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Preliminary investigations of rocks and soil at the lower reach of Al-Shor Wadi for water harvesting

Key words: water investigations, Al-Shor Wadi, water harvesting, Mosul, dams

Introduction

Rainwater harvesting is one of the promising ways of supplementing the surface and underground scarce water resources in areas where existing water supply system is inadequate to meet demand. Rainwater harvesting has been used for generations to cope with water scarcity and climatic uncertainty in arid and semiarid regions (Aladenola & Adeboye, 2010; Adham, Riksen, Quessar & Abed, 2017).

The critical need to the water in western areas of Mosul city and desertification progradation led to the study of the major water resources and to select the best site for the proposed dam on Al-Shor Wadi to store different harvested water types. Water harvesting in Iraq is an old application with limited extent. Western Desert, Jazeera Desert and Eastern Valleys are the zones were the water harvesting must be employed (Abdullah, Al-Ansari & Laue, 2020). Two main sources of water prevailing the area; the precipitation in winter and the karstic spring water runoff in the area around, which collects their waters by the Al-Shor Wadi. The monthly average of: temperature, wind velocity and relative humidity for Tel Afar weathering station for the period 1961–2006 are shown in Table 1.

The dry years pass through Mosul reflected the rainfall declination which eventually affected the agricultural activities particularly in the northeastern part of Mosul and Al-Jazeera, weathering stations display by Mosul, Sinjar and Tel-Afer (Rasheed, 2010; Table 2). As well as, there is limited opportunity to recharge groundwater in Jazeera area due to existence of gypsum layers (Abdullah Al-Ansari & Laue, 2020), which are belong to Fat'ha Formation.

TABLE 1. Monthly average of temperature, wind velocity and relative humidity for Tel-Afer weathering station for the period 1961–2006

Month	Temperature [°C]	Wind velocity [$km \cdot h^{-1}$]	Relative humidity [%]
January	6.7	2.7	74
February	8.7	2.9	67
March	13	2.9	61
April	17.8	2.9	55
May	24.8	3.1	37
June	30.4	3.4	25
July	33.9	3.4	20
August	33.6	3.4	20
September	30	3.1	22
October	22.2	2.8	35
November	14.7	2.4	52
Decemer	8.5	2.9	73

TABLE 2. The highest and the lowest annual precipitation and the statistical medians for Mosul, Tel-Afer and Sinjar weathering stations for the period 1941–2002 (after Rasheed, 2010)

Weathering stations	Annual precipitation [mm]		
	the highest	the lowest	median
Mosul	632	129	377
Tel-Afer	613	134	331.2
Sinjar	670	164	392.8

The harvested water could be used for small agricultural projects and animals drinking. As well as, the stored water could be used as a good source for groundwater recharge. In an attempt of water harvesting west of Mosul, Al-Hamadani, Abdul-Baqee and Al-Shakarji (2010) used the WMS program to determine the best sites of dams on Al-Mur Wadi and Al-Shor Wadi. Twelve potential water-harvesting sites within Salah Al-Din Governorate, northern Baghdad, Iraq have been identified according to the remote sensing and GIS-based techniques, which are used for this purpose (Alwan, Karim, Nadia & Aziz, 2019).

Al-Shor Wadi

The wadi runs in SW–NE direction, collects its rainfall water from the catchment area from the northeastern limbs of Shaikh Ibrahim and Saasan anticlines and the southwestern limbs of Qusair anticline (Fig. 1), to unite with Al-Mur Wadi and eventually to drain water south of Aski Mosul in the Tigris river. In the

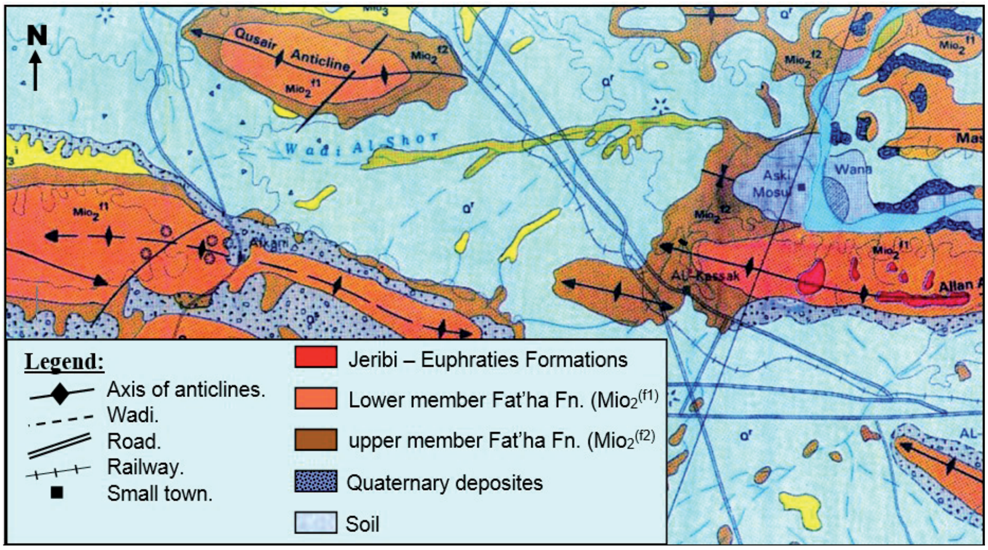

FIGURE 1. Geological map of the proposed dam site on Al-Shor Wadi (after State Establishment of Geological Survey and Mining, Geological map of Mosul Quadrangle, sheet HJ-38-13)

selected dam area, the wadi forms curve and give the northwestern Alaan anticlinal plunge its rounded shape.

Geology

It is worth mentioning that Alaan anticline extends nearly E–W direction with a slight shift to the NW–SE direction for its western plunge. Fat'ha Formation dominating all the outcrop areas and the Quaternary sediments furnishing the peneplain areas which were mostly used for agricultural activities.

The Fat'ha Formation was divided into two members by Al-Mubarak and Youkhana (1976); the lower and the upper one (Fig. 2). Both members were made up of a cyclic pattern of marl, limestone, and gypsum, but the upper one has a distinctive addition of red clastics of mudstone and fine sandstone. These additives represent successive coarsing upward cycles of fluvial dominated deltas (Al-Naqib & Aghwan, 1993).

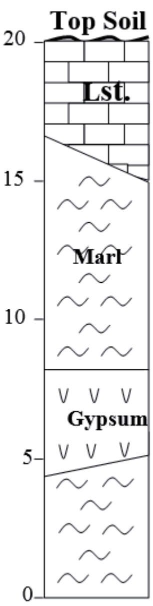

FIGURE 2. Lithologic section of the proposed dam site

The best position selected for dam construction on Al-Shor Wadi is confined due 3630.084N and 04240.499E in Figures 3 and 4 (according to the local GPS program). The selection relays on the presence of suitable very tough limestone bedrock foundation, least gypsum thickness, and high marl thicknesses, suitable elevation for dam height to achieve expected large water volume storage and the least or absence of karsts.

Anyhow, the main rock types furnishing the proposed dam site and lake beyond, from bottom to top:

– Marl 3–6-meter thick, yellow to yellowish brown, tough to medium tough, sometimes shows blocky appearance in fresh samples.
– Nodular gypsum 3–5-meter thick overlain the previous marl bed. The nodular gypsum bed is characterized by white to yellowish-white, sometimes greyish white, tough to very tough and has secondary gypsum along bedding planes. Very thinly laminated marl seams are occasionally coating the nodules. This bed forming scarps on both wadi sides and is overlain by thick marl bed.
– Marl 7–9-meter thick, yellowish-brown, medium tough to tough giving rise to its overlaying limestone bed to appear as the ridge.
– Limestone 3–5-meter thick, pale brown to yellowish brown, thinly bedded, jointed and fractured forms V-shape valley. It is well outcropped at the eastern (right) side of the wadi forming ridge. The angle of bedding planes went gentler at the western side of the rounded Alaan plunge furnishing relatively wide areas and forming small limestone fragments on the peneplane areas although its

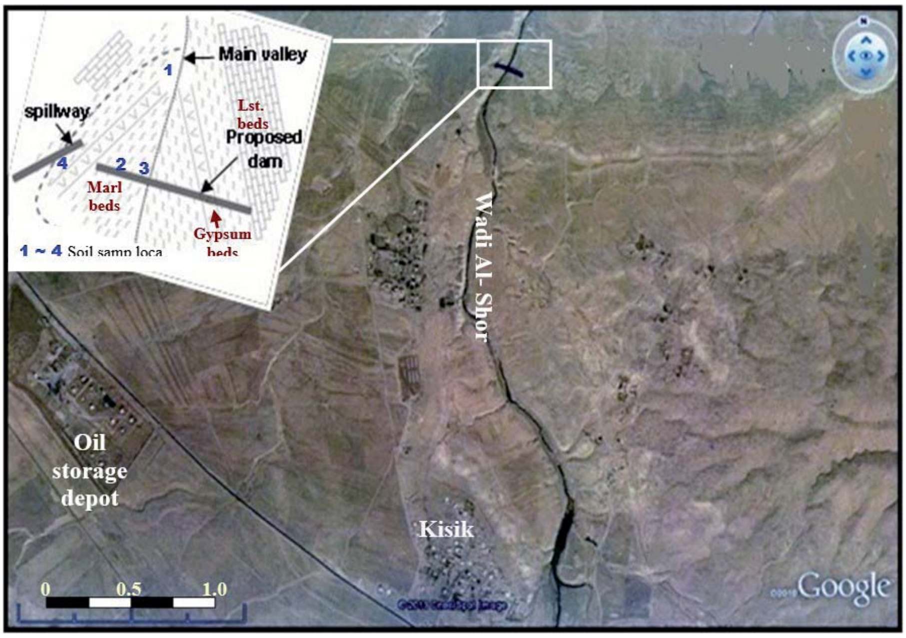

FIGURE 3. Satellite view of the proposed dam location with geological structure of the area

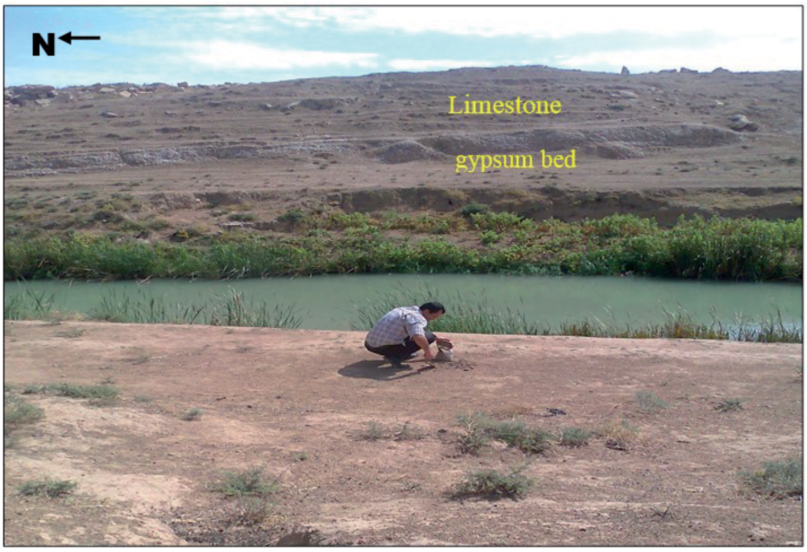

FIGURE 4. Location of the proposed dam

bed roots still appear in the valley bottom.

Bader (2008) studied the soil in the Al-Jazira area near Al-Jazira Irrigation Project, she indicated that about 60% of the area be saline and rising the level of the groundwater. Sulaiman and Abdul--Baqee (2013) studied the water quality of Al-Mur Wadi, they indicated that its water is regarded as very high saline, which is considered negative indicators for irrigation. Al-Youzbakey and Sulaiman (2017) studied the chemical composition of the springs in Al-Shor Wadi for cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anion (HCO_3^{-}, SO_4^{2-}, Cl^{-} and NO_3^{-}), which shows that there is an increase in calcium and sulfate concentrations due to the dissolving of aquifer rocks (gypsum, limestone, and marly limestone). So that Al-Shor Wadi water is not suitable for drinking but it may be used for irrigation for the high salinity bearing plants.

Methodology

1. The office works involved geologic map preparation and Google Earth photographic interpretation.
2. Fieldworks:
   a) Field checking for the selected proposed dam construction site.
   b) Sampling of various rock types and soils in the selected site of the dam and the proposed lake.
3. Water sampling from the Al-Shore Wadi tributaries.
4. Laboratory works:
   a) Soil and rock samples preparation and physical tests for the soil texture, field density, porosity, bulk density, and salt contents, according to soil physical treatment standards (Blake & Hartage, 1986).
   b) Water quality for cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anion (HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-}) were

analyzed in the geochemical laboratory in Dams and Water Resources Research Center according to the water analysis standard methods (Abawi & Hassan, 1990). Sodium and potassium were analyzed by flame spectrophotometer, calcium, magnesium, and alkalinity by titration, sulfates by UV-method and the other ions by the colorimetric method.

Results and discussion

The high temperature during the summer season, the dry years about 56% and the wet years about 44%, according to Rasheed (2010), and the drop in relative humidity for the years 1961–2006 could indicate the need for water harvesting in the drylands.

Table 3 revealed high clay and silt percent and low sand percent in sites 1, 2, and 4 giving rise to silty clay. The sand percent is noticed to be increased in site 3 which displays the valley bottom, which can be classified as silty loam. The latter resulted from different depositional processes like; valley shoulder rock washing and sediments derived by surface runoff from nearby areas. The results show relatively low to medium permeability and the salt content ranges from 1 to 1.6%, whereas the total porosity ranges from 43.1 to 56.7%. So, the increase of clay percent and the total porosity may indicate a good sign for the increase of field soil capacity. Consequently, less water infiltration will be produced. This has resulted in a marked increase in water storage within the soil. Anyhow, the high salt content in the area, in general, could cause increase its solubility during water storage and hence leads to increase water movement activities within the soil according to their persistence in the proposed dam lake.

The chemical properties of the water as shown in Table 4 represent the high concentration of calcium, magnesium and bicarbonates, which reflected the effect of dissolving and leaching on limestones of Fat'ha Formation. Additionally, the higher concentration of sulfates could be related to the calcium in the evaporite rocks (e.g. gypsum and anhydrite). Magnesium also presents in clay minerals (e.g. chlorite) in marls in the same formation, this type of rocks exposed to the water activity which causes dissolving magnesium.

In addition to the presence of secondary minerals-like halite, which dissolved easily by infiltrated water and groundwater led to increased sodium and chloride in the water. Potassium and

TABLE 3. The soil texture, porosity, and density of the soil in the studied sites

Location	Soil type	Total porosity [%]	Salts [%]	Clay [%]	Silt [%]	Sand [%]	Bulk density [$gm \cdot cm^{-3}$]	Field density [$gm \cdot cm^{-3}$]
1	silty clay	53.5	1.0	41.6	53.4	5.0	2.64	1.23
2	silty clay	43.1	1.6	43.5	46.5	10.0	2.30	1.13
3	silt loam	43.4	1.2	12.6	65.8	21.6	2.59	1.47
4	silty clay	56.7	1.2	47.2	44.8	8.0	2.70	1.17

TABLE 4. The physical and chemical properties of water from the stream

Water sample	Physical properties		Chemical properties							
	EC [µmhs·cm^{-1}]	pH	anion [ppm]				cation [ppm]			
			NO_3^-	Cl^-	SO_4^{2-}	HCO_3^-	K^+	Na^+	Mg^{2+}	Ca^{2+}
S1	2 721	8.0	5	174	1 624	435	2	35	178	632
S2	2 932	8.2	5	187	1 774	448	3	46	171	671
S3	2 966	8.1	3	161	1 482	391	1	32	144	612
S4	3 139	8.1	3	182	1 561	475	3	49	128	635
Water sample	TH [mg·l^{-1}]	TDS [mg·l^{-1}]	anion [epm]				cation [epm]			
			NO_3^-	Cl^-	SO_4^{2-}	HCO_3^-	K^+	Na^+	Mg^{2+}	Ca^{2+}
S1	2 240	3 346	0.08	4.90	33.83	7.13	0.05	1.52	14.65	31.60
S2	2 290	3 471	0.08	5.27	36.96	7.34	0.08	2.00	14.07	33.55
S3	1 870	3 569	0.05	4.54	30.88	6.41	0.03	1.39	11.85	30.60
S4	1 810	3 552	0.05	5.13	32.52	7.79	0.08	2.13	10.53	31.75

nitrites were found in low concentrations because they represent mostly the activity of limited fertilization.

The most physical properties reflected by the type of aquifer rocks and their ability to dissolve in groundwater.

The pH of the water samples about 8.0–8.2, it may be due to the effect of alkalinity (bicarbonates), which yields from the dissolution of limestones within Fat'ha Formation. The electrical conductivity (EC) related to the dissolution of ions to groundwater from limestones and gypsum. The EC values range of 2,721–3,139 µmhs·cm^{-1} reflected the high concentration of ions. The dissolution process by groundwater sharing with the infiltration of runoff water rises the activity of the dissolution of sulfate and bicarbonate rocks of the aquifer. This is increasing the total dissolved solids (TDS) 3,346–3,569 mg·l^{-1} and the total hardness (TH) 1,810–2,290 mg·l^{-1}.

According to the chemical and physical properties of Al-Shor Wadi, which related to the water quality of the many small springs along the wadi, the suitability of water to use for agriculture is low and related to the plants that bear the high salinity water conditions, so that it is not suitable for drinking too.

The water of Al-Shor Wadi is classified as very hard because TH > 300 mg·l^{-1} (Tchobanoglous & Schroeder, 1985), and this water is a moderate saline water type depends on the TDS value are between 1,000–10,000 mg·l^{-1} (Davis & De Wiest, 1966). It is clear that, the solubility of evaporites of Fat'ha Formation. Classified the water as non-carbonate hardness due to the high concentration of sulfate which pointed in the sixth area of Piper diagram (Khattab, 2000). Train (1979) classified the water depending on the TDS. The TDS values are between 2,000–5,000 mg·l^{-1}, which indicates the ability to use water for irrigation plants that bear high salinity water conditions. As well as, the American Saline Lab. classified the water according to EC and TDS to four types (C1–C4), the studied water samples represent the type C4, which used for plants that bear the high salinity water conditions.

The above assessment of Al-Shor Wadi water encourage to improve the water quality by water harvesting technique. This technique will collect the precipitation behind a small dam in the selected location. The precipitation will dilute the concentration of dissolved salts and improve the usage of water for agricultural purposes.

Conclusions

The primary soil tests, the proposed geological site for both the dam and the lake behind it, and the good proposed height of the dam at the site of about 17 m, can provide adequate water storage volume, and improve water quality for agricultural purposes, in addition to the least karstification in the proposed lake give good importance for the recommendation of the dam site.

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Summary

Preliminary investigations of rocks and soil at the lower reach of Al-Shor Wadi for water harvesting. The last four decades weather forecasting data marks the precipitation declination and increase dry years, in addition to the desertification migration on the west and northwestern Mosul city. This led to studying the Al-Shor Wadi area to try to make use of the karstic spring water flow through it and to harvest the rainfall flow water. These need to select the best site to construct a dam taking into consideration the geological and geotechnical characteristics of both dam site and lake behind. The dam site appears to be appropriate relying on the large thickness and frequencies of the marl bed, the restriction of gypsum bed thicknesses and frequencies as well as, of the approximate nill karstification.

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