Study of Shallow Groundwater in Al-Diwaniya City / South Iraq

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Abstract. Al-Diwaniya city suffers from shallow groundwater levels, which cause serious problems on the foundation of builds in the area and affect the general health of citizens in residential areas. For investigating this problem, four different paths perpendicular to Shatt Al-Diwaniya were selected, along 11 hand-dug wells in the city to observe groundwater levels during a whole year (2019-2020). The work included observation boreholes water levels and comparing results with water levels in the Shatt al-Diwaniya. Along each of the four selected paths (A, B, C, and D), two boreholes are observed on each side of the Shatt al-Diwaniya. Depths of boreholes are from 6 to 12 m. All boreholes paths that represent shallow groundwater within residential districts. The water level of Shatt Al-Diwaniya and groundwater levels is monitored twice-per-month, especially over high and low water conditions within Shatt Al-Diwaniya. Hydrometric results showed a relationship between shallow groundwater and Shatt Al-Diwaniya levels in track A. The nature of this interaction along with the track A due to many local factors such as depth of water in Shatt Al-Diwaniya, amount of rainfall, factors of high water levels, conditions and climatic changes, soil factors and the current state of the deterioration of the sewage network in Diwaniya city. Finally, the results of the rest tracks indicated that the city is flooded with shallow groundwater due to the large sewage leakage in addition to the rainwater and that Shatt Al-Diwaniya does not affect groundwater in the area. Still, it works discharge groundwater in the city.

Keywords: AL-Diwaniya City, Shallow Groundwater, Shatt Al-Diwaniya.

1. Introduction

Diwaniya City, 180 km south of Baghdad City, between Longitude (44° 52 13.70 to 44° 58 29.16) E and latitude (31° 57 18 to 32° 01 30) N. Shatt Al-Diwaniya (design discharge of 67.30 m³/sec.) is the only surface water source in the area, and it passes through Al-Diwaniya City dividing it into two parts. The examined areas characterized by extremely shallow groundwater systems which lead to many negative impacts on the agricultural, civil construction activities socio-economic aspect [1]. In densely populated residential cities that lack a sewage system, leakage from domestic water supplies [2] and sewage discharge leads to shallow groundwater levels [3]. This could lead to serious problems
in stabilizing the foundations of buildings, roads, and other structures [4,5]. Shallow groundwater systems present another problem in the studied area, i.e. soil salinity and soil alkalization, which affects building foundations by weakening the soil stability and reduce its bearing capacity. Groundwater flooding happens during lengthy stretches of heavy rainfall, which will continue for months, in some instances, even longer than river flooding [6]. Understanding the interaction between surface water and groundwater is critical to managing water resources [7,8]. Water transferred from rivers and rainfall is one of the most important sources of nutrition for shallow groundwater [9]. Despite the negative effects of the rise in groundwater levels in Diwaniya city, the city has not got with interest and previous studies on the causes of high levels of groundwater and their treatment. Then, this paper consider a major aim on the assumption that Shatt Al-Diwaniya caused a recharge of shallow groundwater in the region. The studied area is divided into four zones between the four selected tracks perpendicular on the Shatt Al-Diwaniya course (A, B, C, and D), Figure 1, and Table.1. Along each track shallow groundwater in hand-dug wells were monitored. The levels for both surface and shallow groundwater systems in the studied area had been monitored.

Figure 1. The study site, and locations of the boreholes and the proposed tracks in Diwaniya city.
Table 1. Location and depth of boreholes in the study area.

| Samples Local     | No | Latitude         | Longitude        | Depth m | Elevation m |
|-------------------|----|------------------|------------------|---------|-------------|
| Al-Jameih District| 1  | 3539519.33       | 488596.81        | 6       | 20.47       |
| Um Al-Khail /3 D. | 2  | 3541085.22       | 490050.68        | 10      | 20.44       |
| Al-Furat District | 3  | 3542648.61       | 490980.99        | 9       | 20.65       |
| Ramadan District   | 4  | 3538427.86       | 490241.98        | 10      | 20.90       |
| Um Al-Khail /1 D. | 5  | 3539315.26       | 491083.30        | 12      | 21.50       |
| Al-Motkaden D.    | 6  | 3540249.86       | 492408.25        | 6       | 21.56       |
| Al-Askari /2 D.   | 7  | 3541035.61       | 493679.39        | 6       | 19.71       |
| Al-Asri District  | 8  | 3539146.77       | 493702.79        | 6       | 21.51       |
| Al-Askari /3 D.   | 9  | 3540301.11       | 495054.67        | 6       | 20.21       |
| Al-Askan District | 10 | 3537569.71       | 495467.35        | 6       | 21.63       |
| Al-Zahraa District| 11 | 3538825.76       | 496618.39        | 6       | 20.71       |

1.1 Surface morphology

The general slope of the study area is from the northwest to the southeast. The contour line (21 meters above sea level) passes in the centre of Al-Diwaniya. The study area is part of the Mesopotamian plain known for its flat surface and its less slope, Figure 2.

![Figure 2: Digital Elevation for the investigation area, using GIS and the website http://earthexplorer.usgs.gov.](image)

1.2 Hydrogeology

Groundwater in the study area within the flood plain, inside sandy sediments in the Quaternary, in the Mesopotamian River Valley [10]. Dating back to the Holocene era, and old river sediments dating back to the Pleistocene era—geological structure effects on groundwater recharge through filtration processes within surface formations with high permeability. The study area is a part of the flood plain area, within the unstable land, as the downward state is still evident in its properties due to the surface and sub-surface formations, which are imperceptible. The pressure of the water under the
land surface is greater than the atmospheric pressure because of the soil pressure layers and the rocks above it [11]. The water rises to the surface of the land the pressure will decrease to negative values as in the case of the study site.

In different regions and with a certain depth the water pressure is equal to the atmospheric pressure and this is called the groundwater levels.

Typically, the level of the groundwater follows the shape of the surface; however, the shape of the groundwater level is not very similar to surface topography. In the study site, the shallow groundwater layer is very close to the surface level with a depth of about (0.5 - 1) m. The study area within the division of zone Mesopotamia, which the soil is often composed of silty clay [10], [12].

1.3 Soil

Investigations generally showed that the soil is consisting of different successive layers, the texture ranges between clay and sand, formed as a result of sediment transportation. The amount of infiltrated water in sandy soils increases because of the large pores between its particles, as the sandy soil reduces its ability to trap water, which leads to large amounts of water leaking into the land and mixes with groundwater. The clay soils, as a result of the lack of intermediate distances between their particles or their absence, leads to retain water and collect it on the surface. On this basis, the soil in the study site is classified into two types:

1.3.1 River levee soil

This levee soil extends along Shatt Al-Diwaniya from the north of the study area to the south. The level of levee is high and extends parallel to both sides of the river for a distance of (100 - 500) m. The soil was mainly formed due to large amounts of sediments carried by the Euphrates River during the period of repeated floods. As large-scale sediments such as sand were positioned near Shatt Al-Diwaniya while fine deposits such as clay and silt were far about the river. Its height ranges between (1 - 1.5) m distinguishes the soil body compared to the neighboring lands. Most of its main components are silt, clay and sand, as shown in Figure 3. The soil that extends with Shatt Al-Diwaniya is similar to a path, shows that the topsoil to depth (2 m) tend to the fine texture (clay loam), but most pits are medium or high permeable because there are porous pockets intertwined with this layer. The deep soil (2-5) m, tends to the coarse texture (sandy mixture) and these layers are near the river bottom, it has a great effect on the amount of water flowing from the river to the sides.

1.3.2 River basin soil

This basin soil is found in the lowlands nearby the river basins that extend on both sides of Shatt Al-Diwaniya. The distance ranges between (1 - 7) km about Shatt Al-Diwaniya in both sides of low lands (1 - 1.5) m below the level of the banks of the rivers that border them. The soil was formed as a result of frequent floods, and this soil consists of silt, clay and sand, it is often silty clay. A cross-section was prepared perpendicular on Shatt Al-Diwaniya and extended from the east to the west of the city. The cross-section of the areas near the river are coarse-textured soils tend to sandy, and the soil is fine texture tends to clay, whenever to move away from the path of the river. In general, there are layers of sandy soil extending from the path of the river to the sides, Figure 3.
1.4 Hydrological characteristics of Shatt Al-Diwaniya.

Shatt Al-Diwaniya passes in Al-Diwaniya city, a length of 12 km. It is an extension of Shatt Al-Hillah. The maximum design discharge for Shatt Al-Diwaniya is in Diwaniya city (67.3) m³/s, with a hydraulic gradient of 8 cm/km, and the water level at km (51.5) is (20.35 m). A mathematical model is executed to increase the discharge of Shatt Al-Hilla to 300 m³/s. It indicated that there would be an increase in the water levels in Shatt Al-Hilla canal of 0.70 m [13]. Thus will cause an increase in Shatt Al-Diwaniya level, which will provide new conditions for shallow groundwater levels in Al-Diwaniya city. Shallow groundwater levels depend on several factors, such as water levels and depth of Shatt Al-Diwaniya, periods of high and low water levels, the nature of area topography, the hydraulic conductivity of the soil, and the leakage of wastewater, in addition to the efficiency of the sewage network in the city, the rate of rainfall in the city and the nature of land use. Groundwater samples were examined and the results showed that the water quality is poor as salinity values ranged between 1792-34304 mg/l. The groundwater in the investigation area was classified as unused groundwater, and it is highly salty [14],[15].

The directions of groundwater movement in the region is controlled by factors such as soil permeability, recharging conditions, topography, and surface water height. Groundwater gradients in the studied area are directly controlled from local surface sources, and precipitation; therefore, the movement of groundwater in the studied area is complicated. It is important to note that the contribution of water in the shallow groundwater in the area from the sewage generated by residential neighborhoods within Diwaniya city is very important in terms of quantity and quality. Rainfall water is another important source of fresh water that has leakage into Groundwater system through the pores of sediments in the area [9].
2. Methodology

For achieving the goal of the study, the following methodology was applied:

1. Dug boreholes by a manual method with a depth of (6-12) m in the form of four perpendicular paths from Shatt Al-Diwaniya. Then insert a 10 cm diameter plastic tube into the hole and place a fine gravel filter between the tube and the boreholes wall to prevent deposits from entering the tube holes. A concrete base was casted at the top of the borehole to protect it from vandalism. After completing the installation of the monitoring boreholes on-site, a level (Bench Mark) was placed near each borehole, and the following information was recorded:
   - The coordinates of the location of each borehole.
   - Ground-level at each borehole.
   - The groundwater level in the borehole, the level changed over time.
   - The water level in Shatt Al-Diwaniya changes over time (In the river stations located in front of each borehole).
   - The type of soil was determined according to previous work.
   - Determination of hydraulic conductivity.
   - Groundwater levels in the well are recorded every 15 days (twice a month).

2. After collecting data and taking a good idea about the relationships between groundwater and surface water, a shallow groundwater flow chart and an explanation of the hydraulic relationship between them and between the levels of Shatt Al-Diwaniya water are drawn.

3. Results and Analysis

Results were collected during the monitoring of groundwater levels and Shatt Al-Diwaniya levels. The purpose of this monitoring program is to determine the fluctuation of groundwater levels and their relationships with Shatt Al-Diwaniya, Table 2 as well as the distance of the impact of the Shatt Al-Diwaniya water on Shallow groundwater. The permeability of the study area was computed using the inverse auger method [16]; the permeability changed from region to another. Figure 4 gives different hydraulic properties. The depth of shallow groundwater in the study area ranges between (0.5 m to 1.5 m). Because Shatt Al-Diwaniya levels are lower than groundwater levels in the city, it will provide excellent conditions that allow the discharge of shallow groundwater towards the river basin and reduce the level of shallow groundwater according to the change of soil characteristics.

| Permeability (K) (m/day) | Name of District      |
|-------------------------|-----------------------|
| 15                      | Al Jameih District    |
| 9.75                    | Al Thaqlin District   |
| 6.41                    | Al Zahraa District    |
| 0.88                    | Al Asri District      |
3.1 Track A.

Boreholes track (A) is located at the beginning the city and intersects with Shatt Al-Diwaniya in the station (500 + 52 km). The cross-section of Shatt Al-Diwaniya in the intersection area the depth of the water is (2.5) m, and this allows water to leak through the cavities of sandy soil by interacting with shallow groundwater. Figure 3 shows the values of the water levels in boreholes, compared with Shatt Al-Diwaniya levels.

Table 3 shows that track A, passing through the Districts (Jameih, Um Al-Khail-3, and Al- Furat ). There is an interaction between surface and groundwater, especially in Jameih and Um Al-Khail-3 because the permeability of soil is (15) m/day and shallow groundwater level is close to ground surface with depth of (0.62-0.88)m, respectively, and depth of groundwater in Al- Furat District about (1.12) m. The active distance of interaction between Shatt Al-Diwaniya and shallow groundwater is 500 meters. Therefore, the average level of shallow groundwater is close to the average level of Shatt Al-Diwaniya water. The sewage and rain network do not served the Districts passing through track A, and this causes another problem is leakage of sewage and rainfall to shallow groundwater. During investigations, it was noticed that there is a pumping station located near borehole 2 draws shallow groundwater and discharge it outside the study area. This station helps to avoid high levels of shallow groundwater in Um Al-Khail-3 District due to sewage leakage.
Figure 5. Average contour map showing groundwater levels and its direction inside Al-Diwaniya city. (Using a program Surfer 13)

3.2 Track B.

It is the longest track located in the middle of Diwaniya city. It intersects with Shatt A-Diwaniya. Table 3 shows that shallow groundwater levels in track B is higher than Shatt Al-Diwaniya levels about (0.81, 1.41 and 12.1) for the Districts (Ramadan, Um Al-Khail-1, and Motkaden), respectively. Whereas Shatt Al-Diwaniya level is higher than the groundwater levels in Al-Askari- 2 about (1.16) m, the reason is the presence of a drain near the borehole 7 in Al-Askari District as shown in Figure 5. The drainage reduces shallow groundwater level in the area surrounding it. The depth of shallow groundwater from the ground surface was about (0.71, 0.60, 0.97, and 1.40) m, respectively. In this track, Shatt Al-Diwaniya works as discharge stream for shallow groundwater, but insufficiently to reduce the levels of groundwater because the soil nature close to Shatt Al Diwaniya Basin is low permeability about (0.88) m/day. The districts in this track need a sewerage and rain network. It is important to install a covered drainage network to control shallow groundwater heads, and decrease the direct impact on public utilities.

3.3 Track C.

Track C is the shortest path within the residential city. The depth of Shatt Al-Diwaniya at this track is (2.5) m, Figure 5. Track C is passing through two Districts (Al-Asri and Al-Askari-3). Table 3 shows that the highest shallow groundwater level is in Al-Asri District about (1.70) m higher than
Shatt Al-Diwaniya water. The depth of water near the ground surface about (0.61) m. In this track, Shatt Al-Diwaniya is shallow discharge groundwater. The recharge of shallow groundwater is mostly wastewater with the contribution of rainfall. The water table in Al-Askari-3 district is moderate in level and with depth of 1.34 m. This is due to the located of borehole 9 near sewage drain that discharges shallow groundwater.

3.4 Track D.

The last track at the study site (located at the end of the city). The depth of Shatt Diwaniya is (2.5) m. Table 3 also shows the levels of Shatt Al-Diwaniya and shallow groundwater on this track.

Table 3. observing water levels in track A, B, C and D, comparing it with Shatt Al-Diwaniya, two measurements each month.

| Observation Well | Site Elevation (m.s.a.l.) | October 2019 | November 2019 | December 2019 | January 2020 | February 2020 | March 2020 | Average (m) |
|------------------|--------------------------|--------------|--------------|---------------|--------------|---------------|-------------|-------------|
| Jameih District  | 20.47                    | *19.47       | 19.82        | 19.77         | 20.00        | 20.00         | 19.81       | 19.19       | 19.77       | 20.11       | 19.81       |
| Um Al-Khail-3    | 20.441                   | *19.55       | 19.57        | 19.66         | 19.71        | 19.75         | 19.95       | 19.97       | 19.98       | 20.06       | 20.15       | 19.85       |
| Furat District   | 20.653                   | 19.22        | 19.56        | 19.52         | 19.76        | 19.78         | 19.59       | 19.76       | 19.70       | 18.94       | 19.52       | 19.86       | 19.57       |

Track A

| Observation Well | Site Elevation (m.s.a.l.) | October 2019 | November 2019 | December 2019 | January 2020 | February 2020 | March 2020 | Average (m) |
|------------------|--------------------------|--------------|--------------|---------------|--------------|---------------|-------------|-------------|
| Ramadan District  | 20.90                    | *19.03       | 19.36        | 19.33         | 19.56        | 19.62         | 19.42       | 19.57       | 19.52       | 18.75       | 19.33       | 19.67       | 19.38       |
| Um Al-Khail-1    | 21.50                    | *19.06       | 19.38        | 19.36         | 19.58        | 19.64         | 19.44       | 19.59       | 19.54       | 18.78       | 19.36       | 19.70       | 19.40       |
| Motkaden District | 21.554                   | 19.11        | 19.45        | 19.41         | 19.65        | 19.69         | 19.50       | 19.65       | 19.59       | 18.83       | 19.41       | 19.75       | 19.46       |
| Askari-2 District | 19.71                    | 19.13        | 19.46        | 19.43         | 19.65        | 19.70         | 19.51       | 19.67       | 19.61       | 18.85       | 19.43       | 19.77       | 19.47       |

Track B

| Observation Well | Site Elevation (m.s.a.l.) | October 2019 | November 2019 | December 2019 | January 2020 | February 2020 | March 2020 | Average (m) |
|------------------|--------------------------|--------------|--------------|---------------|--------------|---------------|-------------|-------------|
| Al-Asri District | 21.51                    | 18.85        | 19.17        | 19.15         | 19.37        | 19.45         | 19.26       | 19.39       | 19.39       | 18.57       | 19.15       | 19.49       | 19.20       |
| Al-Askari - 3 District | 20.21 | 18.85 | 19.17 | 19.15 | 19.37 | 19.45 | 19.26 | 19.39 | 19.39 | 18.57 | 19.15 | 19.49 | 19.20 |
| Al-Zahraa District | 20.71                    | 18.78        | 18.81        | 18.90         | 18.84        | 18.34         | 18.90       | 19.09       | 19.10       | 19.13       | 18.70       | 19.13       | 18.87       |

Track C

| Observation Well | Site Elevation (m.s.a.l.) | October 2019 | November 2019 | December 2019 | January 2020 | February 2020 | March 2020 | Average (m) |
|------------------|--------------------------|--------------|--------------|---------------|--------------|---------------|-------------|-------------|
| Al-Asri District | 21.63                    | *18.62       | 18.92        | 18.92         | 19.13        | 19.24         | 19.05       | 19.16       | 19.10       | 18.34       | 18.92       | 19.26       | 18.97       |
| Al-Askari - 3 District | 20.21 | 18.84 | 19.15 | 19.14 | 19.35 | 19.44 | 19.24 | 19.38 | 19.32 | 18.56 | 19.14 | 19.48 | 19.19 |
| Al-Zahraa District | 20.71                    | 18.30        | 19.33        | 19.39         | 19.40        | 19.39         | 19.50       | 19.35       | 19.50       | 19.86       | 19.87       | 19.90       | 19.53       |

*: Shatt Al-Diwaniya, *: Groundwater,
The track D indicates that shallow groundwater levels in Alaskan district are highest than Shatt Al-Diwaniya level about (1.49) m. Observing water levels indicate that the recharge of groundwater as a result of sewage and rainfall leakage in very high proportions. Shatt Al-Diwaniya in this track is discharging part for shallow groundwater and works as drain in the city. As for water levels in borehole 11 located at Al-Zahraa district will be moderate due to the presence of nearby drainage that contributes to addressing the high shallow water levels in the area. Groundwater depth in this track is about (1.18) m from the ground surface.

Figure 6. Distribution of shallow groundwater levels within the investigation area

Figure (6) shows the distribution of groundwater levels in the city. Districts (Al-Asri, Um Al-Khail-1, Motkaden, Al-Askan, and Ramadan) are waterlogged, their levels range (20.19 - 20.90) m. Districts (Al-Askari-2, Al-Askari-3, and Al-Zahra) appeared with moderate shallow groundwater levels, range (18.31 - 19.53) m, due to the presence of drainage passing through these districts. Shatt Al-Diwaniya in the upper part interacts with shallow groundwater for a distance of 500 m. As for the lower part, it works as drainage for groundwater discharge within a distance of 500 m and makes groundwater levels range between (18-19) m.

4. Conclusions

The following conclusions can be summarized:

1- The shallow groundwater levels within the investigation area depend on several factors such as Shatt Al-Diwaniya levels and depths, the topography of the study area, the infrastructure of the city represented by the sewers and rainfall networks, and the amounts of rainfall in the city

2- In Track A, there is an interaction between shallow groundwater and Shatt Al-Diwaniya water, where the active reaction distance is 500 m from the edge of Shatt Al-Diwaniya. The groundwater levels in this track are close to Shatt Al-Diwaniya water. The important
conclusion in this track is rehabilitation and completion of the pumping station close to borehole 2, due to its importance in reducing groundwater levels as a result of wastewater leakage into shallow groundwater, which is a major factor with a contribution of rainfall to recharge of shallow groundwater.

3- The districts located in the middle of city (Track B) suffers from high shallow groundwater. It is recharged from sewage leakage, with a contribution rainfall due to lack of a sewage and rainwater network in the city. An important conclusion was noted in this track that the drainage located near borehole 7 works to maintain groundwater levels within Al-Askari-2 district, where the construction of covered drains for other districts is required to control on the height of harmful levels.

4- It is observed from Track C data that Al-Asri district is the highest with a shallow groundwater level of 20.90 m, and that groundwater is close to ground surface with a depth of 0.61 m. Note that Shatt Al-Diwaniya does not feed this area, because groundwater levels are higher than Shatt Al-Diwaniya level about (1.70) m.

5- Groundwater levels in two boreholes located on track D noted that borehole10 in Al-Askan district have groundwater levels about (20.46) m, compared with borehole 11 of groundwater level about (19.53) m. The important conclusion is the presence of drain near borehole 11 that addresses the high groundwater level in the district. On the contrary for borehole 10 which lacks drain or sewer network.

6- Finally, the groundwater levels in the city directly affect the foundations of the building. They require real treatment by constructing a sewage network and maintaining the existing ones. Presence of Shatt Al-Diwaniya contributes to the discharge of a quantity of shallow groundwater throughout the city.

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