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Delineating Groundwater Contaminant Plums Using Self-Potential Surveying Method In Perth Area, Australia

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Abstract: *Self-potential survey was carried out in Kalamunda area of Perth, Western Australia with aim of delineating groundwater contaminant plums/ leakages. Two self-potential electrode configuration, the roving dipole, where one electrode is left in a base position, while the other electrode scouts each survey position, and the leapfrogging approach were potential differences are measured between consecutive sample stations along the line were employed to collect data. Results obtained from the experiments shows numerous small circular potential anomalies which could be interpreted as sources of leakages due to geothermal activity but the only trends that could be correlated across all surveys were the linear E-W trend which shows the location and the direction of the pipe underground to a depth of perhaps 2m. Other anomalies on the map show variations which could be as a result of trees interference on the observed data.*

Key Words: *Leakages, Underground pipe, self-potential, roving, leapfrog*

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1 INTRODUCTION

Adequate protection of underground water from different source pollution is most desirable because of the risk associated with salt water encroaching into the fresh water aquifer (Khesin, 2005, Reynolds, 2007, Corwin and Hoover 1979, Sheriff, 1991). For decades now, application of self-potential surveying method for remedial studies has fallen into disuse despite the fact that the method is easy to apply, needs quite simple equipment and is relatively fast to execute in field and thereby of low cost (Corry, E., et al 1983, Nyquist and Corry 2002). Spontaneous potentials are generated by electrokinetic, electrochemical and thermoelectric mechanisms, and can be measured using two liquid junction electrodes and a voltmeter. When mapping contaminant plumes the electrochemical component of SP is of interest as it is thought that the redox gradients in the degradation halo generate measurable electrical gradients. (Butler and Llopis 1990, Corwin 1990, Lange and Kilty 1991). Lateral resolution is a function of station spacing. One electrode is fixed as the reference electrode, and the second roves. The primary application of surface SP is assessing seepage from dams and embankments. Surface SP can also be used to investigate subsurface water movement and landslides, location of faults, drainage structures, shafts, tunnels and sinkholes, and coal mine fires. (Fagerlund and Heinson 2003, Aubert and Atangana 1996, Eriksen, 2011, Keary and Brooks 2002). SP can also be used to map geochemical variations associated with contaminant plumes (Mussett A.E, Khan and M.A 2009, Parasnis, 1986, Stanley, 2004, Wightman et al, 2003). The basic principle of the electrical resistivity method is based on Ohm's law, which states that current (I) passing through any two points in a circuit is directly proportional to the potential difference (dv) and inversely proportional to the resistance (R) between them. The resistance (R) of any medium or conductor depends on the length (l) and cross-section area (A) through which the current is passing. These two relations are expressed in the following equations 1 and 2

$$I = dv / R \tag{1}$$

$$R = \rho l / A \tag{2}$$

2. SURVEY AREA

The area for the survey is chosen on an open field above our target away from the AC power lines, metal fences. However, the area is at some close distance to the trees just to provide a real life situation with effects from the plants bioelectric on our data. Three profile lines of 5 m apart which contribute a 15m easting were drawn to have a good coverage of our target. The stations were spaced 2m apart along profile lines which constitute a total of 40 stations to provide much coverage of the target. The self-potential survey was conducted by measuring the electrical potential difference between pairs of electrodes that contact the surface of the earth. The target which is the buried pipe runs EW direction; hence the lines were taken perpendicular to the pipe (NW direction) to enable a proper attraction of the anomaly. Within the subsurface area covered by our survey, various potentials are produced. There is occurrence of natural potentials about dissimilar materials very close to the concentrations of electrolytic solutions and maybe due to flow of some fluid. The anomalous surface potential within the area is measured in mill volts (mv) in relation to the base station whose potential is assigned to be zero. It can also be inferred that our potential of interest which is the buried pipe is always negative above a conductive materialised body as shown in figure 1 (Sato and Mooney, 1960).

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- *where is the constant of proportionality, known as the resistivity of the medium through which the current is passing*

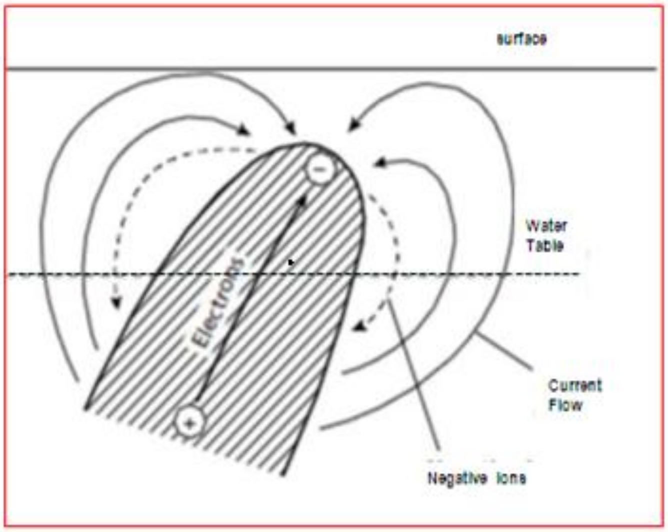

Figure 1: *A physico-chemical model (Sato and Mooney, 1960)*

3. MATERIALS AND METHODS

We performed two SP surveys at Kalamunda area of Perth in order delineate groundwater organic contaminant plumes. The basic equipment consisted of non-polarizable pair of electrodes connected by wire to a Goldstar-type digital multimeter with a high input impedance (larger than 10 Moham) capable of a reading accuracy of 20.00001 volts Figure 2. The use of non-polarizable electrodes is preferred over normal metal electrodes since electrochemical reactions between the metal and the moisture in the ground can build up charges which may obscure the small natural self -potential (Parasnis 1966). We chose a field above the buried pipe which is our expected anomaly, the area we chose is located such that it is not near AC power lines, metal fences and quite some distance away from the surrounding trees where we expected some contributions to our data from the trees to create a real life situation. Two set of measurements were collected using the roving dipole and leapfrog approach. For roving potentials surveying method, measurement was taken between a far negative electrode which is some 20m from the survey area and each station location with a positive electrode while the potential at each station was measured from north to south. The roving potential is a technique where potential is measured relative to a fixed point so the potential electrode measures absolute potential and only one pot is moved. The leap frog method was used to measure the potentials between stations two meters apart along the lines from north to south. Leapfrog method is a surveying technique which measures potential gradient between stations and minimises the zero errors by moving only one pot at a time (Telford et al, 1976, 1990). The first station on each line was repeated after the line was complete to measure the drift with time.

Figure 2: *Equipments used for the survey (1 is a pair of electrode, 2 the porous pot, 3 multi-meters, 4 hammer and 5 phone*

4 RESULTS

The results were computed by measuring voltage potential through a high impedance multimeter. Figures 3 and 5 shows the voltage versus distance plots for (leaf frog and roving dipole) surveying methods while figures 4 and 6 are the corresponding grid of voltage reading. Drift was corrected using linear best fit correction assuming stations were measured at equal time intervals. Drift measurement was taken on the first two stations of each line where a repeated and reverse readings of particular loop-end stations and checking base locations were observed to enhance the quality of our data. For roving potential, drift measurement was taken by placing one electrode stationary where one station and all potentials are referred to that point. Polarity of the leapfrog data potential was reversed for all positive north measurements after the drift correction was done. Interpretation of results was greatly affected by random errors (noise). The major source of the errors may include; changes of solution in the pots, or instability of connections throughout the day, changes in ionospheric and telluric currents which can affect potentials in the ground, cultural noise and contact resistances and soil moisture which can greatly affect the voltage readings.

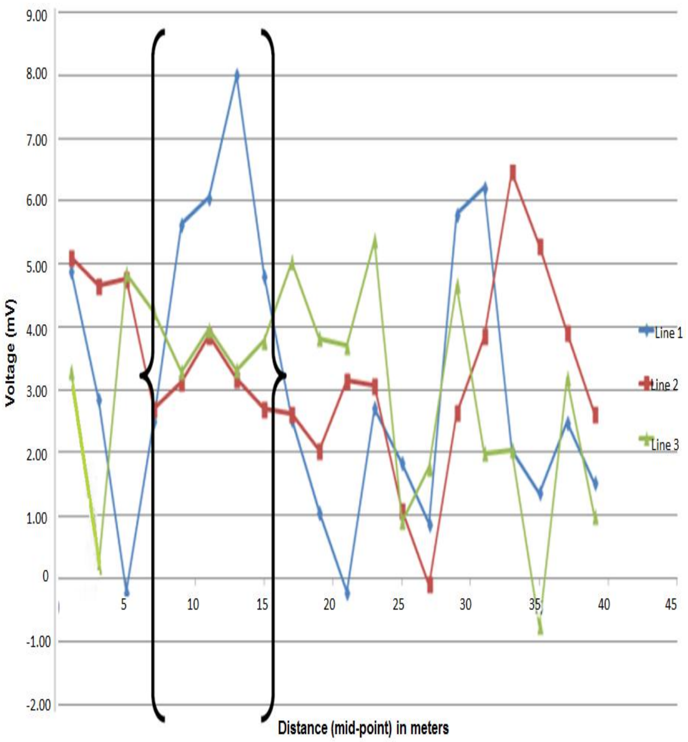

Figure 3: Leap frog plot of voltage vs distance

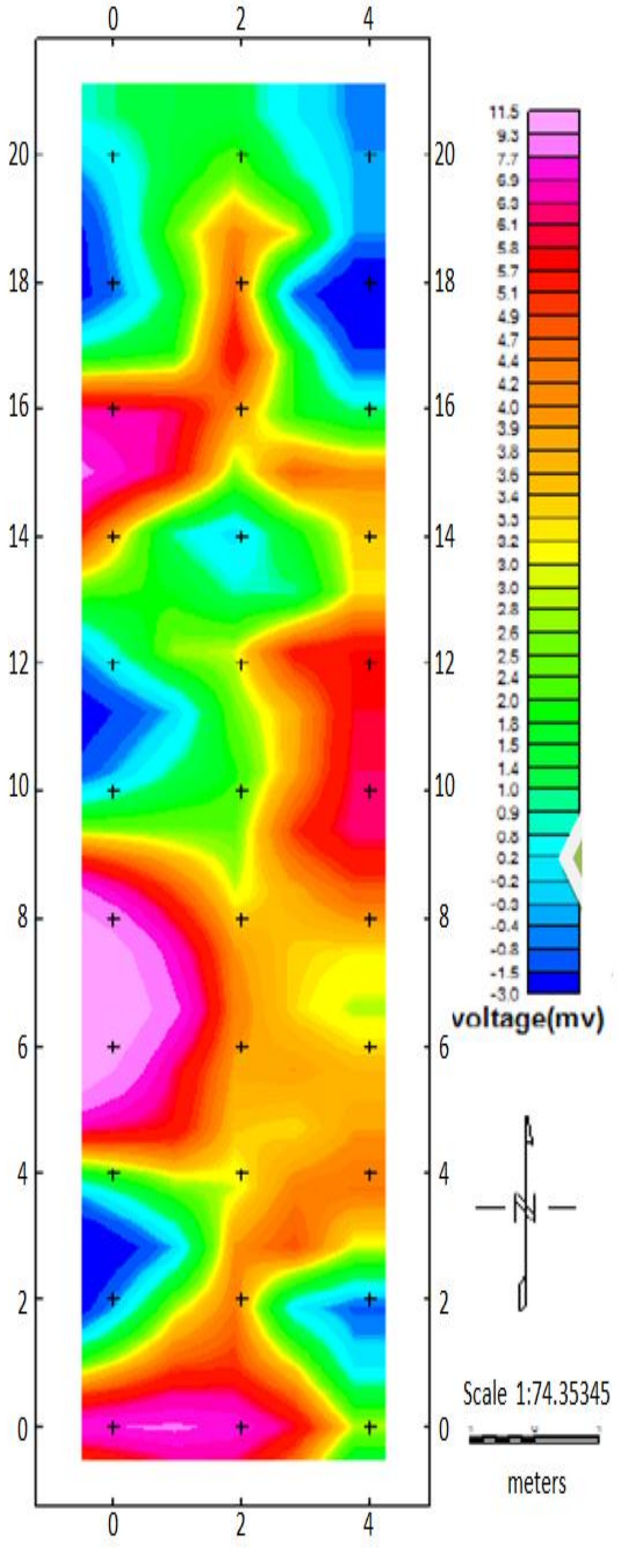

Figure 4: *Grid of voltage readings across survey area for leap frog*

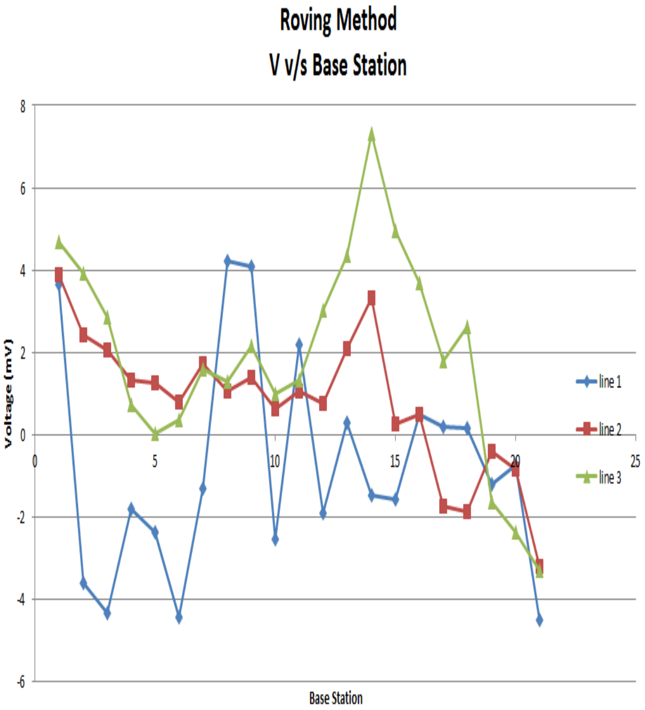

Figure 5: *Plot of voltage for the roving dipole data*

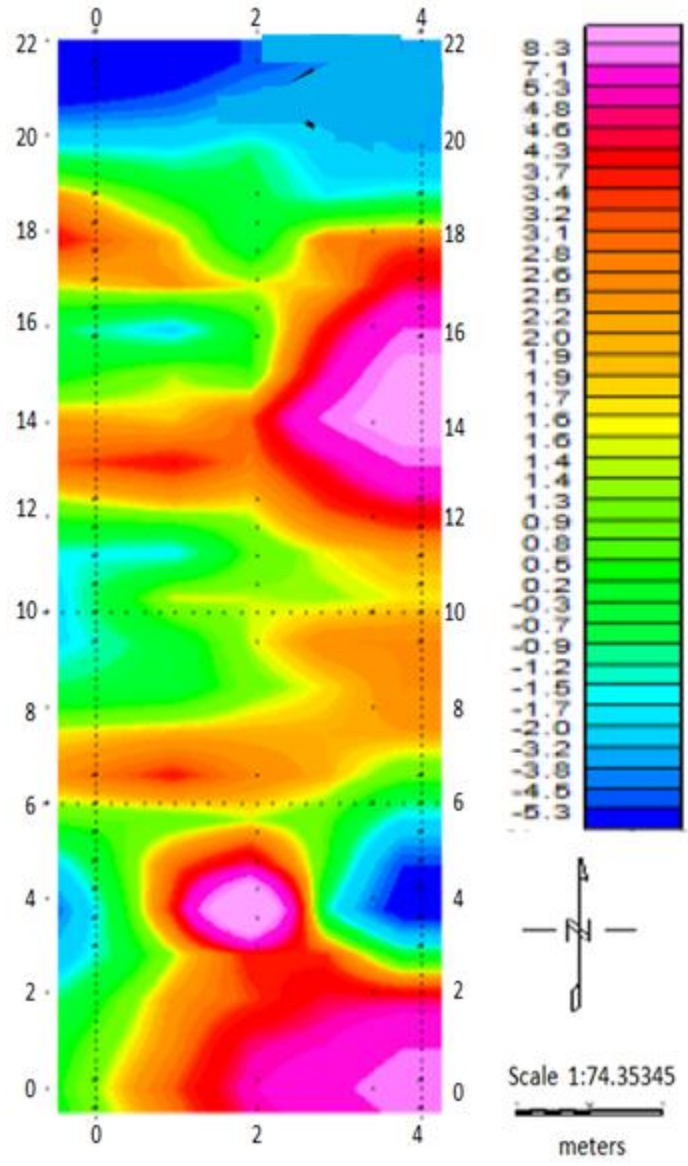

Figure 6: *Grid of voltage readings across survey area for roving dipole*

5. DISCUSSION

Interpretation of self-potential anomalies requires us to define the possible sources of self-potential in the survey area. Generally the self-potential sources in the ground are produced either by; thermoelectric, electrokinetic or electrochemical processes that occurs in nature. Thermoelectric potentials are sourced from thermal gradients in the semiconductors in the ground. Based on our survey location, it is not likely to have much of a thermal gradient hence thermoelectric effects is negligible. Self-potential anomalies in this area are likely to be produced by electrochemical and electrokinetic processes occurring within the ground (Corwin and Hoover 1979). Electrokinetic potentials occur via the movement of material in differing phase. In nature this is commonly from water based solution flowing through solid sediments. Electrochemical effects occur anywhere there is a concentration gradient of chemicals with electrical bias. In nature this commonly occurs through; ionic concentration gradients, the reduction - oxidation zone, the concentration of hydrogen ions in areas with acidic gradients, bioelectric processes that concentrate ionic salts or anywhere metallic materials are in solution (Telford 1976).

Figures 4 and 6 above represent a linear feature showing the location and the direction of the pipe underground to a depth of perhaps 2m. Other anomalies on the map may be as a result of trees interference in our observed data while the negative voltage readings show the presence of the pipe and water flowing through it. The interpretation of SP data requires a higher sensitivity survey that may be achieved in future surveys by continuously monitoring noise and using more accurate potential electrodes.

6. Conclusion

Self - Potential electrical surveys were conducted over an area known to contain underground leakages. High sensitivity was desired to detect passive source anomalies of only tens of millivolts but the survey was strongly influenced by noise up to five millivolts. There were numerous small circular potential anomalies but the only trends that could be correlated across the two surveys were the linear E-W trend which shows the location and the direction of the pipe underground to a depth of around 2m.

REFERENCES

[1] B. Khesin, “Use of Geophysical Methods for the Solution of Environmental Problems in Israel”, HALT Journal of Science and Engineering B, Volume 2, Issues 1-2, pp. 95-124, 2005

[2] C.E. Corry, G.T. De Moully, M.T. Gerety, “Field Procedure Manual for Self-Potential Surveys” Z.E.R.O. Publishing, Arizona, USA 1983.

[3] J.E. Nyquist, and C.E Corry, “Self-potential: The ugly duckling of environmental geophysics” The Leading Edge, 21(5), 446-451 2002.

[4] D.K. Butler, and J.L. Llopis “Assessment of anomalous seepage conditions” Geotechnical and Environmental Geophysics, Vol. 2: Environmental and Groundwater. S. H. Ward, ed., Society of Exploration Geophysicists, Tulsa, OK (1990)

[5] R.F. Corwin, “the Self-Potential Method for Environmental and Engineering Applications, Geotechnical and Environmental Geophysics. Volume I: Review and Tutorial. S.H. Ward (ed.) Society of Exploration Geophysics (1990)

[6] A. Lange. & K. Kilty Natural-potential responses of karst systems at the ground surface; Proceedings of the Third Conference on Hydrogeology, Ecology, Monitoring, and Management of Hydrogeology in Karst Terrains, 179-196 (1991).

[7] F. Fagerlund,. & C. Heinson, Detecting subsurface groundwater flow in fractured rock using self-potential (SP) methods; Environmental Geology 43, 782-794 (2003).

[8] M. Aubert, & Q. Atangana, Self-potential method in hydrogeological exploration of volcanic areas, Ground Water 34, 1010-1016 (1996)

[9] M.A. Eriksen, Field Geophysics 4th Edition, Wiley, Pp 213-214 (2011).

[10] P.M. Keary, Brooks, I An Introduction to Geophysical Exploration; 3rd Edition; Blackwell Science Pp 183-185 (2002).

[11] A.E. Mussett, Khan, M.A. Looking into the Earth: An Introduction to Geological Geophysics; Cambridge: Cambridge University Press (2009)

[12] D. Parasnis, D. Principles of Applied Geophysics, Chapman and Hall, New York, 402 pp (1986).

[13] J. M. Reynolds, An introduction to Applied and Environmental Geophysics. 1st Edition, Wiley Pp 127 (2007)

[14] R.F. Corwin & D.B. Hoover the self-potential method in geothermal exploration, Geophysics, 44, pp. 226–245 (1979).

[15] R.E Sheriff Geophysical Methods Prentice Hall. Englewood Cliffs, New Jersey 1989

[16] H.W. Stanley Resistivity and Induced Polarization Methods: Science and Research document, University of Utar Research Institute (2004).

[17] W.E. Wightman, F. Jalinoos, P. Sirles, & K. Hanna “Application of Geophysical Methods to Highway Related Problems”, accessed September 15, 2015 (2003).

[18] M. Sato, & H.M mooney “the electrochemical mechanism of supplied self-potentials” Geophysics, 25, 226-2 (1960)

[19] E.S. Parasnis “Mining geophysics” New York, Elsevier, 356p. 1966,

[20] W.M. Telford, C.P. Geldart, R.S. Sheriff, and O.A. Keys,) Applied geophysics Cambridge University Press Cambridge (1976)