

Geophysical Self-Potential Investigation to Detect Buried Water Supply Pipe Location in Kirkuk City-Northern Iraq

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Abstract

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The newly established Seikanian suburban area is located about 5 km north of Kirkuk City. The area has a civil engineering problem concerning the unknown location of the water supply buried pipe in a road which might be destroyed during excavation works for maintenance operations. The geophysical surface self-potential method is chosen to find the pipe's location and depth. For acquiring data grid self-potential 20 and 22 points measurements were taken around the suspected location of the pipe within non-streaming water and streaming water in the pipe conditions respectively. Additional two survey lines of gradient configuration of 28 m length away of 3.5 m from the suspected buried pipeline carried out in the two conditions also. The grid self-potential points are rendered into observed, regional, and residual contour maps using Surfer software 8. The interpreted self-potential gridded points in non-streaming water pipe conditions yielded positive anomalies in the observed map but the streaming water produced dominantly negative anomalies map. The residual self-potential maps in the two conditions showed positive and negative anomalies, all anomalies in the self-potential maps were spread along the center line of the maps where the suspected buried water supply pipe is extended, the residual maps showed it more clearly. To constrain the location of the buried water supply pipe second horizontal derivative technique upon the residual self-potential maps was applied and the constructed maps revealed accurately the anomalies aroused from the buried pipe spread over the center line. The gradient surveyed line profiles indicated that the self-potential signals submit to potential field theory formulations. The curve anomaly analysis of the survey line across the suspected buried pipe in the streaming water condition determined the depth of the buried pipe as 1.4 m.

Keywords: Self-potential; Gradient survey; Buried pipe; Kirkuk ; Iraq

1. Introduction

Different Geophysical methods contribute in identifying and delineating subsurface materials, Self-potential (SP) method is one of them used to investigate the location of karsts, caves, underground water pathways and buried conduit and pipes. The SP present in near the surface of the earth is created by electrokinetic or streaming potential due to fluid in the ground, diffusion potential in a boundary of different chemical substances and redox reaction of subsurface metal materials (Fritjof and Graham, 2003). The flow of the pore water in a porous material is responsible for generating an electric current known as the streaming current (Revil et al., 2017). The natural electric potential difference yielded by streaming, or electrokinetic potential due to the underground movement of water is which more efficiently detected by the SP method more than any other geophysical techniques. The SP method has

been widely used in groundwater flow studies due to its effectiveness in detecting subsurface water movement (Zakaria et al., 2018). There are many research papers were published in the world concerning the SP method in subsurface investigation for buried objects (Tajudeen et al., 2018).

Infiltration test from a ditch has been conducted aimed at monitoring the evolution of the piezometric levels using SP measurements (Suski et al., 2006) applied at the ground surface and the investigation shows the effectiveness of the SP method in field conditions to monitor small variations of the water table.

Investigation carried out to find the relationship between SP signals and redox potential distributions were associated with the corrosion of metallic materials within the subsurface (Rittgers et al., 2013). The results of the SP inversion were found to be in excellent agreement with the measured distribution of the redox potential, this relationship can be applied in monitoring corrosion processes.

In order to find the preferential flow pathway in a sandbox a laboratory experiment was carried out using a heat pulse monitored by time-lapse SP measurements to explore the capability of this method for tracing preferential flow paths (Ikard et al., 2015). They determined preferential flow pathways especially in a very permeable environment and in real time.

Electrical resistivity and SP survey were applied to find the location of an inferred trunk conduit which is feeding the major spring in the Inner Bluegrass region of Kentucky (USA) at three sites (Tripathi and Fryar, 2016). The results showed a negative SP anomaly corresponded to a low electrical resistivity anomaly for most of the profiles.

SP investigations was carried out in the farming land nearby Quldara village northeast of Kirkuk, Iraq, the acquired data was processed and presented as profiles and contour maps (Ali, 2018). The interpreted data indicated the occurrence of the groundwater in the study area.

3D time-domain induced polarization survey in a way similar to a SP time-lapse method has been applied to find the location of the underground metallic pipes (Shao et al., 2018). The results showed that the SP method is effective for localizing those pipes.

An experimental earth dam was investigated to know the ability of the SP method to characterizing the water seepages, they used finite element technique to simulate the ground water flow in a porous heterogeneous material (Ahmed et al., 2019). They deduced that the detecting a SP anomaly amplitude is consistent with that obtained from numerical modelling.

A water pumping test process has been carried for monitoring the water level changes and SP measurement to evaluate the hydraulic characteristics of the aquifer in Laylan area in the northeast of kirkuk City (Sultan et al., 2022). They deduced a mathematical relationships between the SP measurements and the water table drawdown with its elapse time.

In a study of SP method applied to map the leachate flow around landfill in Indonesia in the Sungai Raya district area using fixed base configuration (Muhadi, 2023) . The results determined the location of the leachate indicated by SP negative values.

Seikanian is a Suburban recently established in the north of Kirkuk city, around 5km far from the city center, with coordinates of latitude 35°56'56"-35°56'58"N and longitude 44°36'23"-44°36'25"E (Fig. 1). This area is located in the northeastern limb of Kirkuk Anticline, the site is underlain by Mukdadiya Formation rocks composed of inclined beds of sandstone, mudstone and conglomerate (Jassim and Goff, 2006; Abo-Khomra et al., 2022). The site surface is covered by Recent deposits of silty clay and silty sand with gravel sediments. There are many population services should be introduced such as road pavement, power lines and water supply pipes laying in the area in addition to make maintenance to underground laying waste and water supply pipes. There is a problem concerning part of a buried water supply pipe that provides civilian water should be cared during excavation, filling works and its position in a road is not very clear.

The importance of the present work is to explain the potentiality of surface SP geophysical method application as a tool to solve troublesome concerning underground buried materials. The aim of the recent research is to delineate the location and depth of the pipe by surface SP geophysical method.

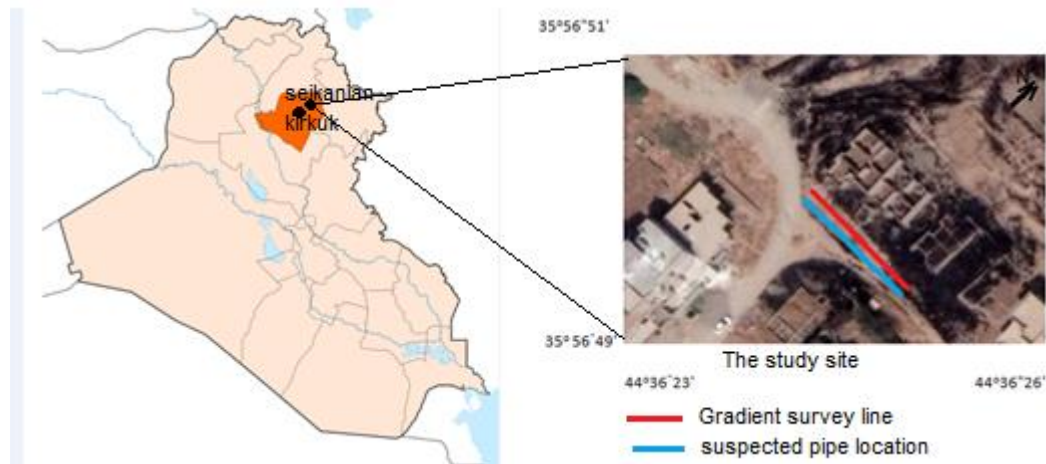


Fig. 1. Location of the study area within the Kirkuk City

2. Materials and Methods

Geophysical surface SP method is applied on the ground by measuring the electric potential difference in mV using two non-polarized electrodes connected by low electrical resistance cable. There are two configurations of the electrodes (Fig.2), the first one is the gradient (or frog leap) in which the two electrodes are moved in a constant distance along the survey line, the second configuration is the fixed base (or Total) one of the electrode is fixed out the survey line as a reference base and the other is moved in a certain distance along the survey line. In the study site we carried out a gradient configuration survey line which was (3.5) m away from suspected buried pipe extend of (28) m length along the road (6 m width) underlain by the water supplied buried pipe (6-inch diameter) during the streaming water and non-streaming water situations. Additional 20 and 22 grid points of SP measurements around the suspected location of the underlain pipe in the road of the two situations, 2 m was used between the grid points (Fig.3).

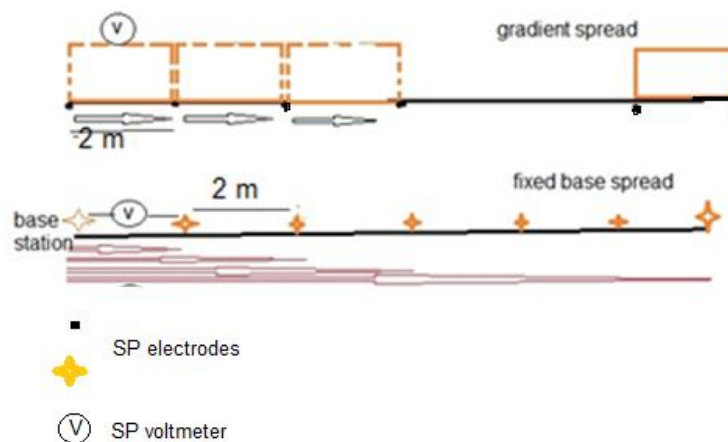


Fig.2. SP survey showing the two electrode configurations in the study area

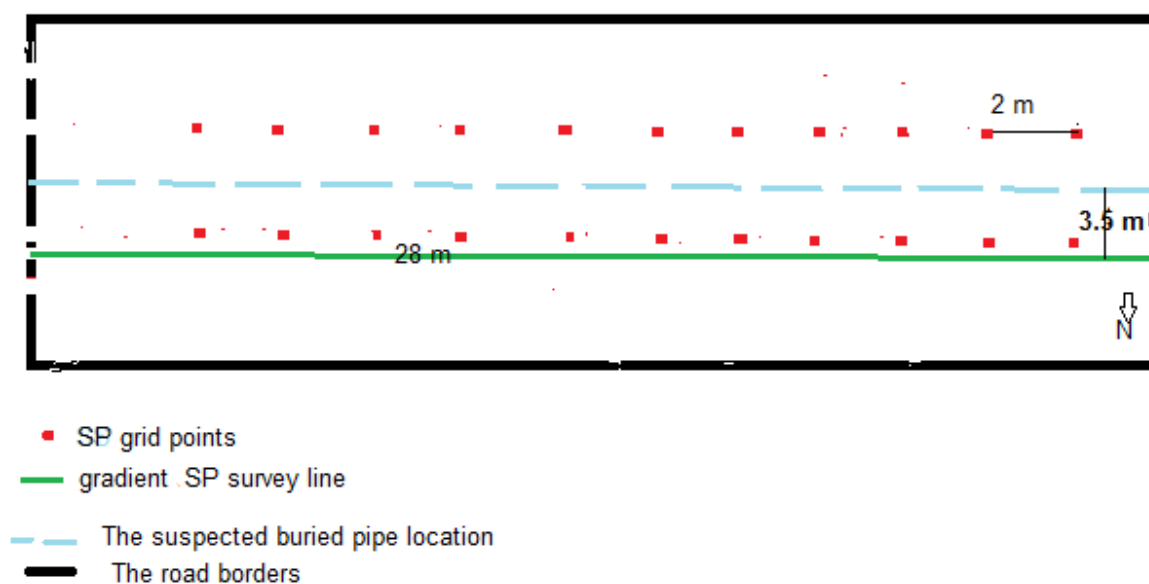


Fig.3. Site plan showing the measured SP points and SP gradient survey line design at the study area

The SP acquired data interpreted as profiles, the grid points of SP measurements rendered into contour maps using surfer 8 software. The observed SP contour maps constructed by Kriging interpolation operation of the SP grid points, the regional contour maps by second order polynomial regression operation and the residual contour maps yielded by subtraction the regional grid contour maps from the observed contour grid maps.

3. Results and Discussion

3.1. Interpretation of Contour SP Maps (Non-Streaming Water Condition)

3.1.1. Observed SP contour map

The observed SP contour map (Fig.4) poses many semicircles of maxima and minima positive anomalies, SP positive values ranged from 2 to 52 mV (i.e 2mV minima and 52 mV maxima), these anomalies buildup from the underlain pipe effect which is located in the center of the map along the survey line run through the zero coordinate.

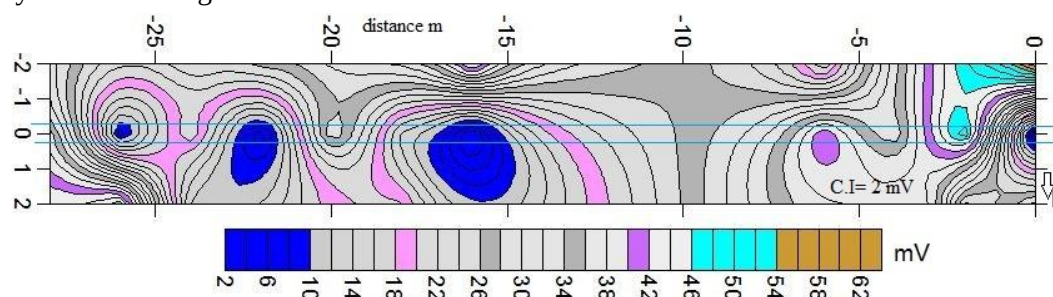


Fig.4. Observed SP contour map in non-streaming water condition

3.1.2. Regional contour map

The observed SP map was subjected to the second order method for separating the residual anomaly from the regional one. However (Fig. 5) revealed the regional contour map with positive values ranging from 14 to 50 mV spread as broad elliptical isopotential contour lines, it represents the background effect of the buried pipe on near surface soil of the site.

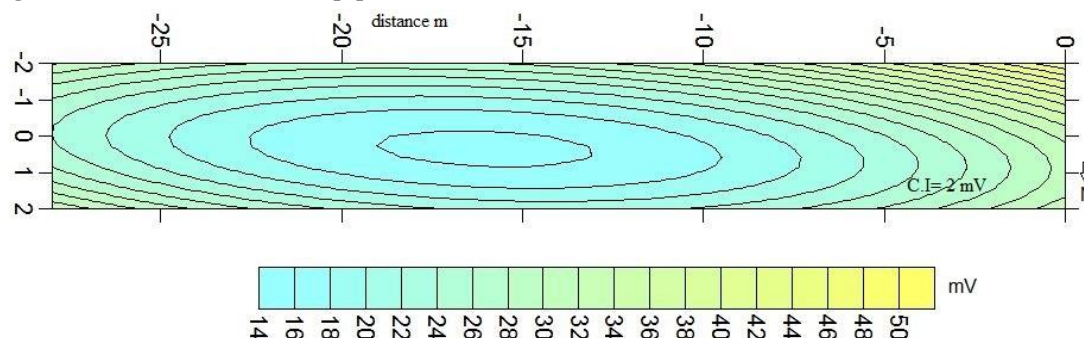


Fig.5. Regional second order SP contour map in non-streaming water condition

3.1.3. Residual SP contour map

The residual map, on the other hand, involved many semicircles positive and negative anomalies as shown in (Fig. 6), the positives are 2 mV, 12 mV and 20 mV, whereas the negative anomalies are -26 mV and -12 mV. Most of these anomalies which generated by the buried pipe effect are within the center line of the map.

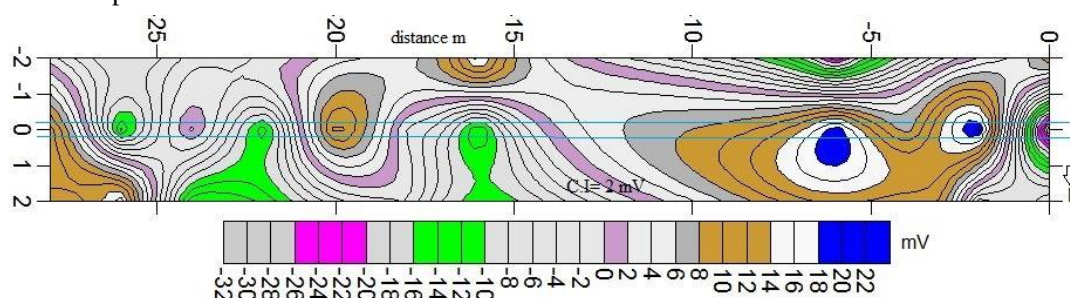


Fig.6. Residual SP contour map in non-streaming water condition

3.2. Interpretation of SP Contour Maps (Streaming Water Condition)

3.2.1. Observed contour SP map

The observed SP contour map (Fig. 7) in the water streaming condition is dominated by negative SP amplitudes ranging from -2 to -44 Vm, because of the water is streaming in the pipe where considered as porous media in which it gives rise to accumulation of excess mobile ions (negative) in the water and then yields a streaming of the electric current, subsequently potential streaming condition, (Arens et al., 2020), this is unlike situation in the non-streaming water condition. The positive SP of 6 mV is the unique effect present in the circumference, and the negative semicircle anomalies of -42 mV and -30 mV spread over the map along the center line of the map.

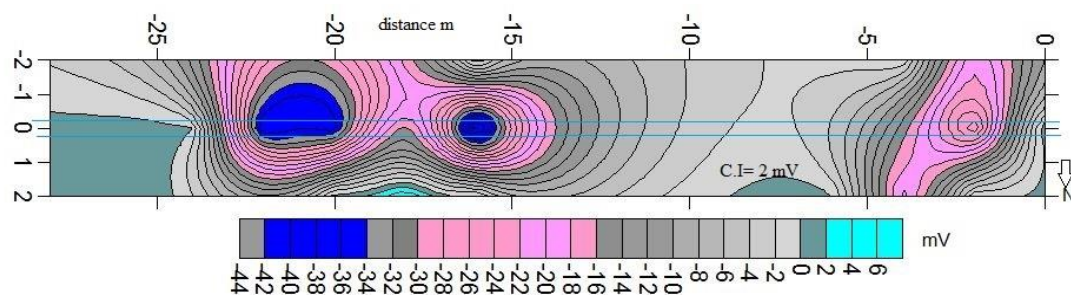


Fig.7. Observed SP contour map in streaming water condition

3.2.2. Regional SP contour map

The second order regional SP contour map composed of broad elliptical negative isopotential contour lines predominantly with positive contour lines in a small part of the map, it represents the effect of background of near surface soil in the water streaming environment (Fig. 8).

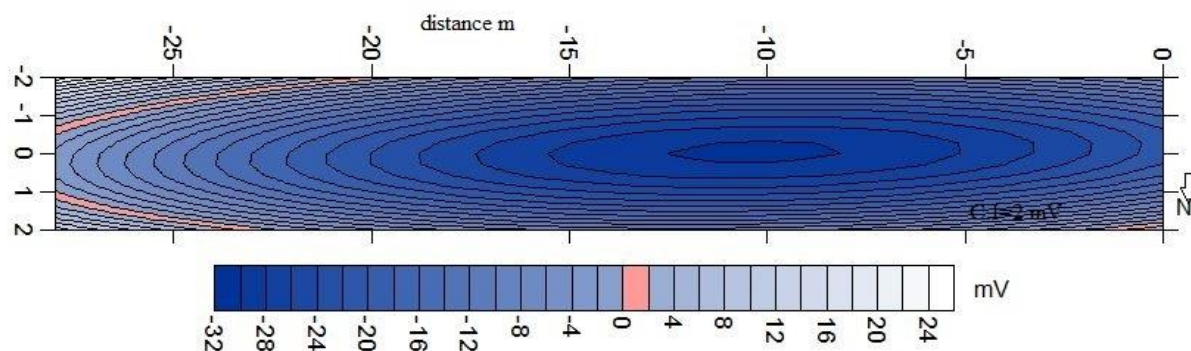


Fig.8. Second order Regional SP contour map in the streaming water condition

3.2.3. Residual SP contour map

The residual SP contour map (Fig.9) comprised predominantly many positive anomalies, two elliptical forms of 25 and 10 mV, another semicircle of 20 mV. There is a negative anomalies of -5 mV and -15 mV in the center line of the map, another negative anomalies of -15 mV and -35 mV are situated in the border of the map. The buried pipe printed its effect on the SP measured on the ground, which indicated by the arrangement majority of the anomalies in the center line of the previous maps.

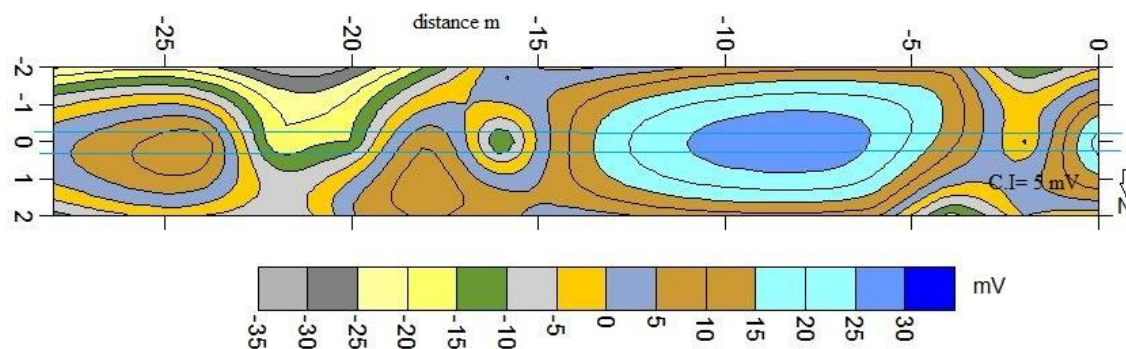


Fig.9. Residual SP contour map in streaming water condition

3.3. Second Horizontal Derivatives SP Contour Map

The interpretation of the potential field data to determine location of the horizontal boundaries of the subsurface objects caused anomalies, and determine the edge of the geological contact boundaries by second horizontal derivative analysis are the important issues in the geophysical investigations (Fedi et al., 2001; Ibraheem et al., 2019). For location detection of the buried pipe more accurately, the second horizontal derivative operation was applied to yield residual contour maps in the non-streaming and streaming conditions via surface 8 software. Fig. 10 is the gave way second horizontal derivative SP map in non-streaming water condition that composed of different negative and positive anomalies, most of them located along the center line that run through the zero coordinate of the map.

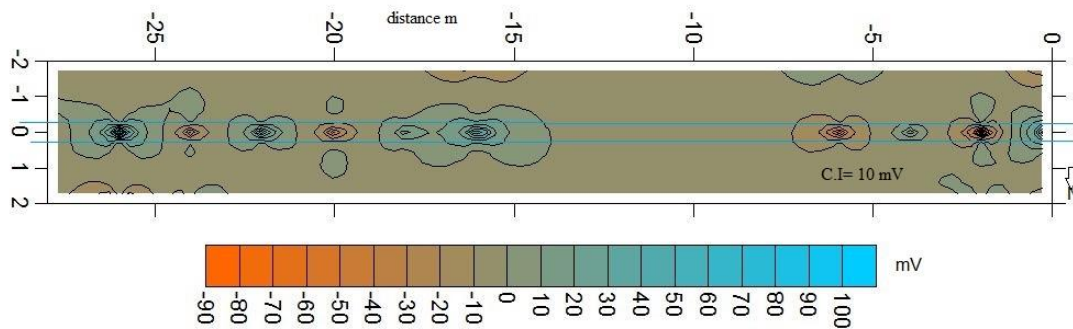


Fig.10. Second horizontal derivative SP contour map in non-streaming water condition

Fig.11 reveals the second horizontal derivative SP map in the streaming water condition that comprised also a positive and negative anomalies, the major of them are situated in the center line along the map. These two maps (Fig.10 and 11) accurately emphasised the location of the buried pipe which is lain in the center line of the studied area.

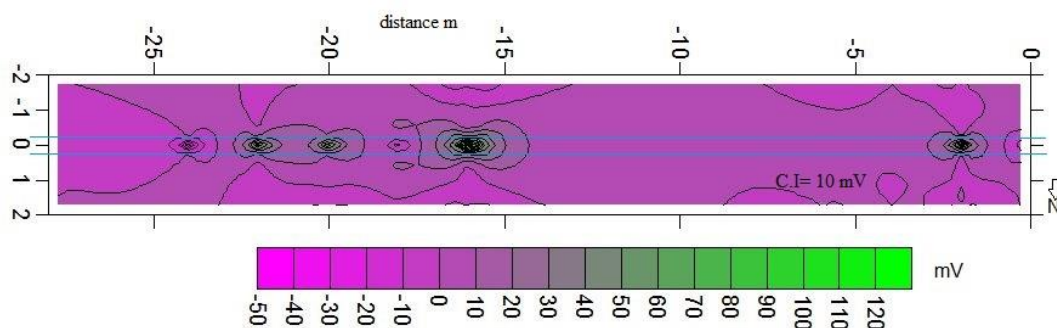


Fig.11. Second horizontal derivative SP contour map in streaming water condition

3.4. Gradient Survey SP lines

The SP acquired data covered the road which enclose the buried pipe yielded the previous SP contour maps, in order to experience how the pipe print its showed the effect onto the measured SP signals of the near surface soil in some distance away from expected location of the pipe, we carried out a survey line of gradient configuration of 28 m length, 3.5 m away from the expected underlain pipe location in the two non-streaming and streaming conditions. Fig.12 is a non-streaming condition profile showing the SP positive ranged from 30 to 50 mV which are generally lower than the SP amplitudes of the observed contour map.

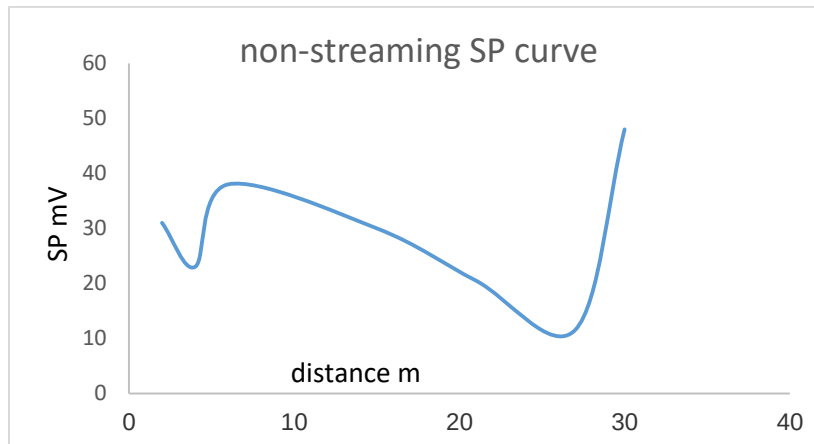


Fig. 12. Gradient survey line curve in non-streaming water condition

Fig. 13 represent the profile of streaming water condition, there are low positive (SP) measurements ranged from 0.2 to 1.5 mV while the observed contour map SP point measurements were dominated by negative values, but it is more disturbed than the non-streaming curve, it indicates that buried pipe impact upon the near surface soil of the studied site, it was more clearly shown in the water streaming situation. (Telford et al., 1990) realized the strength of the potential field (magnetic field) decreasing with a square of distance from the source (El-Araby, 2004), on the other hand, formulated the SP anomaly expression produce by most polarized structures in which the source depth is inversely proportional with the SP amplitude, this means that the SP signal conform the potential source theory and its dimension effects. As it was observed that the measured SP values above the suspected pipe location are more than the measured SP values of the gradient survey lines curves in the two non-streaming and streaming water condions which are 3.5 m away from center line, (i. e) there is an inverse relationship between the SP values and the distance from the source (pipe).

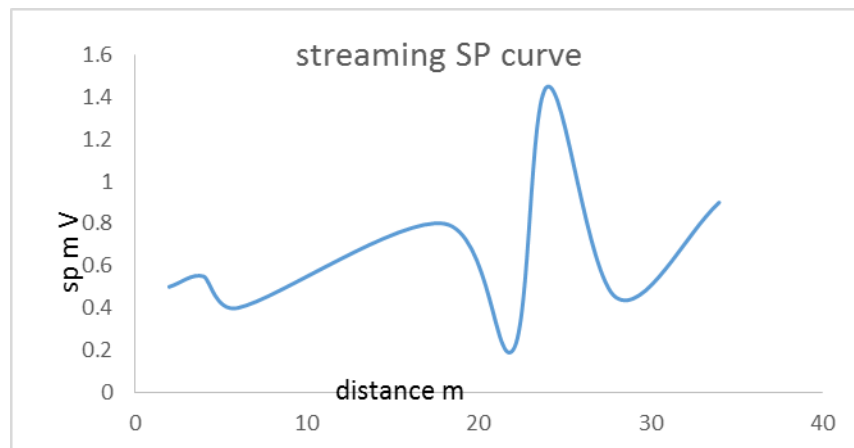


Fig.13. Gradient survey line curve in streaming water condition

3.5. Depth Determination

There are many methods applied to determine the depth of SP signal aroused from subsurface object sources, one of them is (Nwosu et al., 2011) in which it was used the Half-Max Width by graphical analysis for SP anomaly survey curve line to determine the depth of the target.

We conducted a survey line across the suspected buried pipe of 8 m length in the streaming water condition, which yielded a sharp and smooth anomaly curve, the anomaly analysis by the half-width method illustrated the pipe depth at 1.4 m (Fig. 14).

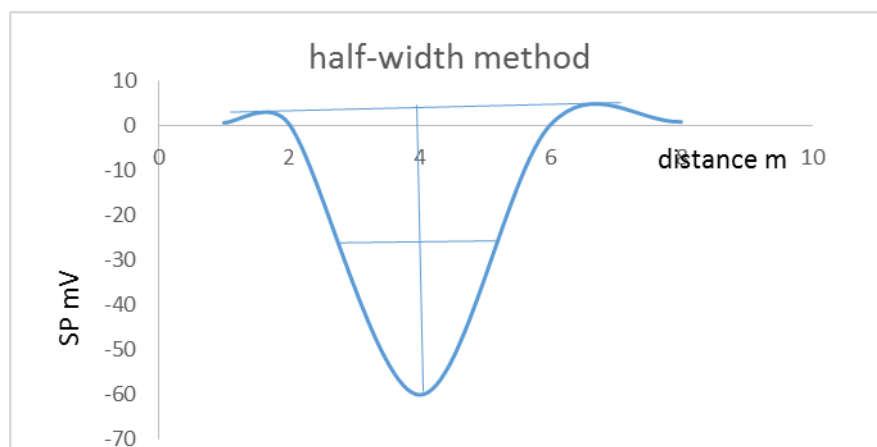


Fig.14. Half-width analysis to determine the depth of the pipe

4 . Conclusions

Geophysical surface SP method was carried out on the road underlain by a buried water supply pipe to find its location and depth, the investigation were in non-streaming and streaming water conditions. The observed contour map in a non-streaming condition yielded positive SP anomalies but observe map in streaming condition revealed dominantly negative anomalies with few positive of its border as result of contrast factor in electric properties between buried underlain pipe and the background near surface soil. The majority of these anomalies are located in the center line of the maps where the buried pipe is extended. The pipe electric potential effects are shown more clearly in the residual SP maps of the two conditions characterized by negative and positive anomalies spread along the center line of such maps. Second horizontal derivative method was applied upon the gridded contour residual maps, the aroused anomalies accurately spread over the center line of the maps. The SP signal amplitudes was reduced in distance from buried pipe location indicate that the SP signal submit to potential theory formulations. Half-width method in quantity interpretation of SP anomaly was used to determine the depth of the buried pipe, it was obtained as 1.4 m.

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