Geophysical and Hydrochemical Characteristics of Groundwater at Kerian Irrigation Scheme

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Abstract. A study was conducted to determine the potential of groundwater uses at the Kerian irrigation scheme, specifically the Selinsing irrigation area. Resistivity image profiling method was employed at four sampling locations within the study area to identify the depth and variation of aquifer layer and the possibility of hard layer presence. Investigations conducted revealed that the thickness of aquifer within the study area varies between 5 m and 10 m, which is located at a depth of 30 m to 70 m below the ground surface. The thickness of clay layer is between 1 m and 80 m which dominates the upper subsurface layer. Seven samples of groundwater were used in determining their hydrochemical and physicochemical characteristics, ionic composition, and the quality suitability for irrigation use. A preliminary characterisation based on the piper diagram provides the hydrofacies classification while Stiff diagram is used to exhibit the ionic relationship. The degree of correlation between cations and anions has been estimated in order to assess their mutual relationships. Strong positive correlation exists for \( \text{Ca}^{2+} - \text{Mg}^{2+} \), \( \text{Ca}^{2+} - \text{Na}^{+} \), \( \text{Na}^{+} - \text{Mg}^{2+} \), \( \text{Na}^{+} - \text{K}^{+} \), \( \text{Ca}^{2+} - \text{K}^{+} \), \( \text{Mg}^{2+} - \text{Cl}^{-} \), \( \text{K}^{+} - \text{HCO}_{3}^{-} \), and \( \text{Na}^{+} - \text{Cl}^{-} \). Profusion of elements also reflects the composition of aquifer and the climatic conditions, which possibly contribute to the genetic relationship.

Keywords: Geophysical, groundwater, hydrochemical.

1. Introduction
Groundwater is an integral part of water resources. It is a main source of water supply and plays a vital role in the eco-environmental maintenance and socio-economic development in arid and semi-arid regions of the world [1]. Sustainable water management is vital for maintaining the ecosystem’s balance and economic development [2] and [3].

Geophysics is the application of physics to study the earth such as by taking measurements at or near the surface of the earth. As these surfaces were influenced by the internal distribution of physical structures and properties, the variation of subsurface structure which possesses different physical attributes is estimated to reflect the condition of the earth structure [4].

Non-intrusive geophysical techniques such as electrical resistivity survey has been applied for many decades to determine the thickness and resistivity of the layered media as well as to map the
geological environment of existing aquifer. This method has been greatly favored due to the contrast between the electrical properties of water and soil [5]. In other words, the subsurface material is represented by unique bulk electrical conductivity value. The measure of ground conductivity shows the strength of the secondary magnetic field detected by a current-carrying transmitter coil [6]. In the past, Schlumberger sounding is commonly used in determining the resistivity variation with depth [7]. However, it is very difficult to perform resistivity soundings everywhere without prior information. These classical geophysical techniques determine the physical properties of the subsurface, which are only indirect indicators of water content and hydraulic conductivity. Due to rapid development of technology, geophysical hardware and software tools have provide the opportunity to obtain high resolution quality of geophysical data. They are widely applied to supplement conventional borehole sampling which is expensive and provide information based on the effects at the sampling site [8]. They are also chosen due to the simplicity of the techniques, easy interpretation and rugged nature of the associated instrumentation.

Meanwhile, hydrochemistry is the subdivision of hydrology which deals with chemical characteristics of water. The sustainable development and effective management of the valuable groundwater resources of an area requires better understanding of hydrochemical characteristics of the groundwater and its evolution under natural water circulation processes, as well as the origin and residence time of the groundwater [9]. The quality of groundwater is equally important in identifying suitable uses of water. Water quality investigation is a significant agenda in groundwater studies. The ever increasing new knowledge on the hydrochemical processes governing groundwater quality has led to more exploration of groundwater use. Hydrochemistry studies provide insight into the interaction between groundwater and its environment and contribute to better groundwater resource management and planning [10]. Variation of groundwater quality of an area is a function of physicochemical parameters that are greatly influenced by geological formations and anthropogenic activities [11].

Due to the importance of hydrochemical characteristics and its influence on water quality, the aim of this study is to assess the spatial distribution of hydrochemical constituents of groundwater. The proposed method relates the assessed constituents for better understanding of hydrogeological and its suitability for agriculture use, with an application to Kerian irrigation scheme.

1.1 Study area
Currently, approximately 20% of the land in Malaysia is utilised for agricultural purposes. More than two thirds are for industrial crops, mainly rubber and oil palm plantations while paddy cultivation covers 660,000 ha (2% of total land area)[12].

Selinsing irrigation scheme located in the southern part of Kerian district (4°56’10”N - 4°57’34”N and 100°38’27”E - 100°39’21”E) is a typical irrigation scheme and is one of the granary areas in Malaysia.

Selinsing scheme experiences a humid tropical climate with high average annual rainfall of about 2,420 mm and temperature between 27°C and 28°C. The scheme lies mostly along the coastal fringe where flat marine alluvial soil provides favorable environment for the agricultural activities such as paddy growing [13].

Selinsing canal originating from Bukit Merah reservoir is designed to supply water for agricultural activities in compartments G and H (Figure 1), covering an area of almost 12,166 ac. (49.23 km²).
2. Methods

2.1 Geophysical

Resistivity image profiling (RIP) survey was conducted on field using Terrameter SAS 4000 system, LUND ES464 electrode selector system, multi-core cables with total layout length of 800 m span with 10 m spacing between each electrodes. It is a fully automated technique that uses a number of electrodes connected by a multicore cable. Since measurements are done automatically, settings of electrode array and others have to be configured according to the tasks by taking account into the depths of interest, data density, and time spent.

The resistivity meter controls the positions of current and potential electrodes through a microprocessor controlled electronic module [14]. The RES2DINV resistivity inversion software [15] was used to automatically invert the apparent resistivity data from field and forward it into the two-dimensional models. RES2DINV is a least square inversion that uses smoothing technique [16] and [17]. By applying the appropriate survey and data interpretation techniques, 2D and 3D visualisations of the subsurface profile can be obtained. The smoothness-constrained least-square inversion method is used to produce the subsurface resistivity models. This inversion method minimises the square of the differences between the measured and calculated apparent resistivity values and produces earth resistivity models with gradual transitions across zones of different resistivities [18]. The smooth inversion method gives better results for areas where the subsurface resistivity changes in a gradual manner, while the blocky inversion method gives significantly better results where there are sharp boundaries [19].

However, the model with the lowest possible RMS error occasionally shows large and unrealistic variations in the resistivity values. Most of the inversion models produce very small RMS error, i.e. less than 3% [14]. Generally, the most prudent approach is to choose the model at the iteration after which the RMS error does not change significantly. This usually occurs between the 3rd and 5th iterations (Loke, 2004). Resistivities are adjusted iteratively until an acceptable agreement between the input data and the model responses is reached [20].
2.2 Hydrochemical
Groundwater samples from 7 tube wells were analysed between April and July 2009. The samples were extracted at depths ranging between 5 m and 45 m. Water samples were collected using suction pumps after purging at least three well volumes. Samples were stored in pre-sterilised polyethylene bottles without any preservative to avoid contamination.

In order to eliminate any potential contaminant, the sample bottles were triple-rinsed with MilliQ water (18 mΩ·cm) and then filled with 50%, v/v solution of reagent-grade HCl and MilliQ water prior to sampling [21]. Before collecting the sample, the bottle was rinsed 3 times with the sample water for conditioning purposes. Only ultra-pure water and deionised water were used for preparing solutions for analysis.

Concentrations of unstable parameters such as total dissolved solids (TDS), pH, temperature, and electrical conductivity were determined on site with Hanna HI9828 multiparameter probe to minimise the contact with air. The water samples were preserved and brought to the laboratory in minimum period of time for further analyses, as determined by [22] standard methods.

For analysing major cations (Na\(^+\), Mg\(^{2+}\), K\(^+\), Ca\(^{2+}\)) and anions (Cl\(^-\), SO\(_4^{2-}\), NO\(_3^-\)), the groundwater was filtered with a hand-held syringe using 0.45 μm membrane filter. The cations and anions were analysed by Dionex ICS-1000 with AS-DV50 auto sampler. Calibration for anion and cation analyses was performed using appropriately diluted standards which are issued by the ICS supplier periodically. Alkalinity was determined by the Gran titration method using 0.1 N HCl.

3. Results and discussion

3.1 Resistivity image profiling (RIP) survey
The 2D resistivity imaging survey was conducted along the Selinsing canal. Electrical signals were used to identify the resistivity value of the subsurface soil layers, and the data is inversed into the 2D resistivity model profiles by the RES2DINV software. The x-axis of the model signifies the distance along the cross section of the ground while the y-axis represents the vertical depth of the ground from the surface. The intensity of the resistivity is differentiated by various colors, thus the layer of aquifer can be identified. The resistivity of aquifer layer which contains groundwater ranges between 10 Ωm and 100 Ωm [23] and [24].

For Selinsing 1 area (Figure 2a), layer of clay was found at the earth surface, extending to a depth of 20 m below. The aquifer layer was found at a depth of about 30 m below the ground. Wide thin layer of low resistivity (blue colored zone) having 10 Ωm to 75 Ωm is observed to have depth varying between 20 m and 50 m below ground surface. This resistivity is either influenced by the clay layer or due to the infiltration from the nearest waterway.

Similar to S1 profile, Selinsing 2 (Figure 2b) and Selinsing 3 (Figure 2c) also show the same characteristics of the low resistivity layer.

![Figure 2a](image-url) Two-dimensional resistivity profile for Selinsing 1 (S1).
The thickness of aquifer layer is found to be varying between 5 m and 10 m. The aquifer layer is located at the depth of 30 m to 70 m below the ground surface, and even up to 140 m in some exceptional case. The main feature of the inverted resistivity profiles is that the aquifer occur in layers, which can be considered as consolidated porous media. The observation at Selinsing 4 (Figure 2d) showed that the aquifer layer is encountered at the depth of 40 m to 80 m, with moderate aquifer thickness of about 20 m.
3.2 Hydrochemical analyses

Table 1 shows the concentration of physicochemical parameters in the groundwater along Selinsing canal. Correlation matrix among 7 groundwater quality parameters of Selinsing canal is shown in Table 2. Meanwhile, the sodium concentration (NA%), SAR, total hardness (TH), and RSC of the groundwater are provided in Table 3.

Table 1. Ionic variation in the groundwater along Selinsing canal (April-July 2009).

| Well | pH  | EC  | TDS | Ca<sup>2+</sup> | Mg<sup>2+</sup> | Na<sup>+</sup> | K<sup>+</sup> | CO<sub>3</sub><sup>−</sup> | HCO<sub>3</sub><sup>−</sup> | Cl− | SO<sub>4</sub><sup>2−</sup> | NO<sub>3</sub>− |
|------|-----|-----|-----|-----------------|----------------|------------|----------|-----------|----------------|-----|----------------|---------|
| BH1  | 7.10| 590 | 45  | 7.73            | 0.94           | 1.82       | 1.42     | 0         | 135.6          | 19.89| 4.66           | 0.12    |
| BH2  | 6.85| 495 | 74  | 8.09            | 1.08           | 4.97       | 3.10     | 0         | 119.8          | 15.32| 46.18          | 5.51    |
| BH3  | 6.17| 129 | 46  | 7.83            | 0.58           | 1.79       | 2.69     | 0         | 164.7          | 3.61 | 17.81          | 2.88    |
| BH4  | 7.00| 516 | 122 | 8.34            | 2.65           | 39.96      | 2.28     | 18        | 125.7          | 54.44| 11.61          | 0.44    |
| BH5  | 7.06| 629 | 101 | 6.14            | 2.95           | 21.60      | 1.84     | 0         | 122.0          | 33.50| 28.40          | 0.59    |
| BH8  | 5.36| 721 | 30  | 3.00            | 0.61           | 7.38       | 1.20     | 10        | 115.3          | 44.98| 3.71           | 2.93    |
| BH12 | 7.50| 732 | 62  | 22.74           | 0.19           | 6.88       | 2.22     | 13        | 36.79          | 2.43 | 5.68           | 0.66    |

Note: All values are in mg/L except pH and EC

Table 2. Correlation of groundwater physicochemical parameters along Selinsing canal (April-July 2009).

|          | Ca<sup>2+</sup> | Mg<sup>2+</sup> | Na<sup>+</sup> | K<sup>+</sup> | CO<sub>3</sub><sup>−</sup> | HCO<sub>3</sub><sup>−</sup> | Cl− | SO<sub>4</sub><sup>2−</sup> | NO<sub>3</sub>− |
|----------|-----------------|-----------------|---------------|-------------|----------------|----------------|-----|----------------|---------|
| Ca<sup>2+</sup> & Ca<sup>2+</sup> | 0.955           |                |               |             |                |                |     |                |         |
| Mg<sup>2+</sup> & Mg<sup>2+</sup> | 0.965           | 0.971           |               |             |                |                |     |                |         |
| Na<sup>+</sup> & Na<sup>+</sup> | 0.942           | 0.906           | 0.973         |             |                |                |     |                |         |
| K<sup>+</sup> & K<sup>+</sup> | 0.445           | 0.178           | 0.229         | 0.317       |                |                |     |                |         |
| CO<sub>3</sub><sup>−</sup> & CO<sub>3</sub><sup>−</sup> | 0.851           | 0.866           | 0.909         | 0.905       | 0.624          |                |     |                |         |
| HCO<sub>3</sub><sup>−</sup> & HCO<sub>3</sub><sup>−</sup> | 0.872           | 0.918           | 0.945         | 0.871       | 0.389          | 0.885          |     |                |         |
| Cl− & Cl− | 0.044           | 0.125           | 0.028         | −0.006      | 0.495          | 0.144          | 0.034 |                |         |
| SO<sub>4</sub><sup>2−</sup> & SO<sub>4</sub><sup>2−</sup> | −0.374          | −0.379          | −0.369        | −0.278       | −0.133         | −0.191         | −0.400| 0.520          |         |
### Table 3. Total hardness (TH), RSC, SAR, and Na concentration of groundwater along Selinsing canal.

| Borehole ID | TH   | RSC | SAR | Na%  |
|------------|------|-----|-----|------|
| BH1        | 23.18| 1.80| 0.16| 27.20|
| BH2        | 24.65| 1.50| 0.44| 46.84|
| BH3        | 21.94| 2.30| 0.17| 34.76|
| BH4        | 31.74| 2.00| 3.09| 79.35|
| BH5        | 27.48| 1.50| 1.79| 72.01|
| BH8        | 10.00| 2.00| 1.02| 70.39|
| BH12       | 57.57|-0.11|0.39| 28.41|

The groundwater is considered suitable for irrigation purposes if the TDS concentration is less than 1000 mg/L. TDS concentration between 1000 mg/L and 2000 mg/L shows fair quality while the quality is inferior when the salinity exceeds 2000 mg/L. All 7 groundwater wells being sampled were considered suitable for irrigation use (Table 1).

### Table 4. Major ions distribution in the shallow groundwater along the Selinsing canal.

| Elements | Min. (mg/L) | Max. (mg/L) | Mean (mg/L) |
|----------|-------------|-------------|--------------|
| Na⁺      | 1.79        | 39.96       | 12.06        |
| K⁺       | 1.20        | 3.10        | 2.11         |
| Ca²⁺     | 3.00        | 22.74       | 9.12         |
| Mg²⁺     | 0.19        | 2.95        | 1.29         |
| Cl⁻      | 2.43        | 54.44       | 24.88        |
| HCO₃⁻    | 36.79       | 164.70      | 117.13       |
| CO₃⁻     | 0.00        | 18.00       | 5.86         |
| SO₄²⁻    | 3.71        | 46.18       | 16.86        |
| NO₃⁻     | 0.12        | 5.51        | 1.88         |

Sodium is the most abundant element found in the groundwater at the study area. Its concentration ranges from 1.79 mg/L to 39.96 mg/L with a mean of 12.06 mg/L (Table 4). Quite the opposite, the concentration of potassium is consistent, with value of 1.20 mg/L to 3.10 mg/L and an average of 2.11 mg/L. Both sodium and potassium have good solubility and mobility, and will not precipitate at any pH. The possible source of contamination is from the seawater.

As shown in Figure 3a, the mutual relation between Na and Cl is a linear correlation which indicates genetic relation with meteoric water [25]. This is proven by the correlation between the ions as shown in Table 2, where Na⁺–K⁺ is 0.973, Na⁺–Cl⁻ is 0.945, and K⁺–Cl⁻ is 0.871.
The Mg$^{2+}$ and SO$_4^{2-}$ relationship shows dual characteristics (Figure 3b). Sulphate SO$_4^{2-}$ concentration varies from 3.71 mg/L to 46.18 mg/L with an average of 16.86 mg/L and 2.95 mg/L, respectively. The maximum limit for sulphate and magnesium as prescribed by WHO for usage are 200 mg/L and 50 mg/L, respectively. The sampled groundwater has Mg$^{2+}$ and SO$_4^{2-}$ concentrations below the limits.

The correlation coefficient $r$ between the 7 groundwater quality parameters (in Table 2) shows the statistical measure of the interdependence of two or more parameters. The closer correlation value to 1, the relationship between the physicochemical parameters of underground water becomes stronger, which is given as

$$ r = \frac{N \Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{N \Sigma x^2 - (\Sigma x)^2 \left[N \Sigma y^2 - (\Sigma y)^2\right]}} $$ (1)

where,

$x, y$ = two different parameters,
$N$ = size of the sample

Distribution of the major ions shows compositional variations in the shallow groundwater samples (Table 3). In general, the trend of concentration distribution among cations shows Na$^+$ > Ca$^{2+}$.
$K^+ > Mg^{2+}$. Anions exhibit similar distribution pattern, where $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{CO}_3^{2-}$. The dispersion of ions in the groundwater at the Kerian irrigation scheme probably indicates similar geochemical environment, climatic conditions and pH, except for few anomalies.

pH of the groundwater varies between 5.36 and 7.50, with the mean of 6.72, indicating slight acidity. According to WHO standard, the desirable limit of pH for drinking water is between 6.5 and 8.5. Only BH3 and BH8 samples are not within the desired limit.

Electrical conductivity (EC) of groundwater is due to the presence of various dissolved salts. EC obtained from the groundwater samples recorded values between 129 $\mu$S/cm and 732 $\mu$S/cm, with an average of 544.6 $\mu$S/cm. WHO prescribed the maximum limit of EC for drinking water as 1500 $\mu$S/cm. Thus, all the groundwater samples do not exceed the maximum permissible limit. However, for irrigation purposes, water with conductivity less than 2250 $\mu$S/cm has been used without problem for a considerable time. The U.S. Salinity Laboratory Staff (1954) has categorised groundwater based on EC (Table 5). According to this categorisation, the sample of BH3 is in the excellent category while the other six samples, i.e. BH1, BH2, BH4, BH5, BH8, and BH12 is in the good category.

### Table 5. Water quality classification (U.S. Salinity Laboratory Staff, 1954).

| Quality of water | Electrical conductivity (µS/cm) | Sodium adsorption ratio (epm) |
|------------------|---------------------------------|------------------------------|
| Excellent        | Up to 250 (BH3)                 | Up to 10 (all samples)       |
|                  | 250 – 750 (excluding BH3)       | 10 – 18 (nil)                |
| Good             | 750 – 2250 (nil)                | 18 – 26 (nil)                |
| Poor             | > 2250 (nil)                    | > 26 (nil)                   |

*nil – not in list

Generally, most of the groundwater samples have hardness due to the presence of calcium and magnesium. The total hardness (TH) is given as

$$TH = 2.497\text{Ca}^{2+} + 4.115\text{Mg}^{2+}$$ (2)

This study has found that the total hardness of the groundwater samples ranges between 10 mg/L and 57.57 mg/L. The permissible limit of total hardness is 100 mg/L for drinking water as designated by WHO international standard. It has been shown that none of the groundwater samples exceed the maximum permissible limit. It also indicates that most of the groundwater samples fall in the soft water category.

According to [26], the residue sodium carbonate (RSC) has maximum influence on the aptness of water for irrigation purposes. Thus, SAR value acts as a significant tool to evaluate the aptness of irrigation water. It is important to ensure that all the samples have low RSC. The index quantifies the proportion of Na to Ca and Mg ions in a sample. RSC is the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium which is given as

$$\text{RSC} = \left(\text{CO}_3^{2-} + \text{HCO}_3^-\right) - \left(\text{Ca}^{2+} + \text{Mg}^{2+}\right)$$ (3)

where, the concentration is in meq/L.

The classification of irrigation water according to RSC is provided in Table 6. All the groundwater samples are categorised as good for irrigation.
Table 6. Groundwater quality based on the residual sodium carbonate (RSC).

| Quality of water | RSC            |
|------------------|----------------|
| Good             | < 1.25 (BH12)  |
| Doubtful         | 1.25 – 2.5 (BH1, BH2, BH3, BH4, BH5, & BH8) |
| Unsuitable       | > 2.5 (nil)    |

*nil – not in list

The calculated SAR of the samples (Table 3) is between 0.16 and 3.09 with a mean of 1.01. SAR of less than 10 indicates that the groundwater has low sodium hazard, according to Todd (1980). EC and SAR are plotted on the US salinity diagram, as shown in Figure 4. EC is taken as salinity hazard and SAR is the alkalinity hazard. Groundwater samples from BH1, BH2, BH4, BH5, BH8, and BH12 fall in the C_{2}S_{1} quality, i.e. with medium salinity hazard and low sodium hazard. Sample of BH3 has the C_{1}S_{1} quality, i.e. low salinity hazard and low sodium hazard.

This indicates that the groundwater of Selinsing canal can be used for irrigation since it is low in SAR with medium salinity hazard. Table 5 summarises the groundwater quality classification of salinity hazard and sodium hazard.

Figure 4. Suitability of groundwater for irrigation purposes based on the USSL diagram.

Sodium percentage obtained from the groundwater samples varies between 27.20% to 79.35%, with an average of 51.28%. Na% reflects that the classification of groundwater, i.e. either excellent, good, permissible, doubtful, and unsuitable [27]. Table 7 shows that four out of the seven samples are in the good and permissible categories, while the others are doubtful for irrigation. Sodium ions have the tendency to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions if the concentration of sodium is high in irrigation water. This chemical reaction process is soil resulted in the reduction of permeability and internal drainage.
| Quality of water | Na%               |
|----------------|------------------|
| Excellent      | < 20% (nil)      |
| Good           | 20 – 40% (BH1, BH3 & BH12) |
| Permissible    | 40 – 60% (BH2)   |
| Doubtful       | 60 – 80% (BH4, BH5 & BH8) |
| Unsuitable     | > 80% (nil)      |

*nil – not in list

The hydrochemical facies analysis reflects the chemical processes in certain lithological environment and specific geochemical condition. The general classification and trend of variation of the groundwater samples are shown in the Hill-Piper diagram in Figure 5 [28], [29] and [30]. The hydrochemical pattern diagram helps in hydrogeochemical facies classification [31]. The diagram has been classified into four hydrochemical facies based on the dominance of particular cations and anions, i.e. facies 1: Ca²⁺–Mg²⁺–HCO₃⁻ type I; facies 2: Na⁺–K⁺–HCO₃⁻ type II; facies 3: Na⁺–K⁺–Cl⁻–SO₄²⁻ type III and facies 4: Ca²⁺–Mg²⁺–Cl⁻–SO₄²⁻ type IV. Most of the groundwater samples fall in type II facies, i.e. BH4, BH5, and BH8 and type IV facies, i.e. BH1, BH2, BH3, and BH12.

The Ca²⁺/Mg²⁺ and Na⁺/Cl⁻ ratios are valuable in the determination of salinisation [25]. All the samples have Ca²⁺/Mg²⁺ ratio of extremely higher than 1.0, which indicates the exposure of carbonate rocks in the study area (Table 8).
Table 8. Salinisation based on Ca\(^{2+}/\)Mg\(^{2+}\) and Na\(^{+}/\)Cl\(^{-}\) ratios.

| Borehole ID | Ca\(^{2+}/\)Mg\(^{2+}\) ratio | Na\(^{+}/\)Cl\(^{-}\) ratio |
|-------------|-----------------------------|---------------------|
| BH1         | 8.223                       | 0.692               |
| BH2         | 7.491                       | 1.475               |
| BH3         | 13.500                      | 0.496               |
| BH4         | 3.147                       | 0.734               |
| BH5         | 2.081                       | 0.645               |
| BH8         | 4.918                       | 0.975               |
| BH12        | 119.68                      | 2.831               |

However, the Na\(^{+}/\)Cl\(^{-}\) ratio is below 1.0, indicating fresh water existence. The Na\(^{+}/\)Cl\(^{-}\) ratio of the collected groundwater samples is between 0.496 and 2.831 with a mean of 1.121. The samples with high Na\(^{+}/\)Cl\(^{-}\) ratio of more than 1.0 shows evaporation and concentration [32].

4. Conclusion

From the resistivity image profiling and lithological data constructed from the deep boring method, the presence of shallow groundwater has been detected along the Selinsing canal. The thickness of the aquifer varies between 5 m and 10 m, located at depths ranging from 30 m to 70 m below the mostly-clayey ground surface. The top ground surface consists of clay with thickness between 1 m and 80 m. Resistivities of clay varies between 3 \(\Omega\)m and 100 \(\Omega\)m [23] and [24] whereas aquifer resistivities ranges from 10 \(\Omega\)m to 100 \(\Omega\)m.

The major ionic composition showed wide disparities in the hydrochemical properties of the groundwater at Kerian irrigation scheme. The degree of correlation between cations and anions is determined to assess their relationship. Profusion of elements was interpreted in relations to the composition of aquifer and the climatic conditions. The significant hydrogeophysical parameters have been estimated for reasonable assessment of groundwater quality for irrigation purposes. Relationships between various elements were identified from correlation coefficient, which reflects genetic association. Strong positive correlation exists for Ca\(^{2+}\)–Mg\(^{2+}\), Ca\(^{2+}\)–Na\(^{+}\), Na\(^{+}\)–Mg\(^{2+}\), Na\(^{+}\)–K\(^{+}\), Ca\(^{2+}\)–K\(^{+}\), Mg\(^{2+}\)–K\(^{+}\), Mg\(^{2+}\)–Cl\(^{-}\), K\(^{+}\)–HCO\(_3\)\(^{-}\), and Na\(^{+}\)–Cl\(^{-}\).

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