EXPERIENCE OF AQUATORIAL ELECTRICAL SURVEY AT BRANDENBURG LAND IN GERMANY


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For the control of a hydro-geological situation on the channel Oder-Spree in Brandenburg land, Germany a firm Umweltanalytik Brandenburg GmbH together with MSU developed hardware and software for aquatorial electrical survey.

At construction of such instrumentation the basic problem consists in management of measuring process. The measurements on aquatoria are carried out in a movement in real time and without an opportunity to re-measure of separate readings. The software is intended for work in multitask operating systems as Windows 3.xx, that has caused necessity of synchronisation of all hardware parts in the process of measurement. The hardware complex includes the managing Notebook computer, A/D converter, clock generator and an analog measuring part, which includes a measuring cable with electrodes and amplifiers.

On each site of measurement signals from 32 channels were measured during two seconds. As A/D 16 channel converter was used, switching between groups of 16 channels was made on each site. Measurements of four $\Delta U_{SP}$ values (Ex1, Ex2, Ex3, Ey), water resistivity and dipole axial sounding (DAS) on 20 spacings were made. On each channel amplification a signal and canceling of industrial noise were made. To increase of reliability the measurements on each channel were carried out with readings' accumulation and averaging.

The instrumentation at the present provides the following operations:

- Self-potential (SP) measurements of Ex component on three channels and Ey component intended for search of water outflows and discharges. SP method is based on study filtration potentials, which are raised under action of groundwater, filtered through capillaries of rocks. Thus the water outflow through aquatoria bottom causes negative SP potential, and the discharge subterranean water in the river raises positive SP anomalies;

- Resistivimetry (R) serves for determination of an electrical resistivity of water, which depends on its mineralization and can specify places of subterranean waters' discharge and sites of aquatorial pollution;

- Dipole axial sounding (DAS) is carried out with the help of multi-electrodic cable, on which measuring and current electrodes are placed. The maximal 56 m DAS spacing can study depth about 20 m. At aquatorial work this method receives some additional advantages. Firstly, there is an opportunity of an automatic operation, that raises survey productivity. Secondly, the water layer has a high degree of uniformity and, thus, there are the favorable conditions for processing and interpretation of geophysical materials. Thirdly, there are good conditions for measuring and current electrodes' grounding.

In November 1996 the firm Umweltanalytik Brandenburg GmbH spent field tests in Mullrose region on Katarinen lake, Oder-Spree channel and connecting

![Fig. 1. The map of the Mullrose area and their Katarinen channel (fig 1).](image)

The most interesting results were received from SP and resistivimetry. The SP and R anomalies have allowed to trace in details an interaction of subterranean and surface waters, to reveal places of water outflows and discharges, places where waters with different mineralization mixture, areas of subterranean lake feeding. Measurement of two orthogonal components (Ex, Ey) allows to determine position of SP anomaly source sideways from measuring profile (Vladov et al., 1996).

At aquatorial measurements of SP field from a vessel it is not possible to measure of SP potential values, but only a potentials' difference (or SP gradient) in MN line of definite length. As the potential values rep-
resent the greater interest for interpretation, there is the necessity of recalculation of SP gradient values into potential. Therefore values of Ex components were recalculated into SP potential. According to the spectral theory the recalculation of SP gradient into potential for one MN line is incorrect operation (fig. 2). Therefore the recalculation was carried out with usage of $\Delta U_{SP}$ values for two or three MN lines of different length. Such recalculation according to the theory of spectra has the main error at a zero harmonic. The additional complexity is connected with the fact, that the line MN of final length does not provide reconstruction of potential on a spatial frequency, appropriate to its length. Therefore we decided to carry out measurements with several MN lines and to calculate potential from these joint data. The example of $\Delta U_{SP}$ field on fig. 2A is drawn with noise and without noise. Its spectrum (fig. 2B) has zero amplitudes at frequencies connected with MN length. Noise presence prevents spectrum from zero amplitudes and in potential spectrum these frequencies give noticeable spectral amplitude increasing (fig. 2C). That adds errors in recalculated SP potential values.

On fig. 3 the results of numerical experiment on reconstruction of potential from $\Delta U_{SP}$ for MN lines of different length are shown. The central line represents true value of potential (without noise). These data were recalculated in $\Delta U_{SP}$ for MN = 5 (A), 15 (B) and 45 m (C), and after addition of noise were reconstructed into potential. The bottom drawing (D) corresponds to reconstruction of potential from the data for all three MN lines. In this case SP field contains only the casual noise, which can be removed by smoothing. The smoothing of initial $\Delta U_{SP}$ values gives result much worse, because some frequencies that were absent in the spectrum then appeared.

The given technology, checked on models, was used for recalculation of practical $\Delta U_{SP}$ results. The estimation of accuracy in this case can be carried out at processing of repeated measurements on the same sites (fig. 4, 6, 8). Detailed study of control measurements shows, that in the basic details, the potential graphs coincide with very high accuracy. In some cases the discrepancies are nevertheless observed. On experience of similar work on Moskva river, carried out during 12 years, the basic reason of discrepancies is connected to pass of a vessel near to local river-bed anomalies along different parts of a waterway (Kalinin et al., 1991).

For checking the instrumentation operation, and for the control of a hydro-geological situation on the channel Oder-Spree in the beginning of November 1996 some experiments of measurements SP, resistivimetry and DAS in a vicinity of town Mullrose were spent. The scheme of the area is shown on fig. 1. For the further description of results all region was divided into areas: Katarinen lake, Katarinen channel and the Oder-Spree channel. Katarinen channel connects Katarinen lake to the Oder-Spree channel.

**RESULTS OF WORK ON KATARINEN LAKE**

The survey was carried out on an internal circular route of length about 850 m (fig. 5). Hydrologically the lake is closed from outside directions and has not any inflows. Hence, it has only rain and snow feeding, and probably an underground water exchange. Resistivimetry has shown, that a resistivity of water is about 40 Ohm.m.

The procedure of SP potential reconstruction has shown high quality of received materials. Practically two graphs of restored potential, received on different passes, have completely coincided with accuracy about (1 - 3 mV) (fig. 4). On SP results the coastal zone of lake is divided on two parts: south-western part, where positive SP anomaly (about + 10 - 15 mV) is observed, and north-eastern one, where negative SP anomaly (about - 15 mV) is observed (fig. 5). The lake has water resistivity about 41 Ohm.m. The water depth in the lake is about 3-3.5 m. The bottom is covered by a sand layer with thickness from 0.3 up to 1.5 m and resistivity from 100 up to 300 Ohm.m. Below sand there is the waterproof layer, which probably keeps all lake in a suspended state. Its thickness is about 1 m. Probably it is a layer of loamy sands. or possibly loams, which has resistivity about 35 Ohm.m.
We note, that the groundwater level (GWL) is located near the lake on absolute depth marks 42 m, while the water level in the lake corresponds to a mark of 41.5 m. According to resistivity sounding interpretation the top of loamy aquiclude should place on marks about 38 m. Hence this aquiclude does not carry functions of a hydro-geotogical screen. On the contrary, it can be a surface, on which subterranean water flow unloaded in lake. What supplies this subterranean flow? The answer is evident: a source of Katarinen lake feeding is Mullrosen lake, which is placed close to Katarinen lake from south-east. Area of Mullrosen lake feeding is more than 50 km², here several streams, small rivers and lakes enter. Small dam, established in a mouth of lake, a little bit raises water level. This stimulates lateral water outflow from Mullrosen lake into Katarinen lake. Small natural dam about 250 m width, sharing two lakes, is easily overcome by a subterranean flow, which unloads in Katarinen lake. So, two lakes represent a hydrologic system, which works as a single natural mechanism. The area of outflow is located in a northeast part of the lake. It is characterized by increased values of water resistivity (subterranean waters from the feeding area mix up with rain waters and get a higher resistivity), and negative SP anomaly as an outflow sign.

RESULTS OF WORK ON KATARINEN CHANNEL
This channel has 1100 m length and connects Katarinen lake to Oder-Spree channel. The traverse begins in a mouth of Katarinen lake, and ends near Oder-Spree channel. Water resistivity on that piece varies in large limits (fig.6). The traverse can be divided into 5 zones. The first zone begins from Katarinen lake up to a mark +100. Here the water resistivity is stable and equal to 41 Ohm.m. The second zone meets at interval 100 - 430. Here the resistivity is gradually lowering to 33 Ohm.m. The third zone in interval 430 - 630 a minimum of resistivity about 31.7 Ohm.m is observed. In the fourth zone (interval 630 - 850) a stable resistivity at a level of 33 Ohm.m is marked. In the fifth zone the resistivity gradually falls to 25 Ohm.m.

On our opinion, these zones, differed on water resistivity, are in a good correlation with SP anomalies (fig.6) and geoelectrical cross-section (fig.7). On this traverse four SP anomalies -- three positive anomalies and one negative are revealed. The first wide low-amplitude positive anomaly (+ 10 mV) is in interval 0-300. Just here a reduction of water resistivity begins. Geoelectrical cross-section at this interval shows that the bottom layer is sand with resistivity about 300 Ohm.m and below it a low resistive layer exists and goes upwards. It outcrops at a mark 430. Diminishing of the upper sand layer throw water jet upwards. As the discharge goes in a zone of width about 300 meters, and the resistivity gradually falls as grows salinity of water in the channel. On a mark 430 a narrow positive anomaly of SP potential is marked. It corresponds to the low resistive layer outcrop in the bottom. After this site water resistivity is leveled. Since a mark 900, the third positive SP anomaly is marked, with which further downturn of water resistivity is obviously connected. It is visible from resistivity diagrams for three passes, that the zone of resistivity changes can move at least on 100 m upwards -- downwards the channel, depending on water regime in Oder-Spree channel.

RESULTS OF WORK ON ODER-SPREE CHANNEL
The measurements were made on a ten-kilometer piece of Oder-Spree channel near to town Mullrose in between "99" and "108" kilometer marks. Width of the channel on this place is 30 - 70 m, and depth - about 3 m. The groundwater level places on absolute marks of 41-42 m. The area of outflow is located in a northeast part of the lake. It is characterized by increased values of water resistivity (subterranean waters from the feeding area mix up with rain waters and get a higher resistivity), and negative SP anomaly as an outflow sign.

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Only in east part of the traverse GWL is lowered below 40 m. Water surface in the channel corresponds to a mark of 40.7 m. Thus, the water in the channel places below GWL in surrounding, that should result in positive balance of water in the channel. However, SP measurements show at that interval the anomalies, as positive sign (subterranean water discharge into channel) and negative sign (water outflow from the channel). Moreover on that interval there is no place, where SP field remains quiet. It specifies an existence of intensive hydro-geological processes around Oder-Spree channel.

SP method gave interesting results (fig.8). Two positive anomalies, engaging in a central part of a site (so-called mouth anomalies), are rather simply explained: - on a site 103 km and in an interval 103.8 - 104.8 km.

The first small anomaly with 10 mV amplitude and 500 m width is dated to a mouth of anonymous stream, which at 103 km run in the channel. The second SP anomaly has also small amplitude and 1 km width and is dated to mouth part of the Mullrosen lake. Thus the peak anomaly by amplitude about 15 mV is located in the channel just opposite the lake. These two anomalies are classical case of the river flowing in reservoir of a higher rank. In this case the discharge of water goes not only along real river channel, but also through subterranean rocks.

The largest negative anomaly is located in an interval 105 - 107.5 km. Its amplitude makes from -20 up to -25 mV. This anomaly marks a zone of downturn groundwater. It is interesting, that the authors of a hydro-geological map (see its fragment on fig.9) have very curiously lead contours of GWL in this place. Looking attentively at this map, at interval 105 - 107.5 km a saddle or GWL maximum, extended in meridional direction is drown. Apparently, the authors of a map had some indirect indications, that the groundwater level is here raised. That can be only in one case. if in this place there is the outflow of water from the channel. By the way, here in reality is visible, that water level in the channel is raised above surrounding (water level in Alte Schlaube stream is below that in the channel). Thus, there is the favorable situation for outflow of water from the channel.

Separation the channel on two sleeves is marked of small positive SP anomalies. Such situation is observed, for example, on sites 100.3 km, 101.5 km, 108 km. Similar SP anomalies were frequently observed on Volga river (Kalinin et al., 1985.a). We named such anomalies Cape-origin (from a word “Cape” - an end of an island or peninsula). Practically all sandy islands have on the opposite ends positive and negative SP anomalies, which arise due to a horizontal water filtering through a porous rock formation. As a rule, such hydro-geological phenomena have local, closed character and do not influence on general water balance in reservoir. The final results of work at Oder-Spree channel are shown on fig.9.

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REFERENCES