PDGPS and Multi Beam Echosounder Systems for Precise Surveying of Waters in the FRG

Dr.-Ing. Joachim BEHRENS, Germany

Key words: Hydrography, Surveying of Waters, Surveying System for "Peilungen", PDGPS, Multi Beam Echosounder System, Federal Waterways and Shipping Administration.

ABSTRACT

In the surveying of waters mainly the geometrical information about the morphologic-topographical structure of any kind of offshore and inshore waters is recorded. This is necessary for passing on detailed information e.g. for the safety of trade vessels or tourist ships on rivers, canals and coastal waterways.

The Federal Waterways and Shipping Administration (WSV) is responsible for coastal and inland waterways in the Federal Republic of Germany (FRG). Within the last 30 years not only the developments in surveying systems but also the reorganization of the WSV with its 7 directorates and 39 offices led to an optimization in the surveying of waters.

It will be demonstrated how the WSV is working today in managing the surveying of waters, mostly for monitoring the riverbeds of the Federal Waterways in FRG. The use of precise differential GPS (PDGPS) for positioning the surveying vessels, leads to the best results in surveying. On the other hand there is a change from multi channel to multi beam echosounder systems with a mass of information, which is referred as digital terrain model. Some examples for managing the data flood will be shown.

The increasing transportation of goods by inland navigation makes it necessary to have more information for ship navigation in marked narrow river channels, which are normally supervised more often than the riverbanks. Therefore it is necessary to have a special river information system for the Rhine river called ARGO.

CONTACT

Dr.-Ing. Joachim Behrens, Head of Department Geodesy
Federal Institute of Hydrology
Bundesanstalt für Gewässerkunde
Kaiserin-Augusta-Anlagen 15 – 17
D–56068 Koblenz
GERMANY
Tel. + 49 261 1306 (0) 5230
Fax + 49 261 1306 5280
E-mail: behrens@bafg.de , BfG Internet: http://www.bafg.de/

PDGPS and Multi Beam Echosounder Systems for Precise Surveying of Waters in the FRG

Dr.-Ing. Joachim BEHRENS, Germany

1 INTRODUCTION

The **Federal Waterways and Shipping Administration** (**WSV** := Wasser- und Schifffahrtsverwaltung) is responsible for the coastal and inland Federal Waterways and has to supervise the navigational traffic routes and the traffic itself. The flood, the waste water from industry and the water quality - by mentioning some of the essential topics - is in the responsibility of the 16 States of the Federal Republic of Germany (FRG). Only if there is a conjunction with navigational traffic, then the WSV has been involved.

The organization of the WSV is: the Federal Ministry of Transport, Building and Housing (BMVBW), the 7 regional Waterways and Shipping Directorates (WSD'en, plural), the 39 local Waterways and Shipping Offices (WSÄ) and 8 Offices for Planning and Construction (NBÄ). In addition to this organization there are the Federal Institute of Hydrology (BfG := Bundesanstalt für Gewässerkunde), the Federal Institute of Hydraulic Engineering (BAW) and Federal Maritime and Hydrographic Agency (BSH) as principal authorities of the FRG under the jurisdiction of BMVBW (Behrens 1992b).

The length of the **Federal Waterways in the FRG** is about 7.300 km, 800 km from that are so-called sea waterways. Opposite to that the inland waterways are decided in free flowing rivers, channelized rivers (whose streaming water is regulated by locks), and canals. 75 % of the river net belongs to natural beds by streaming water, and the other part is constructed by mankind. The Federal Waterways are in the right of possession of the FRG. The regulations and especially the rivers and their length are described in the Federal Waterways Act in the FRG, the Bundeswasserstraßengesetz (BWaStrG 1990). As the FRG is situated in the heart of Europe, so the Federal Waterways have a central importance for European Waterways and their navigation traffic. The main rivers of the FRG are Rhine, Danube and Elbe, where you can find most traffic activities.

2 SURVEYING OF WATERS

In the surveying of waters mainly the geometrical information about the morphologic-topographical structure of any kind of offshore and inshore waters is recorded. This is necessary for passing on detailed information e.g. for the safety of trade vessels or tourist ships on rivers, canals and coastal waterways. Within the last 30 years not only the developments in surveying systems but also the reorganization of the WSV with its 7 directorates and 39 offices led to an optimization in the surveying of waters.

2.1 Definition

Surveying of waters consists in measuring the morphology of the water bed, that means the form (sometimes the consistence of the bottom material) and the topography of the shores and banks, including the underwater banks and slopes and the bottom. These three-dimensional co-ordinates (triples) are recorded, in dependence on the special water region, with systems aboard vessels / boats or, in certain cases, with simple surveying instruments from shore or bank. Measuring vehicles like measuring vessels, amphibian vehicles, trailerable boats or barks, are used, which have special standards in construction and motorization to meet the requirements of the area to be surveyed and of the surveying equipment (Behrens 1993).

The two-dimensional position of the measuring vehicle (e.g. latitude and longitude or other national co-ordinate systems) is determined by position fixing systems using various methods. The measurement of water depth or sounding is made from the surveying vessels mostly with echosounders or echosounder systems. The measured depth data are related either to the surveying vessel or to the surrounding water surface. The data of positioning and of depth sounding have to be assigned together simultaneously (Behrens 1993). If there are shallow waters or if trailerable boats or amphibian vehicles are not available, only tachymeters with prismatic rod or sounding rod are used. It is in any case important to ensure the flow of data because of the immense recorded information. For the later use of the data triples - especially for comparison with data from earlier surveying epochs or campaigns - the measured water depth data have to be related to a mostly homogeneous levelling reference system, cf. figure 1.

The main task of the WSV is to guarantee the safety of navigation on the Federal Waterways in Germany, requires the permanent monitoring of the morphology of the waterway beds and of the changes they undergo. These measuring exercises, called in German "Peilungen" consist of the following operations:

- position fixing of moving surveying boats or vessels (location);
- depth measurements (sounding), related to the position of surveying boats;
- time measurements, associated simultaneously with the above operations (time reference).

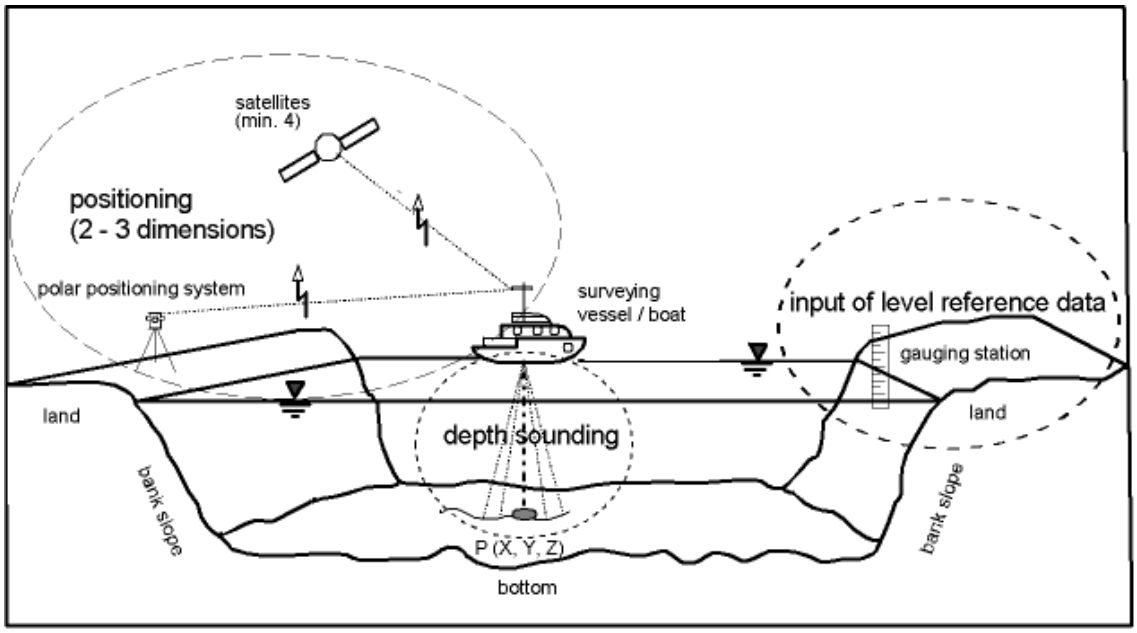


Figure 1: Principle of surveying of waters by vessel or boat

The extent and the accuracy of surveying tasks is to be optimizes, depending on the demands brought forward by the multi-users of the data, for instance in the field of maintenance dredging, development or new construction of waterways. Mostly the surveys are so-called multi-purpose surveys, with the intention to optimize the quality (e.g. accuracy) of the measurements and to chose the most economical method.

2.2 Developments for Systems for "Peilungen"

As the author is Head of **Department "Geodesy" of BfG** some information are necessary to explain. The BfG is the scientific institute of the Federal Government in Germany for research, assessment, and consulting in the fields of hydrology, water-resources management, ecology and water conservation. It acts as consultant for federal ministries and their subordinated authorities in general and detailed decision-making, especially for WSV in matters of regarding the planning, development and new construction of Federal Waterways as well as their operation and maintenance (BWaStrG 1990, § 45 (3)). The main tasks of Department "Geodesy" in the field of surveying of waters are research, development of instruments, surveying systems and measuring methods as consultation, support or assistance and aid for the WSV.

The last 30 years had been marked by several developments of surveying systems on board of hydrographic vessels. In nearly each case the members of BfG had been involved: first study the international innovations or create (own) prototypes, then make examinations, ability tests and applicability reports before buying the instrumentation. Today very often the geodesy staff gave aid during the phases of placing. In the conditions of contracts it is our part to establish the performance characteristic. After buying and delivering we had - together with

the WSV-Office - to test the instrumentation and to give an efficiency report for use as component (or more) in the systems for "peilungen".

On the Federal Waterways **surveying systems for "peilungen"** are used. This surveying system is installed on board the measuring vessels. This system has 3 main components, which are equal to a higher data processing level by the stream of data sampling:

- The sensors, measuring the raw data
- The computer for the continuous working process and
- The actual data information units for the operator and the helmsman and the recording instruments.

The sensors are normally: the positioning board system, inclusive an antenna or prism circle outside the steering house, the echosounder system, inclusive the acoustic oscillator (transducer) and the height referencing system, cf. figure 2. If needing highest accuracy, it is necessary to have a motion sensor (for heave, roll, pitch) and a gyro compass for the stability of the surveying vessel (as the platform for all sensors) in the short moment of measurement during practical work.

If you will not correct the depth data with tide gauges (called in German "Beschickung"), when working in near distances (until 500 m) to the boarders of the river, so-called niveaulaser systems are in use (Behrens 1993). Another way of hydrographic height adaptation is to use the vertical angle of polar-fixing systems or nowadays the use of satellite positioning systems.

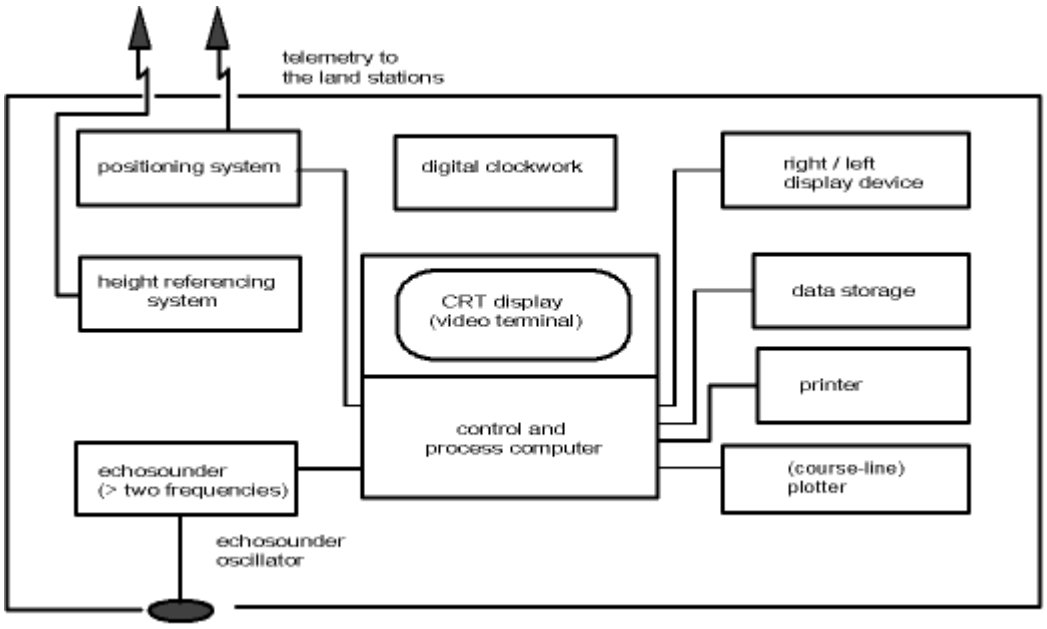


Figure 2: Principle of a surveying system for “peilungen” (board station)

In general there is a **data-flood** and for the hydrographer it is necessary to get the sensor-data into the processor for calculating and navigating for the helmsman. The raw data with so-called first plausibility on board are recorded on CD's. This is a very difficult process, because the surveying system for "peilungen" must be able to decide, that the correct time for each sensor-measurement is chosen. Only by this the calculation of the co-ordinates P(X, Y, Z) for each bottom-point is truthful possible. By our researches over a period of years we can mention, that the minimum time for position data must be better than 2 data per second. The minimum time for sounding data must be better than 10 data per second. The data for the height reference of depth measurements must be close to the positioning data rate. Besides that there is often the problem to have acknowledge over the stabilisation of the measuring vessel itself. For that high precise surveying of waters, we use sensors for heave, pitch and roll too.

In 1994 / 95 a lot of trials had been made to install the **Hydrographisches Mess- und Auswertesystem (HYMAS)** - a modern combined surveying system for "peilungen" - on board the new developed, 16 m length surveying vessels for use on Federal Waterways. The components of HYMAS are PDGPS (cf. chapter 3.1), a single beam echosounder system with 2 frequencies (e.g. 15 kHz / 100 kHz), a multi tasking processor unit and a lot of software modules (develop by firms and the staff of Department "Geodesy"-BfG) under Windows NT is leading the measurements from the beginning to the end of surveying work. The software is able to recognize mistakes, defects or failure data from the sensors during the process on board. It is a great help for the operator and the helmsman, seeing the complete documentation - not only for the surveying data - on the processor screen. This HYMAS are in use since the end of 1995 in WSA Cologne for a river part of the Lower Rhine Region (Brüggemann 1995). Until today there are in use about 20 surveying vessels with HYMAS for inland waterways, see HYMAS-Grafic at appendix.

The recorded data are given to a computing centre in a local Waterways and Shipping Office (WSA := Wasser- und Schifffahrtsamt). There a second plausibility will be used for the combination of the data sampled for each surveying track to a digital river-bottom modelling. Other results are drawings of profile tracks, depth figure or depth-lines charts, difference depth-lines charts and digital cartographic information for different users. The intern users in the WSV are responsible for navigational safety, dredging, hydrology, inspection of all sorts of underwater buildings and planning and new construction of waterways.

3 POSITIONING AND ECHOSOUNDER SYSTEMS

In the text before the components of the surveying system of "peilungen" and their developments until now had been explained. In this chapter the newest technology of hydrographic instrumentation - installed on hydrographic vessels of WSV - will be shown in detail. There are a lot of problems with them, not only of the high technology integrated in the separate systems, but also of giving the WSA-Staff good aid with the change in their daily tasks.

3.1 Use of PDGPS in Federal Republic of Germany

At the beginning of 1995 the Working Committee of the Surveying Authorities of the States of the FRG (**AdV**) decided to build up the **SA*POS* - Satellite Positioning Service of the German National Survey**. It has to be mentioned that the WSV is itself member of the AdV. The AdV first elaborated as a joint project the SA*POS* and thus made available by modern methods the official reference system at a nation-wide level. SA*POS* provides by modern techniques up-to-date spatial references for everyone (AdV 2002). This is the part of the legal tasks of the German National Survey which include the provision of basic infrastructure facilities. SA*POS* establishes a permanently operated multifunctional Differential GPS (DGPS) Service. A system of GPS reference stations forms the basis of this system. There are 4 SA*POS* services with different characteristics and accuracies:

- SA*POS* EPS - Real Time Positioning Service
- SA*POS* HEPS - High-Precision Real Time Positioning Service
- SA*POS* GPPS - Geodetic Precision-Positioning Service
- SA*POS* GHPS - Geodetic High-Precision Positioning Service.
-

Standard components enable the user to have easy access via communication paths of high technology. EPS and HEPS can be used in real time. The **SA*POS* HEPS** is very important for the surveying of waters, because you can reach an **accuracy of σ = 1 ... 5 cm** (P = 95% confidence level) **for objects in a non-kinematic status**.

The user may have recourse to the carrier phase correction data of the satellite signals in real time (in standardized telegrams), which make precise positioning possible for him. The correction data are transmitted in the 2 m band via the own GPS reference stations of National Survey. Alternative the data can be called by telephone in the internationally introduced standard RTCM SC-104. The data are transmitted at intervals of a second, but it is necessary to have a decoder module of the AdV. Several GPS reference stations work on an interlinked basis and can thus record site-dependent error influences. Specific position-dependent correction values are supplied to the user, which means a further increase in reliability and accuracy.

The **development of the positioning systems for surveying of waters by WSV** since 1969 has been shortly described in the Paper for FIG Working Week 2001 in Seoul (Behrens 2001); detailed c.f. the references there.

During 1984 - 1988 the BfG took part in the "Examination of Optimization the Hydrographic Surveying of the Inland Federal Waterways" (Untersuchung zur Verbesserung des Peilwesens auf den Binnenwasserstraßen - Behrens 1992a, 1992b, 1996). The main aspect for the geodesy staff of BfG was to study the surveying of waters - especially getting more accuracy in depths measurements. One of the important results was to test GPS for future tasks of WSV. This led to a Positioning Concept for WSV (Behrens 1992a, 1993, 1996) with some main aims:

- General use of DGPS for surveying of waters
- Integration of DGPS board station in the surveying system for "peilungen"

- Optimized distances between measuring vessel and GPS reference stations along the river banks without loss of highest accuracy for surveying.

Before beginning with the tests along the Inland Federal Waterways the geodesy staff of BfG tested together with staff of SV (Seezeichen-Versuchsfeld := authority e.g. for sea-mark testing and telemetry) of WSV the GPS reference stations Wustrow and later on Helgoland for using the GPS signals for **accuracies of about σ = 3 ... 5 m** (P = 95%) **for surveying on coastal waters**. The mentioned two reference stations are part of the IALA-network in Europe, for North Sea and Baltic. (IALA := International Association of Lighthouse Authorities)

For the WSV some staff-members of Department "Geodesy"-BfG had been made a lot of **experiences from 1990 until 1993 with DGPS** and later on with **Precise-DGPS (PDGPS)**. These tests ended successfully for use of PDGPS aboard the surveying vessels (Wirth 1990, Wirth, Brüggemann 1993). Another famous thing was, that the Geodetic Survey of the 16 States of the FRG decided to build up the so-called **SA*POS*** , see above. Normally the GPS reference stations of SA*POS* have range distances about 50 km over the whole area of the States; that means over the FRG. Along the Rhine river the GPS reference stations are combined by SA*POS* and some stations of those from WSV (Behrens 1999a). By this there is a higher density at a range distance of about 20 km, so that the **accuracy is about σ > = 10 cm** (P = 95 % confidence level) **for kinematic use and positioning in real-time**. The last described positioning is well known as **PDGPS**.

Since 1995 until 2000 the BfG was for WSV participant of the **AdV-Expertgroup "GPS Permanent Stations"**, which developed the field structure and telemetry connections in the whole country of the FRG. Parallel to this, it was possible to get the user frequencies by German Post- and Telecommunication Authority. In this case the SV of WSV had been done the negotiations for the complete SA*POS* -network. Today the geodetic staff of BfG - as representative for WSV - is co-ordinating the installation and use of GPS reference stations for daily tasks of WSV. We work together with the Surveying Authorities of the States of the FRG and with SV of WSV we made the measurements of signal strength for each GPS reference station in use for surveying of waters **along the rivers Rhine, Main and Danube**. Today there are GPS reference stations in use or in planing:

- Along the northern part of the Rhine are 6 working, under them 3 own stations,
- Along the southern part of the Rhine will be 8 necessary, 1 own station is installed,
- Along the Main are 3 working and
- Along the Danube are about 3 working.

By the use of all kind of positioning systems in daily practice at the Federal Waterways we **develop accuracies for position fixing of the surveying vessels / boats**. Long-years of practical experience have shown that the systems can yield accuracies in the following ranges, in dependence on the quality of the systems and the handling of the operators (with statistical accuracy of 95 percent):

Sea regions	more than 10 m

Coastal waters	less than 10 m
Estuaries and tidal rivers	between 3 m to 5 m
Inland waterways	less than 1 m until 10 cm

(i.e. free-flowing or channelized rivers, canals).
Greater lakes less than 5 m until 10 cm, just as the demand.

3.2 Multi Beam Echosounder Systems for WSV

There had been a lot of **experiences with echosounder systems for the use of the Federal Waterways in the FRG during the last 30 years (Behrens 1999b)**. Also the measuring principle and the special factors, which had to be consider in echosounding measurements, should never be forget for getting best results with highest surveying accuracies (Behrens 2001). I myself remember of the manual position fixing on rivers as an old method on the one side, and on the other side as a method nearby depth founded buildings in practice today. To this method belongs manual depth measuring by plumb, and the length of the rope or steel wire, which crosses the water, must be measured to know the full meter points of the depths (Behrens 1999b).

Otherwise there is **no use of** high technology like **laserscanning systems with green shining laserbeam**, which comes through the water-body more than 10 m of depth. But in the FRG the quality of water is not so clear for that kind of measurement, and the given accuracy of about 30 cm per 10 m of depth is too bad for the navigational safety of Federal Waterways. The depths of these river routes is about 3...5 m in average, for the canals about 5 m, and sometimes, but rarely, depths of 15 m (Rhine - Loreley) are possible. That is the reason why the WSV has to look for every decimetre of depth more or less, and there is need of systems for shallow waters. Sometimes the intern user of data want to know a higher resolution of depth measuring ("only few centimetres"!), when modelling with hydrographic data. That is why the WSV use the special echosounder systems for surveying adapted to the regional conditions of rivers or canals.

The data of water depths measured by sounding are to be considered as raw information about the water depth below the immersed oscillator and the time of the recording. To enable **comparisons with future measurements**, it is necessary to bring these raw data into relation to a fixed permanent levelling system. In hydrology, the common reference systems are the mean sea level, the zero of level of sea charts, or reference gauges. The network of fixed points along waterways is connected to the network of fixed points of the superordinated land surveying system and supplies height and position references for engineering purposes. The height of these fixed points is determined by so-called **main levelling exercises** along the Federal Waterways which are repeated very 10 to 15 years. Simultaneously with these measurements, for each water level gauge, the so-called zero-of-gauge level is fixed by means of three gauge reference points. Since the supply of height reference data for measurements on inland waterways is beyond the scope of this paper, it should be mentioned that such examples can be found in the literature (Behrens, Henoch, Keydana 1990; Behrens 1993).

As the network of gauging stations on coastal waters and tidal rivers is wide-meshed (distance normally more than 10 km) and the stations are mostly located near the coast, reference data here can today be supplied only by help of computer models, which are able to consider the influences of the tides. The best accuracy achieved here is in the decimetre range. Especially for coastal waters and tidal rivers, a substitution of the conventional reference data supply by a DGPS could yield notable improvements for the methodology and in accuracy. A precondition is the existence of a homogenous height reference system on a nation-wide scale and in the whole of Europe, as well as the use of suitable geoid models for the oceans and seas.

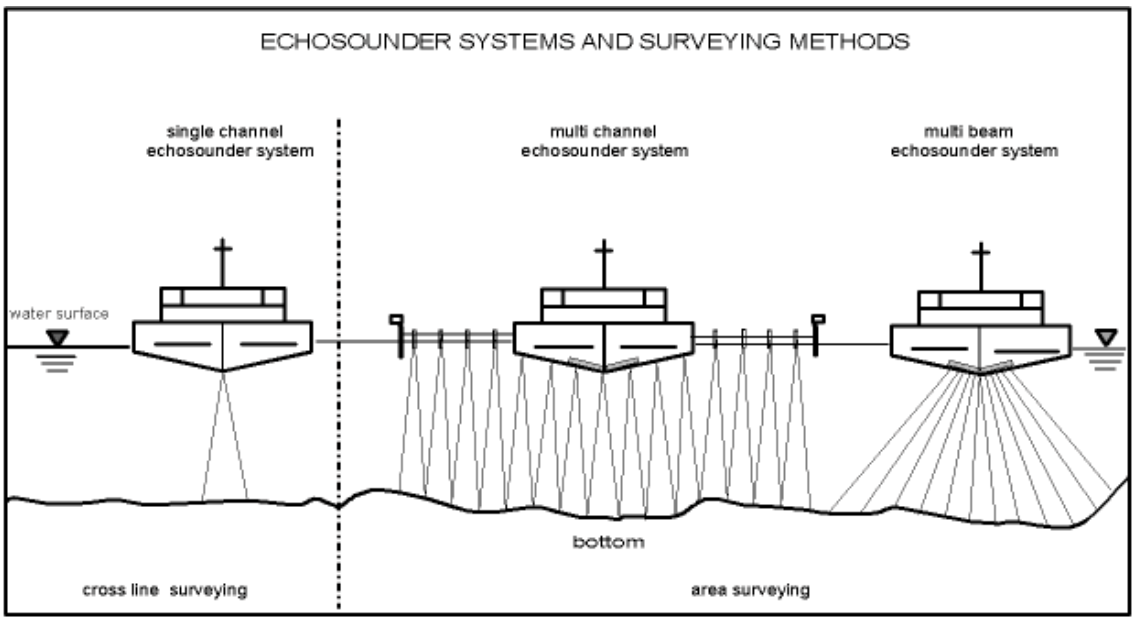


Figure 3: Principles of echosounder systems for cross line and area surveying

In 1996 the BfG had become order to made researches on multi beam echosounder systems for use in shallow waters, c,f. figure 3. We had got an overview after looking at the international market, especially the firms: L3-Communications Honeywell Elac, Reson, Simrad and STN Atlas Elektronik. The staff-members of "Geodesy"-BfG made together with members of WSA Duisburg-Rhine a lot of trials with the Simrad EM 3000 system of about 4 weeks in the Lower Rhine Region near by Duisburg in 1997. The handling with the system, the installation on board and the resulting accuracies in the Rhine river as well as the recognition of underwater buildings, of locks and of obstacles had been the main aspects during the tests (Wirth, Böth 1997).

Here are some results of the **tests with Simrad EM 3000**. The multi beam echosounder system data can be used until 8 times the water depth, e.g. 8 x 3 m = 24 m is the width of the surveying lane on the bottom. The **depths accuracy is about σ = 10 cm** (P = 95 % confidence level) under mentioned conditions. The accuracy of the vessel stability itself to a fixed position is on average 11 cm under a measurement velocity of 2 m / s. A large multi channel echosounder system have 40 m width, but the extend metallic construction needs a big vessel and demands for a very good steering by helmsman. So it is easier to use multi

beam echosounder system, although you need twice lanes for surveying the same bottom area.

As a conclusion out of the testing results, it is necessary to **reduce the digital data for multi beam echosounder systems**. The data density must be reduced in that way, so that after computing and data plausibility the whole bottom area is characterized by single but essential points of obstacles (Wirth 1999). I think for that aspect and for handling the huge mass storage of data, an enormous task is to do in future for all hydrographers!

After ending the tests described above with reports (Wirth, Böth 1997, Böth 1998), the BfG developed a long list on the **performance characteristics** which must be necessary, if one WSA will buy a multi beam echosounder system. It was worth to do that for such kind of complex system! It was very difficult to get all information from the firms, because some parts or modules of the systems had to be develop in future and some descriptions are not so quite specified for the user. Today there are 7 multi beam echosounder systems in use on the Federal Waterways in the FRG (river regions: Rhine: 2, Danube: 1, Elbe: 1, Weser: 2, Eider: 1) and 4 systems are purposed for the next two years (river regions: Elbe and Weser, for each two).

3.3 Experiences with Surveying Systems of WSV

All three main groups of echosounder systems: single and multi channel and multi beam echosounder system are in use today for getting surveying profiles or a complete information (depths, topology and morphology) of the whole river or canals body, the coastal bottom as well as the water areas of harbours, cf. figure 3 (Behrens 1999b). I think we take and had been taken that special echosounder system, which is and had been demanded by each different user of surveying information.

For the surveying systems for "peilungen" you need special hydrographic vessels, which construction or inner installation of instrumentation is adapted to the surveying of waters. For the coastal regions there are needed larger vessels than on inland waterways. And today the staff of WSA tried to make zero-measurements of all components and the sensors installed onboard for getting best results. Normally the **surveying of waters** will be done in the following way:

- **Starting of measuring system:** installation (on board, at land), measuring of sensor-fixing, controlling of sensors, calibration, prove of complete system.

- **Co-ordination of daily tasks**

- **Surveying of water bottom:** start data of surveying, surveying by vessel (choice of positioning method, set up the project, planing of vessel tracks, water acoustic velocity profiles, area surveying, data screening), checking of surveying results

- **Analyse of surveying data:** examine of data, calculation of co-ordinate triples (plausibility of sensor data, height referencing, co-ordinate transforming, elimination of

incorrect results, reduction the volume of data, calculation of DHM- / TIN-Models), area plausibility, data reduction, calculation of height modelling.

- **Calculations by using TIN-Data:** depth profile calculation, depth contour line calculation, volume / mass calculation.

- **Storage of surveying data**.

The data are used to supply several users in WSV and not only surveyors, especially for the WSV-Tasks: **navigational safety, dredging, hydrology, construction, obstacle search and implementing works in hydraulic engineering**. That is the reason why we spoke of multi-purpose surveying, adapted to the highest accuracies for each project in accordance with the demands. This leads although to a wide-fan of different results and presentations: data lists, plans, charts, TIN-Models and DHM-Models.

By this there is a change from big measuring vessels to small working boats of WSV for surveying Federal Waterways, each **multi beam echosounder system** for river lengths of about 150 km. Otherwise there is more flexibility with multi beam than with single beam or multi channel echosounder systems. The surveying systems has less weight and better quality by modern technology. The surveying vessels are more rapidly than with heavy or ancient systems. In addition to the technical side of a surveying system for "peilungen" there are the staff members of WSV, who need very good training and help for working with the new hydrographic systems. After installation the systems onboard and introduction in the new software the few members of Department "Geodesy" of BfG make **workshops** for solving the problems in handling the multi beam echosounder systems.

4 RHINE RIVER-CHANNEL INFORMATION SYSTEM "ARGO"

The increasing transportation of goods by inland navigation makes it necessary to have more information for ship navigation in marked narrow river channels, which are normally supervised more often than the riverbanks. Therefore it is necessary to have a special river-channel information system for the Rhine river called ARGO. The increasing vessel traffic and often merchants ships loading with containers You can see on the Rhine river, as the most traffic river of the Federal Republic of Germany today. Instead of that, it will be used an automatic navigation system, researched and developed by the University of Stuttgart, and an inland waterway chart on the basis of **Electronic Chart and Display Information System (ECDIS)**. In the automatic navigation system there will be a radar map matching, controlled by DGPS with an accuracy of abut 3 m in X/Y-positioning for the merchant ship using ARGO. If we look at the inland waterway chart, so it is necessary to get the Z-co-ordinates, represented by the depth data from the surveying, with an accuracy of about 20 cm. The problem of course is the actualisation of the data for each bottom-point P(X, Y, Z) out of surveying of waters. This is an optimization of men power, number of measuring vessels and financial resources for the WSV. This needs a very good planning and organization with a help by a **quality assurance system** until a certification analogue to **ISO 9000 (DIN)**.

For this purpose had been installed a project group "Concept for Using Surveying Systems for Bottom-Areas" in the year 2000. To this belongs a working group "Standardisierte und qualitätsgesicherte Gewässervermessung", which main tasks are to create or to look for standard rules for surveying of waters under the help by a quality assurance system. It is a very long way, but only by this way it is guaranteed that the surveying results could be given to other user than in the WSV itself.

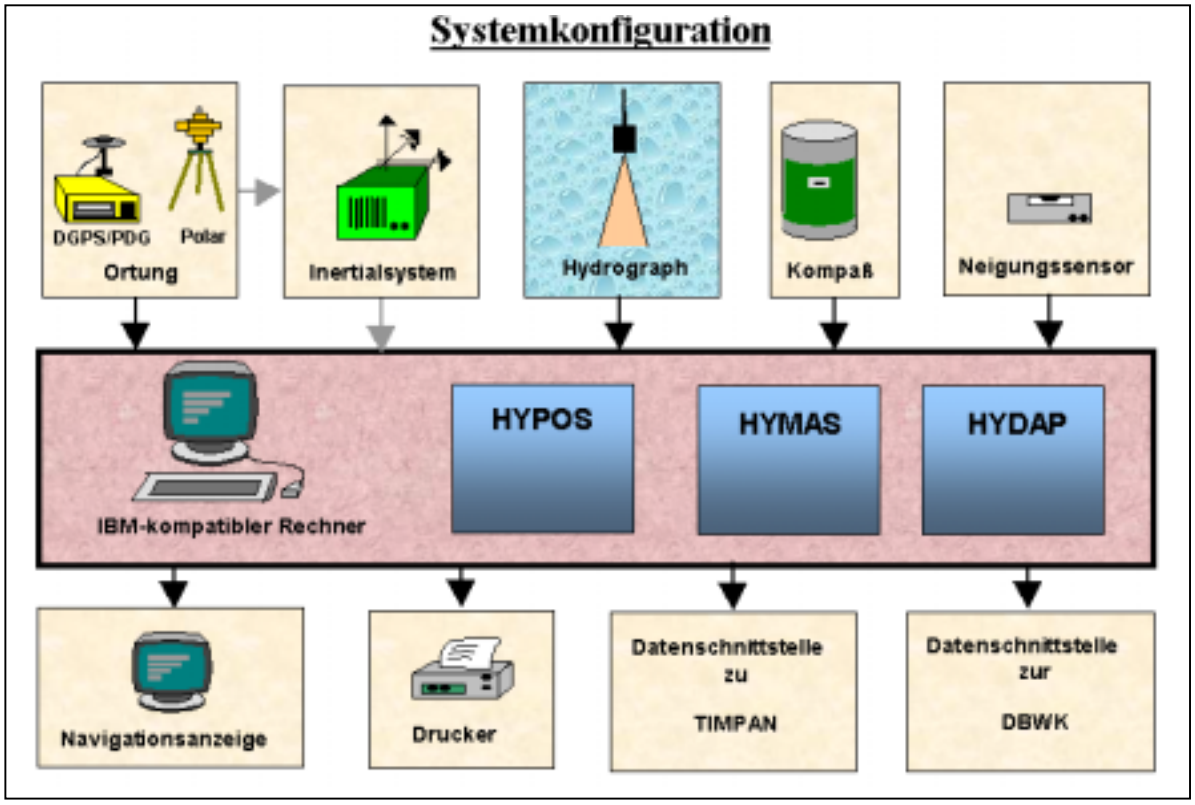
5 FACIT, FUTURE ASPECTS

It had been demonstrated how the Federal Waterways an Shipping Administration (WSV) is working today in managing the surveying of waters, mostly for monitoring the river beds of the Federal Waterways in the FRG. The use of **Precise-Differential-GPS (PDGPS)** for positioning the surveying vessels led to the best results in surveying today. On the other hand there was a change from multi channel to **multi beam echosounder systems** with a mass of information, which can shown as digital terrain model.

With all modern technology, presented in this paper, it is necessary to have a well educated staff for correct use of the **surveying systems for "peilungen"**. At second you need **measuring vessels**, which have very good ship dimensions in its construction and hydrographic systems installed for surveying, so that staff of WSV can optimize their daily work. And third there must be a good **conception for surveying of waters** in a controlled way, e.g. by a quality assurance system, for getting topical results of the hydrographic measurements. These surveying data will be the best assumption for navigational traffic - to have no bad obstacles in the water beds, as future wish of hope. On the other side there is the interest of people outside the WSV, who want to buy **the river-channel information data** - today is **ARGO** tested on 10 merchants ships driven on the Rhine - , for aiding the (private) traffic vessel navigation. I hope both sides will do their best for the navigational safety on waterways!

Appendix

Hydrographic surveying and processing system (HYMAS)



Sensor field:

- Positioning with satellites or polar systems
- Inertial system for aid of positioning
- Echosounder systems: single channel (Hydrograph) or multi channel
- Orientation of surveying vessel / boat by gyro system
- Separate sensor for roll of surveying vessel / boat.

Processor field:

- Computer system (IBM-compatible) for all kinds of data from sensors
- Very important: reducing of time delays or time lags
- After analyzing the data the computed results are used for graphic information, e.g. imaginations or charts.

Interface field:

- Navigation display on a computer screen for helmsman
- Overview on actual vessel position and used parameters
- Ink jet printer for all kinds of recording data or charts
- Interfaces for further data processing are realized.

REFERENCES

AdV (Working Committee of the Surveying Authorities of the States of FRG): SAPOS - Satellite Positioning Service of the German National Survey. (http://www.adv-online.de/english/products/sapos.htm) 01/2002

Behrens.J., Henoch, H., und Keydana, W.: Future concept for inspecting the stream-flow regime on the Niederrhein: Increasing the accuracy of depth soundings by application of land-based laser Systems. 27th International Navigation Congress, Osaka, May 20 - 26, 1990, Sect. l, Subj. 1, p. 45 - 52.

Behrens, J.: Der Einsatz von GPS in der Gewässervermessung für die Wasser- und Schifffahrtsverwaltung des Bundes. In: Anwendungen des Global Positioning Systems, 25. DVW-Seminar, 18.-19.02.1991, Universität Hannover. DVW-Schriftenreihe Nr. 2. S. 154-167. Konrad Wittwer Verlag, Stuttgart 1992a.

Behrens, J.: Gewässervermessung auf Bundeswasserstraßen. In: Vorträge zum 76. Dt. Geodätentag, Hamburg 16.-19.09.1992. Zeitschrift für Vermessungswesen 117, S. 507-516, Stuttgart 1992b.

Behrens, J.: Gewässervermessung (Surveying of Waters). In: Schwerpunktthema: "Hydrographie". Zeitschrift für Vermessungswesen 118, S. 143 - 151. Stuttgart 1993.

Behrens, J.: Gewässervermessung an Bundeswasserstraßen - heute und im Jahr 2000. In: Festschrift 60. Geburtstag Prof. Dr. mult. H. Pelzer. Wissenschaftliche Arbeiten der Fachrichtung Vermessungswesen der Universität Hannover, Hannover 1996.

Behrens, J.: DGPS bei der Gewässervermessung (DGPS for Surveying of Waters). In: GPS-Praxis und Trends, 46. DVW-Seminar, 29.09. - 01.10.1997, Frankfurrt/M.. DVW-Schriftenreihe Nr. 35, S. 358 - 375. Konrad Wittwer Verlag, Stuttgart 1999a.

Behrens, J.: Echolote -- Historie und Überblick (Echsounder Systems -- History and Overview). In: Gewässervermessung und Hydrographische Informationssysteme. 49. DVW-Seminar, 28.-29.09.1999, TU Dresden. DVW-Schriftenreihe Nr. 37, S. 54 - 75. Konrad Wittwer Verlag, Stuttgart 1999b.

Behrens, J.: Surveying of Waters in the FRG by the Federal Waterways and Shipping Administration. In: New Technology for a New Century. FIG Working Week 2001, 06 - 11 May 2001, Seoul Korea, Korea Confederation of Surveyors - Seoul, 2001

Bechteler, W.; Hartmann, S.; Behrens, J.; Schrenk, G.: Volumenermittlung von Stauräumen (Volume determination of catchment areas by surveying). KA - Wasserwirtschaft, Abwasser, Abfall. GFA - Gesellschaft zur Förderung der Abwassertechnik e.V., Hennef, 2001

Böth, H.: Evaluation of a Shallow Water Multibeam Echosounder for Inland Waterways. Proceedings of Canadian Hydrographic Conference. Victoria, British Columbia, March 10-12, 1998.

Brüggemann, Th.: Hydrographisches Mess- und Auswertesystem (HYMAS) mit satellitengestützter Ortung für den Binnenbereich der Bundeswasserstraßen. BfG-Bericht 0902, Koblenz Juni 1995.

BWaStrG: Bundeswasserstraßengesetz i.d.F. vom 23.08.1990, BGBI. L S. 1818.

Eden, H.: Detection of Sediment-Layers and Properties (DSLP)-Method - A New Serving Technology (Das DSLP-Echolotverfahren - eine neuartige Vermessungstechnologie im Einsatz). In: Gewässervermessung und Hydrographische Informationssysteme, 49. DVW-Seminar, 28.-29.09.1999, TU Dresden. DVW-Schriftenreihe Nr. 37, S. 106 - 115. Konrad Wittwer Verlag, Stuttgart 1999.

Wendt, G.: Die Vermessung von Meeres- und Gewässerböden mit parametrischen akustischen Sediment-Echoloten. In: Gewässervermessung und Hydrographische Informationssysteme, 49. DVW-Seminar, 28.-29.09.1999, TU Dresden. DVW-Schriftenreihe Nr. 37, S. 89 - 105. Konrad Wittwer Verlag, Stuttgart 1999.

Wirth, H.: Untersuchung der erreichbaren Ortungsgenauigkeit mit dem Verfahren Differential-GPS (DGPS), Teil l. BfG-Bericht 0571, Koblenz Juli 1990.

Wirth, H., Gertig, R.: Messprogramm zur Beurteilung der Genauigkeit von Polarortungs-systemen dargestellt am Beispiel des POLARTRACK Laser Tracking System. BfG-Bericht 0619, Koblenz Juli 1991.

Wirth, H., Brüggemann, Th.: Untersuchung der erreichbaren Ortungsgenauigkeit mit dem Verfahren Differential-GPS (DGPS). Teil II. BfG-Bericht 0777, Koblenz Oktober 1993.

Wirth, H., Böth, H.: Untersuchung zur Eignung von Fächerlotsystemen für den Einsatz auf Bundeswasserstraßen. BfG-Bericht 1082, Koblenz September 1997.

Wirth, H.: Flächenhafte Plausibilisierung von Peildaten. In: Gewässervermessung und Hydrographische Informationssysteme, 49. DVW-Seminar, 28.-29.09.1999, TU Dresden. DVW-Schriftenreihe Nr. 37, S. 117 - 130. Konrad Wittwer Verlag, Stuttgart 1999.

BIOGRAPHICAL NOTES

Dr.-Ing. Joachim Behrens, born 1948 in Bremen, Federal Republic of Germany (FRG)
I studied Geodesy at (Technical) University Hannover. In 1987 I obtained a doctorate with the paper:

Zur Genauigkeit von Peilungen in der Gewässervermessung (nearly adequate to: About Accuracy of "Peilungen" in Surveying of Waters)

I'm since 1977 at the Federal Institute of Hydrology (BfG := Bundesanstalt für Gewässerkunde), part of the Federal Waterways and Shipping Administration (WSV) in the FRG. I'm Head of Department "Geodesy" at BfG since 1988. One of our main task at the BfG is to look forward for future developments in hydrography - especially to optimize the complex systems for surveying of waters used for monitoring the Federal Waterways.