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Application of Spontaneous Potential Method to the Engineering Investigations of Open Freshwater Reservoirs

A.V. Kazak* (Moscow State University), V.V. Kalinin (Moscow State University) & M.L. Vladov (Moscow State University)

SUMMARY

Article begins with short SP method history and application review. It also contains a very brief overview of a project initiated and supported by the authors in Moscow State University in summer 2005. The project is targeted to the application of SP method to a reservoir filtration processes study and continues to present day. Modern vision of gathering and processing Spontaneous Potential data, collected on the water surface of freshwater reservoirs is presented. A case study of SP Survey on Moscow river is discussed.

As is known there is a big variety of natural electric fields, which are referred to as SP – Spontaneous Potential fields. SP fields are caused by various events that take place in nature. All natural physical-chemical processes that deal with SP fields can be divided into several groups: oxidation-reduction processes which produce electrochemical (ore) electric fields, liquid and gas filtration processes which are prerequisites for electrokinetic (filtration) electric potentials occurrence, and processes in surrounding of membranes which lead to membrane potential existence [4].

To study all these fields in the vicinity of the geosphere there was introduced a special geophysical method, known as Spontaneous Potential – SP method. At the beginning of the development it was applied to sulfide ore deposits prospecting. In the process of SP method development the area of investigation has expanded to graphite, anthracite coal and magnetite ore deposits [3]. There is also a water areas engineering investigation task, which stays apart from ore prospecting. The area of author's investigation is concerned with water filtration processes in the water environment, which cause the occurrence of natural electric fields.

It should be mentioned, that the application of geophysical SP method for studying filtration processes in geospheres is not a new idea and SP method is widely applied to solve nowadays tasks. The area of SP method application concerning liquid and gas filtration processes is huge: from the monitoring of oil reservoir fluid flow from surface [1] through cave detection case studies [6] to engineering and groundwater applications [5]. The filtration processes in the water reservoir environment investigation task stays apart from mentioned ones, although is very important at present. The scope of this expanded abstract is the overview of current state of affairs in the named area of geophysical SP method application.

At present, investigation of filtration processes occurring on bottom and sidewalls of natural and artificial reservoirs is very actual and urgent task. It's explained by the existence of undesirable filtration zones on bottom of water reservoirs, which modify the original functions of reservoirs and cause a disbalance of ecological environment of adjacent embankment regions. From this point of view, all artificial water reservoirs can be classified on clear, such as impoundments, and contaminated, such as dirt collectors. Natural water reservoirs, especially in big cities (for example Moscow river), require intensified monitoring of its internal filtration processes [2]. While inflows can cause contamination of clear water, outflows may result in intensification of weathering processes on adjacent regions (for example karst processes in Moscow city).

Comparing to other investigation methods SP method has several serious advantages such as simplicity and relatively low cost of field survey, high speed of data gathering, relatively simple preprocessing and express interpretation algorithms. All these make possible to perform both reconnaissance work for location and investigation of filtration zones and ecological monitoring of filtration zones.

The following part of the abstract contains a very brief overview of a project initiated and supported by the authors in Moscow State University in summer 2005. The project is targeted to the application of SP method to a reservoir filtration processes study and continues to present day.

The first stage of research project dealt with development and realization of algorithm of forward geophysical problem for simplified water reservoir model for SP method. Like in any geophysical method, forward modeling is of primary importance. The spatial distribution of physical field is also a significant result of forward problem solution. It makes possible to develop the optimal field observations technique. Algorithm of forward SP filtration potential modeling on the water surface for simplified natural water reservoir model (flat water surface and flat homogeneous bottom) was developed and realized as the modeling software (Fig. 1). Result of forward modeling performed with typical natural water reservoir parameters shown that the electric field potential anomalies caused by bottom filtration processes are so large in amplitude and are that can be successfully measured on the water surface with modern hardware in field.

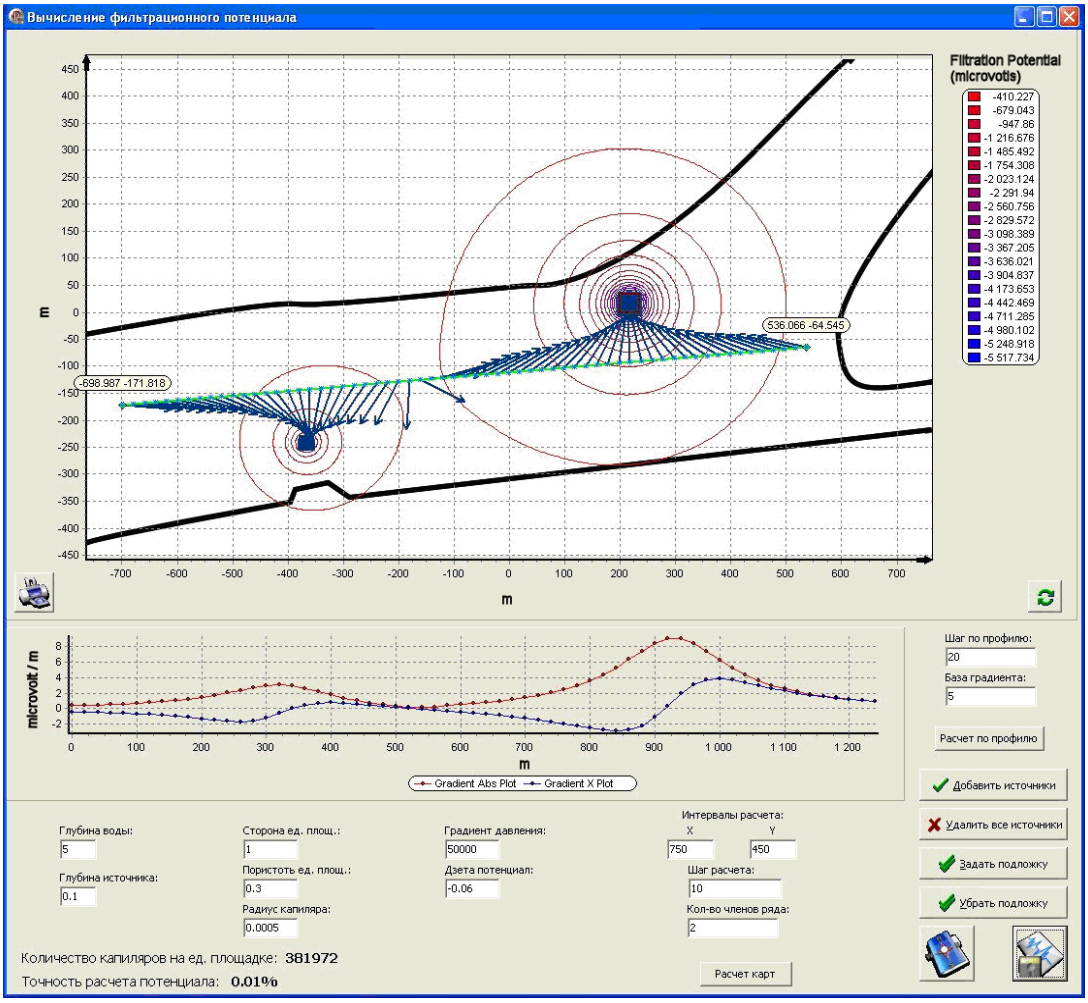

Fig. 1. Screenshot of filtration SP modeling software. Filtration potential values contour map is shown in central part of the screen as well as electric field gradient vectors among the profile. Two filtration of leakage type are show in blue color. To the right from map the color scale of filtration potential values is shown. Below map the electric field gradient plots along profile are presented.

The second stage of research was intended to the creation and testing of data acquisition hardware and development of SP data logging software. It's necessary to note that electric voltage values to measure lay in range of 10^{-6} – 10^{-1} Volts. That is the reason of rigid requirements to electric field acquisition hardware: except wide dynamic range it should be well protected from noise and stray electric fields and at the same time it should have stationary working parameters. Such hardware-software complex has been developed, made and successfully tested by authors in southern-western part of the Moscow river. As a result of numerous laboratory and field tests the enhanced data logging software has been successfully designed and written. The basic structure of made complex is shown on Fig. 2. Developed hardware-software complex allows authors to acquire 4 channel of SP and other sensors data, GPS coordinates, water depth and other parameters in field conditions.

The third stage of project was in SP field acquisition field tests and trials in order to adjust the acquisition parameters and gather SP field data. The typical SP data acquisition layout can be observed on Fig. 3. All activities were carried out in southern-western part of the Moscow river. As a result of these efforts a number of full SP surveys have been conducted on different regions of the investigation area.

On a fourth stage of research project authors used collected data to develop new and improve existing data processing and interpretation algorithms. The first part of processing included intensive data filtration, because all data was gathered in the city-side, where the

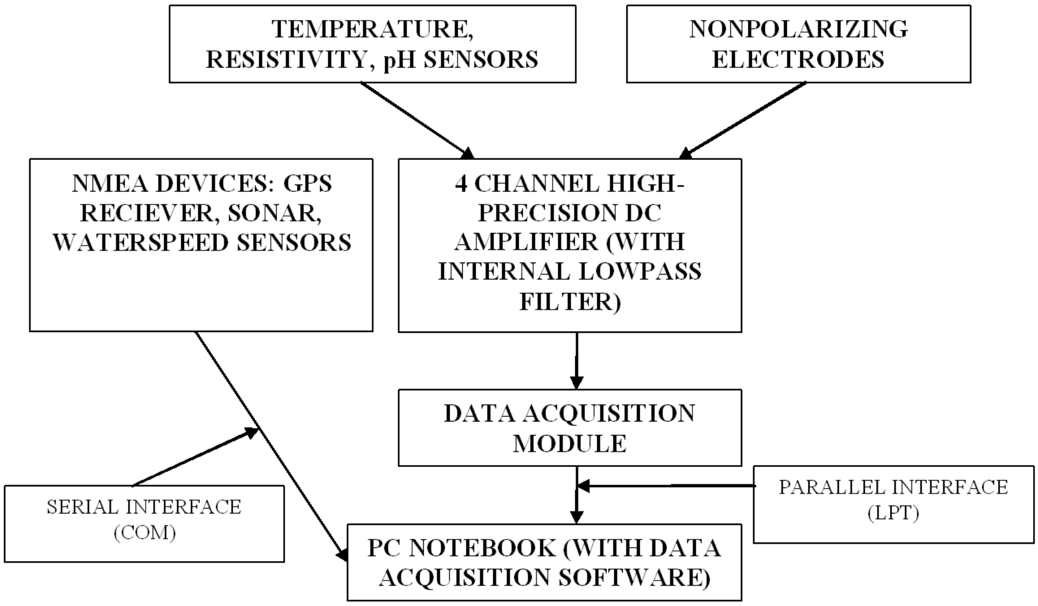

Fig. 2. Basic structural diagram of hardware-software complex for SP field complex measurements.

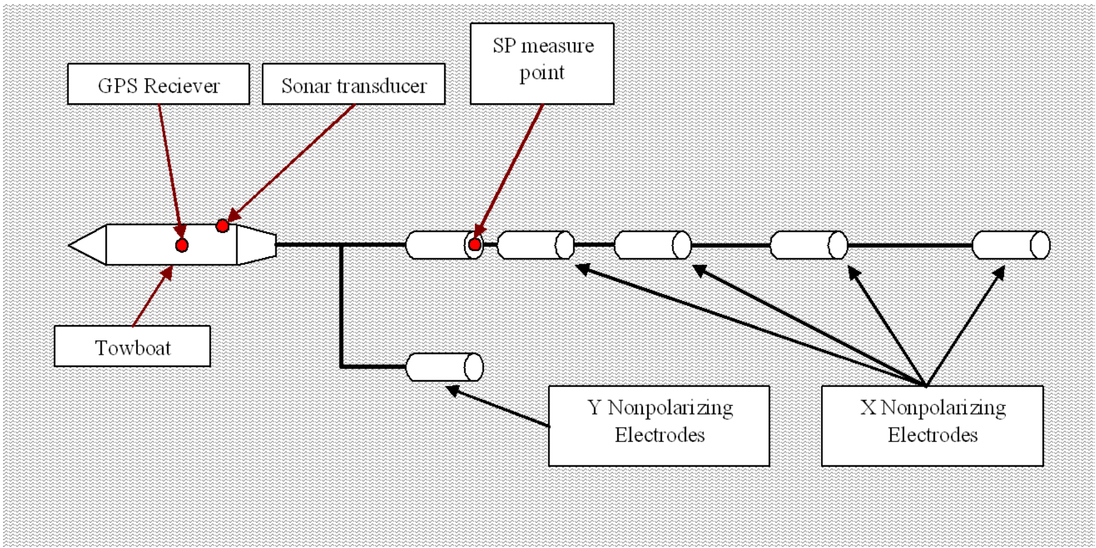

Fig. 3. SP data acquisition configuration.

level of technical noise is very high. Thus, the challenge faced up to the research team during this stage was evaluation and exclusion of different noises in the SP data record. On the next step data was corrected for zero drift of nonpolarizing electrodes, which was measured on each SP survey. Because of exclusive construction of nonpolarizing electrodes the level of zero drift was very low (20 – 200 microvolt/hour). As we measure SP signal in at least two points, so called gradient method, the stand-alone task is to recover true potential from record of gradient. Processing sequence finishes by recovered potential data filtration coordinate-depth tie.

Example of processed SP data plot is shown on Fig. 4. The data on the figure is the result of potential recovery of SP gradient record, which was made along Moscow river channel with length 12 km. There is one notable region on the shown picture – area around 8500 m. On one hand an anomalous for Moscow river depth water ~ 12 m is seen on the water depth plot. From other hand a strong SP potential anomaly ~ 14 mV occurs on the same distance along profile. As know from a priori information this part of Moscow river is occupied with

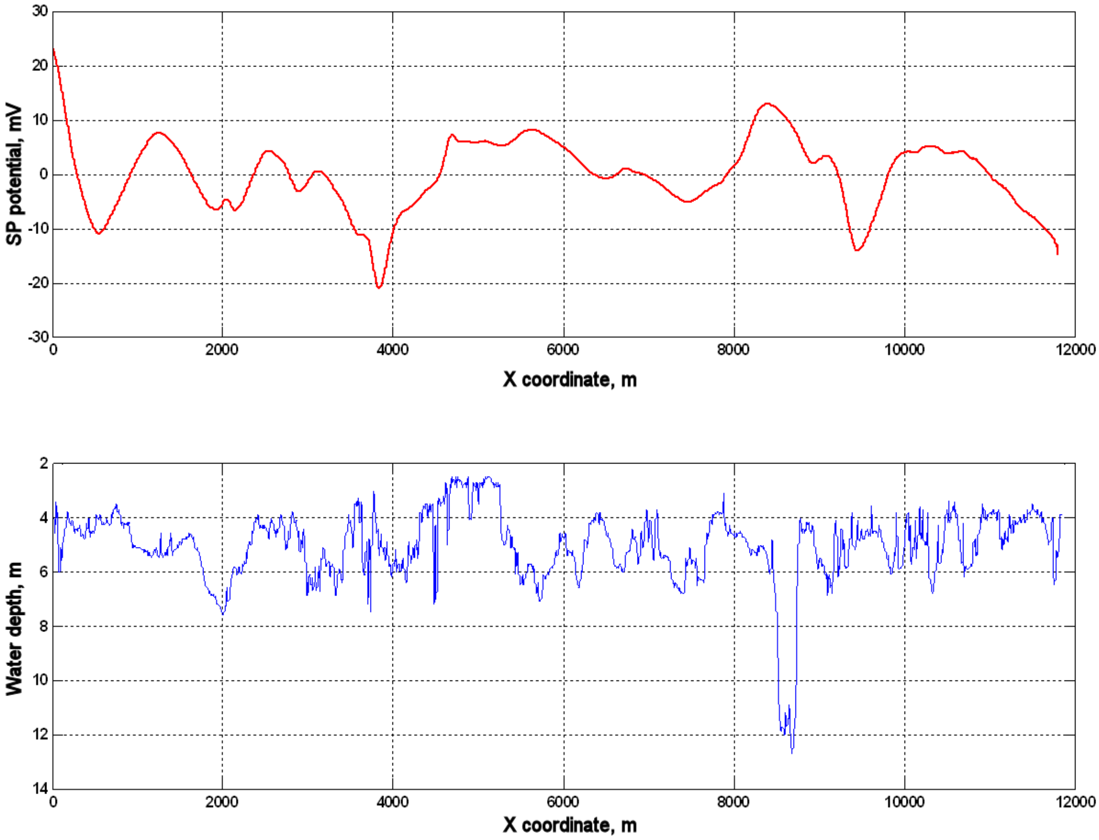

Fig. 4. Example of the final SP potential data plot. The big SP potential anomaly ~ 14 mV is clearly seen around 8500 m.

series of filtration zones of outflow type. There are some more intensive anomalies on the plot, but most of them connected with sources of low-frequency industrial noise which is very usual event in Moscow city. Having good knowledge about the sources of this industrial noise helps in efficient discrimination of SP anomalies from natural sources.

Finally all collected data have been processed. At present authors are analyzing data and making efforts to make qualitative interpretation of it. Also authors are permanently improving the existing technique and developing new methods. Future challenges include the followings: enhancement, tuning and expanding data acquisition unit, creation of forward modeling algorithm for more complex models of water reservoirs and solving inverse geophysical problems for different reservoir models.

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