	Thorkild Høy	1975	231-148	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.
Vedsted Sø	7.8	Printed_map	4000	0	Transect survey	Thorkild Høy	1982	231-190	Høy, Thorkild (1982): Vedsted Sø, Vojens Kommune, Sønderjyllands Amt
Vejlesø	16.5	Digital_data	5000	20.55	XYZ Point Survey	Thomas Vedel	2009		Vedel, Thomas (2011): Personal archive
Vessø	59.1	Printed_map	5000	22.4	Transect survey	Thorkild Høy	1982	231-132	Høy, Thorkild (1982): Vessø, Ry Kommune, Århus Amt
Vestbirk Sø	11.2	Printed_map	5000	42.3	Transect survey	Thorkild Høy	1974	231-111	Høy, Thorkild (1974): Vestbirk Søerne (Vestbirk Sø, Naldal Sø & Bredvad Sø), Brædstrup og Gedved kommuner, Vejle Amt
Vesterborg Sø	18.3	Printed_map	5000	0.7	Transect survey	Thorkild Høy	1978	231-088	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Virket Sø	8	Printed_map	5000	9.5	Transect survey	Thorkild Høy	1978	231-086	Høy, Thorkild & Dahl, Jørgen (1991): Danmarks Søer Bind 1, Søerne i Storstrøms Amt og på Bornholm. Strandbergs Forlag
Vommesø	15.7	Printed_map	5000	17	Grid Survey (Soundings)	Fyns Amt	1980		Høy, Thorkild et al (2000): Danmarks Søer Bind 5, Søerne i Fyns Amt. Strandbergs Forlag
Vullum Sø	13.9	Printed_map	5000	3.7	Grid Survey (Soundings)	Thorkild Høy	1992	231-151	Høy, Thorkild et al (2004): Danmarks Søer Bind 6, Søerne i Nordjyllands og Viborg amter. Strandbergs Forlag.

Appendix C

Python GPX parser

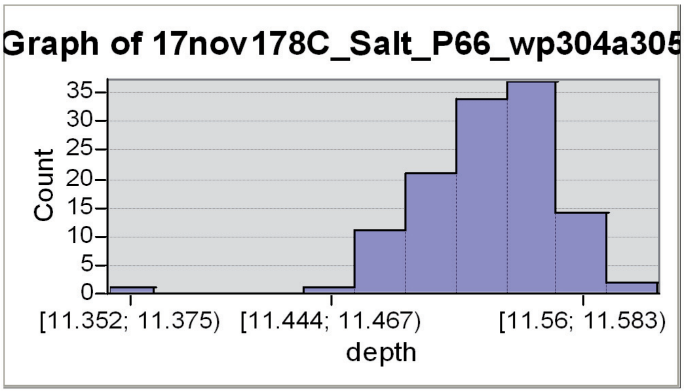
gpx2layer931_dybder_temp_offset.py

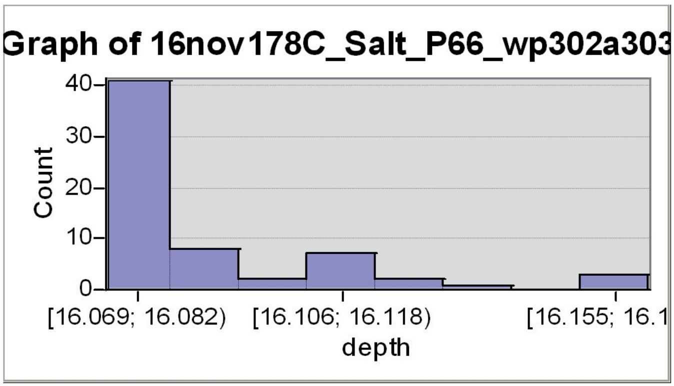
```
#--------ESRI 2010------------------------------------
# GPX (from XML) to layer : 9.3.1
# This script will take a GPX file as input and convert it to a feature class
# INPUTS:
# GPX file (FILE)
# OUTPUTS:
# Output Feature class (FEATURECLASS)
# By Kevin Hibma - ESRI
# Date: May 24, 2010
# -----------------------------------------------------
# By Thomas Vedel --------------
# Date: January 6, 2012
# This is a modified version to include GPX files from Garmin marine units
# depicting both track and adding recorded depth to a shape file.
# -*- coding: cp850 -*-

from xml.etree import ElementTree
import string, arcgisscripting

gp = arcgisscripting.create(9.3)

offset = 0
SVC = 0
Kote_DVR90 = 0
Frequency=""
Instrument=""
Latency = 0
def trkpt2dict(gpxfile):
   '''    Generator : for each trkpt return point + all other attributes as a dictionary
   '''
   TOPOGRAFIX_NS = './/{http://www.topografix.com/GPX/1/1}'
   TRACKPOINT_NS = TOPOGRAFIX_NS +
'extensions/{http://www.garmin.com/xmlschemas/GpxExtensions/v3}TrackPointExtension/{http://www.garmin.com/xmlschemas/GpxExtensions/v
3}'

   tree = ElementTree.parse(gpxfile)

   for node in tree.findall(TOPOGRAFIX_NS + 'trkpt'):
      d = {}
      y = node.attrib.get('lat')
      x = node.attrib.get('lon')
      t = node.find(TOPOGRAFIX_NS + 'time').text

      try:
          z = node.find(TRACKPOINT_NS + 'Depth').text
      except:
          z = 0

      try:
          depth = node.find(TRACKPOINT_NS + 'Depth').text
      except:
          depth = 0

      try:
         temp = node.find(TRACKPOINT_NS + 'Temperature').text
      except:
         temp = 0
      #yield results from reading GPX.
      yield x,y,z, t, depth, temp

if __name__ == "__main__":

   #Get GPX and Output directory paramaters
   gpxfile = gp.GetParameterAsText(0)
   Offset = gp.GetParameterAsText(1)
```

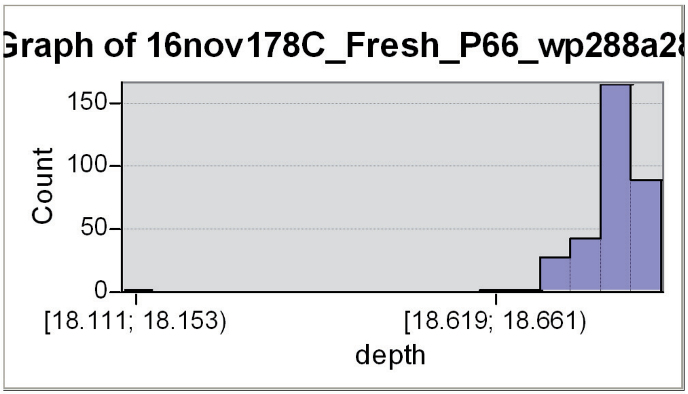
```
SVC = gp.GetParameterAsText(2)
Kote_DVR90 = gp.GetParameterAsText(3)
outFC = gp.GetParameterAsText(7)
Frequency = gp.GetParameterAsText(4)
Instrument = gp.GetParameterAsText(5)
Latency = gp.GetParameterAsText(6)
gp.overwriteoutput = 1

outPath = outFC[0:outFC.rfind("\\")]
outName = outFC[outFC.rfind("\\")+1:len(outFC)]

try:
   gp.CreateFeatureclass_management(outPath, outName, "POINT", "", "", "ENABLED",4326)
   gp.AddField_management(outFC, "Date_Time", "TEXT")
   gp.AddField_management(outFC, "depth", "DOUBLE")
   gp.AddField_management(outFC, "temp", "DOUBLE")
   gp.AddField_management(outFC, "Trans_offs", "DOUBLE")
   gp.AddField_management(outFC, "SVC", "DOUBLE")
   gp.AddField_management(outFC, "Kote_DVR90", "DOUBLE")
   gp.AddField_management(outFC, "Frequency", "TEXT")
   gp.AddField_management(outFC, "Instrument", "TEXT")
   gp.AddField_management(outFC, "Latency", "DOUBLE")
except Exception, ErrorDesc:
   gp.AddError(str(ErrorDesc))

gp.Workspace = outPath

rows = gp.InsertCursor(outFC)
pnt = gp.CreateObject("Point")

recComplete = 0

# walk through each trkpt, create and insert a record into the feature class for each
for x,y,z, t, depth, temp in trkpt2dict(gpxfile):
   row = rows.newRow()
   pnt.x = x
   pnt.y = y
   pnt.z = z
   row.SHAPE = pnt
   row.Date_Time = t
   row.depth = depth
   row.temp = temp
   row.Trans_offs = Offset
   row.SVC = SVC
   row.Kote_DVR90 = Kote_DVR90
   row.Frequency = Frequency
   row.Instrument = Instrument
   row.Latency = Latency
   rows.insertRow(row)
   recComplete += 1

   if (recComplete % 2000) == 0:
      gp.AddMessage("Processed " + str(recComplete) + " records.")
```

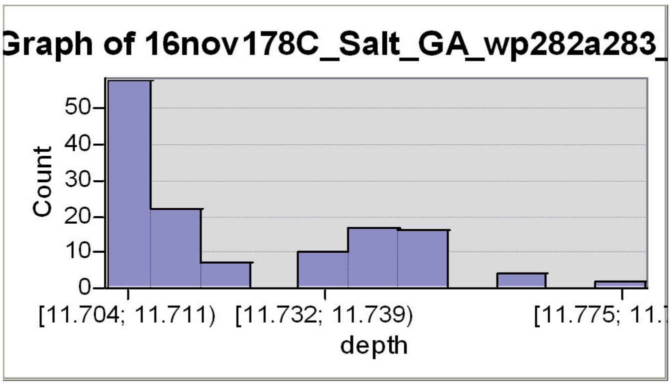
Appendix D

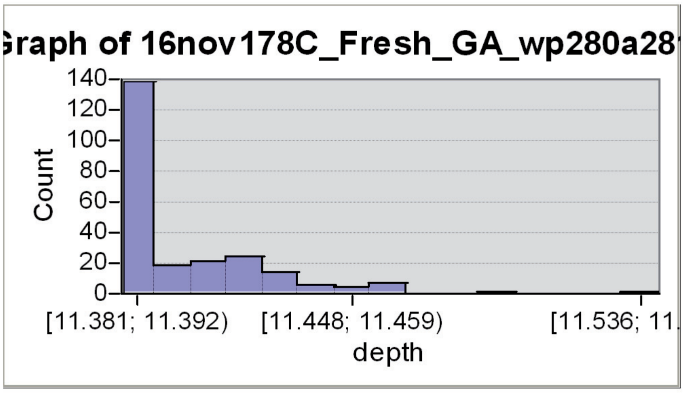
Error distribution for depth test

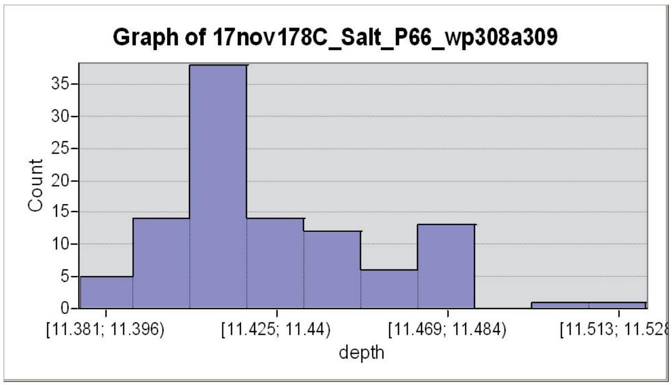

Graph of 17nov178C_Salt_P66_wp304a305
Count
[11.352; 11.375)
[11.444; 11.467)
[11.56; 11.583)
depth

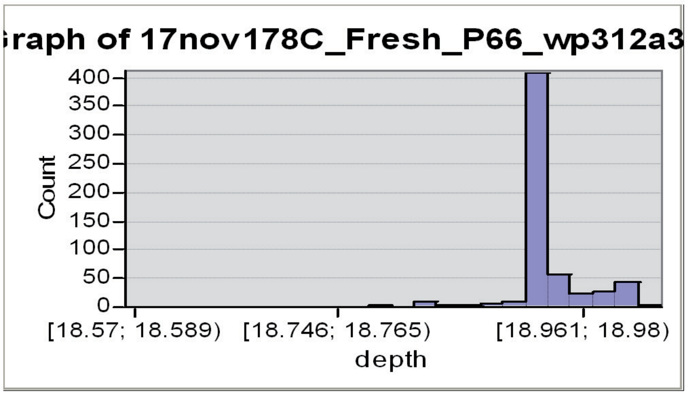

Graph of 16nov178C_Salt_P66_wp302a303
Count
[16.069; 16.082)
[16.106; 16.118)
depth

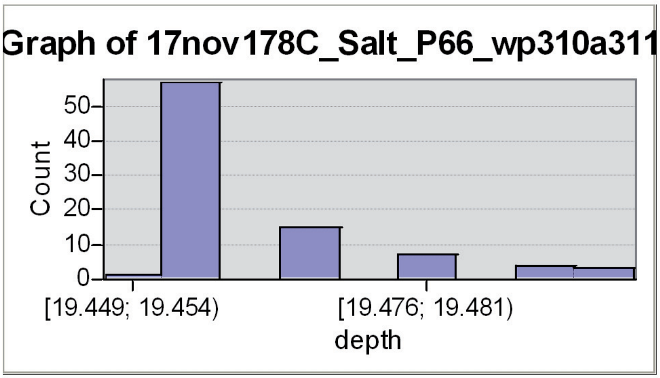

Count
[18.111; 18.153)
[18.619; 18.661)
depth

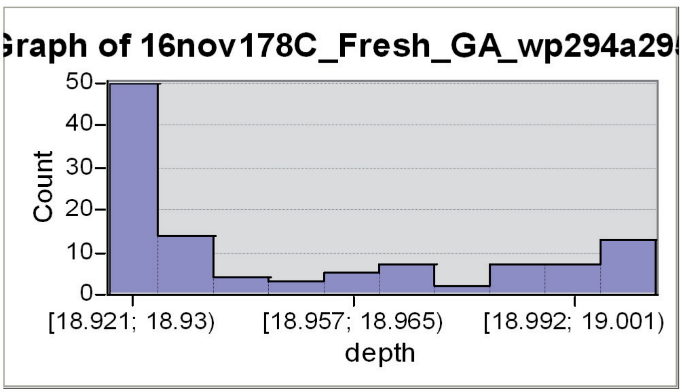

Count
[11.704; 11.711)
[11.732; 11.739)
depth

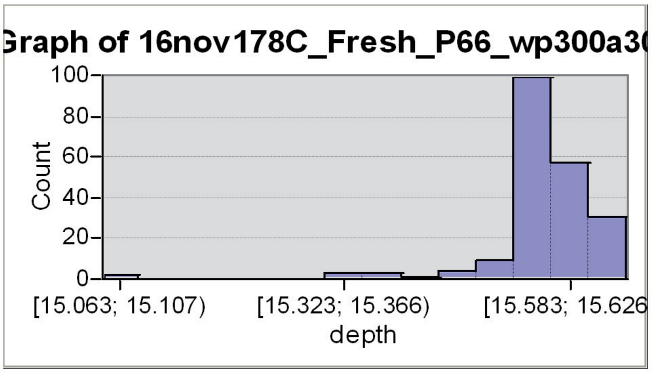

Count
[11.381; 11.392)
[11.448; 11.459)
depth

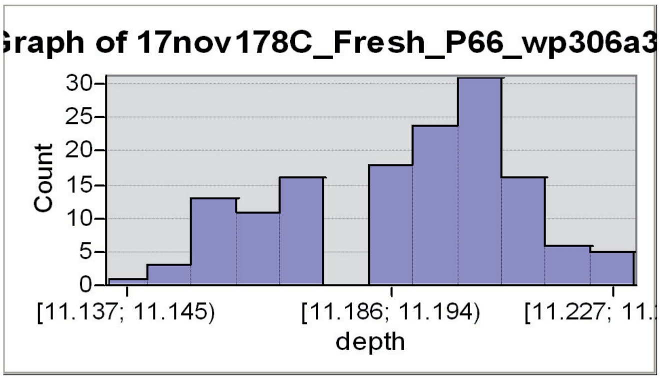

Graph of 17nov178C_Salt_P66_wp308a309
Count
[11.381; 11.396)
[11.425; 11.44)
[11.469; 11.484)
depth

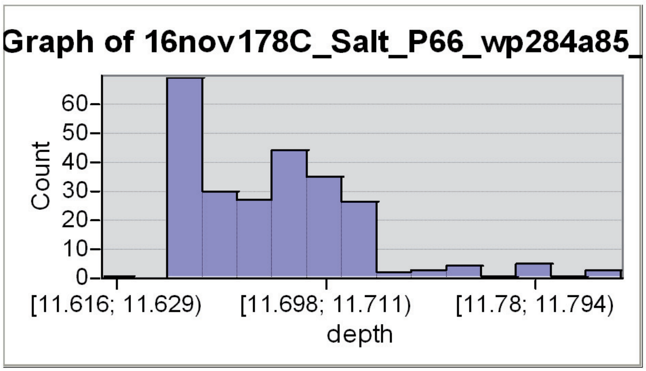

Count
[18.57; 18.589)
[18.746; 18.765)
[18.961; 18.98)
depth

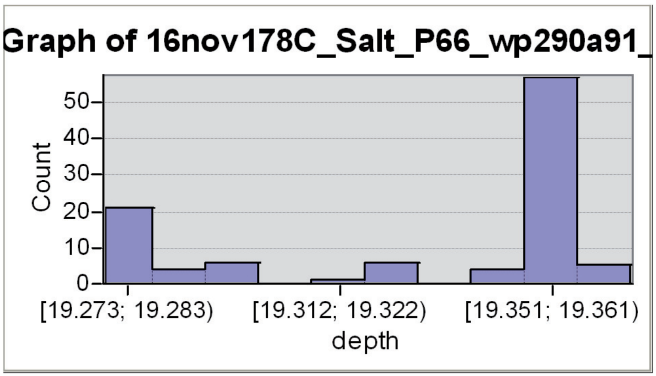

Graph of 17nov178C_Salt_P66_wp310a311
Count
[19.449; 19.454)
[19.476; 19.481)
depth

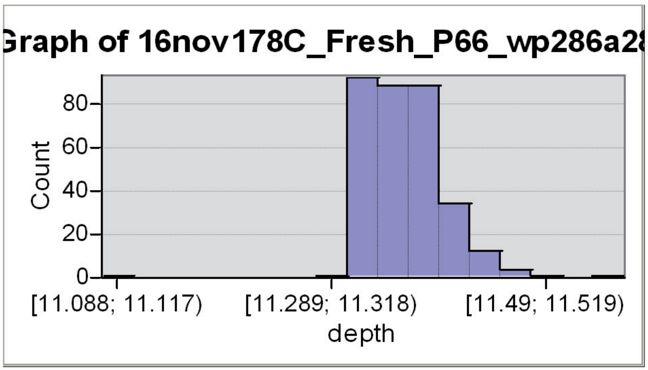

Count
[18.921; 18.93)
[18.957; 18.965)
[18.992; 19.001)
depth

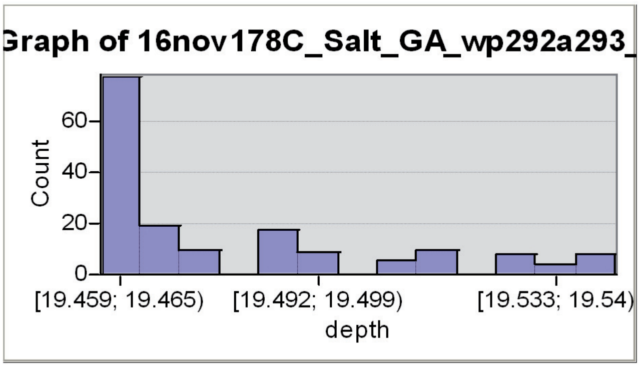

Count
[15.063; 15.107)
[15.323; 15.366)
depth

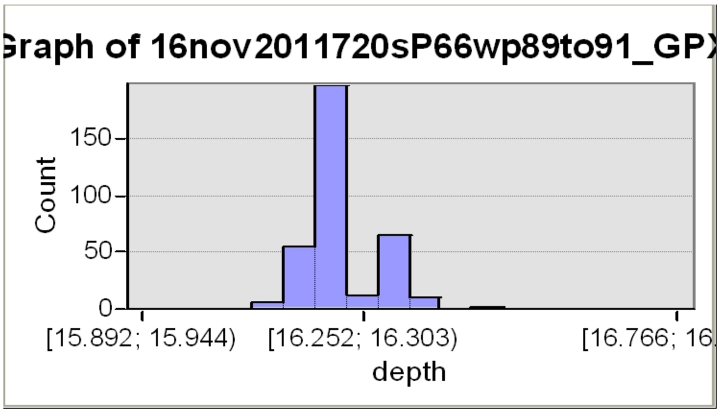

Graph of 17nov178C_Fresh_P66_wp306a3
Count
30
25
20
15
10
5
0
[11.137; 11.145)
[11.186; 11.194)
[11.227; 11.
depth


Graph of 16nov178C_Salt_P66_wp284a85_
Count
60
50
40
30
20
10
0
[11.616; 11.629)
[11.698; 11.711)
[11.78; 11.794)
depth

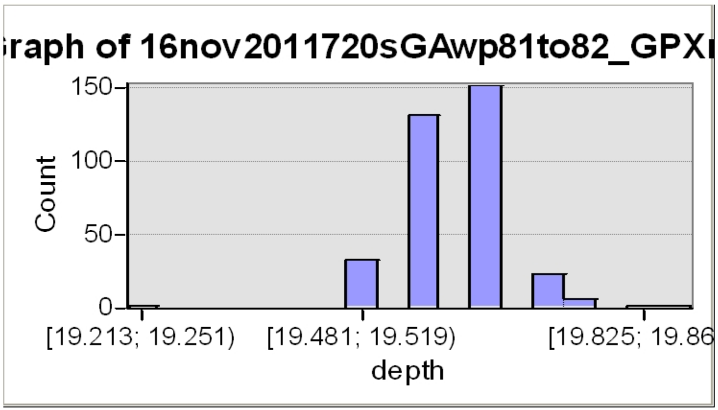

Graph of 16nov178C_Salt_P66_wp290a91_
Count
50
40
30
20
10
0
[19.273; 19.283)
[19.312; 19.322)
[19.351; 19.361)
depth


Graph of 16nov178C_Fresh_P66_wp286a2
Count
80
60
40
20
0
[11.088; 11.117)
[11.289; 11.318)
[11.49; 11.519)
depth

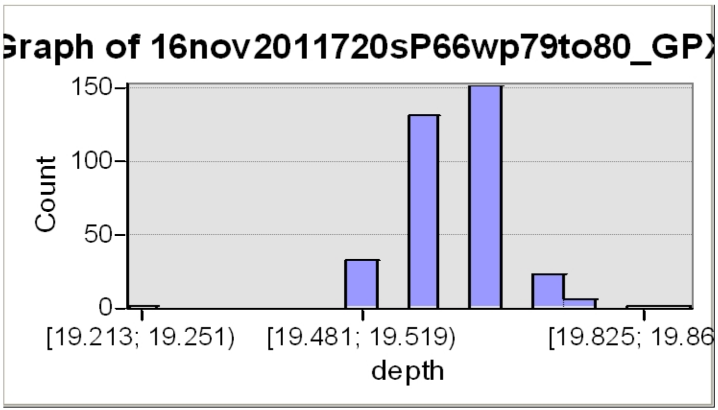

Graph of 16nov178C_Salt_GA_wp292a293_
Count
60
40
20
0
[19.459; 19.465)
[19.492; 19.499)
[19.533; 19.54)
depth



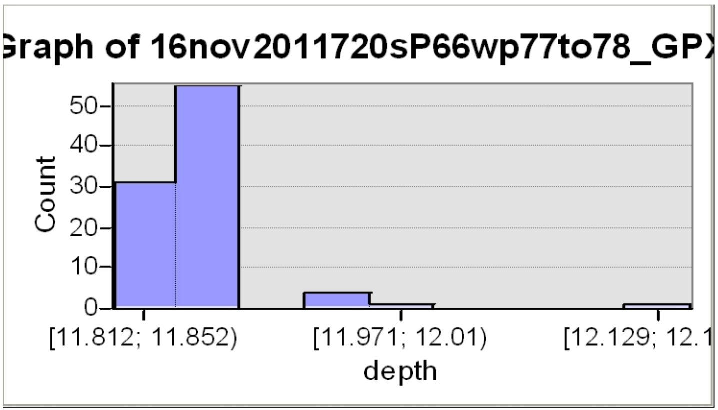
Graph of 16nov2011720sP66wp89to91_GPX
Count
150
100
50
0
[15.892; 15.944)
[16.252; 16.303)
[16.766; 16.
depth



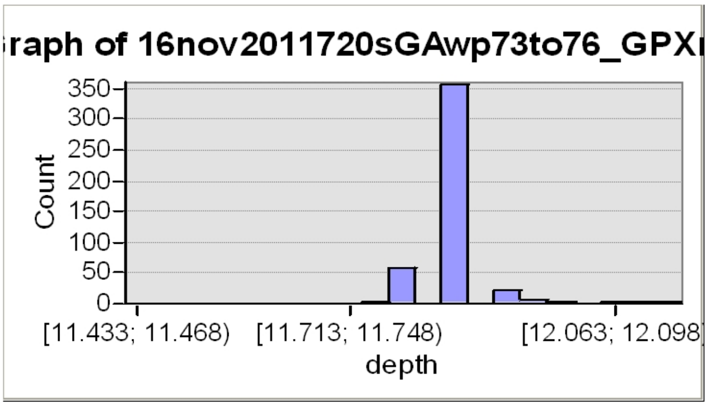
Graph of 16nov2011720sGAwp81to82_GPX
Count
150
100
50
0
[19.213; 19.251)
[19.481; 19.519)
[19.825; 19.86
depth



Graph of 16nov2011720sP66wp79to80_GPX
Count
150
100
50
0
[19.213; 19.251)
[19.481; 19.519)
[19.825; 19.86
depth



Graph of 16nov2011720sP66wp77to78_GPX
Count
50
40
30
20
10
0
[11.812; 11.852)
[11.971; 12.01)
[12.129; 12.1
depth

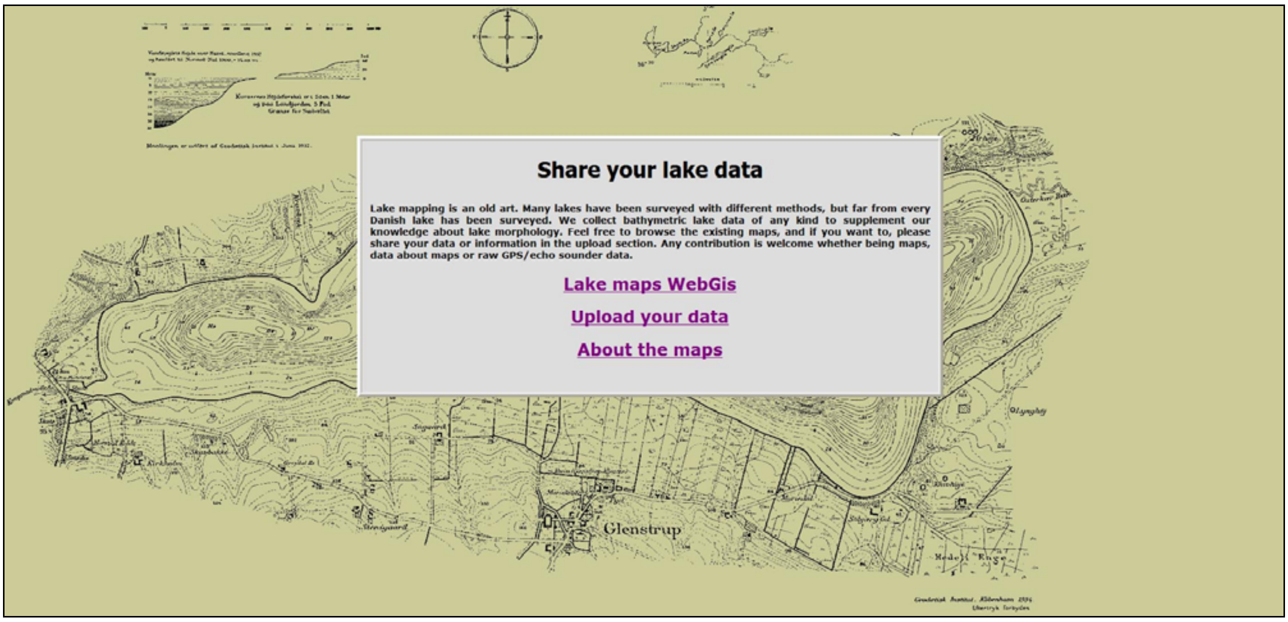


Graph of 16nov2011720sGAwp73to76_GPX
Count
350
300
250
200
150
100
50
0
[11.433; 11.468)
[11.713; 11.748)
[12.063; 12.098)
depth

Appendix E

Webgis

1. Code of front page

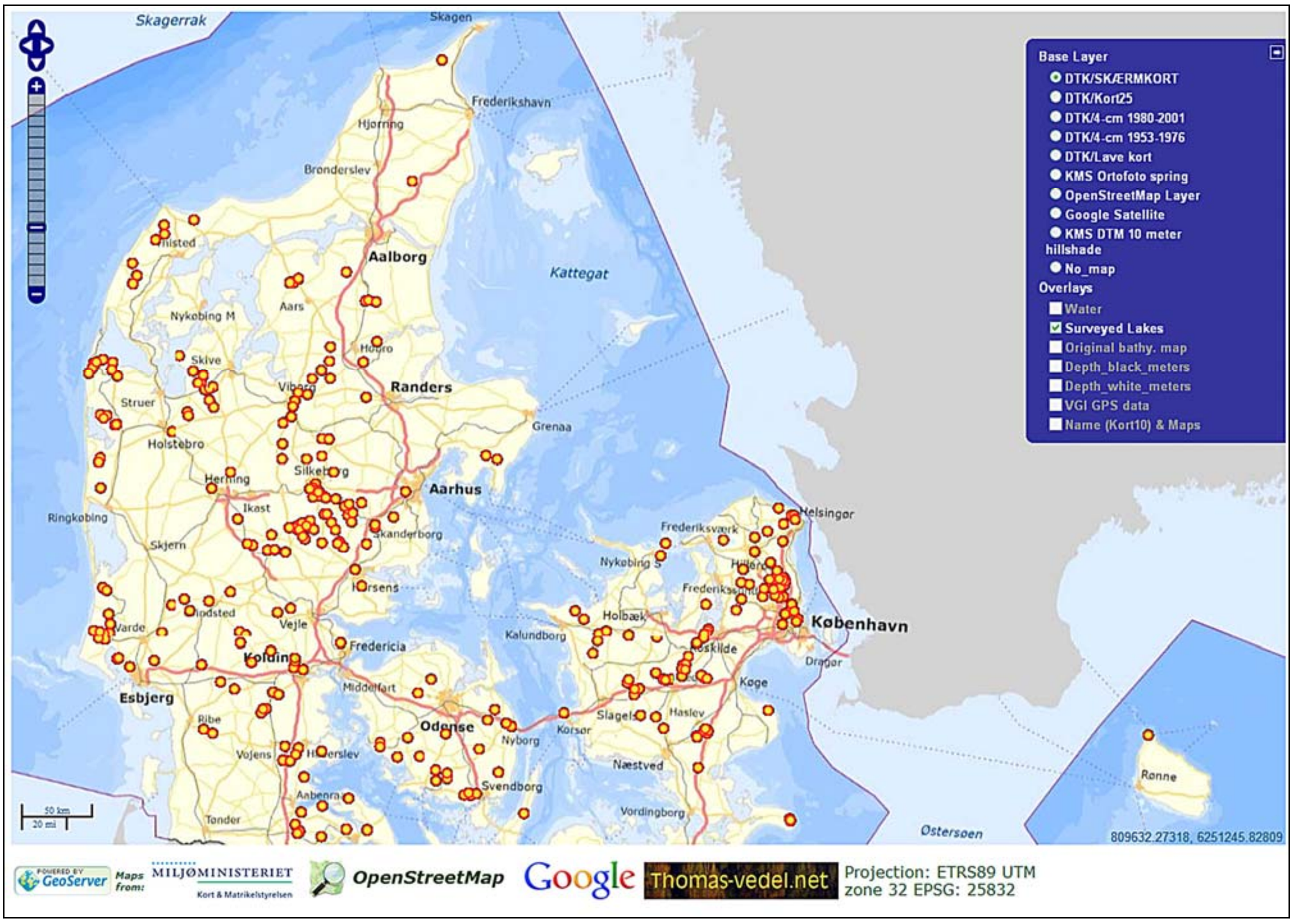


Code:

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
<title>Share your lake data</title><style type="text/css">
<!--
body {
			font: 100% Verdana, Arial, Helvetica, sans-serif;
			background: #666666;
			margin: 0;
			padding: 0;
			text-align: center;
			color: #000000;
			background-image: url(Images/Glenstrup.png);
			background-repeat: no-repeat;
			margin-left: 20px;
			margin-top: 50px;
			margin-right: 20px;
			background-color: #CC9;
			margin-bottom: 20px;
}
.oneColElsCtrHdr #container {
			width: 46em;
			background: #FFFFFF;
			margin: 0 auto;
			border: 1px solid #000000;
			text-align: left;
}
.oneColElsCtrHdr #header {
			background: #DDDDDD;
			padding: 0 10px 0 20px;
}
.oneColElsCtrHdr #header h1 {
			margin: 0;
			padding: 10px 0;
			text-align: center;
			font-size: 24pt;
			font-family: Tahoma, Geneva, sans-serif;
}
.oneColElsCtrHdr #mainContent {
			padding: 0 20px;
/
			background: #FFFFFF;
			font-size: 14pt;
			text-align: justify;
			font-weight: bold;
```

```
}
.oneColElsCtrHdr #footer {
				padding: 0 10px;
				background:#DDDDDD;
}
.oneColElsCtrHdr #footer p {
				margin: 0;
				padding: 10px 0;
}
.oneColElsCtrHdr #container #mainContent h1 {
				text-align: center;
}
.v {
				font-size: 16%;
}
.x {
				font-size: 14px;
}
.z {
				font-size: 10pt;
}
.oneColElsCtrHdr #container #mainContent .z {
				font-size: 14pt;
}
.oneColElsCtrHdr #container #mainContent h2 {
				font-size: 10pt;
}
.oneColElsCtrHdr #container #mainContent h2 a {
				font-size: 14pt;
}
.j {
				text-align: justify;
}
.oneColElsCtrHdr #header tr td #mainContent2 p {
				font-weight: bold;
				text-align: justify;
				font-size: 14px;
}
.d {
				text-align: center;
}
.oneColElsCtrHdr #header tr td #mainContent2 p a {
				font-size: 18px;
}
.kkkk {
				text-align: center;
}
-->
</style></head>
<body bgcolor="#FFFFCC" background="Images/Glenstrup.png" leftmargin="20" topmargin="50" marginwidth="20" marginheight="20"
class="oneColElsCtrHdr" tracingsrc="Images/Glenstrup.png" tracingopacity="32">
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<table width="46%" height="324" border="4" cellpadding="12" id="header">
  <tr>
    <td height="312"><div class="x" id="mainContent2">
      <h1 class="z">Share your lake data</h1>
      <p>Lake mapping is an old art. Many lakes have been surveyed with different methods,  but far from every Danish lake has been surveyed. We
collect bathymetric lake data of any kind to supplement our knowledge about lake morphology. Feel free to browse the existing maps, and if you
want to, please share your data or information in the upload section. Any contribution is welcome whether being maps, data about maps or raw
GPS/echo sounder data.</p>
<h2 align="center"><a href="webgis.htm">Lake maps WebGis</a></h2>
      <h2 align="center"><a href="VandUP.php">Upload your data</a>
        <!-- end #mainContent -->
        <a href="webgis.htm"></a></h2>
      <h2 align="center"><a href="About_maps.html" class="kkkk"> About the maps</a></h2>
<p align="center"> </p>
</div></td>  </tr></table><p> </p></body></html>
```

2. Map client



Webgis.htm:

The code:

```
<html>
       <head>
        <script src="http://maps.google.com/maps/api/js?sensor=false&v=3.2"></script>
        <script src="http://www.openlayers.org/api/OpenLayers.js"></script>
        <script src="http://www.openstreetmap.org/openlayers/OpenStreetMap.js"></script>
        <script src="proj4js-compressed.js"></script>
        <script src="webgis.js"></script>
        <style type="text/css">
<!--
#map {
                        color: #369;
}
body {
                        background-color: #FFF;
}
.hh {
                        font-family: Verdana, Geneva, sans-serif;
                        font-size: 9px;
}
.gg {
                        font-family: Verdana, Geneva, sans-serif;
                        font-style: italic;
                        font-weight: bold;
                        font-size: 9;
}
.ll {
                        font-family: Verdana, Geneva, sans-serif;
}
a:link {
                        text-decoration: none;
                        color: #FFF;
```

```
}
a:visited {
			text-decoration: none;
			color: #FFF;
}
a:hover {
			text-decoration: none;
			color: #FFF;
}
a:active {
			text-decoration: none;
			color: #FFF;
}
body,td,th {
			color: #063;
}
-->
	</style>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1/"></head>
<div class="kolonner" id="map" style="width:100%; height:90%"></div>
<body text="#F4F3EE" link="#FFFFFF" vlink="#FFFFFF" alink="#FFFFFF" onLoad="init();">
<table width="84%" border="0">
  <tr>
    <td width="8%" height="70"><a href="http://geoserver.org" ><img src="http://static.geoserver.org/images/pbGS-Bttn100x30.png" width="100"
height="30" border="0" alt="GeoServer Logo" /></a></td>
    <td width="7%" class="gg">Maps from:</td>
    <td width="12%"><span class="hh"><a href="http://http://www.kms.dk"><img src="KMS.jpg" width="144" height="38"
alt="Copyright_basemap"></td>
    <td width="17%"><a href="http://http://www.openstreetmap.org"><img src="osm_logo_new.png" width="223" height="49"></td>
    <td width="9%"><a href="http://code.google.com/apis/maps/index.html"><img src="nav_logo78.png" width="115" height="41"></a></td>
    <td width="16%" class="ll"><a href="http://www.thomas-vedel.net/"><img src="TV-logo.png" width="200" height="38"></td>
    <td width="31%" class="ll"><p>Projection: ETRS89 UTM zone 32
    EPSG: 25832</p></td>
  </tr>
</table>
<p> </p>
</body>
</html>
```

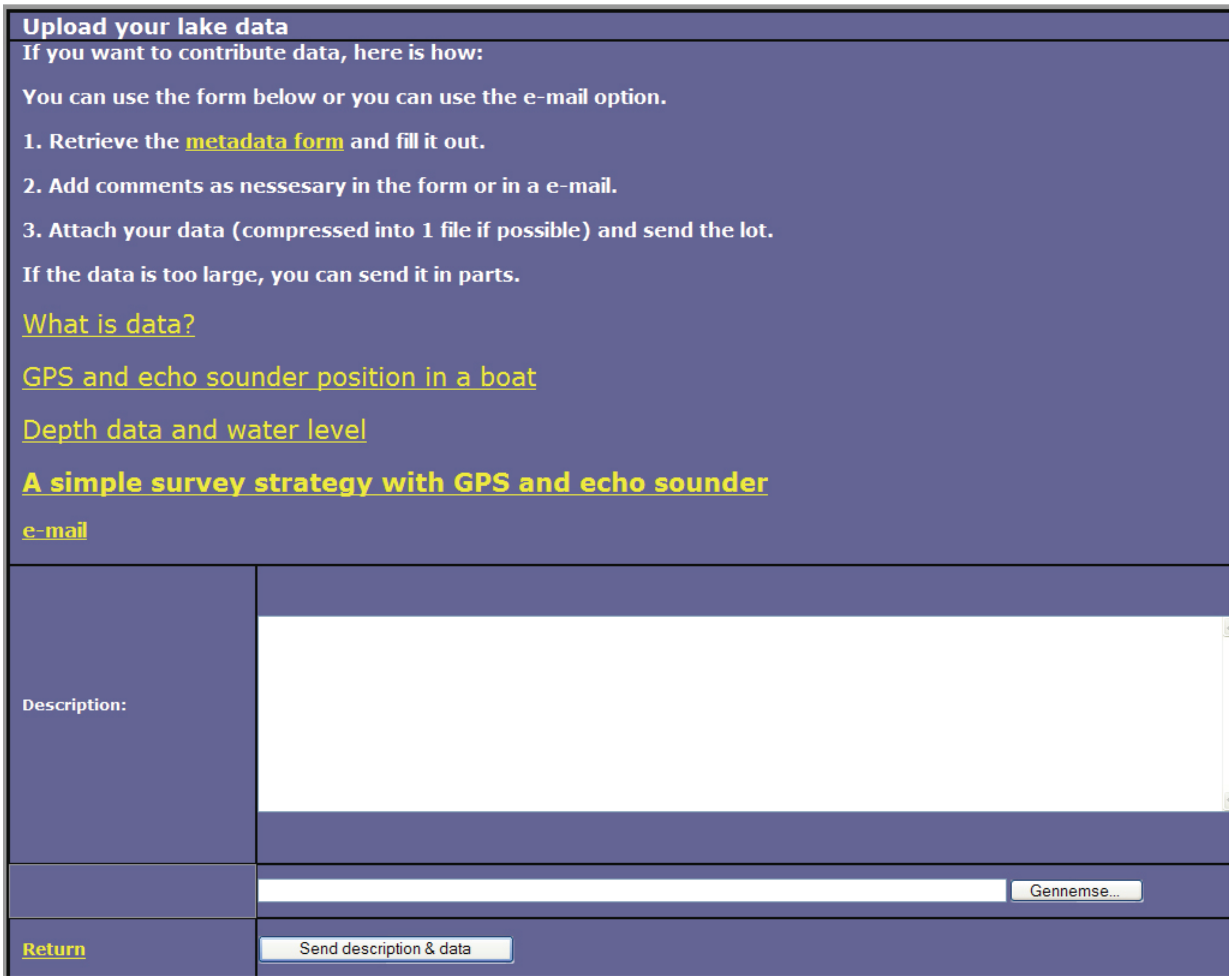
Webgis.js

The code:

```
var lat=55.50
var lon=11.51
var zoom=6;
var map;

function init() {
Proj4js.defs["EPSG:25832"] = "+proj=utm +zone=32 +ellps=WGS84 +datum=WGS84 +units=m +no_defs";
			map = new OpenLayers.Map ("map", {
						controls: [
						new OpenLayers.Control.Navigation(),
						new OpenLayers.Control.PanZoomBar(),
						new OpenLayers.Control.LayerSwitcher(),
						new OpenLayers.Control.MousePosition()
				],
						maxExtent: new OpenLayers.Bounds(-2500000.0,3500000.0,3045984.0,9045984.0),
						maxResolution: 21664.0,
						minExtent: new OpenLayers.Bounds(-1,-1, 1, 1),
						numZoomLevels: 18,
						units: 'm',
						projection: new OpenLayers.Projection("EPSG:900913"),
						displayProjection: new OpenLayers.Projection("EPSG:25832")
			} );

var wmsurl = "http://localhost:8080/geoserver/wms";

map.events.register('click', map, function (e) {
    var url = wmsurl
      + "?REQUEST=GetFeatureInfo"
      + "&EXCEPTIONS=application/vnd.ogc.se_xml"
      + "&BBOX=" + map.getExtent().toBBOX()
```

```
    + "&X=" + e.xy.x
    + "&Y=" + e.xy.y
    + "&INFO_FORMAT=text/plain"
    + "&QUERY_LAYERS=Database,VGI_data"
    + "&LAYERS=Database,VGI_data"
                         + "&FEATURE_COUNT=3"
    + "&SRS=EPSG:900913"
    + "&STYLES="
    + "&WIDTH=" + map.size.w
    + "&HEIGHT=" + map.size.h;
   window.open(url,
    "getfeatureinfo",
    "location=0,status=0,scrollbars=1,resizable=1,width=800,height=300"
   );
  });
var osm_layer = new OpenLayers.Layer.OSM.Mapnik("OpenStreetMap Layer",{isBaseLayer: true});
var google_satellite = new OpenLayers.Layer.Google("Google Satellite",{type: google.maps.MapTypeId.SATELLITE});

var wms_1 = new OpenLayers.Layer.WMS("DTK/SKÆRMKORT","http://localhost:8080/geoserver/wms",
{layers: "dtk_skaermkort",tiled: true,visibility: true,transparent: false},{opacity:1});
                        var wms_2 = new OpenLayers.Layer.WMS("DTK/Kort25","http://localhost:8080/geoserver/wms", {layers:
"topo25_klassisk",visibility: true,transparent: false},{opacity:1});
                        var wms_3 = new OpenLayers.Layer.WMS("DTK/4-cm 1980-2001","http://localhost:8080/geoserver/wms", {layers:
"dtk_4cm_1980_2001",visibility: true,transparent: false},{opacity:1});
                        var wms_4 = new OpenLayers.Layer.WMS("DTK/4-cm 1953-1976","http://localhost:8080/geoserver/wms", {layers:
"dtk_4cm_1953_1976",visibility: true,transparent: false},{opacity:1});
                        var wms_5 = new OpenLayers.Layer.WMS("DTK/Lave kort","http://localhost:8080/geoserver/wms", {layers:
"dtk_lave_maalebordsblade",visibility: true,transparent: false},{opacity:1});
                        var wms_6 = new OpenLayers.Layer.WMS("KMS Orthofoto spring","http://localhost:8080/geoserver/wms", {layers:
"orto_foraar",visibility: true,transparent: false},{opacity:1});
                        var wms_7 = new OpenLayers.Layer.WMS("No_map","http://localhost:8080/geoserver/wms", {layers: "",visibility:
true,transparent: false},{opacity:0.8});
                        var wms_9 = new OpenLayers.Layer.WMS("KMS DTM 10 meter hillshade","http://localhost:8080/geoserver/wms", {layers:
"DTM_10M",visibility: true,transparent: false},{opacity:1});

                        var wms_12 = new OpenLayers.Layer.WMS("Water","http://localhost:8080/geoserver/wms", {layers: "Water",transparent:
true},{visibility: false,opacity:1, minScale: 151648.0});
                        var wms_8 = new OpenLayers.Layer.WMS("Name (Kort10) & Maps","http://localhost:8080/geoserver/wms", {layers:
"Lake_names",transparent: true},{visibility: false,opacity:0.8, minScale: 151648.0});
                        var wms_10 = new OpenLayers.Layer.WMS("Surveyed Lakes","http://localhost:8080/geoserver/wms", {layers:
"Database",transparent: true},{visibility: false,opacity:0.8});
                        var wms_17 = new OpenLayers.Layer.WMS("Original bathy. map","http://localhost:8080/geoserver/wms", {layers:
"All_org_map",transparent: true},{visibility: false,opacity:1, minScale: 86656.0});
                        var wms_16 = new OpenLayers.Layer.WMS("Depth_black_meters","http://localhost:8080/geoserver/wms", {layers:
"Depth_black",transparent: true},{visibility: false,opacity:0.8, minScale: 43328.0});
                        var wms_11 = new OpenLayers.Layer.WMS("Depth_white_meters","http://localhost:8080/geoserver/wms", {layers:
"Depth_white",transparent: true},{visibility: false,opacity:0.8, minScale: 43328.0});
                        var wms_15 = new OpenLayers.Layer.WMS("VGI data","http://localhost:8080/geoserver/wms", {layers:
"VGI_data",transparent: true},{visibility: false,opacity:0.8, minScale: 43328.0});

                        map.addLayers([wms_1,wms_2,wms_3,wms_4,wms_5,wms_6,osm_layer,google_satellite,wms_9,wms_7]);
                        map.addLayers([wms_12,wms_10,wms_17,wms_16,wms_11,wms_15,wms_8]);

                        map.addControl(new OpenLayers.Control.LayerSwitcher());
                        map.addControl(new OpenLayers.Control.ScaleLine());
                        map.addControl(new OpenLayers.Control.MousePosition());
                        map.addControl(new OpenLayers.Control.KeyboardDefaults());

                        if( ! map.getCenter() )
                        {var lonLat = new
OpenLayers.LonLat(lon, lat).transform(new OpenLayers.Projection("EPSG:4326"),
map.getProjectionObject());
map.setCenter (lonLat, zoom);
                        }
}
init();
```

3. The Upload page



Vandup.php

The Code:

```
<html>
<head>
<title> Upload a File </title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1"><style type="text/css">
<!--
body {background-color: #999;color: #69F;}
.Tekst {color: #FFF;font-family: Arial, Helvetica, sans-serif;}
.Fed {
        font-weight: bold;
}
.Fed {
        font-weight: bold;
        font-family: Verdana, Geneva, sans-serif;
}
.Overskrift {
        font-size: 18px;
}
.Fed2 {
        font-weight: bold;
        font-size: 18px;
        text-align: center;
}
.Overskrift span {
        font-size: 18px;
}
.Uden {
        font-weight: normal;
```

```
}
body,td,th {
			color: #FFF;
			text-align: left;
			font-family: Verdana, Geneva, sans-serif;
			font-size: 16px;
			font-weight: bold;
}
.nonfed {
			font-weight: normal;
}
.mail {
			color: #FF0;
}
.hvid {
			color: #FFF;
}
a:link {
			color: #FF0;
			font-size: 16px;
}
.v {
			text-align: center;
}
.uu {
			font-family: Arial, Helvetica, sans-serif;
}
.ff {
			font-weight: bold;
}
.ll {
			font-weight: bold;
}
.pp {
			font-family: Arial, Helvetica, sans-serif;
}
.rr {
			font-size: 14px;
}
.our {text-align: center; font-weight: bold;}
.hh {
			font-size: 12px;
}
.qw {
			font-size: medium;
}
.qw {
			font-size: 14px;
}
.qw a {
			font-size: 16pt;
}
a:visited {
			color: #FF0;
}
a:hover {
			color: #FF0;
}
a:active {
			color: #FF0;
			font-size: 18px;
			font-weight: bold;
}
.Overskrift .Fed2 {
			font-size: 18px;
}
-->
</style></head>
<body bgcolor="#FFFFFF">
<form enctype="multipart/form-data" name="frmUploadFile" action="grabvanddata.php" method="post">
<table width="55%" border="2" align="center" cellpadding="0" cellspacing="0" bordercolor="#111111">
<tr>
<td width="100%" bgcolor="#666699" height="22" colspan="2">
<p style="margin-left: 10; font-size: 18px; font-weight: bold;"><b><font color="#FFFFFF" size="2" face="Verdana" class="Overskrift">
```

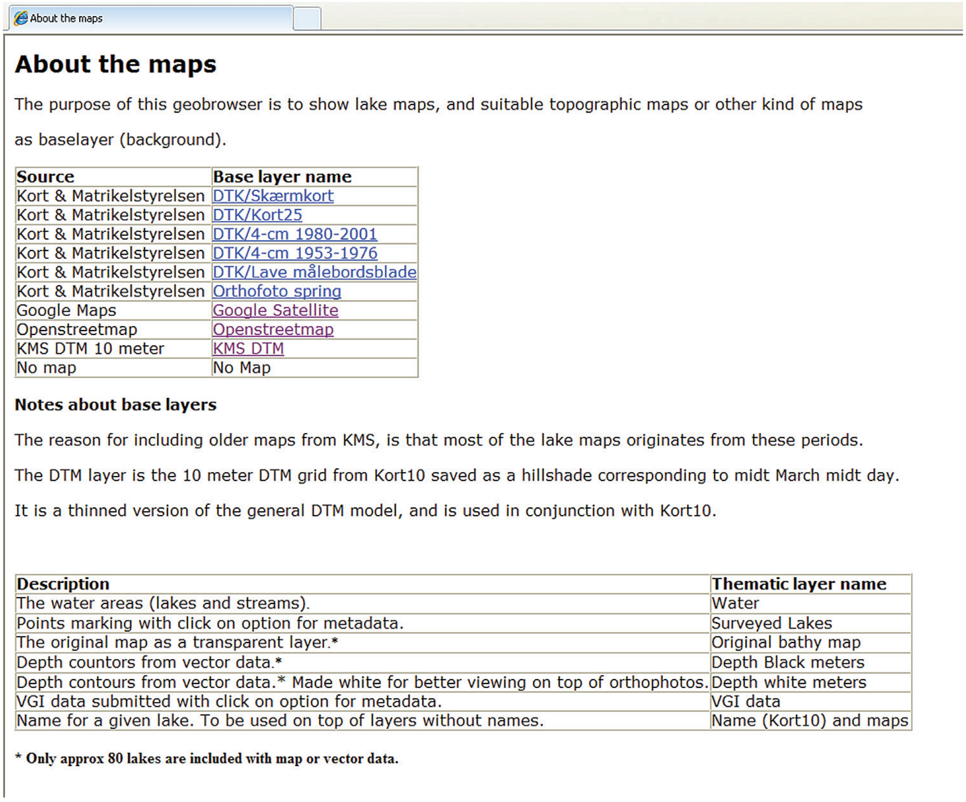
```
<span class="Fed2" style="text-align: center"> Upload </span><span style="text-align: center">your</span></font></b><span style="text-align: center">  lake data </span></td>
</tr>
<tr>
<td width="100%" height="427" colspan="2" bgcolor="#666699">
<p style="margin-left: 10; margin-right: 10; color: #FFF; font-weight: bold;">
<p style="margin-left: 10; margin-right: 10; color: #FFF; font-weight: bold;">If you want to contribute data, here is how:
<p style="margin-left: 10; margin-right: 10; color: #FFF;">You can use the form below or you can use the e-mail option.
<p style="margin-left: 10; margin-right: 10; color: #FFF;">1. Retrieve the <a href="Metadata.pdf">metadata form</a> and fill it out.
<p style="margin-left: 10; margin-right: 10; color: #FFF;">2. Add comments as nessesary in the form or in a e-mail.
<p style="margin-left: 10; margin-right: 10; color: #FFF;">3. Attach your data (compressed into 1 file if possible) and send the lot.
<p style="margin-left: 10; margin-right: 10; color: #FFF;">If the data is too large, you can send it in  parts.
<p style="margin-left: 10; margin-right: 10; color: #FFF; font-weight: normal;"><span class="qw"><A href="What_is_data.html">What is data?</A>
  </span>
<p style="margin-left: 10; margin-right: 10; color: #FFF; font-weight: normal;"><span class="qw"><a href="Boat_correct.html">GPS and echo sounder in a boat?</a>
  </span>
<p style="margin-left: 10; margin-right: 10; color: #FFF; font-weight: normal;"><span class="qw"><a href="Water_levels.html">What about water level corrections?</a></span>
<p style="margin-left: 10; margin-right: 10; color: #FFF;"><font face="Verdana" size="2"><a href="mailto:vanddata@thomas-vedel.net">e-mail</a></font>
<p style="margin-left: 10; margin-right: 10; color: #FFF;"></td>
</tr>
<tr>
<td width="15%" height="249" bgcolor="#666699">
<p style="margin-left: 10"><font size="2" face="Verdana" class="Tekst">
<span class="Fed">Description:</span></font>
<p style="margin-left: 10; font-family: Arial, Helvetica, sans-serif; font-size: 12px;"></td>
<td width="85%" bgcolor="#666699"><textarea name="strDesc" cols="100" rows="10"></textarea></td>
</tr>
<tr>
<td width="15%" height="45" bgcolor="#666699">
  <p style="margin-left: 10; color: #FFF; font-weight: bold;"></td>
<td width="85%" bgcolor="#666699">
  <p><font face="Verdana" size="2">
  <input type="hidden" name="MAX_FILE_SIZE" value="10000000" />
  <input type="file" name="fileUpload" size="60">
  </font></td>
  </p>
  <p> </p></td>
</tr>
<tr align="center" valign="middle">
<td width="33%" height="52" bgcolor="#666699">
<p style="margin-left: 10"><font face="Verdana" size="2">
<br>
<a href="index.php" class="qw">Return </a><br>
 </font></td>
<td width="67%" bgcolor="#666699">
<span class="v">
</span><font face="Verdana" size="2">
<input type="submit" value="Send description & data" name="cmdSubmit">
</font></td>
</tr>
</table>
<p> </p>
<p> </p>
</form>
</body>
</html>
```

Grabvanddata.php

```
<?php
$strDesc;
$fileUpload;
$fileUpload_name;
$fileUpload_size;
$fileUpload_type;
// Make sure both a description and
// file have been entered
if(empty($strDesc) || $fileUpload == "none")
die("Remember description and data");
// Database connection variables
$dbServer = "localhost";
```

```
$dbDatabase = "VGI_DATA";
$dbUser = "root";
$dbPass = "no";
$fileHandle = fopen($fileUpload, "r");
$fileContent = fread($fileHandle, $fileUpload_size);
$fileContent = addslashes($fileContent);
$sConn = mysql_connect($dbServer, $dbUser, $dbPass)
or die("Could not connect to database server");
$dConn = mysql_select_db($dbDatabase, $sConn)
or die("Could not connect to database $dbDatabase");
$dbQuery = "INSERT INTO VGI_UPLOAD VALUES ";
$dbQuery .= "(0, '$strDesc', '$fileContent', '$fileUpload_type')";
mysql_query($dbQuery) or die("Could not add your data to database");
echo "<h1>Your data is sent</h1>";
//echo "The details of the uploaded file are shown below:<br><br>";

echo "<a href='VandUP.php'>Do you want to send more data?</a><br>";
echo "<a href='index.php'>Back</a>";
?>
```

4. About the maps



About the maps

The purpose of this geobrowser is to show lake maps, and suitable topographic maps or other kind of maps

as baselayer (background).

Source	Base layer name
Kort & Matrikelstyrelsen	DTK/Skærmkort
Kort & Matrikelstyrelsen	DTK/Kort25
Kort & Matrikelstyrelsen	DTK/4-cm 1980-2001
Kort & Matrikelstyrelsen	DTK/4-cm 1953-1976
Kort & Matrikelstyrelsen	DTK/Lave målebordsblade
Kort & Matrikelstyrelsen	Orthofoto spring
Google Maps	Google Satellite
Openstreetmap	Openstreetmap
KMS DTM 10 meter	KMS DTM
No map	No Map

Notes about base layers

The reason for including older maps from KMS, is that most of the lake maps originates from these periods.

The DTM layer is the 10 meter DTM grid from Kort10 saved as a hillshade corresponding to midt March midt day.

It is a thinned version of the general DTM model, and is used in conjunction with Kort10.

Description	Thematic layer name
The water areas (lakes and streams).	Water
Points marking with click on option for metadata.	Surveyed Lakes
The original map as a transparent layer.*	Original bathy map
Depth countors from vector data.*	Depth Black meters
Depth contours from vector data.* Made white for better viewing on top of orthophotos.	Depth white meters
VGI data submitted with click on option for metadata.	VGI data
Name for a given lake. To be used on top of layers without names.	Name (Kort10) and maps

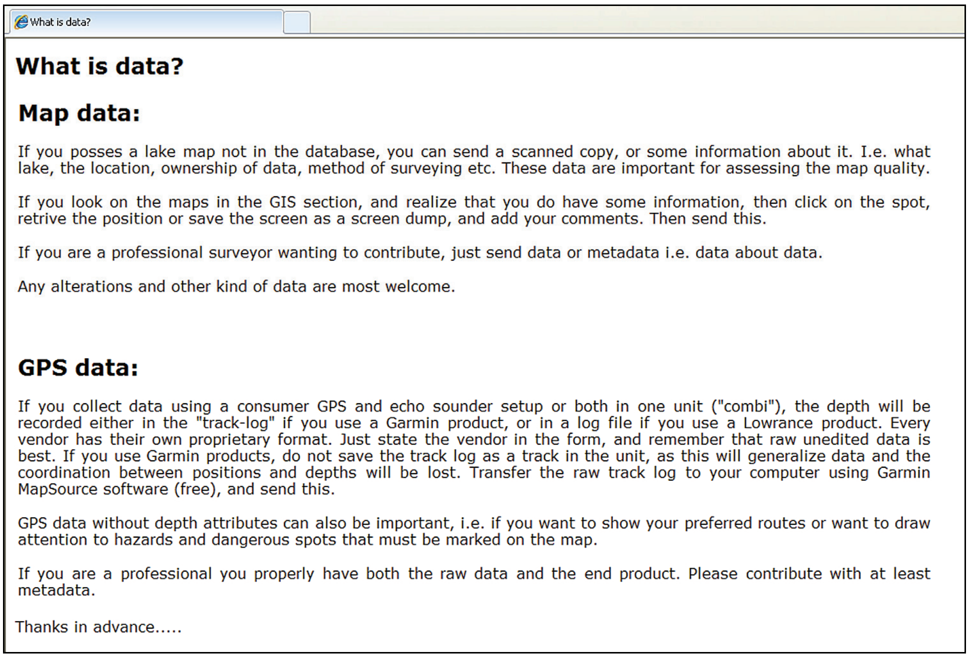
*** Only approx 80 lakes are included with map or vector data.**

About_maps.html
Code:

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<title>About the maps</title>
<style type="text/css">
<!--
.ggg {
			font-family: Verdana, Geneva, sans-serif;
			font-weight: bold;
			font-size: 24px;
}
.hhhh {
			font-family: Verdana, Geneva, sans-serif;
}
.kkk {
			font-weight: bold;
}
-->
</style>
</head>

<body>
<p class="ggg">About the maps</p>
<p class="hhhh">The purpose of this geobrowser is to show lake maps, and  suitable topographic maps or other kind of maps </p>
<p class="hhhh">as baselayer (background).</p>
<table border="1" cellspacing="0" cellpadding="0">
  <tr>
    <td width="204" valign="top"><p class="hhhh"><strong>Source</strong></p></td>
    <td width="187" valign="top"><p class="hhhh"><strong>Base layer name</strong></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Kort    &amp; Matrikelstyrelsen</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.kms.dk/NR/rdonlyres/C029E725-204C-43CA-AF59-
A4F33C12EA71/0/dtk_skaermkort.pdf">DTK/Skærmkort</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Kort    &amp; Matrikelstyrelsen</span></p></td>
    <td valign="top"><p><span class="hhhh"><a
href="http://www.kms.dk/Emner/Landkortogtopografi/TopografiskeDatabaser/Kort25/Kort25.htm">DTK/Kort25</a></span></p></td>
  </tr>
  <tr>
```

```
    <td valign="top"><p><span class="hhhh">Kort    &amp; Matrikelstyrelsen</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.kms.dk/NR/rdonlyres/46C302B9-DC44-4A85-955F-D114F8D8B3C3/0/dtk_produktblad.pdf">DTK/4-cm
1980-2001</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Kort    &amp; Matrikelstyrelsen</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.kms.dk/NR/rdonlyres/46C302B9-DC44-4A85-955F-D114F8D8B3C3/0/dtk_produktblad.pdf">DTK/4-cm
1953-1976</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Kort    &amp; Matrikelstyrelsen</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.kms.dk/NR/rdonlyres/46C302B9-DC44-4A85-955F-D114F8D8B3C3/0/dtk_produktblad.pdf">DTK/Lave
målebordsblade</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Kort    &amp; Matrikelstyrelsen</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.kms.dk/Emner/Landkortogtopografi/Flyfotos/Flyfotos.htm">Orthofoto spring</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Google    Maps</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.google.com/earth/index.html">Google    Satellite</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Openstreetmap</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.openstreetmap.org/">Openstreetmap</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">KMS DTM 10 meter</span></p></td>
    <td valign="top"><p><span class="hhhh"><a href="http://www.kortforsyningen.dk/Omdata/pdf/DK_DHM_Terraen_Januar_2011.pdf">KMS
DTM</a></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">No map</span></p></td>
    <td valign="top"><p><span class="hhhh">No Map</span></p></td>
  </tr>
</table>
<p class="kkk"><span class="hhhh">Notes about  base layers</span></p>
<p><span class="hhhh">The reason for including older maps from KMS, is that most of the lake maps originates from these periods.</span></p>
<p><span class="hhhh">The DTM layer is the 10 meter DTM grid from Kort10 saved as a hillshade corresponding to midt March midt day. </span></p>
<p><span class="hhhh">It is a thinned version of the general DTM model, and is used in conjunction with Kort10.</span></p>
<p> </p>
<table border="1" cellspacing="0" cellpadding="0">
  <tr>
    <td width="266" valign="top"><p><span class="hhhh"><strong>Description</strong></span></p></td>
    <td width="209" valign="top"><p><span class="hhhh"><strong>Thematic layer name</strong></span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">The water areas (lakes and streams)</span>.</p></td>
    <td valign="top"><span class="hhhh">Water</span></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Points marking with click on option for metadata.</span></p></td>
    <td valign="top"><p><span class="hhhh">Surveyed Lakes</span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">The original map as a transparent layer</span>.*</p></td>
    <td valign="top"><p><span class="hhhh">Original bathy map</span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Depth countors from vector data</span>.*</p></td>
    <td valign="top"><p><span class="hhhh">Depth Black meters</span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Depth contours from vector data.* Made white for better </span><span class="hhhh">viewing on top of
orthophotos.</span></p></td>
    <td valign="top"><p><span class="hhhh">Depth white meters</span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">VGI data submitted with click on option for metadata.</span></p></td>
    <td valign="top"><p><span class="hhhh">VGI data</span></p></td>
  </tr>
  <tr>
    <td valign="top"><p><span class="hhhh">Name for a given lake. To be used on top of layers without names.</span></p></td>
    <td valign="top"><p><span class="hhhh">Name (Kort10) and maps</span></p></td>
  </tr>
</table>
<p><strong>* Only approx 80 lakes are included with  map or vector data.</strong></p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
</body>
</html>
```

5. What is data?



What is data?

What is data?

Map data:

If you posses a lake map not in the database, you can send a scanned copy, or some information about it. I.e. what lake, the location, ownership of data, method of surveying etc. These data are important for assessing the map quality.

If you look on the maps in the GIS section, and realize that you do have some information, then click on the spot, retrive the position or save the screen as a screen dump, and add your comments. Then send this.

If you are a professional surveyor wanting to contribute, just send data or metadata i.e. data about data.

Any alterations and other kind of data are most welcome.

GPS data:

If you collect data using a consumer GPS and echo sounder setup or both in one unit ("combi"), the depth will be recorded either in the "track-log" if you use a Garmin product, or in a log file if you use a Lowrance product. Every vendor has their own proprietary format. Just state the vendor in the form, and remember that raw unedited data is best. If you use Garmin products, do not save the track log as a track in the unit, as this will generalize data and the coordination between positions and depths will be lost. Transfer the raw track log to your computer using Garmin MapSource software (free), and send this.

GPS data without depth attributes can also be important, i.e. if you want to show your preferred routes or want to draw attention to hazards and dangerous spots that must be marked on the map.

If you are a professional you properly have both the raw data and the end product. Please contribute with at least metadata.

Thanks in advance.....

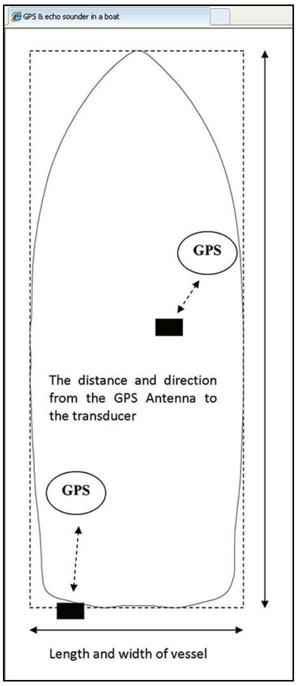
What_is_data.html

The Code:

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<title>What is data?</title>
<style type="text/css">
<!--
.g {
	font-weight: bold;
}
.ww {
	font-weight: bold;
}
.qq {
	font-weight: bold;
}
.jj {
	font-weight: bold;
	font-size: 18px;
}
.jjgg {
	font-family: Verdana, Geneva, sans-serif;
	font-size: 24px;
	font-weight: bold;
}
.tt {
	font-family: Verdana, Geneva, sans-serif;
}
.jj {
	font-family: Verdana, Geneva, sans-serif;
}
.jj {
	font-weight: normal;
}
.jj {
	font-size: 16px;
}
.jj .jj .jj {
	text-align: justify;
	font-size: 24px;
	font-weight: bold;
}
.uu {
	font-family: Verdana, Geneva, sans-serif;
}
```

```
.jj .jj .jj {
	font-size: 24px;
}
.pp {font-weight: bold}
.oioi {font-weight: bold}
.w {font-weight: bold}
.r {font-weight: bold}
.oioi span {
	font-family: Verdana, Geneva, sans-serif;
}
.g {
	font-weight: bold;
}
.oioi {
	font-weight: normal;
}
.oioi .g {
	font-weight: bold;
}
.pppp {
	font-family: Verdana, Geneva, sans-serif;
}
.pppp {
	text-align: justify;
}
.uu {
	text-align: justify;
}
-->
</style>
</head>

<body>
<p class="jj"><span class="jjgg">What is data?</span></p>
<table width="1000" border="0">
  <tr>
    <td><p class="jj"><span class="jj"><span class="jj">Map data:</span></span></p>
      <p class="pppp"><span class="pppp">If you posses a lake map not in the database, you can  send a scanned copy, or some information about it. I.e. what lake, the  location, ownership of data, method of surveying etc. These data are important  for assessing the map quality.</span></p>
      <p class="pppp"><span class="pppp">If you look on the maps in the GIS section, and  realize that you do have some information, then click on the spot, retrive the position or save the screen as a screen dump, and add your comments. Then send  this.</span></p>
      <p class="pppp"><span class="pppp">If you are a professional surveyor wanting to  contribute, just send data or metadata i.e. data about data.</span></p>
      <p class="pppp"><span class="pppp"><span class="pppp">Any alterations and other kind of data are most  welcome</span>.</span></p>
<p class="oioi"> </p></td>
  </tr>
  <tr>
    <td><p class="qq"> </p></td>
  </tr>
  <tr>
    <td><p class="qq"><span class="jjgg">GPS data:</span></p>
      <p class="uu">If you  collect data using a consumer GPS and echo sounder setup or both in one unit  (&quot;combi&quot;), the depth will be recorded either in the  &quot;track-log&quot; if you use a Garmin product, or in a log file if you use a  Lowrance product. Every vendor has their own proprietary format. Just state the vendor in the form, and remember that raw unedited data is best. If you use  Garmin products, do not save the track log as a track in the unit, as this will  generalize data and the coordination between positions and depths will be lost.  Transfer the raw track log to your computer using Garmin MapSource software  (free), and send this.</p>
      <p class="uu">GPS data  without depth attributes can also be important, i.e. if you want to show your  preferred routes or want to draw attention to hazards and dangerous spots that  must be marked on the map.</p>
    <p class="uu"><span class="uu">If you are  a professional you properly have both the raw data and the end product. Please  contribute with at least </span>metadata.</p></td>
  </tr>
</table>
<p class="jj">Thanks in advance.....</p>
<p class="g"> </p>
<p class="qq"> </p>
<p class="qq"> </p>
<p class="qq"> </p>
</body>
</html>
```

6. GPS & echo sounder in a boat



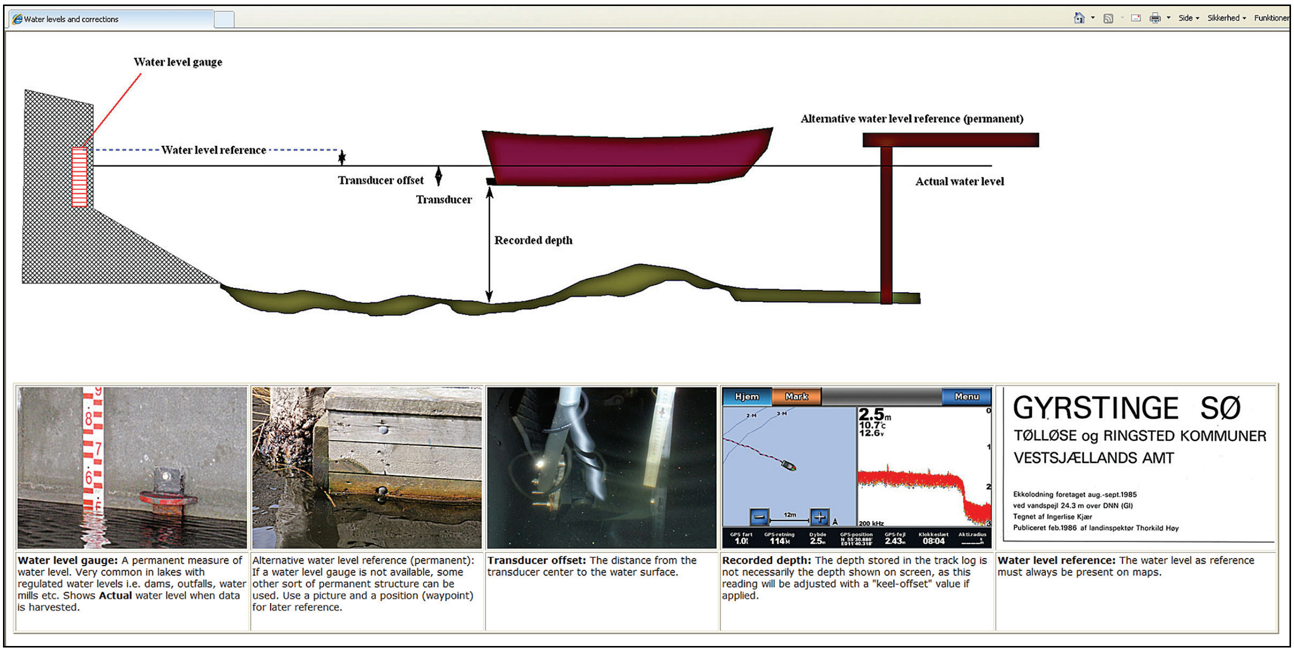
Boat_corrections.html

The code:

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<title>GPS & echo sounder in a boat</title>
<style type="text/css">
<!--
.fed {
			font-weight: bold;
}
.fed {
			font-family: Verdana, Geneva, sans-serif;
			font-size: 14px;
}
.vv {
			font-weight: normal;
}
.fed .fed {
			font-family: Verdana, Geneva, sans-serif;
}
.fed .fed {
			font-size: 14px;
}
.fed .fed {
			font-family: Georgia, "Times New Roman", Times, serif;
}
bb {
			font-family: Verdana, Geneva, sans-serif;
}
.fed .fed {
			font-family: Verdana, Geneva, sans-serif;
}
.l {
			font-weight: normal;
}
.k {
			font-weight: normal;
}
.o {
			font-weight: normal;
}
.ff {
```

```
                    font-family: Verdana, Geneva, sans-serif;
                    font-size: 14px;
}
.gt {
                    font-weight: bold;
                    font-family: Verdana, Geneva, sans-serif;
}
.gg {
                    font-family: Verdana, Geneva, sans-serif;
}
.jj {
                    font-weight: bold;
}
.c {
                    font-family: Verdana, Geneva, sans-serif;
}
.gtw {
                    font-size: 14px;
}
.fed {
                    text-align: justify;
}
.gt .gtw {
                    text-align: justify;
}
.qq {
                    text-align: center;
}
body p {
                    text-align: left;
}
body pk {
                    text-align: left;
}
.qww {
                    font-family: Verdana, Geneva, sans-serif;
                    font-size: 14px;
}
.fre {
                    font-weight: bold;
}
-->
</style>
</head>

<body>
<img src="Placering.jpg" width="400" height="939" />
<p class="qq"> </p>
</body>
</html>
```

7. Water levels and corrections



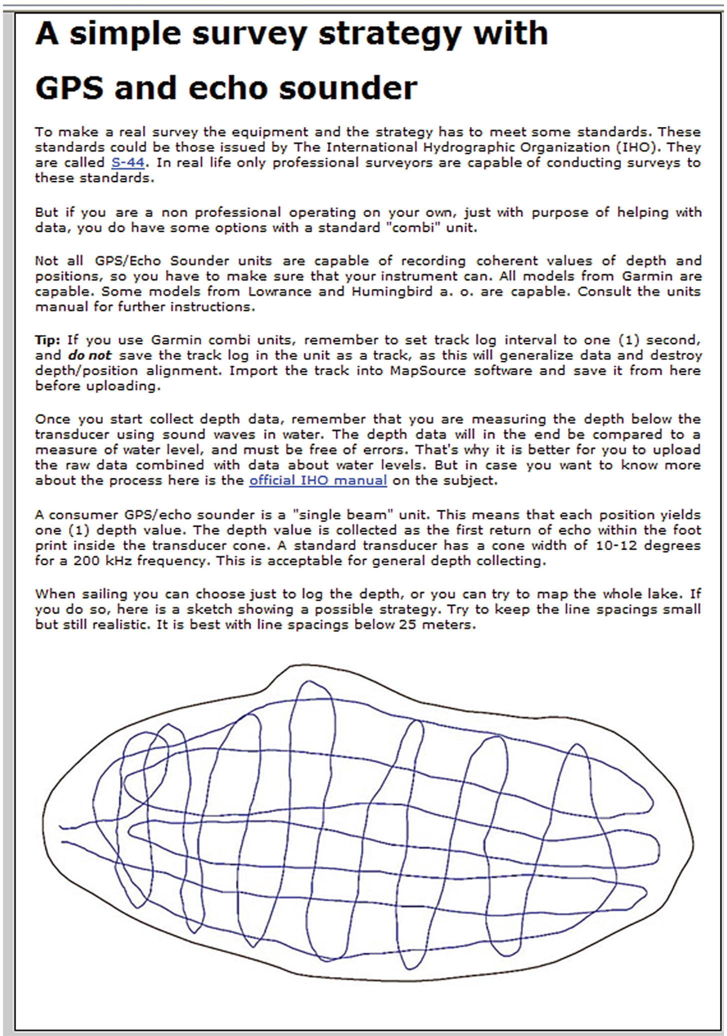
Water_levels.html

The code:

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<title>Water levels and corrections</title>
<style type="text/css">
<!--
.fed {
	font-weight: bold;
}
.fed {
	font-family: Verdana, Geneva, sans-serif;
	font-size: 14px;
}
.vv {
	font-weight: normal;
}
.fed .fed {
	font-family: Verdana, Geneva, sans-serif;
}
.fed .fed {
	font-size: 14px;
}
.fed .fed {
	font-family: Georgia, "Times New Roman", Times, serif;
}
bb {
	font-family: Verdana, Geneva, sans-serif;
}
.fed .fed {
	font-family: Verdana, Geneva, sans-serif;
}
.l {
	font-weight: normal;
}
.k {
	font-weight: normal;
}
.o {
	font-weight: normal;
}
.ff {
	font-family: Verdana, Geneva, sans-serif;
	font-size: 14px;
}
.gt {
	font-weight: bold;
```

```
				font-family: Verdana, Geneva, sans-serif;
}
.gg {
				font-family: Verdana, Geneva, sans-serif;
}
.jj {
				font-weight: bold;
}
.c {
				font-family: Verdana, Geneva, sans-serif;
}
.gtw {
				font-size: 14px;
				font-weight: normal;
}
.fed {
				text-align: justify;
}
.gt .gtw {
				text-align: justify;
}
.qq {
				text-align: center;
}
body p {
				text-align: left;
}
body pk {
				text-align: left;
}
.qww {
				font-family: Verdana, Geneva, sans-serif;
				font-size: 14px;
}
.fre {
				font-weight: bold;
}
-->
</style>
</head>

<body>
<p class="qq"><img src="Setup.jpg" alt="" width="1500" height="424" align="left" class="vv" /></p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p> </p>
<p class="qq"> </p>
<table width="333" border="2" cellpadding="2" cellspacing="2">
  <tr>
    <td><img src="Water_guage.jpg" width="333" height="235" /></td>
    <td><img src="Alternative.jpg" width="333" height="235" /></td>
    <td><img src="Offset.jpg" width="333" height="235" /></td>
    <td><img src="recored.jpg" width="392" height="235" /></td>
    <td><img src="KoteOnMap.jpg" width="402" height="235" /></td>
  </tr>
  <tr>
    <td height="109" valign="top"><span class="fed"><span class="fed">Water level gauge: <span class="vv">A permanent measure of water level. Very common in lakes with regulated water levels i.e. dams, outfalls, water mills etc. Shows </span></span><span class="gtw"><span class="c"><span class="jj">Actual </span></span><span class="gg">water level when data is harvested.</span></span></span><span class="gtw"><span class="gg"></span></span></td>
    <td valign="top"><span class="gt"><span class="gtw">Alternative water level reference (permanent):</span></span><span class="gtw"><span class="ff"> If a water level gauge is not available, some other sort of permanent structure can be used. Use a picture and a position (waypoint) for later reference.</span> <span class="gg"></span></span></td>
    <td valign="top"><span class="fed">Transducer offset: <span class="k">The distance from the transducer center to the water surface.</span></span></td>
    <td valign="top"><span class="fed">Recorded depth: <span class="o">The depth stored in the track log is not necessarily the depth shown on screen, as this reading will be adjusted with a &quot;keel-offset&quot; value if applied.</span></span></td>
    <td valign="top" class="qww"><span class="fre">Water level reference:</span> The water level as reference must always be present on maps.</td>
  </tr>
</table>

<p> </p>
<p> </p>
<p> </p>
<p> </p>
<pre> </pre>
</body>
</html>
```

8. A simple survey strategy



A simple survey strategy with GPS and echo sounder

To make a real survey the equipment and the strategy has to meet some standards. These standards could be those issued by The International Hydrographic Organization (IHO). They are called S-44. In real life only professional surveyors are capable of conducting surveys to these standards.

But if you are a non professional operating on your own, just with purpose of helping with data, you do have some options with a standard "combi" unit.

Not all GPS/Echo Sounder units are capable of recording coherent values of depth and positions, so you have to make sure that your instrument can. All models from Garmin are capable. Some models from Lowrance and Humingbird a. o. are capable. Consult the units manual for further instructions.

Tip: If you use Garmin combi units, remember to set track log interval to one (1) second, and ***do not*** save the track log in the unit as a track, as this will generalize data and destroy depth/position alignment. Import the track into MapSource software and save it from here before uploading.

Once you start collect depth data, remember that you are measuring the depth below the transducer using sound waves in water. The depth data will in the end be compared to a measure of water level, and must be free of errors. That's why it is better for you to upload the raw data combined with data about water levels. But in case you want to know more about the process here is the official IHO manual on the subject.

A consumer GPS/echo sounder is a "single beam" unit. This means that each position yields one (1) depth value. The depth value is collected as the first return of echo within the foot print inside the transducer cone. A standard transducer has a cone width of 10-12 degrees for a 200 kHz frequency. This is acceptable for general depth collecting.

When sailing you can choose just to log the depth, or you can try to map the whole lake. If you do so, here is a sketch showing a possible strategy. Try to keep the line spacings small but still realistic. It is best with line spacings below 25 meters.

How_to.html

The code:

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<title>A simple survey strategy </title>
<style type="text/css">
<!--
body {
			font: 100% Verdana, Arial, Helvetica, sans-serif;
			background: #666666;
			margin: 0; /* it's good practice to zero the margin and padding of the body element to account for differing browser defaults */
			padding: 0;
			text-align: center; /* this centers the container in IE 5* browsers. The text is then set to the left aligned default in the #container selector */
			color: #000000;
			background-color: #CCC;
}
.oneColElsCtr #container {
			width: 46em;
			background: #FFFFFF;
```

```
			margin: 0 auto; /* the auto margins (in conjunction with a width) center the page */
			border: 1px solid #000000;
			text-align: left; /* this overrides the text-align: center on the body element. */
}
.oneColElsCtr #mainContent {
			padding: 0 20px;
			text-align: justify;
}
.oneColElsCtr #container #mainContent h2 {
			font-family: Verdana, Geneva, sans-serif;
			font-size: 14px;
			text-align: justify;
}
.ujuj {
			font-weight: bold;
}
.yy {
			font-weight: bold;
			font-style: italic;
}
.oneColElsCtr #container #mainContent p {
			font-size: 14px;
}
.oo {
			text-align: left;
}
-->
</style></head>

<body class="oneColElsCtr">

<div id="container">
  <div id="mainContent">
    <h1><span class="oo" style="margin-left: 10; margin-right: 10; color: #000;">A simple survey strategy with </span></h1>
    <h1><span class="oo" style="margin-left: 10; margin-right: 10; color: #000;">GPS and echo sounder </span></h1>
    <p>To make a  real survey the equipment and the strategy has to meet some standards. These  standards could be those issued by The International Hydrographic Organization  (IHO). They are called <a href="http://www.iho.int/iho_pubs/standard/S-44_5E.pdf">S-44</a>. In real life only professional surveyors are capable  of conducting surveys to these standards.</p>
    <p>But if you  are a non professional operating on your own, just with purpose of helping with  data, you do have some options with a standard &quot;combi&quot; unit. </p>
    <p>Not all  GPS/Echo Sounder units are capable of recording coherent values of depth and  positions, so you have to make sure that your instrument can. All models from  Garmin are capable. Some models from Lowrance and Humingbird a. o. are capable. Consult the units manual for further instructions. </p>
    <p><span class="ujuj">Tip:</span> If you use Garmin combi units, remember to set track log interval to one (1) second, and <span class="yy">do not</span> save the track log in the unit as a track, as this will generalize data and destroy depth/position alignment. Import the track into MapSource software and save it from here before uploading.</p>
    <p>Once you start collect depth data, remember that you are measuring the depth below the transducer using sound waves in water. The depth data will in the end be compared to a measure of water level, and must be free of errors. That's why it is better for you to upload the raw data combined with data about water levels. But in case you want to know more about the process here is the <a href="http://www.iho.int/iho_pubs/CB/C13_Index.htm">official IHO manual</a> on the subject.</p>
    <p>A consumer GPS/echo sounder is a &quot;single beam&quot; unit. This means that each position yields one (1) depth value. The depth value is collected as the first return of echo within the foot print inside the transducer cone. A standard transducer has a cone width of 10-12 degrees for a 200 kHz frequency. This is acceptable for general depth collecting.</p>
    <p>When sailing you can choose just to log the depth, or you can try to map the whole lake. If you do so, here is a sketch showing a possible strategy. Try to keep the line spacings small but still realistic. It is best with line spacings below 25 meters.</p>
    <p><img src="Images/DYI_Survey.jpg" width="700" height="362" /></p>
<p> </p></div>
<!-- end #container --></div>
</body>
</html>
```

Appendix F

Metadata form

Submit your lake data

Instructions

Fill out this form. Save it. Put it in a folder with your bathymetric data. Compress the folder into a zip archive or similar, and upload the zipped archive via the webpage or via email. If the zipped archive is to large, recompress to multiple archives and upload separately. Data not covered by the form can be submitted aswell. Remember to discribe the data.

User generated Metadata

Name:

Email:

Phone:

Web:

Spatial education?

Accept that data can be distributed by you? ☐ YES ☐ NO

Accept public crediting on this web site? ☐ YES ☐ NO

Reasons for contributing (I.e. help, interests, work):

Echo sounding data

Echo sounder used:

Echo sounder settings:

Transducer used:

Transducer frequency used:

Transducer water level offset:

GPS

GPS used (if same that echo sounder use this):

GPS track settings (seconds or meters) only use raw track log.

Do not save track in unit before export from unit: second(s) *or* meter(s)

Water level in lake (or take a picture & waypoint against pier or dam): meter (DNN) *or* meter (DVR)

Vessel used:

Horizontal distance from transducer to GPS, or submit a picture or drawing:

Wind:

Water temperature (measured by alternative means):

Submitting GPS data

Data format (gpx, Garmin.gdb, Lowrance.slg etc):

Is data edited? ☐ YES ☐ NO

Coordinate system & datum:

Submitting own map or data about a map

Year of production: Position:

Method: ☐ Soundings ☐ Echo sounder transects ☐ GPS & XYZ ☐ Other

Scale:

Surveying tracks:

Water level at time of survey:

Data format (print or digital):

Coordinate system & datum:

Appendix G

Vectorized lakes

Sjælland	Kote (DNN)	Opmålt	Leverandør*
Bastrup Sø	28,70	1976	KMS/TH
Farum Sø	20,50	1976	KMS/TH
Bue Sø	2,60	1990	KMS/TH
Kornerup Sø	4,00	1989	KMS/TH
Sjælsø	18,20	1992	KMS/TH
Gurresø	26,40	1962	KMS/TH
Donse Storedam	40,40	1993	KMS/TH
Buresø	26,50	1981	KMS/TH
Frederiksborg Slotssø	26,55	1996	KMS/TH
Arresø	3,97	1995	KMS/TH
Esrum Sø	9,40	1983	KMS/TH
Gørlev Sø	21,80	1990	KMS/TH
Søndersø	12,45	1982	KMS/TH
Korsør Nor	-	1990	KMS/TH
Vejlesø	20,55	2009	TV
Furesø	20,55	2009	TV
Bagsværd Sø	18,50	1993	KMS/TH
Lyngby Sø	18,50	1989	KMS/TH
Svogerslev Sø	2,50	1990	KMS/TH
Store Kattinge Sø	2,50	1990	KMS/TH
Gjorslev Møllesø	9,30	1984	KMS/TH
Maglesø	50,80	1990	KMS/TH
Ulse Sø	52,90	1978	KMS/TH
Søtorup Sø	56,20	1985	KMS/TH
Gyrstinge Sø	24,30	1985	KMS/TH
Haraldsted Sø	22,00	1981	KMS/TH
Tivolisøen	21,20	1981	KMS/TH
Sorø Sø	34,70	1984	KMS/TH
Pedersborg Sø	33,70	1985	KMS/TH
Tuel Sø	32,10	1985	KMS/TH
Tystrup og Bavelse søer	6,80	1984	KMS/TH
Skarresø	18,50	1984	KMS/TH
Tissø	1,00	1987	KMS/TH

Fyn	Kote (DNN)	Opmålt	Leverandør*
Søholm Sø	49,80	1985	KMS/TH
Langesø	25,30	1986	KMS/TH
Nørresø	40,80	1988	KMS/TH
Søbo Sø	38,80	1988	KMS/TH
Arreskov Sø	32,70	1989	KMS/TH

Bornholm	Kote (DNN)	Opmålt	Leverandør*
Hammersøen	8,50	1984	KMS/TH

Jylland	Kote (DNN)	Opmålt	Leverandør*
Madum Sø	37,10	1932	KMS
Glenstrup Sø	14,08	1932	KMS
Store Økssø	63,90	1932	KMS
Viborg Nørresø	11,10	1988	KMS/TH
Viborg Søndersø	11,10	1988	KMS/TH
Hald Sø	9,10	1986	KMS/TH
Loldrup Sø	11,60	1983	KMS/TH
Flynder Sø	3,00	1986	KMS/TH
Snæbum Sø	35,20	1986	KMS/TH
Vedsø	6,90	1985	KMS/TH
Julsø	20,70	1929	KMS
Brassø	20,70	1929	KMS
Guden Sø	22,30	1975	KMS/TH
Rye Møllesø	22,30	1975	KMS/TH
Vejlsø	20,70	1929	KMS
Silkeborg Langsø	18,71	1932	KMS
Birksø	21,00	1975	KMS/TH
Stilling og Solbjerg Sø	49,90	1991	KMS/TH
Thorsø	22,60	1964	KMS/TH
Salten Langsø	22,60	1929	KMS
Bryrup Langsø	57,60	1972	KMS/TH
Karlsø	58,20	1972	KMS/TH
Mossø	22,30	1929	KMS
Skanderborg Sø	23,46	1932	KMS
Stubbe Sø	1,30	1983	KMS/TH
Fussing Sø	16,90	1979	KMS/TH
Vessø	22,40	1982	KMS/TH
Borresø	20,70	1929	KMS
Ørnsø	19,10	1929	KMS
Almind Sø	21,10	1931	KMS
Fårup Sø	48,10	1981	KMS/TH
Gødstrup Sø	37,40	1986	KMS/TH
Jels Oversø	36,00	1982	KMS/TH
Jels Midtsø	36,00	1982	KMS/TH
Jels Nedersø	36,00	1982	KMS/TH
Søgård Sø	34,40	1983	KMS/TH
Slåen Sø	24,20	1931	KMS
Haderslev Dam	2,10	1985	KMS/TH
Nordborg Sø	4,20	1985	KMS/TH
Sunds Sø	41,80	1988	KMS/TH
Stubbergårds Sø	3,90	1986	KMS/TH

* KMS: Søer opmålt af KMS. Digitaliseret af Thomas Vedel.
KMS/TH: Søer opmålt af Thorkild Høy. Digitaliseret af Thomas Vedel.
TV: Søer opmålt af Thomas Vedel.

Appendix H - Tanktest

GPX parsed with GPS2Layer Toolbox
Output analyzed with NCSS 2004
Absolute values

1. Garmin GPSmap720s

Data set 1: **Frequency Distribution of Depth**

Depth	Count
0.75903511047	650
0.78275489807	1

Data set 2: **Frequency Distribution of Depth**

Depth	Count
0.75903511047	12
0.78275489807	308

Data set 3: **Frequency Distribution of Depth**

Depth	Count
0.73531532288	2
0.75903511047	513
0.78275489807	9
0.80647468567	5
0.85391426086	4
0.87763404846	7

Data set 4: **Frequency Distribution of Depth**

Depth	Count
0.75903511047	314
0.78275489807	6

Data set 5: **Frequency Distribution of Depth**

Depth	Count
0.71159553528	86
0.73531532288	93
0.75903511047	31
0.78275489807	7
0.80647468567	1
0.83019447327	3

Data set 6: **Frequency Distribution of Depth**

Depth	Count
0.73531532288	2
0.75903511047	1489
0.78275489807	324
0.80647468567	5
0.85391426086	4
0.87763404846	7

2. Garmin GPSmap178C

Data set 1: Frequency Distribution of Depth

Depth	Count
0.68648147583	715
0.69624710083	18
0.70601463318	9

Data set 2: Frequency Distribution of Depth

Depth	Count
0.73531723023	525
0.74508476257	1
0.75485038757	1
0.76461791992	1

Data set 3: Frequency Distribution of Depth

Depth	Count
0.73531723023	49
0.91112136841	2

Data set 4: Frequency Distribution of Depth

Depth	Count
0.72554969788	23
0.73531723023	51

Data set 5: Frequency Distribution of Depth

Depth	Count
0.73531723023	142
0.74508476257	8
0.75485038757	7
0.76461791992	2
0.77438354492	4
0.78415107727	3

Data set 6: Frequency Distribution of Depth

Depth	Count
0.68648147583	38
0.69624710083	3
0.70601463318	1
0.73531723023	1