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INVENTORY

DETECTION OF SUBSURFACE FLOW PHENOMENA BY SELF-POTENTIAL/GEOELECTRICAL+THERMICAL METHODS

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Department of Applied Geology

and

Institute of Soil and Rock Mechanics

FEDERAL WATERWAY ENGINEERING AND RESEARCH INSTITUTE (BAW

Karlsruhe

BAW

INTERNATIONAL SYMPOSIUM

DETECTION OF SUBSURFACE FLOW PHENOMENA

SELF-POTENTIAL · GEOELECTRICAL AND THERMOMETRICAL METHODS

US ARMY RESEARCH, DEVELOPMENT & STANDARDIZATION GROUP (UK)
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INTERNATIONAL SYMPOSIUM

DETECTION OF SUBSURFACE FLOW PHENOMENA BY SELF-POTENTIAL / GEOELECTRICAL AND THERMICAL METHODS

PROGRAM AND ABSTRACTS

Karlsruhe, Fed. Rep. of Germany
14-18 March 1988

Objectives:

Geophysical methods can be useful tools for detection of leakages in dams and waste disposals. Self-potential/geoelectrical and thermometrical technics as well as infrared imagery procedure are still under development in this field of application. Major problems concerning these methods are the reproducibility of the data and the elimination of noise effects.

This symposium is planned to serve as an international exchange of knowledge and experiences concerning the application of the methods mentioned above for the detection of subsurface waterflow, especially in connection with leakages in dams and waste disposal sites.

The main topics will deal with fundamental aspects, theory of methods, instrumentation, data acquisition, processing and interpretation as well as noise effects.

Scientific Programme Committee:

H. Armbruster; A. Blinde; D.W. Butler; R.F. Corwin; H.J. Dürbaum; S. Faber; H. Hötzl; P. Hubral; O. Kappelmeyer; H. Militzer; J.R. Schopper; H. Schulz; H. Wilhelm.

Organizing Committee:

H. Armbruster (vice-chairman); J. Brauns; S. Faber; H. Hötzl (chairman); G.-P. Merkler (scientific secretary); A. Kastner (organizing secretary).

Scientific Programme

Three full day symposium will be held with presentation of solicited and volunteered papers. Additional opportunity for discussion and exchange of information is offered with a visit of geophysical research facilities in Karlsruhe and with an excursion to geological and dam-construction sites in the Upper Rhine Rift Valley.

GENERAL INFORMATION:

Venue

The International Symposium "Detection of Subsurface Flow Phenomena by Self-Potential/Geoelectrical and Thermometrical Methods" will be held in the "STEPHAN-SAAL", Ständehausstr. 4, Karlsruhe from 14-18 March 1988.

Registration

Monday, 13 March 1988 from 11.00 - 20.00 h at the conference office in the entrance hall of the STEPHAN-SAAL (see No 1 in the map). Phone number 0721/28487.

During the symposium the conference office will be open as follows:

Monday,	14 March 1988	11.00 - 20.00 h
Tuesday,	15 March 1988	8.00 - 17.30 h
Wednesday,	16 March 1988	8.00 - 18.00 h
Thursday,	17 March 1988	8.00 - 18.00 h

Ice-breaker party

An ice-breaker party will be held on MONDAY, 14 March 1988, from 19.00 h at the Restaurant MONINGER, Kaiserstr. 142 (see No 2 in the map).

Languages:

English; French; German
Simultaneous translation facilities will not be provided.

TUESDAY
15 March 1988

I OPENING

08.30 h of the symposium by the representatives of the University, the Federal Ministry of Traffic and the Federal Institute of Waterway Engineering

Presentation of symposium objectives
H. Hötzl

II GEOELECTRICAL METHODS

Chairman: Prof. Dr. P. Hubral

Invited paper:
Corwin, R.F. (USA):
Data aquisition, reduction and reproductibility for engineering self-potential surveys

COFFEE BREAK

Papers:

Kostyanev, S.G. (Bulgaria):
Mathematical models of self-potential fields (geoelectrical and geothermal) and methods for their interpretation for detection of subsurface flow phenomena

Butler, D.K. (USA):
Geophysical methodology for subsurface fluid flow detection, mapping and monitoring; an overview of U.S. geotechnical applications and research

Fitterman, D. (USA):
SP flow anomalies for engineering and environmental monitoring

Ogilvy, A.A.; Bogoslovsky, V.A. (USSR):
Investigation of subsurface leakage processes by SP and thermometry methods

Wilt, M.J.; Corwin R.F. (USA):
Numerical modelling of SP anomalies due to leaky dams: Model and field studies

Ausaf-ur Rahman (Singapore); Akihiko Kondoh; Isamu Kayane (Japan):
Electrical (streaming) potential in response to hydraulic flow as measured through simulated rain over a sand box model

Schuch, M. (FRG):
Streaming potential in nature

12.30 h LUNCH BREAK

TUESDAY AFTERNOON

14.00 III THERMOMETRICAL METHODS

Chairman: Prof. Dr. J. Brauns

Invited paper:
Militzer, H.; Oelsner, Chr. (GDR):
Some problems reffering to measure streaming potentials and actual possibilities and limitations of the measurement of radiation temperatures for the detection of flow phenomena

Papers:

Florin, Chr. (Switzerland):
Infrared sensing systems and techniques

Brasser, Th.; Kull, H. (FRG) :
Subsurface application of an infrared thermometer to determine zones of prefered water pathways

Venetis, C. (Netherlands):
Temperature disturbance in a dam due to leakage

Florin, Chr. (Switzerland):
Heat transfer and emissitivity in different groundstructures

15.55 h COFFEE BREAK

16.15 h IV GEOELECTRICAL METHODS
17.05 h

Chairman: Dr. A.A.Ogilvy

Papers:

Buchholz, R. (FRG):
Detection of groundwater flow by means of a geoelectrical resistivity equipment

Blum, R. (FRG):
Geoelectrical mapping and groundwater contamination

Yaramanci, U.; Flach, D. (FRG):
Geoelectrical measurements in the salt mine Asse

20.00 h V WELCOME RECEPTION

Participants will be offered a welcome reception (dinner) at the "HEINRICH - HERTZ - HAUS" on the University Campus, Engesserstr. 3 (see No 4 in the map) by the symposium committee (no charge).
Participants are asked to check in at the conference office.

WEDNESDAY,
16 MARCH 1988

08.15 h I RESEARCH PROJECT
VOLKSWAGEN FOUNDATION

Chairman: Prof. Dr. H. Schulz

Introduction:
Armbruster, H.; Blinde, A.; Hötzl, H. (FRG):
Introduction in the research project: experiments to ascertain the relations between hydraulic potentials in the ground and the geoelectrical and thermic potentials set off by these

Papers:

Bernhardt, R.; Hötzl, H.; Merkler, G.-P., (FRG):
Model experiments in a channel. Empirical connection between streaming-potentials and hydraulic events

Armbruster, H.; Hötzl, H.; Kassel, A.; Marschall, P.; Merkler, G.-P.; Peritsch, D. (FRG):
Aspects of modelling of streaming potential and thermometrical measurements at a big laboratory channel

Armbruster, H.; Blinde, A.; Brauns, J.; Degen, F.P.; Mazur, W. ; Merkler, G.-P. (FRG):
Effect of leaks in dams and trials to detect leakages by geophysical means

Kassel, A.; Faber, S.; Merkler, G.-P. (FRG):
Laboratory studies on the characteristics of electrodes used for streaming-potential measurements

Wurmstich, B.; Faber, S. (FRG):
Long term self-potential data acquisition and processing

Schnebele, H.P.; Gerlach, J ; Armbruster, H. (FRG):
Data processing by temperature measurements

10.30 h II VISIT TO THE EXPERIMENTAL TEST SITES
12.30 h

Federal Waterway Engineering and Research Institute (see No 3 in the map)

12.30 h LUNCH BREAK
14.00 h

(Invitation of the Federal Waterway Engineering and Research Institute)

WEDNESDAY AFTERNOON

14.30 h III GEOELECTRICAL AND THERMOMETRICAL METHODS

Chairman: Dr. P. Tedd

Invited paper:
Sartori, M. (FRG):
The application of thermal - IR-techniques for the reconnaissance of dam and barrage defects in an early state, the analysis of dump sites and tunnel condition surveys

Papers:

Armbruster, H.; Blinde, A.; Brauns, J.; Döscher, H.D.; Hötzl, H.; Merkler, G.-P. (FRG):
Geoelectrical, self-potential and temperature sensing measurements applied for detection of leakage by dams

Valiya M. Hamza; Aug. Rigoti; Reinaldo G.N. Ramos (Brasil):
Geoelectric and thermometric techniques used for detecting subsurface fluid flows in Brasil

Zipfel, K.; Horalek, U. (FRG):
Detection of river infiltrated water flow by evaluation of hydrogeological, hydrochemical and hydrothermical data using numerical groundwater models

COFFEE BREAK

16.25 h IV GEOELECTRICAL METHODS
17.45 h

Chairman: Dr. D.K. Butler

Papers:

Ausaf-ur Rahman, (Singapore); Bell, J.P.; Dean, T.J.; Turner, M.; Cooper, D.J.; Boyle, S.A., (U.K.):
Monitoring insitu electrical potential in soil in response to changing hydraulic regime using a three dimensional array of graphite electrodes

Weigl, M. (FRG):
Self potential measurements on waste disposal sites. Theory and practice

Ishido, T.; T. Kikuchi; M. Sugihara (Japan):
Mapping subsurface waterflow in geothermal areas by the self-potential method

Bardossy, A.; Bogardi, I.; Kelly, W.E.; Woldt. W. (USA):
Geostatistics and geoelectrics to detect groundwater pollution

THURSDAY
17 MARCH 1988

08.15 h I GEOELECTRICAL METHODS

Chairman: Prof. Dr. H. Wilhelm

Invited Paper:
Sill, W.R. (USA):
Theory and modelling of cross-coupled flows

Papers:

Morgan, F.D. (U.K.):
Fundamentals of streaming potentials in geophysics

Blinde, A.; Hötzl, H.; Merkler, G.-P. (FRG):
Self-potential measurements for the determination of the underground waterflow directions in rock mass

Morat, P.H.; Le Muel, Jean-Louis (France):
Study of spatio temporal evolution of electric properties of an underground site

COFFEE BREAK

10.10 h II GEOELECTRICAL METHODS

Chairman: Prof. Dr. W.R. Sill

Papers:

Vladut, Th. (Canada):
Utilization of geoelectrical measurements for environmental geotechnical issues associated to the mining industry

Schenk, W.; Kaus, A.; Kaiser, K. (FRG):
Prediction of faulted zones and permeabilities in ground and dam structures by means of resistivity measurements

Nover, G.; G. Will (FRG):
Complex resistivity measurements on granites

Moldoveanu, T.; Georgescu, P.; Suciu, O. (Romania):
Aspects concerning the detection of subsurface waterflow at some Romanian dams by geoelectrical methods

Poirmeur, C.; Pottecher. G. (BRGM Paris, France):
Comparison between crosshole hydraulic tests and hole to hole electrical measurements (MIMAFO method)

12.00 h LUNCH BREAK

THURSDAY AFTERNOON

14.00 h III GEOELECTRICAL AND THERMOMETRICAL METHODS

Chairman: Prof. Dr. O. Kappelmeyer

Invited paper:

Tedd, P.; Hart, J.M. (U.K.):
The use of infrared thermography and temperature measurements to detect leakage from embankment dam

Papers:

Blümling, P.; O. Olson; B.Niva; G. Sattel (Switzerland):
Radar-tomography - a tool to monitor subsurface flow paths

Kubala, P. (Czechoslovakia):
Evaluation of the hydrogeological effect on the heat flow density. Example from the sedimentary Basin of the Bohemian Massif

COFFEE BREAK

15.30 h IV ROUND TABLE DISCUSSION
17.30 h

Chairman: Prof. Dr. H. Militzer

Discussion Committee: D.K. Butler, R.F. Corwin, H.J. Dürbaum, H. Hötzl, O.Kappelmeyer, H. Schulz

19.00 h V INFORMAL CLOSING DISCUSSION

Post Symposium Excursion

A post symposium excursion to the Upper Rhine Graben will take place on Friday, 18 March 1988. Different locations of dam leakages, surveyed with different geophysical methods will be visited. Further on geological aspects of the Rhine Graben will be discussed.

Poster Display Facilities

An exhibition by industrial companies will take place during the symposium. Facilities for scientific posters can be provided if necessary. Please indicate the required size of display boards within the next few weeks.

Publication of papers

The papers presented during the symposium are planned to be published. Please hand in your complete manuscript during the symposium or at the latest till 1 MAY 1988.

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Symposium: Detection for subsurface flow phenomena
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Phone: 0721/608-3096; Teletex: 721 166 UNIKar;
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LIST OF THE AUTHORS

DATA ACQUISITION, REDUCTION AND REPRODUCIBILITY FOR ENGINEERING SELF-POTENTIAL SURVEYS

Robert F. Corwin[1]

Self-potential data can provide valuable information about subsurface fluid flow for engineering seepage investigations. However, signal-to-noise ratios for such self-potential data generally are relatively low compared to those for other self-potential applications such as mineral and geothermal exploration. Therefore great care must be taken to assure data reproducibility and to recognize noise sources before self-potential data are interpreted in terms of seepage flow.

Factors affecting data reproducibility include field procedure (electrode placement and correction of polarization and drift effects) and time-varying potentials caused by natural and artificial sources as well as changing site conditions. Recognition of and correction for such factors can significantly improve the reproducibility of self-potential data.

In addition to the desired signal generated by seepage flow, many self-potential noise sources are present in the typical engineering environment. These include topographic effects, soil property variations, corrosion protection systems, stray currents from electrical machinery, and corrosion currents from buried metal sources such as well casings, pipelines, and reinforced concrete. Recognition of such noise sources and removal of their effects to the greatest possible extent are critical for proper data interpretation.

[1] 406 Sea View Drive, El Cerrito, California 94530, U.S.A.

MATHEMATICAL MODELS OF SELF-POTENTIAL FIELDS (GEOELECTRICAL AND GEOTHERMAL) AND METHODS FOR THEIR INTERPRETATION FOR DETECTION OF SUBSURFACE FLOW PHENOMENA

S.G.Kostyanev[1]

This paper offers mathematical models for determination of the self-potential fields (geoelectrical and geothermal) in media with arbitrary distribution of the geoelectric and geothermal conductivity. The corresponding three-dimensional boundary value problem for the partial differential equation is reduced to a system of linear integral equations of second order. The kernels of this system are constructed by means of Green's function.

The paper discribes the solutions of some inverse geoelectrical and geothermal problems.

The application of the proposed models for getting an effective solution is illustrated by a series of various concrete problems for detection of subsurface flow phenomena in Bulgaria.

[1] Higher Institut of Mining and Geology, Department of Mathematics, Sofia-1156, Bulgaria

GEOPHYSICAL METHODOLOGY FOR SUBSURFACE FLUID FLOW DETECTION, MAPPING AND MONITORING: AN OVERVIEW OF U.S. GEOTECHNICAL APPLICATIONS AND RESEARCH

Dwain K. Butler[1]

Recently, geotechnical applications of and research in geophysical methodology for subsurface fluid flow detection, mapping and monitoring have increased significantly in the United States. Self potential and other geoelectrical techniques are the primary tools of the developing methodology. Prior to 1970, the primary usage of the self-potential method in the U.S. was for mining and geothermal exploration applications; however, successful applications of the technique to detection, mapping and monitoring of anomalous seepage from earth retention structures stimulated interest in the broader field of geotechnical applications of the technique. A special session on geotechnical applications of the self-potential (SP) method at the 1984 Annual Meeting of the Society of Exploration Geophysicists further increased interest in the technique and speeded the technology transfer. In 1986, a Workshop on the SP Method was held at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi; attendees from the Corps of Engineers, Tennessee Valley Authority, and Bureau of Reclamation discussed current practice, lessons learned, future plans, and outlined areas for cooperative effort.

In addition to practical applications of the self-potential method, the Corps of Engineers is sponsoring research to investigate time and environmental factor effects on metallic and nonpolarizing electrodes, quantify the relation between flow quantity, geoelectric structure and SP measurement, and develop SP-source modelling for geotechnical applications. The practical applications have included seepage assessment studies at numerous dam sites and levees and investigations at hazardous waste disposal sites. Much of the work has been accomplished using metallic electrodes, due to the simplicity of their installation in permanently installed arrays and subsequent utilization by field office personnel. Data processing procedures have been developed which attempt to compensate for time-varying electrode polarization effects. Also, we have made some initial attempts to understand the differences between SP anomaly magnitudes relative to background levels measured with metallic and non-polarizing electrodes.

[1] U.S. Army Corps of Engineers, Vicksburg, Mississippi 39180, USA

SELF-POTENTIAL FLOW ANOMALIES FOR ENGINEERING AND ENVIRONMENTAL MONITORING

David V. Fitterman[1]

The flow of fluid in porous media produces electrical potentials by means of the streaming potential mechanism. The magnitude of these potentials is a function of the matrix material and fluid properties, as well as the flow geometry. By measuring these potentials the flow can, in principle, be mapped. In practice, however, there are several obstacles to the application of the self-potential method including the small amplitude of anomalies and poor signal-to-noise ratio. Modelling of the anticipated anomalies is essential to determine if they are of an observable magnitude. Self-potential anomalies are computed by first modelling the hydrologic flows which serve as sources for the electrical flows. The resulting electrical flow sources are then used to compute the observed potentials. Using coupled flow-model studies we examine the magnitude and pattern of anomalies for water flow from leaking dams and industrial waste-fluids leaking from containment structures. Whereas the anomalies are, in general, positive in the direction of fluid flow, the chemistry of the waste fluids may reverse the anomaly polarity. The possibility of anomaly reversal as well as the small anomaly size makes data interpretation difficult for environmental monitoring projects.

[1] U.S. Geological Survey, Box 25046 MS 964, Denver, CO 80225

NUMERICAL MODELLING OF SELF-POTENTIAL ANOMALIES DUE TO LEAKY DAMS: MODEL AND FIELD STUDIES

M.J. Wilt[1], R.F. Corwin[2]

Although it is widely known that substantial self-potential (SP) anomalies are associated with zones of discharge in leaky dams, the mechanism for generating these SP anomalies is less well understood. In a recent paper by Sill (1983) a scheme was outlined where SP anomalies generated by fluid flow processes (streaming potentials) can be calculated for a general two dimensional geometry if permeability, electrical resistivity and fluid flow / electrical cross coupling coefficients are known. In this paper we use Sill's computer code to calculate the SP anomalies for a model of a leaky dam and then apply the code to field results. The numerical models were designed to investigate the dependence of observed SP anomalies on the strength and position of the discharge and the physical properties of the rock.

Our numerical studies found that the primary factors controlling the SP anomaly are the flow-rate of water entering the leakage area, the position of the leak, the cross coupling coefficients of the rock and the electrical resistivity of the rock. Our studies show that it should be possible to estimate the magnitude of the leak and find its location if other parameters are known. To test this hypothesis we interpreted a set of SP field data for a dam site in the United States. Although the field data clearly showed three dimensional complexity and topographic effects we were able to compile several profiles where the two dimensional code could be tested. The SP profiles were interpreted by trial and error fitting of the observed data to calculated data generated by the computer code. The resulting model was consistent with the known geology at the dam site and the results indicated that the zone of leakage in the SP model corresponds to a known fault zone.

[1] Department of Engineering Geosciences, University of California, Berkeley, California 94720, U.S.A.

[2] 406 Sea View Drive, El Cerrito, California 94530, U.S.A.

ELECTRICAL (STREAMING) POTENTIAL IN RESPONSE TO HYDRAULIC FLOW AS MEASURED THROUGH SIMULATED RAIN OVER A SAND BOX MODEL

Ausaf-ur Rahman[1], Akihiko Kondoh[2], Isamu Kayane[2]

This study attempted to measure the electrical (streaming) potential during a two-dimensional flow in sand resulting from induced rainfall. A rectangular (approx. 2m x 1m X 0.5 m) sandbox was filled with different grade quartz sand at varying (surface) slopes. Upto twenty-four platinum electrodes in a rectangular grid were inserted along one side of the sandbox while piezometers and tensiometers were installed along a similar grid on the opposite side of the box. Rainfall was induced through perforated plastic pipes strategically placed within a metal frame over the sandbox. Experiments consisted of inducing a rainfall having an average intensity about 1 mm/minute until steady-state flow conditions were established in the sand and continuously monitoring the electrical potential between the various electrodes as well as water potential at various points.

Preliminary analyses of results indicated that initial build-up of electrical (streaming) potential in response to the water-input depended upon antecedent moisture conditions of the sand; the response being delayed for dry sand but very much quicker for moist sand. The response time also varied according to the grade of the sand; being shorter in coarse grained sand. The response also seemed faster in shallower electrodes and along the downslope section of the sandbox than between the deeper and upslope electrodes. Final values of the elctrical (streaming) potential, which took several minutes to establish seem to be proportional to the steady-state flow rates. Analyses are being attempted to relate the initial development of electrical (streaming) potential to the wetting front and the final values to the steady-state flow rates. Interestingly, the electrical potential between various electrodes continued to vary steadily after the rainfall and apparent free drainage in the sand had stopped.

[1] Geography Department, National Universitiy of Singapore
Kent Ridge, Singapore 0511

[2] Institute of Geoscience, The Tsukuba University
Ibaraki 305, Japan

STREAMING POTENTIAL IN NATURE

Max Schuch[1]

At the first time, Quincke found in 1859 the phenomenon of electric streaming potential. 20 years later Helmholz published a mathematical expression for the streaming potential.

In the following years a number of scientists studied the phenomenon. Bikerman shows in 1932 that each electric streaming potential causes a electric current in the contrary direction. Swartzendruber postulated in 1967, that this electric field tries to stop the streaming potential as a result of the energy balance.

It seems that streaming potentials are very general in nature. In applied geophysics streaming potentials were used in auger hole prospection a long time ago. But streaming potentials were observed in each soil with sufficient capillarity (Schuch a. Wanke 1968), but likewise in peat bog (Schuch a. Wanke 1967) or in living plants, e.g. spruce (Schuch a. Wanke 1968). It is not easy to measure streaming potentials. Beside streaming water or soil solution, temperature differences or concentration differences causes electric potential differences. Unpolarized electrodes must be used. A certain device of calomel electrodes shows good results.

[1] Bayerische Landesanstalt für Bodenkultur und Pflanzenbau
Menzinger Straße 54, D-8000 München 19

SOME PROBLEMS REFERRING TO MEASURE STREAMING POTENTIALS AND ACTUAL POSSIBILITIES AND LIMITATIONS OF THE MEASUREMENT OF RADIATION TEMPERATURE FOR THE DETECTION OF FLOW PHENOMENA

H. Militzer[1], Chr. Oelsner[1]

Starting from a short summary of some possibilities of applied geophysics for the detection and the control of nearsurface flow phenomena advantages, specialities and limitations of the efficiency of the measurement of radiation temperatures at the surface of the earth (infrared geothermics) are discussed and proved on the base of selected examples.

The actual state of the instrumentation for non-imaging and imaging infrared geothermics is explained and methodical aspects of both variants of field measurements are discussed after a short summary of some theoretical fundamentals.

By means of the solution of the equations of the moved point- and line source the conditions of the geothermal proof of flow phenomena are demonstrated.

The examples refer to :

- the temperature field of an in situ test of heat storage
- the localisation of percolation zones in connection with the hydromechanical reextraction of a dump of saltwaste
- the delineation of loose and water bearing materials in the overburden of brown coal deposits
- the detection and delineation of water seeping out at barrages.

[1] Bergakademie Freiberg, Sektion Geowissenschaften, DDR - 9200

INFRARED SENSING SYSTEMS AND TECHNIQUES

Chr. Florin[1]

Many general and special purpose thermal infrared sensing instruments have been developed in the last 10 years. The instruments range from relatively simple detectors to very sophisticated calibrated thermal imaging systems, and range in price from a few hundred sFr. to more than sFr. 200'000.--. The techniques for utilizing these instruments range from simple manual pointing to installation in a stabilized mobile platform for coverage of large areas. The sensor outputs vary from simple alarms or indicator meters to high speed digital recording and image display devices.

Application of thermal infrared sensing instruments requires careful consideration of the purpose and scope of the proposed program in order to select the optimum instrument and implementation technique. In many programs, it will be necessary to employ more than one instrument and measuring technique in order to cost-effectively meet the program objectives.

Classification of thermal infrared sensing systems and application techniques into categories such as size of instrument, target area view, cost, sensitivity, accuracy, output information, speed, measurement technique, etc. will be explained.

[1] Florin & Scherler AG, CH - 6010 Kriens, Switzerland

SUBSURFACE APPLICATION OF AN INFRARED THERMOMETER TO DETERMINE ZONES OF PREFERED WATER PATHWAYS

Thomas Brasser[1], Herbert Kull[1]

The hydraulic properties of the considered disposal floor as well as of the overburden are significant for the safety analysis of a final repository, as a possible propagation of radionuclides e.g. and with that a potential menace of the biosphere is dependent on ground water as transport medium.

Proved computer codes for calculation of ground water transport and a possible propagation of aggressive substances are often established on the basis of the Darcy law and therefore have to assume a porous medium.

In low permeable sediments in greater depth as well as in crystalline rock a water transport - however small - preferably takes place at joint systems.

Because of this model calculations, which are based on a porous medium, may only be applied prudently, if a homogenous joint distribution within a relative great rock volume exists and a quasi-porous medium may be assumed.

Because of this the identification and differentiation of water-bearing joint systems is an important objective of subsurface hydrogeological survey.

In non-ventilated gallery sections the high humidity of the atmosphere can cause a homogeneous irrigation of the rock surface; in ventilated sections the moisture holding capacity of air may lead to a complete drying of the rock.

In both cases low water-bearing joint systems may not be localized and/or quantified. By means of temperature monitoring of the gallery surface it has been tried to identify low water-bearing zones. By correlating these zones with the geological mapping hydraulically effective zones have been determined.

The application of this method in the Grimsel rock laboratory (Switzerland) will be illustrated and the results will be shown.

[1] Gesellschaft für Strahlen- und Umweltforschung mbH
Institut für Tieflagerung, Theodor-Heuss-Straße 4
D-3300 Braunschweig

TEMPERATURE DISTURBANCE IN A DAM DUE TO LEAKAGE

Venetis, C.[1]

Thermal disturbances may be viewed as natural tracers for the detection and localization of leakage. Measurements taken at the model dam in the Bundesanstalt für Wasserbau (Karlsruhe) are very encouraging.

The sealing layer of a dam is assumed to have a leaking fissure. The problem is to estimate the temperature disturbance in the saturated sand of the dam in the vicinity of the fissure due to a temperature difference between reservoir water and the interior of the dam.
Heat is transferred by means of the leaking water.

A long semi-cylindrical fissure and a circular hole are considered.
In both cases radial flow with appropriate boundary conditions makes the problem analytically tractable. Conduction, convection and dispersion are considered.
The problem is time dependent.

[1] Rijkshogeschool, Groningen (Netherlands)

HEAT TRANSFER AND EMISSITIVITY IN DIFFERENT GROUNDSTRUCTURES

Chr. Florin[1]

By measuring thermal heat or differences of the emissitivity from groundstructures with thermal imaging sensors it is necessary to know as much as possible "unknown" parameters.

Variations in emissitivity, different meteorological influences, different groundstructures are some of the parameters which has to be known.

The paper describes effects of heat transfer *in different* groundstructures and emissitivity on different groundstructures.

Theoretical basis and practical measurements will be explained.

[1] Florin & Scherler AG, CH-6010 Kriens

DETECTION OF GROUNDWATER FLOW BY MEANS OF A GEOELECTRICAL RESISTIVITY EQUIPMENT

Buchholz, R.[1]

This paper describes a method to observe the groundwater flow from the surface. It needs a borehole of small diameter into the groundwater, one current electrode A in the borehole, one current electrode B in "infinite" and few couples of potential electrodes MN.

M and N are symmetrically situated (i.e. direction N, N 30°, N 60° etc.). The potential at the surface - caused by current of the electrode A in the borehole - will be observed by these couples of electrodes MN.

The salty water around the electrode will be moved by the groundwater flow and disturbs the potential balance around the electrode A. The different MN couples will indicate changing voltages.

The MN couple, which is in the direction of groundwater flow will indicate the maximum voltage variation.
These MN, which have a position perpendicular to the groundwater flow will indicate no voltage variation.

The distribution of the amplitude of voltage change can be drawn as a vector diagram and shows the direction of groundwater flow.
The variation of the voltage between MN as a function of time depends on the velocity of the groundwater flow.

Some examples of field measurements will demonstrate the method and their possibilities of application.

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GEOELECTRICAL MAPPING AND GROUNDWATER CONTAMINATION

Rainer Blum[1]

Specific electrical resistivity of near-surface materials is mainly controlled by its groundwater content and thus reacts extremely sensitive to any change in the ion content of that. Geoelectrical mapping is a well established, simple and inexpensive technique for observing areal distributions of apparent specific electrical resistivities. Those are a composite result of the true resistivities in the underground, and with some additional information the mapping of apparent resistivities can help to delineate low-resistivity groundwater contaminations, typically observed downstream from sanitary landfills and other waste sites.

The presence of other good conductors close to the surface, mainly clays, is a serious noise source and has to be sorted out by supporting observations of conductivities in wells and geoelectrical depth soundings.

The method may be used to monitor the extent of a groundwater contamination at a specific time as well as the change of a contamination plume with time by doing repeat measurements. Examples for both will be presented.

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GEOELECTRICAL MEASUREMENT AT THE SALT MINE ASSE

U. Yaramanci[1], D. Flach[1]

The salt mine Asse is used as a location of studying various aspects of rocksalt for its usefulness for the disposal of nuclear waste. One aspect of special importance is the detection of possible brine leakages and migration in and around a desposal site, for which geoelectrical DC measurements are very well suited. In a long term project we started to carry out geoelectrical measurements around a barrier construction. This barrier is built to investigate its behaviour and the behaviour of rocksalt around it, after brine has been brought in to a chamber behind the barrier construction.

About 200 electrodes are placed and fixed in 20 boreholes which are drilled from the gallery passing over the barrier gallery and surround a volume of 80 m x 16 m x 20 m, in which a barrier of the size of 60 m x 8 m x 8 m will be built. Special care is taken of the material filled into the boreholes for making good contact between the electrodes and the rock. The measurements are to a great extend automated and can be driven by a remote control software and a multiplexing device for switching and activating the electrodes. An attached software allows immediate processing of the data.

Apart from the study of the effects of the brine, the possibility of continuous observation through different stages of the barrier construction will allow the in situ investigation of electrical properties of the zone of loosening. The construction of the barrier has not yet been started. The test measurements in appropriately prepared boreholes have yielded a resistivity of 10^5 Ohm . m to 10 Ohm.m with no indication of detectable inhomogeneity and anisotropy so far.

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INTRODUCTION TO THE RESEARCH PROJECT: EXPERIMENTS TO ASCERTAIN THE RELATIONS BETWEEN HYDRAULIC POTENTIALS IN THE GROUND AND THE GEOELECTRICAL AND THERMIC POTENTIALS SET OFF BY THESE

Armbruster, H.[1]: Blinde, A.[2]: Hötzl, H.[3]

The relations between the hydraulic potential and the corresponding geoelectrical or thermic potential produced by this are examined using analytical and experimental methods. The paper goes into these experiments. These were carried out on the following physical models (sand) that is to say in-situ:

- with a plexiglass pipe (diam. 0,2 m, length = 1 m)
- with a small plexiglass channel (1,4 m * 0,7 m * 0,5 m)
- with a large plexiglass channel (6,0 m * 2,0 m * 1,5 m)
- with a 3,5 m high isotropic dam in the open
- with an inhomogeneous 12 m high dam at a reach across the valley with "incomplete" diaphragm system (scum board)
- with 4 m to 8 m high inhomogeneous lateral dykes of a canal with "incomplete" diaphragm systems (asphalt)
- with 4 m to 10 m high inhomogeneous lateral systems (core and scum board)

All the measuring equipment and the measuring methods are presented.

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MODEL EXPERIMENTS ON A SMALL TEST CHANNEL. EMPIRICAL CORRELATIONS BETWEEN FLOW POTENTIALS AND THE HYDRAULIC FIELD

Bernhardt, R.[1]; Hötzl, H.[2]; Merkler, G.P.[2]

In connection with the geoelectrical investigations to locate leakages in dykes and dams, tests were carried out on a flow model made of sand, in a small channel, to measure the streaming potential.

By using of a PC-Computer-Scanner system it was possible to simultaneously record the measurements from 20 platnium electrodes and thus also the electric field dependent on the hydraulic streaming processes.

A direct correlation between the electric streaming potentials measured and the water flow processes could not be detected. With regard to the consistency of the measuring results, it was shown that even under different measuring conditions the streaming potentials and the quantity of water seapage measured correspondend well.

Taking Darcy's law and Helmholtz'equation into consideration empirical methods of calculation were derived, which made it possible to determine the quantity of flow via the streaming potentials measured.

In the experiments carried out on the model the actual water flow quantities were consistent with the water flow quantities calculated from the electric field.

The empirically determined correlations between the streaming potentials, water flow quantities and water flow rates and the experiments performed will be described briefly and put to discussion.

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MODELLING OF STREAMING POTENTIALS AND THERMOMETRICAL MEASUREMENTS AT AT BIG LABORATORY CHANNEL

Armbruster, H.[1]; Hötzl, H.[1]; Kassel, A.[2]; Marschall, P.[3]; Merkler, G.-P.[2]; Peritsch, D.[2]

The University of Karlsruhe, represented by the Department of Applied Geology, the Institute of Soil and Rock Mechanics and the Federal Waterway Engineering and Research Institute (BAW), Karlsruhe, have been cooperating for a few years in joint research of hydraulic, geoelectric and thermic fields, especially in the detection of leakages of dykes and dams. From April, 1984 on the Volkswagen Foundation has been sponsoring a research project whose aim has been the determination of the relationship between the hydraulic field on one hand and the appertaining thermic and electric field on the other side.
The construction of a aspecial experimental channel (6m x 2m x 1.5 m) is described. Special attention was paid to optimal feasibilities of measuring the relevant hydraulic and physical properties. About 140 thermosensitive sensors (PT 100), 80 pressure transducers and 45 platinum electrodes were installed and connected with an automatic recording system.
Several streaming tests, which had been carried out in a homogenous sand model built into the channel, gave hints to the evolution of the electric field (self potential) and of the thermic field in relation to the hydraulic field. The results as well as the technical problems occuring during the experiments are represented and discussed in a comprehensive view.

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EFFECT OF LEAKS IN DAMS AND TRIALS TO DETECT LEAKAGES BY GEOPHYSICAL MEANS

H. Armbruster[1], A. Blinde[2], J. Brauns[2], F.-P. Degen[2]
W. Mazur[2], G.P. Merkler[3]

A research project was performed over a period of 3.5 years, dealing with the hydraulics of leaks in dam seals and with geophysical methods to detect and to localize these leaks. The main object of the investigations was to make a large model dam (H = 3.5 m, L = 20 m, V = 600 m^3) in a huge open pit which was sealed with HDPE plates to form a watertight basin and an "impervious base" of the dam. The dam body was made out of sand and had an upstream sealing face which was constructed with a number of artificial leaks to be tested under full reservoir conditions. The instrumentation of the dam body consisted of a number of piezometer and temperature gauges for observing the seepage processes and the related temperature changes. A net of selfpotential electrodes was installed in the downstream face of the dam which were observed along with the numerous tests performed under varying conditions. A thermo-camera was also installed and was used to observe the infrared thermo-reflection of the downstream face of the dam during the leakage tests.

The tests showed that even small leaks in sealing faces can lead to considerable water losses and extensive percolations of embankement dams. Local infiltrations through leaks in an upstream sealing spread out widely into the dam body and do not result in local leakages in the downstream faces of homogeneous embankment dams. Additional safety elements like toe drains are urgently required.

The geophysical measurements show that the selfpotential react immediately to changes in the seepage conditions, at least in certain regions; but a generalisation of these results is not yet possible. Also the temperature measurements show significant reactions, which are substantially influenced by seasonal and day / night fluctuations.

The investigations show that the geophysical methods applied can be useful for the detection of seepages through dams, but only under certain favourable conditions. More research work and systematic investigations seem to be required.

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LABORATORY STUDIES ON THE CHARACTERISTICS OF ELECTRODES USED FOR STREAMING-POTENTIAL MEASUREMENTS

Kassel A.[1], Faber S.[2], Merkler G.[1]

Measurements of streaming potentials are disturbed by various noise effects often exceeding the amplitude of the effective signal. Several electrodes used in laboratory and field experiments have been tested concerning their stability versus time under constant surrounding conditions, and their reliability in self-potential data acquisition.

Different experiments delineating the main characteristics of $Cu\text{-}CuSO_4$ electrodes, placed in a homogeneous sand body, such as temperature coefficient, sensibility to changing moisture content were carried out.

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LONG TERM SELF-POTENTIAL DATA ACQUISITION AND PROCESSING

B.Wurmstich[1], S. Faber[2]

An example of data acquisition and processing due to measurements of self-potential effects of a leaky dam model (scale 1:1) is presented. Every alteration of the leak causes a change in the self-potential anomalies, which is superposed by the effects of temperature and precipitation, ect. Measurement of the self-potential anomalies is done at 40 different locations on the surface of the dam using unpolarizeable electrodes. In addition to the self-potential measurements, measurements of temperatures, water levels, and the quantity of the water leakage are also carried out. All of the above mentioned data is recorded by a data-acquisition-system.

Time series records are frequently disrupted by failures of the measuring instruments and the data-acquisition-system. Such failures cause peaks and gaps in the record, which must be corrected. Other problems are the relatively low signal-to-noise ratio and the influence of drift-effects, caused by oscillations of the temperature. The data-processing consists of interpolating gaps and smoothing peaks, fourier-analysis, digital filtering and noise-reduction.

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DATA PROCESSING BY TEMPERATURE MEASUREMENTS

Schnebele, H.P.[1]; Gerlach, J.[1]; Armbruster, H.[1]

The temperatures are recorded either according to the principle of heat conduction (measurements by contact) or according to the principle of heat radiation (measurements without contact). For both types of measurements, different systems are used, whose measured variables (temperatures) derive from different changes in physical test basis. Here the data derive from point-to-point-measurements, linear measurements or extensive measurements. These are processed firstly by taking over manual readings right up to the computer evaluation of an extensive computer recording system.

The paper provides an overview of recordings in waters and soils i.e. data of surface temperatures and the processing of these within the framework of research projects.

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THE APPLICATION OF THERMAL - IR - TECHNIQUE FOR THE RECONNAISSANCE OF DAM AND BARRAGE DEFECTS IN AN EARLY STATE, THE ANALYSIS OF DUMP SITES AND TUNNEL CONDITION SURVEYS

M. Sartori[1]

The fundamental evaluation of building conditions for large objects requires a fast and non-destructive examination covering the whole visible surface.

Detection of anomalies in the building condition is subject of a procedure, where the thermal - IR - technique claims a large portion. In all cases presented, the existence of a defined heat flux situation through the surface of the building is important.

The reconnaissance of defects in dams and barrages in an early state is mainly oriented in finding anomalies of humidity in the building. A similar process is applied to distinguish areas saturated with gas or humidity on dump sites. In a third part a further development of the IR- and multispectral technique combined with the laser application for connected distance measurement, illumination and stimulation of small surface elements for tunnel condition surveys is presented.

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GEOELECTRICAL, SELF-POTENTIAL AND TEMPERATURE SENSING MEASUREMENTS APPLIED FOR DETECTION OF LEAKAGE BY DAMS

Armbruster, H.[1]; Blinde, A.[2]; Brauns, J.[2]; Döscher, H.D.[1]; Hötzl, H.[3]; Merkler, G.P.[3]

In order to examine 700 km of dams on West-German waterways a method was sought, which would provide quick and prompt information on weak points in dams. For this purpose in the dam area with conventional instrumentation 2 extensive methods were tested in addition, which are performed without disturbing the dam:
Infrared thermography of the dam with a part of the hinterland and geoelectrical resistance and self-potential measurements.

In the paper, the results of such measurements in dams are shown and compared with the results of conventional measuring. It could be seen that both methods provide prompt indications of leakages as well as the extend of existing weak points.

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GEOELECTRIC AND THERMOMETRIC TECHNIQUES USED FOR DETECTING SUBSURFACE FLUID FLOWS IN BRAZIL

Valiya M. Hamza[1], Augustinho Rigoti[1], Reinaldo G.N. Ramos[1]

Geoelectric methods (IP, SP and resistivity) were employed for delineating zones of subsurface seepage behind hydroelectric dams at two sites (Nova Avanhandava and Rio Jaguari) in the State of Sao Paulo. Interpretation of SP measurements proved to be difficult because of interference effects from underground power instalations and grounding of transformers near the work sites. Resistivity and IP surveys provided coherent results that were useful for identifying zones of subsurface flows. High chargeability - low resistivitiy combination was found to be characteristic of water seepage through clay bearing zones while high chargeability - high resistivity combination indicated water flow through sand rich layers.

Thermometric techniques involving down-hole temperature logs were employed for detecting and evaluating groundwater flows at nearly 50 sites in Brazil. These include sedimentary basins (Parana in the South and Potiguar in the Northeast), Precambrian metamorphic terrains and areas covered by Mesozoic flood basalts. Qualitative interpretation of anomalies appearing in temperature logs were found to be sufficient for identifying zones of entry and exit of groundwaters. Seepage velocities were calculated by fitting observed log data to theoretical curves predicted by solution of heat transfer equation with temperature and heat flux boundary conditions. The velocities determined range from 0.6×10^{-8} m/s to 28×10^{-8} m/s in sedimentary strata.

Recent theoretical studies on the decay of transient thermal regimes in wells show that flows behind casing pipes can be detected using artificial heating techniques. This points to the possibility of developing a thermal flow meter device for down hole measurements.

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DETECTION OF RIVER INFILTRATED WATER FLOW BY EVALUATION OF HYDROGEOLOGICAL, HYDROCHEMICAL AND HYDROTHERMICAL DATA USING NUMERICAL GROUNDWATER MODELS

Zipfel K.[1] & Horalek U.[1]

The "Sandoz desaster" has demonstrated the quality problems of river infiltrated water. The use of groundwater near rivers requires more and more detailed knowledge of the transport phenomena of river infiltrated water to pumped wells.

The different flowpaths and their distribution correspond with proportionate rates of flow of river infiltrated water to wells. Because of the different flowtimes of this water along each flow path their distribution determines the quality of pumped water and its possible or necessary treatment.

The flow of river infiltrated water depends on the underground structure and on the time variant influences as the height of the water level of the river and the pumping rates of the wells. Evaluating geological and hydrological data only, the complex flow situations can be recognized and simulated with model methods for different conditions.

Since 1982 such problems have been investigated in a research programm sponsored by the German Environmental Agency, Berlin, concerning of the flow and quality transport of river infiltrated groundwater in the catchment area "Eich" in the Upper Rhine Valley.

The intended model simulations of the flow and the transport phenomena required integrated investigations including hydrogeological, hydrochemical and hydrothermical methods of measurement and evaluation.

Therefore an essential part of the total program has been concentrated on an area near the river Rhine with three pumping wells of 60 m depth in a distance of 100 m to the river. For monitoring the influence of river infiltrated flow in the underground several observations wells with different depth have been installed between the wells and the riverbank.

Especially the measurement of temperature profiles over depth in the monitoring system at different distances from the river bank brought significant results. Comparing these

data with changes of Rhine water temperature over the time evident references have been discovered on the distribution of flow of river infiltrated water.

Combined with hydrological and hydrogeological facts and hydrochemical and hydrobiological data the model simulation of the real underground structure and its influence on the flow and transport of river infiltrated water was possible. Using only hydrological and hydrogeological data these evaluations were impossible due to the uncertainty of the informations. Therefore this first step of integrated investigations was the basis of the second step with additional integration of measured data of the water quality in the calibration of the simulated model and the detection of flow and transport phenomena.

Purpose of the not yet finished studies is the development and testing of suitable methods of measuring and evaluation combined with model simulations to obtain instruments for an optimal development and management of the use of river infiltrated water.

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MONITORING INSITU ELECTRICAL POTENTIAL IN SOIL IN RESPONSE TO CHANGING HYDRAULIC REGIME USING A THREE DIMENSIONAL ARRAY OF GRAPHITE ELECTRODES

Ausaf-ur Rahman[1], John P. Bell[2], Tom J. Dean[2], Mary Turner[2]
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A study is currently being conducted to determine the temporal and spatial variation of the insitu electrical potential (E_p) in soil as it varies with the changing hydraulic regime. This paper describes some preliminary results from this study.

A three dimensional array of electrodes was installed in an open grass field at the Institute of Hydrology, Wallingford, England. Seven sets of electrodes were inserted at various depths ranging from 5 cm to 225 cm within a 10 metre square grid. Electrical potentials between the various electrodes were recorded at regular intervals. Continuous records of rainfall and (later) soil moisture potential (through tensiometers) were also collected.

Initial analyses of results indicated an existence of electrical potential of several hundred millivolts between various electrodes. This potential built up exponentially and in several hours continued varying steadily and linearly. Sudden changes in the hydraulic regime like input of infiltrating rain-water caused changes in the slope of Ep-time curves; the changes being more noticeable for shallower electrodes. These changes in electrical potential values were also more pronounced under drier antecedent conditions. Even though no definite pattern could yet be ascertained, the Ep-depth curves at various times during the progression of a storm may reveal patterns related to the subsurface hydraulic regime. The results were also affected by the type of electrodes (e.g. composition, design). Pure graphite rods in plastic tubes were used in this study. Numerous sources may be cited as the cause of insitu electrical potential. An attempt is made to interpret the variation of electrical potentials with changing hydraulic regime in terms of prevailing electrochemistry of the soil-water system.

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SELF POTENTIAL MEASUREMENTS ON WASTE DISPOSAL SITES THEORY AND PRACTICE

M. Weigl[1]

It is a well known fact that a natural potential difference exists between two points on the ground and can be as much as several volts or as little as a fraction of a millivolt. This phenomenon has been used for many years in the exploration for sulphide ores and even graphite.

Recently the self potential method has been experiencing a boom in numerous areas of application, for example in geothermal exploration, earthquake prediction and in engineering geology.

Conventional measurements, i.e. with a moving electrode, are known from experience to be associated with errors. Possible error sources are for example telluric currents, magnetic discharges and their consequences, and also temperature differences, changes in facies, moisture in rock etc.

In order to eliminate at least some of these error sources PRAKLA-SEISMOS has developed a survey arrangement in which up to 216 non-polarizable self potential electrodes can be connected. Once the electrodes have been connected up to the survey truck the potential differences between the electrodes and one or more base electrodes can be measured virtually simultaneously. The entire survey procedure is repeated at specific time intervals and the survey values are recorded on data carriers.

The survey truck is equipped with a computer system, scanner, floppy disk and printer. Power can be supplied by a generator.

Using a large number of electrodes PRAKLA-SEISMOS has been able to prove leakage points in several waste disposal sites. Likewise the salt contamination in the ground water has been successfully delimited around surface salt disposal sites.

The survey results of several investigations are shown.

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MAPPING SUBSURFACE WATERFLOW IN GEOTHERMAL AREAS BY THE SELF-POTENTIAL METHOD

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Self-potential (SP) surveys were carried out on a number of geothermal areas in Japan during the last decade. Obvious SP anomalies of positive and negative polarity were observed in the areas surveyed; in most cases SP anomalies of positive polarity were found to overlie subsurface upflow zones. Streaming potential generated by hydrothermal circulation is believed to be the most likely cause of the observed positive anomalies. From the quantitative modelling of electrokinetic coupling (Ishido, 1981), the subsurface flow of heated pore waters can generate such positive potentials on the earth's surface. Also through electrokinetic coupling, negative SP anomalies can be generated by the downflow of meteoric waters. Consequently, it seems possible to detect and map subsurface waterflow, especially associated with hydrothermal circulation, using self-potential data.

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GEOSTATISTICS AND GEOELECTRICS TO DETECT GROUNDWATER POLLUTION

A. Bardossy[1], I. Bogardi[2], W. E. Kelly[2], W. Woldt[2]

A geostatistical methodology is presented to estimate the degree and extension of groundwater pollution using a combination of different measurements. The types of measurements include surface resistivity, electromagnetic induced-conductivity and monitoring wells. In the illustrative example a larger number of surface electrical resistivity measurements are combined with a smaller number of direct specific conductance data stemming from monitoring wells. The error of specific conductance estimation is characterized by the estimation variance calculated with the geostatistical method. It is shown numerically how increasing monitoring effort results in smaller estimation error.

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FUNDAMENTALS OF STREAMING POTENTIALS IN GEOPHYSICS

Morgan, D.F.[1]

The fundamental theoretical electrochemical basis for the generation of streaming potentials in rocks will be presented. The methodology of laboratory measurements, with its associated problems, will be discussed in relation to streaming potential data on a variety of rocks/minerals in contact with the electrolytic liquids representative of geological environments. Furthermore, streaming potential data and and models with two-phase fluid flow, and also as a function of temperature, will be briefly discussed.

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SELF-POTENTIAL MEASUREMENTS TO DETERMINE PREFERRED WATER-FLOW DIRECTIONS IN ROCK MASSES

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Determination of the permeability behaviour of rock masses is of essential importance of the judgement of necessary grounting measures.

Geoelectrical self-potential measurements in connection with water pressure tests and grounting experiments in rock masses were carried out to determine preferred flow paths of water or cement in relation with the joint system.

The self-potential measurements proved to be closely related to the amount of the water or cement absorption in the pressure-gauge borehole. The differences between the self-potential measuring values, calculated for various pressure/water or cement absorption proportions in the pressure-gauge boreholes, imply indications of an anisotropic system of water or cement path ways, especially in their direction-statistical evaluation.

The paper deals with the results of geophysical self-potential measurements, which were carried out to determine the preferred directions of the water and grounting material path ways.

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STUDY OF SPATIO TEMPORAL EVOLUTION OF ELECTRIC PROPERTIES OF AN UNDERGROUND SITE

Pierre Henri Morat[1], Jean-Louis Le Mouel[1]

The results presented habe been collected in a cooperative program devoted to the study of stability of an old underground quarry which has been sollicitated by a landfill of 200 000 m^3.

A network of 49 probes has been put in place on a pillar and has permit to investigate:

- quality of data
- the size of sources of variation from decimetric to metric scale.

The first results put in evidence:

1) A mechanical effect due to the sollicitation: the landfill had generated an increase of stress in the order of 5 bars in 6 months which is in the range what can be observed in active tectonic process.

   a) a variation of the order of 1% bar observed all over the network and link to the first sollicitation of the pillar by the first layer of the landfill.

   b) variations in the typical range of 1% of the apparent resistivity the scale of which is decimetric.

2) An effect of hydraulic circulation which generates an annual variation with a typical amplitude variation of some 1% of the apparent resistivity.

Temperatures measurement shows that these previous variations can't be due to some thermic effect on the conductivity of the geomaterial and especially on water. But they sustained the hypothesis of a slight annual evolution of the fluid circulation in the bulk of the limestone.

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UTILIZATION OF GEOELECTRICAL MEASUREMENTS FOR ENVIRONMENTAL GEOTECHNOLOGICAL ISSUES ASSOCIATED TO THE MINING INDUSTRY

Thomas Vladut[1]

Detection of subsurface flow is an environmental concern associated to several components of the mining industry. Examples from Canadian open cast operations are given and evaluation of the potential of contribution of geoelectrical methods are discussed.

Detection of subsurface flow in open pit operations relate on a critical practical means of controlling the stability condition of mine pit slopes. Subsurface flow and the associated groundwater pressure reduce the stability of slopes by reducing the frictional resistance to sliding mainly through reduction of normal forces and by creating a significant driving force along the pit slope which increases the slope instability.

Stability or slope control in mine environment could be achieved by slope flattening or groundwater control. Modification of solpes during mine operation is most often impractical and would interfere significantly in the operation. Groundwater control provides an economic and flexible strategy which is currently implemented in most open pit operations related to effectiveness, operational convenience and relative low cost. Evaluation of practical means of groundwater control refers to the transient nature of the flow movement in mine environment where both slope and drainage conditions are changing continuously and the time parameters are of outmost importance because of dynamic changes along the mining operations. Evaluation of the time component and by this on the efficiency of groundwater control procedures allows implementations of the reliable dewatering procedures such as provided by wells around the pit, horizontal drainholes, drainage adits. This active procedures may be implemented if passive means of unaided drainage or unloading of slopes does not provide enough stability.

Estimation of transient groundwater conditions are related to evaluation of permeability parameters of fisured rocks and geoelectrical detection of the flow conditions provide an economic and realistic alternative for estimation of the effectiveness of drainage procedures.

Assessment of real flow patterns may provide an alternative means to evaluate insitu consolidation parameters for rock materials. Such consolidation parameters are usually well evaluated by laboratory procedures only for clay materials but are mainly a guess for other types of ground materials and application of geoelectrical monitoring of flow may be the only relevant field procedure to estimate such insitu coefficients of consolidations.

Mine practice is often associated to groundwater polution and several examples of geoelectrical measurements contributions are reviewed.

Geoelectrical measurements are significant also in other components of the mine development such as exploration and the geoelectrical components of the Logging While Drilling technology will be discussed.

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PREDICTION OF FAULTED ZONES AND PERMEABILITIES IN GROUND AND DAM STRUCTURES BY MEANS OF RESISTIVITY MEASUREMENTS

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This report should show a new approach of modified resistivity measurements (GDH-Method, Kaus & Kopp, 1986; Kaus 1988) which under certain circumstances enables a prognosis of the distribution and quality of poor rock mass zones and an estimate on rock mass permeabilities as well.

Due to anisotropies of conductivity, i.e. anomalies of the rock masss, a qualitative assessment of faults, crushed zones, master joints of carstification is possible.

In addition, owing to the joint porosity of the rock mass or of a poor zone to be determined, it's geotechnical relevance for design and construction of underground structures can be estimated.

In limestone formations, the determination of the overall joint porosity also allows a rough prediction of its intensity of carstification.

The approach (geological air photo interpretation - resistivity measurements - classification of faults etc.) will be shown examplified by a 10.5 km long tunnel of the German Federal Railways (High-Speed Line) being presently under construction.

The other example to be presented is an old masonry dam in Germany, the permeabilities of which are demonstrated during the improvement measures.

From first promising results it can be expected that site investigations can be optimized by resistivity measurements where applicable.

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Frankfurt/Main, Lyoner Straße 22, Fed. Rep. of Germany

[2] Geohydraulic Data, Mainz-Kostheim, Uthmannstraße 12
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COMPLEX RESISTIVITY MEASUREMENTS ON GRANITES

Georg Nover[1], G. Will[1]

The petrophysical parameters porosity, permeability, compressibility, thermal expansion and zeta potential were determined for selected core samples from the Falkenberg granite massif in north-eastern Bavaria, FRG. This rock status determination forms the basis for the interpretation of the complex electrical resistivity measurements as a function of frequency (.0001 Hz up to 100 kHz). The measurements were performed on cylindrical core samples. In situ conditions were obtained in an autoclave, with pressures from 10 bar up to 150 bar at room temperature. Solutions of NaCl and KCl with different molarity, and distilled water were used as pore fillings. The observed shift in the relaxation time was attributed to different polarization processes whose existence depends on saturant type and concentration.

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ASPECTS CONCERNING THE DETECTION OF SUBSURFACE WATERFLOW AT SOME ROMANIAN DAMS BY GEOELECTRICAL METHODS

Traian Moldoveanu[1], Paul Georgescu[2], Octavian Suciu[3]

The work presents a trial of geoelectrical modelling of the phenomena of underground flow through the body of a dam modelled in a box in the laboratory.

Also, a synthesis is presented regarding the detection by geoelectric methods of self-potential and resistivity of the seepage that occurred in some Romanian dams such as: Vida-Dobresti, Lesul, Racova, Malaia and downstream Riul Mare.

[1] Institute of Hydroelectric Studies and Design, Bucharest, Romania

[2] University of Bucharest, Bucharest, Romania

[3] Institute of Hydroelectric Studies and Design, Bucharest, Romania

COMPARISON BETWEEN CROSSHOLE HYDRAULIC TESTS AND HOLE TO HOLE ELECTRICAL MEASUREMENTS (MIMAFO METHOD)

Poirmeur C.[1] & Pottecher G.[1]

This paper aims to compare and to determine the respective capabilities of two crosshole methods based upon hydraulic or electric properties of inhomogenities (fractures) located within the surrounding rocks.

The tests were carried out at Le Mayet-de-Montagne (Allier). This test site is used by I.N.A.G. (Institut National d'Astronomie et de Geophysique) for Hot Dry Rock experiments. Measurements were performed by using a couple of holes separated by 30 meters.

Hydraulic tests consisted in water injections centered in front of fractured zones thanks to packers; water arrivals were measured in the second hole. This experiment allowed to establish some connections due to fractures between different points of the holes. However, it did not allowed to choose between some hypothesis of fractures geometrics.

Electrical tomography (direct current) was performed in accordance with the MIMAFO method which consists in locating an injection point in one of the holes and in carrying out a series of potential measurements along the second hole; the source point is then moved and the measurements are repeated. Electrical responses are in the relation with the conductivity and the geometry of the inhomogeneities (fractures) connecting the holes or not.

A modeling of the field responses using the three-dimensional modeling program has allowed to define a geometry for the fractures in the zone where hydraulic tests were performed.

Interpretation of MIMAFO measurements gives more informations and seems to be best suited for a structural study.

[1] Dep. Geophysique, Bureau de Recherches Geologiques et Minieres, B.P. 6009, 45060 Orleans Cedex 2, France

THE USE OF INFRARED THERMOGRAPHY AND TEMPERATURE MEASUREMENT TO DETECT LEAKAGE FROM EMBANKMENT DAMS

P. Tedd[1], J. M. Hart[1]

Wet areas are frequently found on the downstream slopes of old embankment dams in the United Kingdom. An investigation to assess the value of infrared thermography in locating wet areas on the downstream slopes of a number of dams in the Pennines has been carried out by the Building Research Establishment. The method depends upon the wet area having a different surface temperature to the surrounding ground which has not been affected by leakage or other ground water. Wet areas were clearly identified on a number of dams where they were already known to exist. The interference effects of different vegetation, types of ground, weather conditions and other variables on the thermal image are discussed.

The relevance of the wet areas to the safety of an embankment dam depends largely upon the source of water. Leakage from the reservoir through a dam could erode the core of the dam and cause high pore water pressures in the downstream fill whereas wet areas resulting from rainfall on the downstream slope are generally of little concern. In an attempt to investigate the source of the water causing wet areas at one dam where infrared surveys had been undertaken, detailed subsurface temperatures in the dam and reservoir temperatures have been measured. The various interpretations of these measurements are discussed.

[1] Building Research Establishment, Garston, Watford, WD2 7JR United Kingdom

RADAR TOMOGRAPHY - A TOOL TO MONITOR SUBSURFACE FLOW PATHS

P.Blümling[1], O.Olsson[2], B. Niva[2], G. Sattel[1]

A radar tomography experiment was conducted at the Grimsel Test Site in Switzerland to investigate the potential of the method for non-destructive imaging of rock discontinuities. The measurements were carried out in 3 different fields covering areas between 11.000 m^2 to 33.000 m^2. The center frequency of the signals used for this study was 20 MHz which gives for the investigated medium a wavelength of approximately 6m. Receiver and station separation for this experiment was 2.5m for the smaller fields respectively 5m for the large field. The recorded data clearly showed first arrivals and additional reflexions. The amplitude as well as the traveltime data were automatically picked and than processed to give the final data base for the tomographic inversion. The tomograms determined from these data showed discontinuities (fracture zone) and the position of well known lamprophyre dykes in the area under investigation.

In a second step the radar measurements were repeated in one of the fields. But at this time saline tracer was injected in an additional borehole in the center of the test field. After the calculation of the differences in the amplitude data between the two experiments before and after the salt injection tomograms were calculated to show the flow path of the tracer. The results of this inversion showed that it is possible to monitor the subsurface flow of the tracer over nearly 100 m and hereby proved the applicability of the method.

[1] Nagra, Parkstraße 23, CH-5400 Baden, Switzerland

[2] Swedish Geological Co., Box 1424, S-75144 Uppsala, Sweden

EVALUATION OF THE HYDROGEOLOGICAL EFFECT ON THE HEAT FLOW DENSITY - EXAMPLE FROM THE SEDIMENTARY BASIN OF THE BOHEMIAN MASSIF

Pavel Kubata[1]

Subsurface temperature fields in large sedimentary basins may be influenced by underground water movement. Convective heat transfer could thus be an essential constituent of heat flow data measurement in the Bohemian Cretaceous Basin; a sedimentary basin with permeable rocks forming aquifer layers in the northeastern sector of the Bohemian Massif. A simple hydrogeological model of a horizontal aquifer bounded by relatively impermeable rocks was used for calculations and an attempt was done to estimate the effect of the underground water circulation in several boreholes of this region.

[1] Geophysical Instiute, Czechoslovak Academy of Sciences, Bocni II / 1401, 141 31 Praha 4, Czechoslovakia

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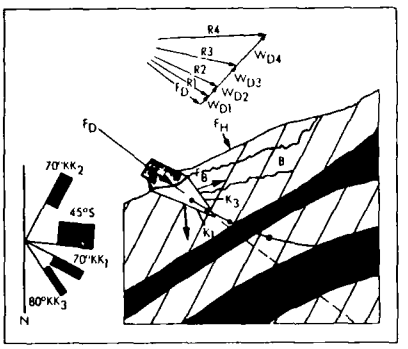
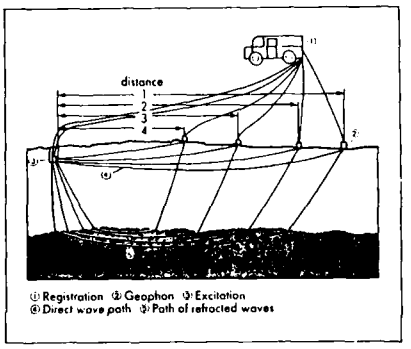


Analytical determination of anchoring forces for an arch dam foundation



① Registration ② Geophon ③ Excitation
④ Direct wave path ⑤ Path of refracted waves

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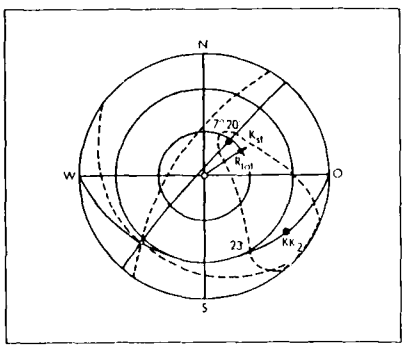

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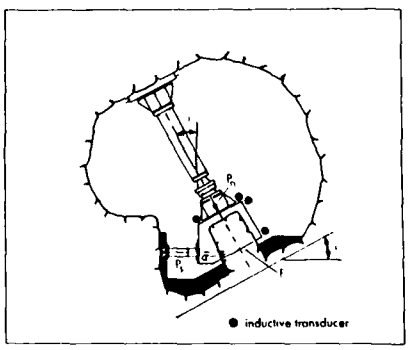

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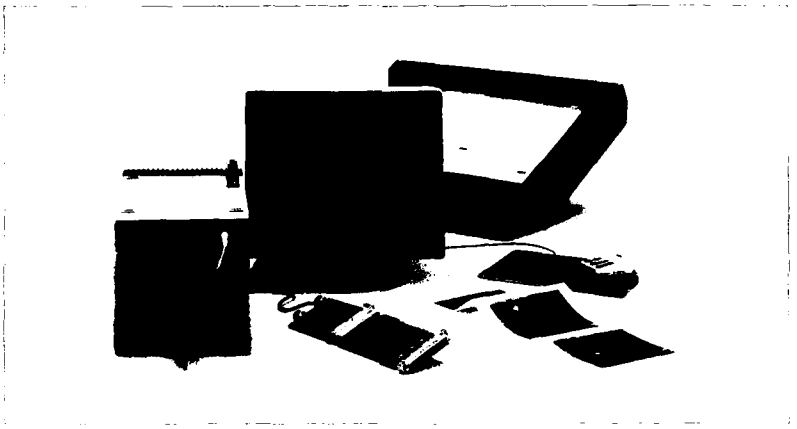

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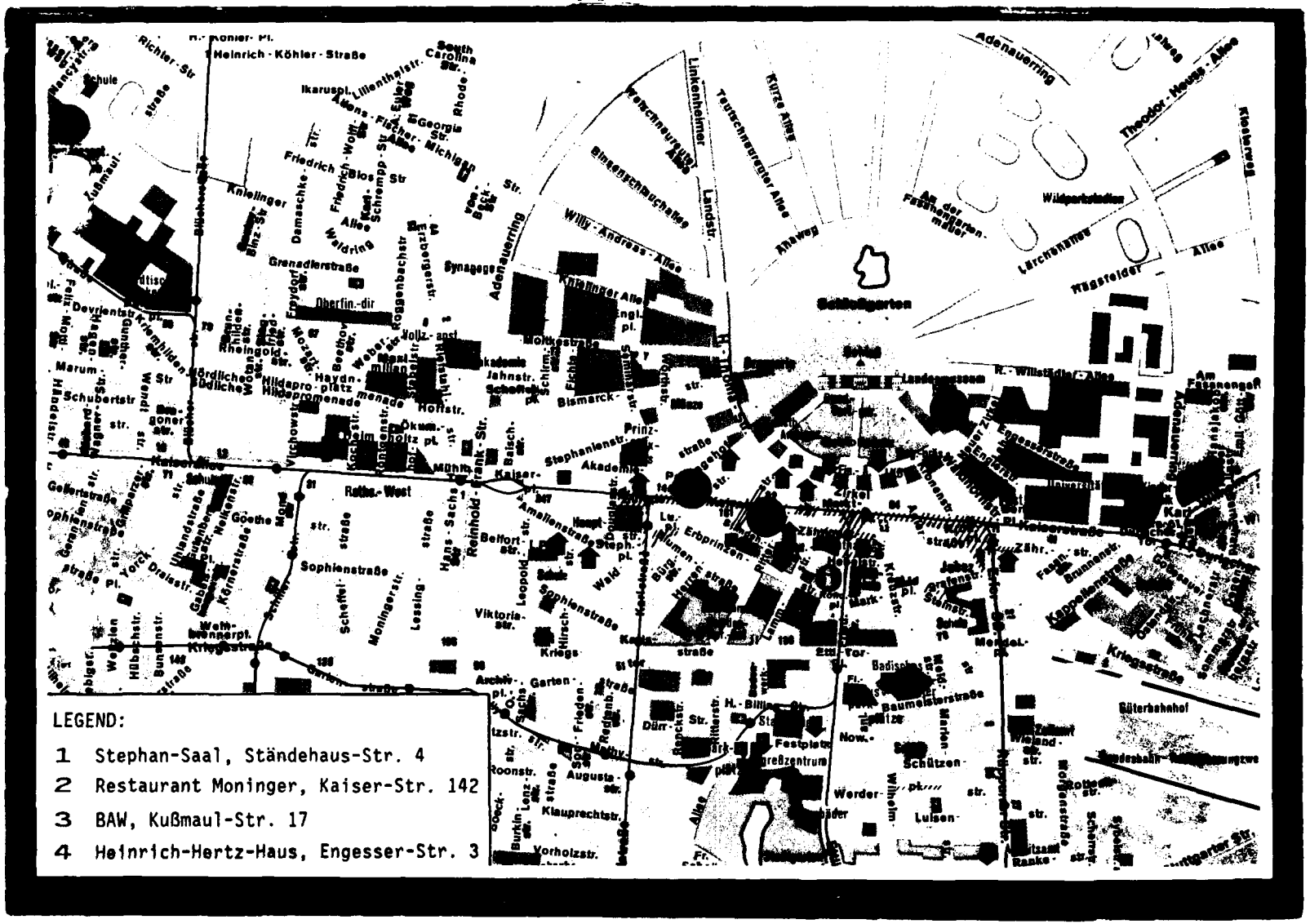
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