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Evaluation of Selected Site Location for Subsurface Dam Construction within Isayi Watershed Using GIS and RS Garmiyan Area, Kurdistan Region

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Abstract

Garmiyan area suffers from many water problems such as poor rainfall rate, water shortage, aridity and absence of groundwater in many places. Hence the subsurface dam is the best solution due to many advantages such as low cost of construction, least maintenance, low evaporation, no contamination, utilization of the land over the dam and better storage. The objective of this study is to evaluate the suitability of the selected site location for subsurface dam construction, to serve as strategic water supply storage, to solute the aridity and water shortage in this area of arid to semi arid climate in Isayi watershed within the stream deposits. Geographic information systems (GIS) and remote sensing through satellite images and Digital Elevation Model (DEM) interpretation and analysis have facilitated the investigation with more accuracy. ArcGIS helped in construction of thematic maps of the studied area. The geologic, structural, geomorphologic, hydrologic and hydrogeologic characteristics with GPR survey show the suitability of the selected site location for construction of subsurface dam. According to the standard water quality for domestic, irrigation and livestock the water quality of all water samples are within the recommended range and the best time to be chosen, for construction of the subsurface dam, is during the autumn season from September to November.

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Keywords

Subsurface Dam, GIS, Water Harvest, Hydrogeology, Geomorphology

1. Introduction

One of the best solutions to overcome the aridity and drought problems in arid and semi-arid areas is building under-ground storage dams (sub-surface dams). According to Ishida *et al.* [1], Borst and de Haas [2], Hoogmoed [3], Şen [4] and Khairy *et al.* [5], such technique has many advantages like decrease of evaporation, decrease of contamination, no problem of land submergence, no silting, no danger of breaching and low construction cost. The studied area is located about 42 km south of Darbandikhan district and 123 km east of Kirkuk city with 19 km northeast of Kalar district at 34˚46'46"N and 45˚27'25"E in Iraqi Kurdistan Region (**Figure 1**).

The aim of the present study is to construct an aquifer (subsurface dam) with high productivity, to serve different human activities and combat aridity and drought that dominates the area.

2. Methodology

The methodology used, to identify appropriate sites for the proposed subsurface dams at the outlet of Isayi watershed within the stream deposits, consists of following steps using ArcGIS 9.3 and Global Mapper 11:

- Visual interpretations of satellite imagery to delineate the geology and geomorphologic units.
- Field verification of interpreted units.

Ground Penetration Radar (GPR) survey had been used to display clear information about the presence of subsurface structure by drawing two profiles; the first profile runs across the ephemeral stream and trending NW-SE, with a length equal to 288 m; and the second profile runs parallel to the first profile and trending NW-SE with a length equal to 340 m.

- Drawing geologic cross section using Adobe Illustrator.
- Temperature and rainfall data for the period (1995-2009) were used in the interpretation.
- Stream discharge was measured using staff gauge method.
- Slope map and profile were prepared using Digital Elevation Model (DEM).
- Groundwater level fluctuations were monitored within the stream deposit for the entire year.
- Hydrogeological and hydrochemical characteristics of the stream deposits were evaluated using pumping and packer tests.

3. Geologic Setting

The present area tectonically lies within the low folded zone. It is part of southwestern limb of Chamchamal south anticline. The pre-Quaternary basement of the site location consists of the Mukdadiya Formation, which is of Upper Miocene to Pliocene Age (**Figure 2**) [6].

The area is composed of alternation beds of claystone, siltstone and sandstone, crossed by Isayi main stream valley that is filled with alluvial deposits. The alluvial deposits are composed of mixture of clay, sand, pebbles and cobbles. The grains size of this mixture is increasing downstream due to washing and removing of the fine grain sediments by the continuous flow of subsurface water as interflow. According to Şen [4], the coarse structure of alluvial deposits minimizes capillary effects and losses by evaporation. Both sides of the selected site are composed of claystone overlaid by thick, hard, jointed and course grained pebbly sandstone.

These sedimentary rocks can be grouped into permeable and impermeable layers. The permeable layer represented by the stream deposits, with width of 340 m and thickness ranging between 3 to 7 m reaching its maximum at the southern part of the section (**Figure 3**). It will form the reservoir upstream of the project's body. The impermeable layer consists of 52 m of claystone under the first layer of alluvial bed.

4. Geologic Structure

The rock strata, at the selected site location for the subsurface dam is part of the southwestern limb of Chamchamal south anticline. These rocks are dipping 30˚ with dip direction of S 70˚E. The thickness of claystone and

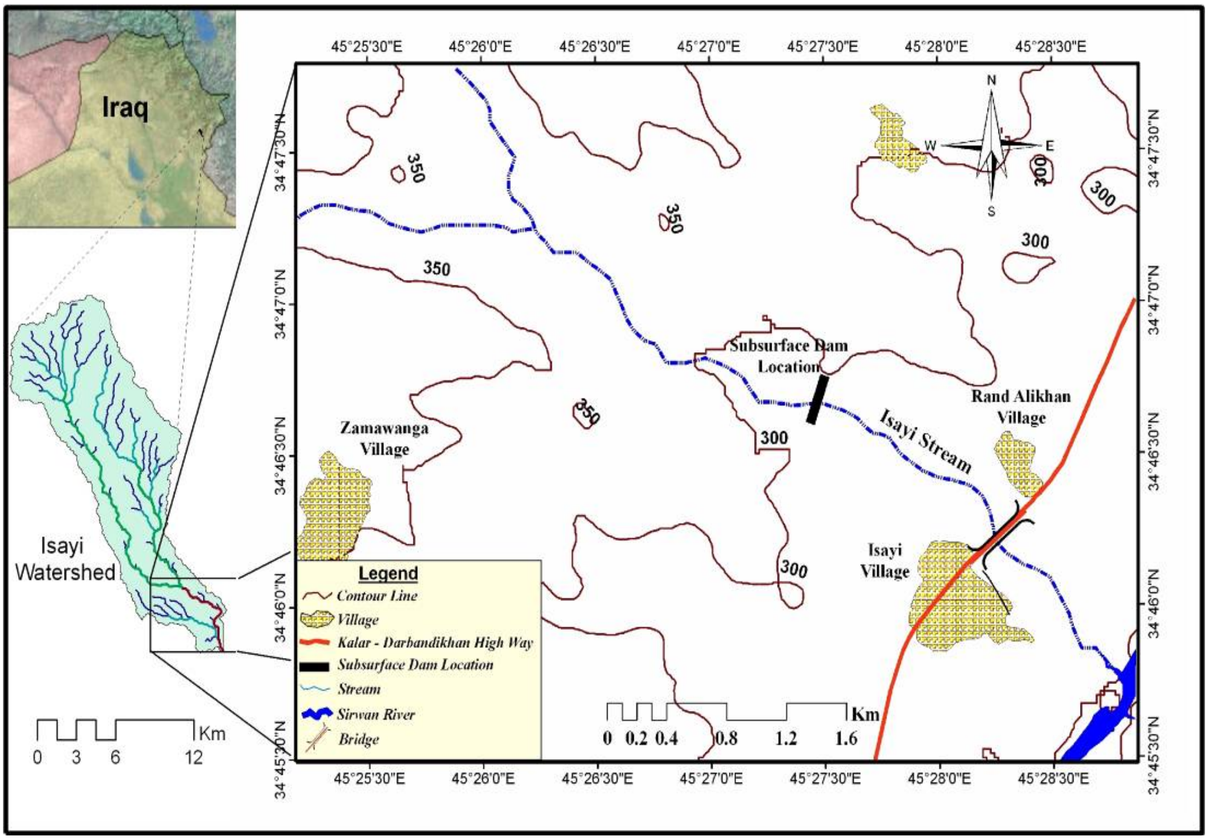

Figure 1. Location of the proposed subsurface dam within Isayi watershed.

sandstone are 52 and 5 m respectively, while the thickness of alluvial beds is ranging from 3 to 7 m. Generally, the stream direction is parallel to the strike. Whereas, the stream at the selected site location crosses and cuts the bed rocks with 80˚ angle from northwest to southeast. The geological and structural situations provide suitable conditions for the proposed subsurface dam construction, which will act as natural barrier and both flanks of the subsurface dam can be supported on them. The GPR survey results of the valley floor over the alluvial deposits revealed that the selected site location is very well for the construction of a subsurface dam across the valley (**Figure 4** and **Figure 5**), because no evidence of faults and cavities were recorded beneath the whole area under consideration.

5. Climate

Rainfall is the basic and direct source of recharge for all kinds of water resources within Isayi watershed (**Figure 6**). Its contribution to groundwater recharge is not regular and uniform throughout the year in all parts of the watershed. Its variation in time and space directly influence the formation and distribution of surface and subsurface water. The upper reach of the watershed receives more rainfall than the lower reach due to the relatively high elevation that exceeds 1000 m. This is evidenced by the flash floods that were recorded at the outlet in the absence of rainfall.

6. Structure Runoff

The hydrologic behavior of the stream flow is affected by the watershed characteristic. Water flows in Isayi stream from autumn to the end of spring (**Figure 7**) and it is obvious that the stream is directly recharged by rainfall. The average daily flow reaches 22,107 m^3/day. Most of the watershed is covered by fine grain sedimentary rocks of low permeability and infiltration rate. The area of Isayi watershed, till the location of the proposed first subsurface dam is 145 km^2 that has been classified as large watershed on the basis of Şen [4].

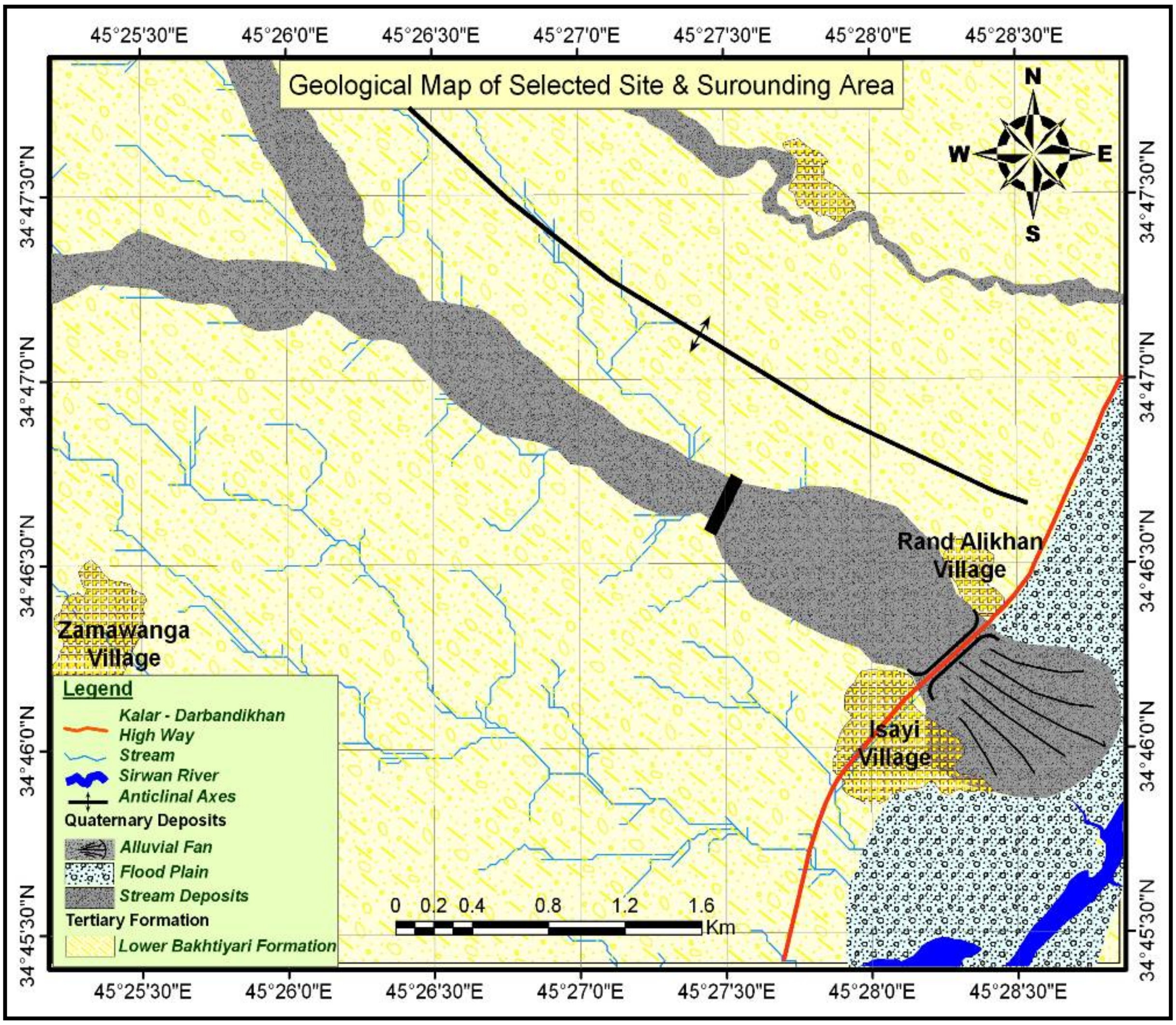

Figure 2. Geological map of the selected site location for construction of subsurface dam.

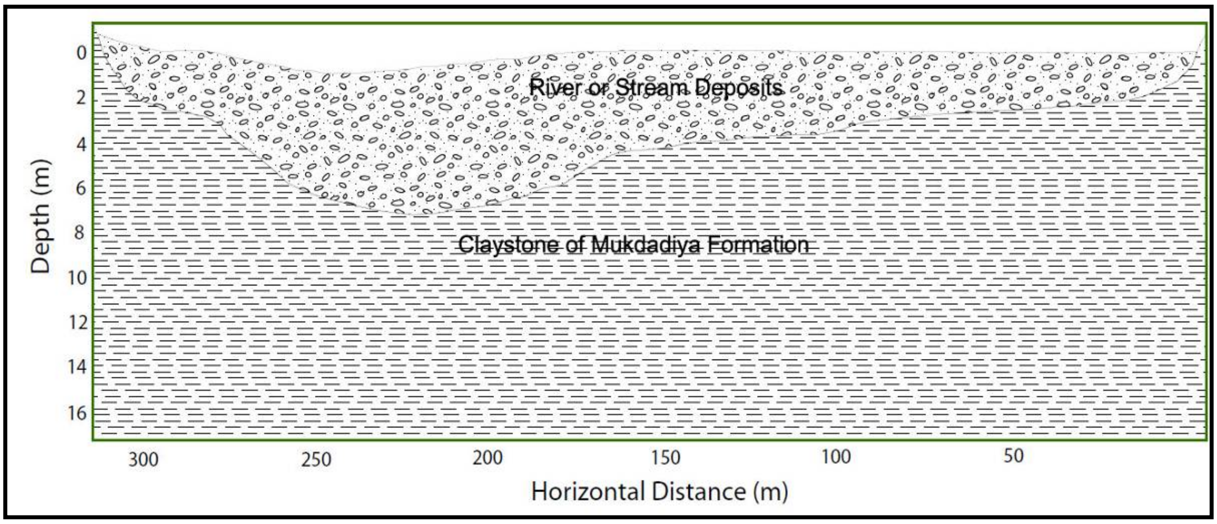

Figure 3. Geologic cross section for the proposed subsurface dam's selected site location.

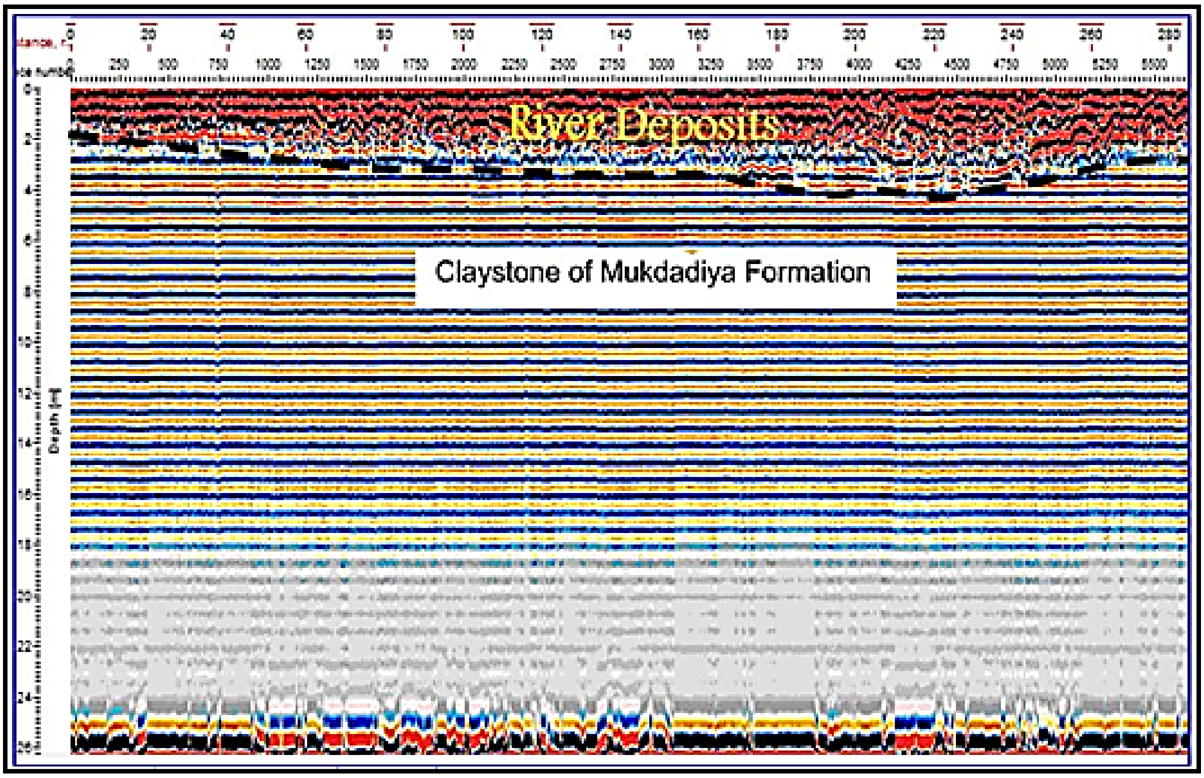

Figure 4. Radar section of the profile NO.1.

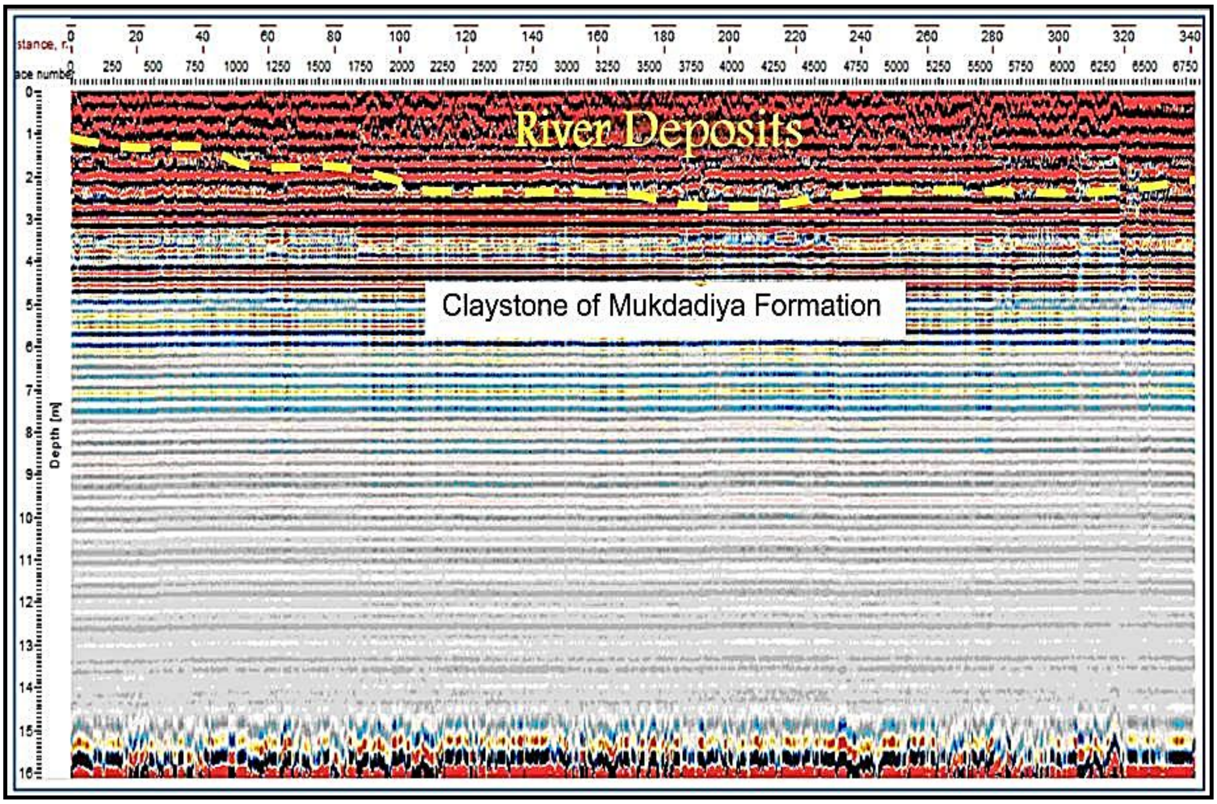

Figure 5. Radar section of the profile NO.2.

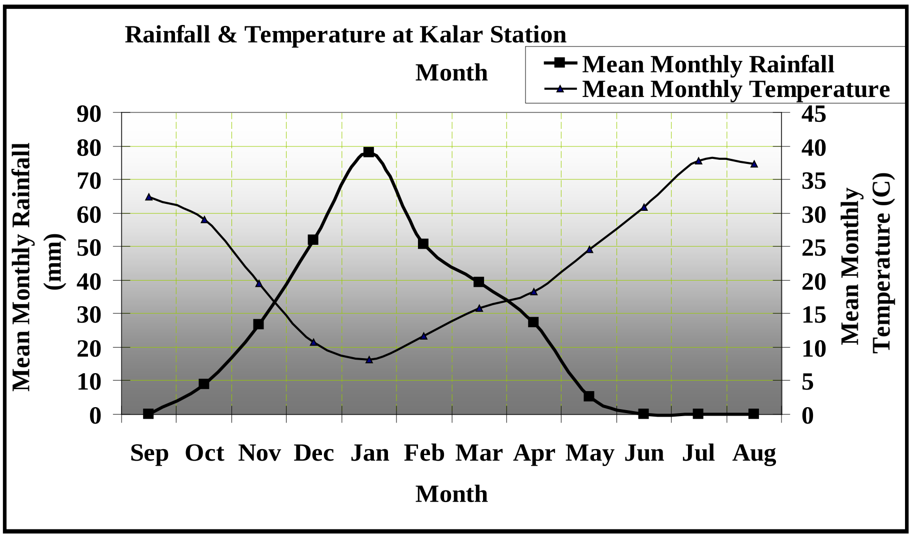

Figure 6. Annual variation of rainfall and temperature according to humid and arid month's distribution.

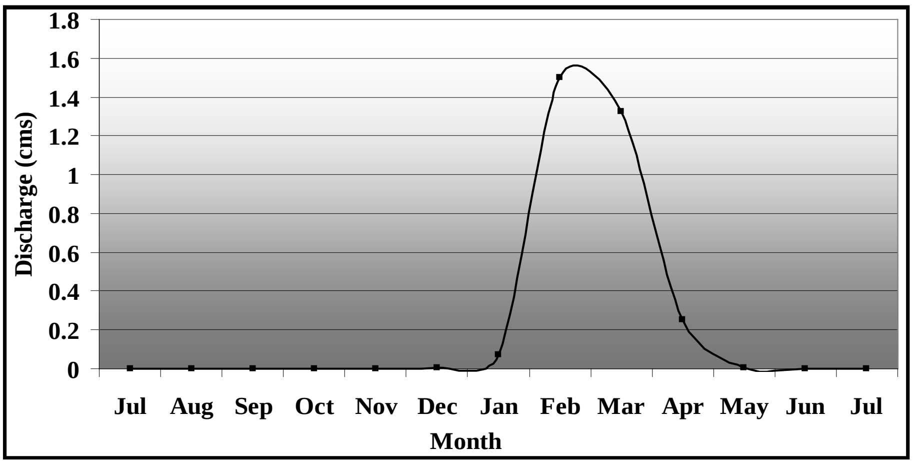

Figure 7. Stream hydrograph in the studied area.

7. Geomorphology

Geological features in terms of rock outcrops and geomorphologic characteristics are important for water resources occurrence, distribution, and movement in any wadi (valley) system [4]. Geomorphologic features or landforms have a great effect on the types of the projects to be implemented. As it is recommended by Nilsson [7], Danida [8] and Ali [9], that suitable geomorphic landforms for the construction of subsurface dam at the site location is alluvial deposits valley with low gradient at the outlet of the watershed. The characteristics of the suggested site are as follow (**Figure 8**):

- Watershed Outlet

The selected site for the subsurface dam is located at the outlet (mouth) of shallow and elongated valley, nearly 2.2 km southeast the confluence of the two main branches of the watershed, which are supplying water to this main valley. This site location lays 1.5 km west of Kalar and Darbandikhan road at Isayi and Randalikhan villages (**Figure 8**).

The main stream is constant and straight with very gentle slope which removes the risks of bypass. The surface and subsurface water flow down and pass the watershed's outlet with adequate discharge in other word good quantity of water.

- Alluvial Deposits Valley

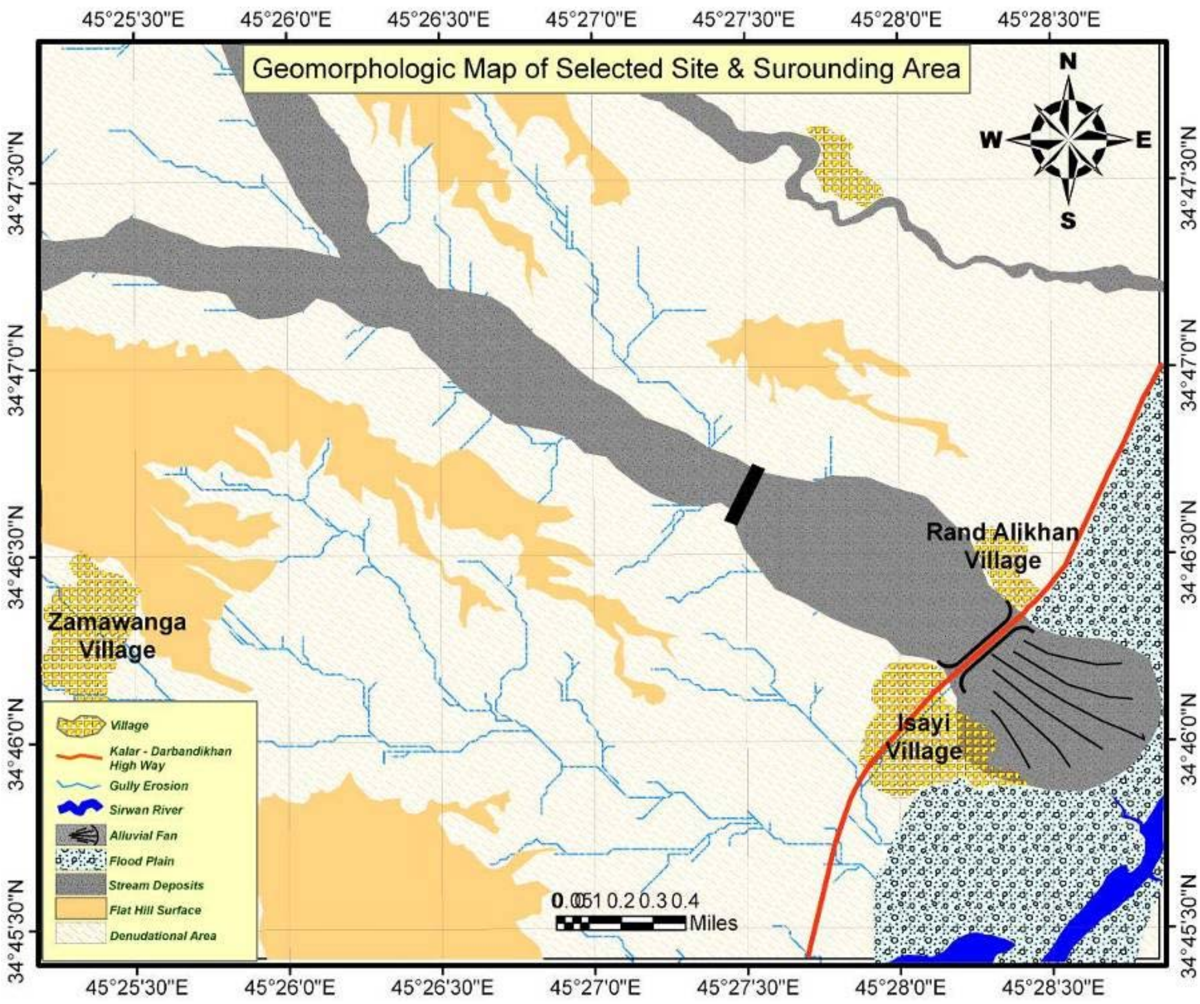

Figure 8. Geomorphological map of the selected site location of the proposed subsurface dam.

The valley chosen is an alluvial deposits valley. From geomorphic and geological structure perspective it meets the requirements for building subsurface dam. Its lithology enables percolation and infiltration of water into the porous and unconsolidated sediment. It preserves the water of the stream as subsurface water interflow. In addition, it does not have irregular water bypaths and this means less risk of water leakage. This is due to the fact that the valley's sides are of impermeable bed rocks represented byclaystone.

- Gradient or Slope

Sites with minimum topographical gradient will render best services for building the subsurface dam [7]-[9]. The slope of the alluvial deposits is level to very gentle (0˚ - 2˚ degrees with an average value of 1.7˚) which is within the recommended limits (**Figure 9**). This level or very gentle slope will allow more and enough time for water infiltration into alluvial deposits, which will be beneficial for rapid storage, and increase of subsurface dam capacity due to the increase of sedimentation upstream of subsurface dam body.

8. Hydrology

In order to identify hydrogeological characteristics of the alluvial deposits the following detailed field surveys were carried out at the selected site location:

8.1. Subsurface Water Level Observations

The groundwater level depends on the annual and seasonal recharge of the alluvial deposits by rainfall. The

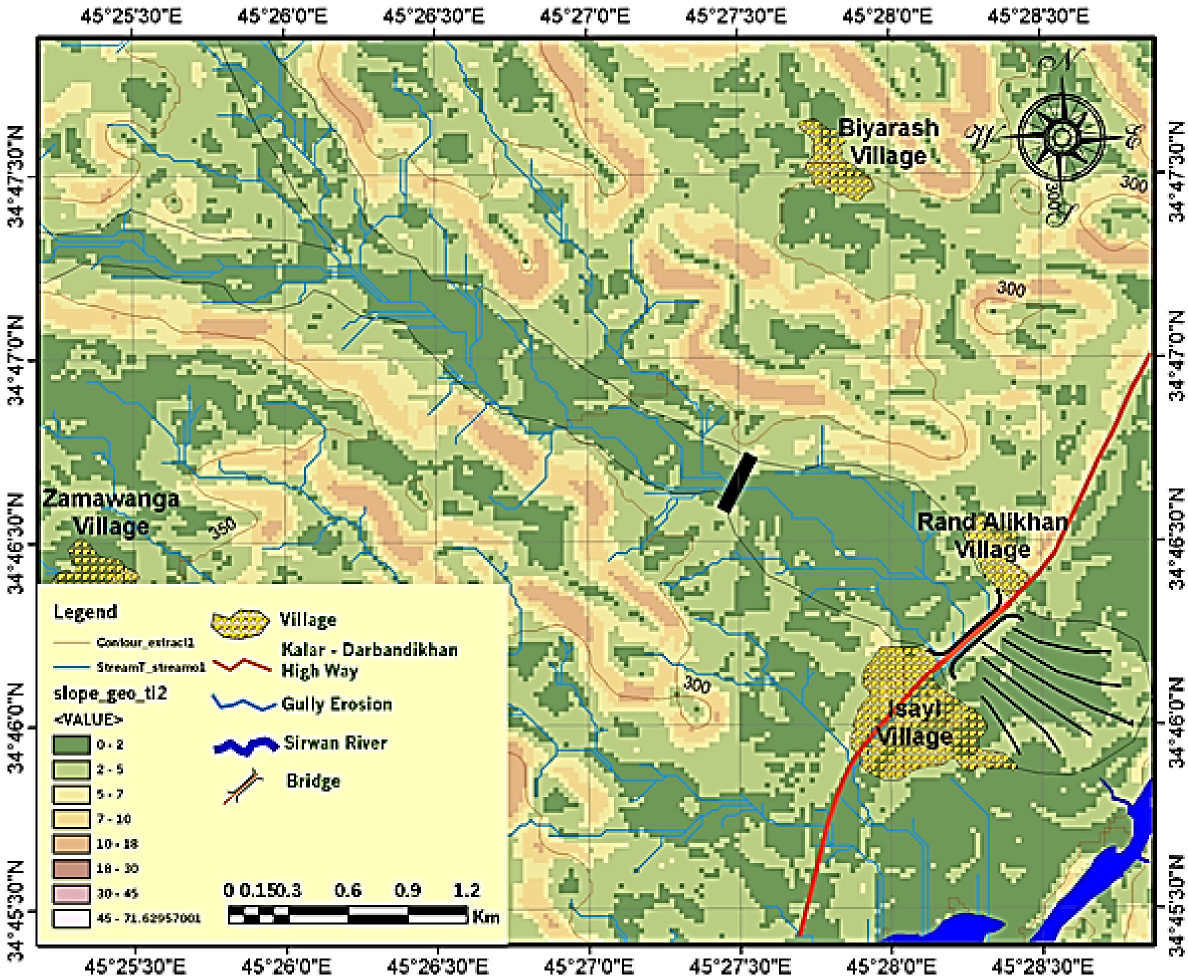

Figure 9. Topographic and slope maps of selected site location for subsurface dam project.

groundwater level is rising and dropping concordant with wet and dry seasons respectively (**Figure 10**). The maximum drop of groundwater level was at autumn season (2011), while the minimum drop was during the spring season (2012). The reason behind the maximum drop of groundwater level, within the stream deposits at autumn, is the ceasing of groundwater recharge by rainfall.

Although the groundwater level is dropping during dry period within the stream deposits, but it is flowing continuously through the whole year as interflow toward Sirwan River. This is the most important characteristic of the study area, because the upstream parts of the drainage basin receives more water as orographic rainfall feeding the main channel due to high elevations.

8.2. Hydraulic Characteristic of Open Well

A dug well situated on the stream deposit of Isayi watershed at an elevation of 390 m above sea level was tested. The aquifer layer of the well is a mixture clay, sand and gravel, which is completely penetrated by the dug well and unconfined in type. The nature of the aquifer is characterized mainly by inter granular mixture of sands and gravels.

If the water is pumped in alluvial deposits at a high rate the depression head will increase, which may cause excess gradients Raghunath (2006). Then these data will substitute into appropriate well-flow equation and the hydraulic characteristics of the aquifer can be calculated. According to Raghunath [10] proper analyses of these data lead to the determination of hydraulic characteristics such as specific yield (Sy), specific capacity (Sc), safe yield (Qy), transmissibility (T) or hydraulic and conductivity (permeability) (Kf).

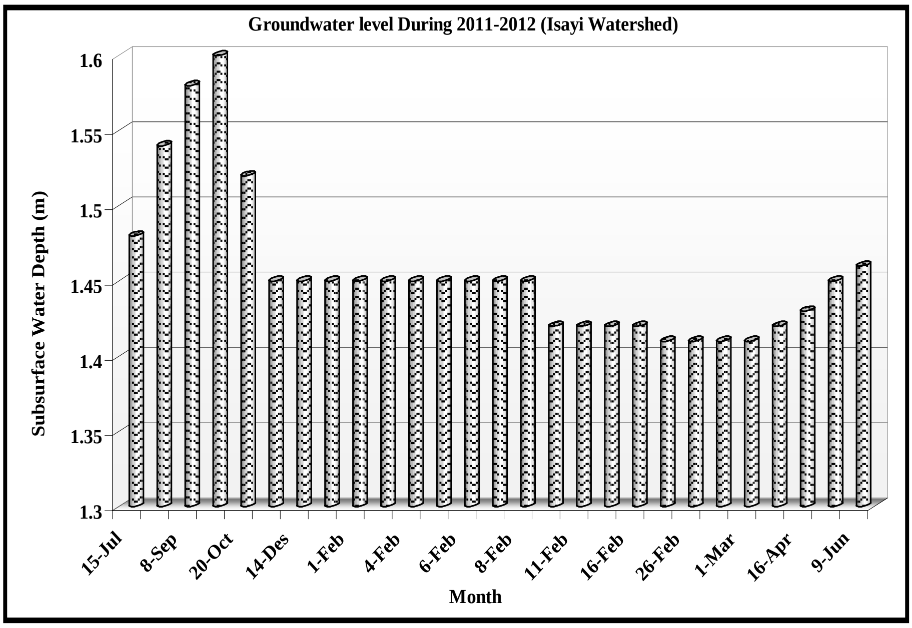

Figure 10. Observed groundwater level fluctuation within the stream deposits.

Among the 8 productive hand dug wells, within the stream deposits upstream Randalikhan village in Isayi watershed, pumping test was conducted at one dug well in which the pumping operation took 31 minutes. The recovery duration time was 21 minutes. The dimension of the dug well was 3.60 m deep and with 0.75 m in diameter. The delivery rate of the pump for the well was constant at a rate of 28.811 m^3/hour. Accordingly, the pumping test duration is relatively slower than the recovery rate.

In the pumping test, the water level in the well was depressed to an amount equal to the safe working head for the sub-soil. Then the water level was kept constant by making the pumping rate equal to the percolation of water into the well [10]. The quantity of water pumped in a known time gives an idea of the probable yield of the well of the given diameter. The test had been carried out in an existing open well within the stream deposits in Isayi watershed.

Let the water level inside the well rise from s1 to s2 which is measured below static water level (swl) in time (T). If (s) is the head at any time (t), from Darcy's law then:

$$Q = K A I$$

where:

I = Hydraulic head

A = cross sectional area

K = Hydraulic conductivity

Q = Discharge

According to Raghunath [10], the value of Sy is usually determined from a recuperation test and (Q = Sy) when (A = 1, H = 1), *i.e.*, the specific yield of the soil is the discharge per unit area under a unit depression head and has dimension of T – 1 (l/time) and the usual values are:

Sy = 0.25 hr – 1 for clayey soil

Sy = 0.50 hr – 1 for fine sand

Sy = 1.00 hr – 1 for coarse sand

The recovery test has been done during 22 minutes after the pumping stopped as illustrated in **Table 1**. The total volume of water pumped during 31 minutes of pumping was 14.89 m^3.

8.3. Packer Test

According to Fetter and Brassington [11] [12], packer test is an aquifer test performed in an open borehole and the segment of the aquifer to be tested, it should be sealed off by inflating seals in the borehole, called packer,

Table 1. Hydraulic characteristics of open well within the stream deposits.

Time Since Pumping Stopped (min)	Water Level Depth (m)	Residual Drawdown S2 = WL – SWL (m)	Ratio (s1/s2)
0.000	3.45	1.95	1.000
1.000	2.9	1.4	1.393
2.000	2.69	1.19	1.639
3.000	2.48	0.98	1.990
4.000	2.29	0.79	2.468
5.000	2.14	0.64	3.047
6.000	2.01	0.51	3.824
7.000	1.89	0.39	5.000
8.000	1.8	0.3	6.500
9.000	1.75	0.25	7.800
10.000	1.7	0.2	9.750
11.000	1.68	0.18	10.833
12.000	1.66	0.16	12.188
13.000	1.645	0.145	13.448
14.000	1.63	0.13	15.000
15.000	1.625	0.125	15.600
16.000	1.62	0.12	16.250
17.000	1.61	0.11	17.727
18.000	1.605	0.105	18.571
19.000	1.6	0.1	19.500
20.000	1.595	0.095	20.526
21.000	1.59	0.09	21.667
22.000	1.585	0.085	22.941

both above and below the segment. It is used to determine the permeability of the rock strata, in the boreholes.

In this project, four boreholes were drilled using drilling machine for shallow wells. Core samples have been taken during drilling. They were used to estimate the lithology and geological structure (**Table 2**). Packer test was carried out to assess claystone bed rock that underlies the alluvial deposits in the studied area by calculating the transmissivity and permeability to ensure that the aquifer for the dam should be underlain with bedrock having low permeability to retain water for collection and to prevent seepage. Injection test has been used for 3 m of claystone of the borehole and injecting water under pressure into the rock to determine the effective transmissivity (T) of the zone. However, it was particularly easy to distinguish the unconsolidated permeable stream deposits layer from the impermeable basement rock that is represented by claystone. These boreholes have been used for packer test process to assess the hydraulic conductivity or permeability of the claystone that underlies the stream deposits.

8.4. Result

The continuous groundwater flow, within the stream deposits, was continuously supplying water for different purposes through the whole year even during the dry season. According to the results of the pumping test (**Table 3**), the stream deposits can be classified as moderate according to Şen [13] as illustrated in **Table 4**. The stream deposits at the selected site location for the subsurface dam can be considered as unconfined aquifer because there is no impermeable rock stratum ceasing its upper part. The results of the groundwater discharge revealed that the discharge depends on the seasonal groundwater level fluctuations through whole year. This is due to the fact that it is recharged by rainfall and it flows continuously within the stream deposits to discharge Sirwan River through the whole year. During the wet season the groundwater discharge shows high value whereas during the dry season the groundwater discharge is decreasing.

During the packer test, the flow rate did not change with increasing the exerted pressure and remains the

Table 2. Characteristics of the drilled boreholes at the site location for subsurface dam construction.

Well NO.	Depth of Well (m)	Lithology	Depth of Water Table (m)	Remarks
1	4	First 2 m layer is unconsolidated stream deposits and the rest is claystone	1.5	The thickness of the unconsolidated materials reaches its maximum at well NO.2 at southern part of the section. The clay content within the unconsolidated materials decrease down ward due to washing by flowing interflow within the stream deposits
2	7.5	First 6.73 m layer is unconsolidated stream deposits and the rest is claystone	1.5	
3	7	First 4 m layer is unconsolidated stream deposits and the rest is claystone	1.5	
4	3.20	First 3.5 m layer is unconsolidated stream deposits and the rest is sandstone	1.5	

Table 3. Hydrogeologic characteristics of the stream deposits at the study area.

Hydrogeological Parameters	Equation		Author	Values
Rate of Delivery	/	/	Raghunath (2006)	
Rate of Seepage ($Q_{seepage}$)	$Q_{seepage} = (Q\,t - ((\pi\,D^2/4) \times d))/t$	D = diameter of the well (m). d = depth of water column (m). Q = pumping rate (m^3/hour). t = time required for emptying the well (hour).	Raghunath (2006)	10.95 m^3/hour
Specific Yield (S_y)	$S_y = (2.303/T)\log_{10} s1/s2$	s1/s2 = desidual drawdown ratio T = Time required for water level rising (hour).	Raghunath (2006)	8.546 hr^{-1}
Specific Capacity (S_c)	$Sc = S_y \times A$	S_y = Specific yield of the stream deposits. A = Area of the dug well section	Raghunath (2006)	90.624 $m^2\ day^{-1}$
Safe Yield (Qy)	$Q_y = S_y\,A\,H$	Q_y = safe yield of the well (m^3/s). A = area of cross section of the well (m^2). H = Safe working depression head (m). S_y = Specific yield of the soil.	Raghunath (2006)	176.694 m^3/day
Transmissibility (T)	$T = S_c \times 1.2$	T = Transmissibility (m^2/d). S_c = Specific Capacity	Raghunath (2006)	108.749 m^2/day
Hydraulic Conductivity (K)	$K = T/H$	T = Transmissibility (m^2/d). H = Saturated thickness (m)	Raghunath (2006)	51.79 m/day
Yield of Alluvial Bed (Q_G)	$Q_G = K\,A\,dh/dl$	A = Cross sectional area (m^2) K= Hydraulic conductivity (m/day) dh/dl= Hydraulic gradient	Darcy's Law	308.876 m^3/day
Packer Test	$T = Q\,ln(R/r_b)/2\pi\,P_i$ $K_p = T/L$	T = transmissivity (m^2/day). Q = injection rate (m^3/day) and it was Zero. R = radius of influence (m). r_b = radius of borehole (m). P_i = net injection pressure (m). T = Transmissivity (m^2/day). L = Length of test zone and equal to 3 m.	Brassington (2007)	0

Table 4. Standards of transmissivity (m^2/day) [13].

Transmissivity (m^2/Day)	Potential
>500	High
500 - 50	Moderate
50 - 5	Low
5 - 0.5	Weak
<0.5	Negligible

same. This means that the water did not penetrate into the clay stone. Hence according to the above equations of transmissivity and permeability for the clay stone the values are equal to zero. This suggests that the clay stone is capable to retain water and prevent seepage to create an ideal location for water collection.

9. Subsurface Dam Capacity

Large parts of Garmiyan area suffers from shortage of water supply during dry periods. Rainfall, both spatially and temporally is decreasing due to the effect of climate change [14]-[18]. In addition, the situation becomes more severe where the populations growth rate is increasing. One of the solutions to this problem is increasing the water storage within the stream deposits to secure water supply to local communities.

The storage capacity of the subsurface dam within Isayi stream can be calculated depending on the surface area of the stream deposits upstream the project, average saturated thickness and effective porosity of the stream deposits. The yield of the stream deposits can be increased by building another subsurface dam at nearly 1 km upstream the first one as illustrated in **Figure 11**. Hence the upstream area of stream deposits, between the first subsurface dam and the confluence of Isayi stream's main two branches that can be exploited by both projects, will be 835,250 m^2. The average saturated thickness is 4.5 m, and the groundwater level (depth below the ground surface) is kept at a depth of 1 m to prevent evaporation as recommended by Hellwig [19], then, the calculated total storage capacity for the both subsurface dams is 1,014,829 m^3 as shown in **Table 3**. This storage capacity can retain nearly 1/3 of the total stream discharge of Isayi stream that had been measured during (2011-2012) and compared with the rain fall during that period as it illustrated in **Table 5**, **Table 6**. This ratio can be increased if additional subsurface dams constructed within the stream deposits upstream the suggested locations.

These projects can be applied in Garmiyan area beside each village with less cost to harvest the available surface and subsurface water. **Figure 12** suggests that rainfall begins to recharge the subsurface water from autumn to the begging of the summer and the ceases effective surface runoff from January to the end of March.

10. Water Utility

According to the common water uses in the studied area, groundwater quality has been evaluated for domestic, irrigation and live stocks purposes as follow:

10.1. Domestic Use

The groundwater samples have been compared with drinking water standards that are prescribed by World Health Organization [21] and Iraqi drinking water standards [22] as given in **Table 7**.

The physical, chemical and biological characteristics of all samples indicated that groundwater within the stream deposits is suitable for drinking purpose with slight hardness regardless of the slight elevated groundwater temperature. Because subsurface water is recharged with rainfall rapidly and there is no dense urbanization and industrial developments in the upstream parts of the watershed to cause contamination.

10.2. Irrigation Use

Irrigation is the major agricultural practice in the watershed. Most of the farmers intensively use water from hand dug wells in the study area. Based on the EC, irrigation water can be classified into four categories [23] as shown in **Table 8**. Based on this classification, all the water samples are classified as C2 water class for irrigation.

10.3. Livestock Use

In the studied area, farmers use the ground water for their animals. Livestock water can be classified on the basis of TDS concentration [24] as illustrated in **Table 9**. According to this classification, all water samples in the study area are safe for livestock.

11. Time of Construction

Subsurface dams are generally built at the end of the dry season when there is minimum water in the aquifer [25]. The maximum variation of fluctuated water level was 20 cm which means that the interflow are not originated

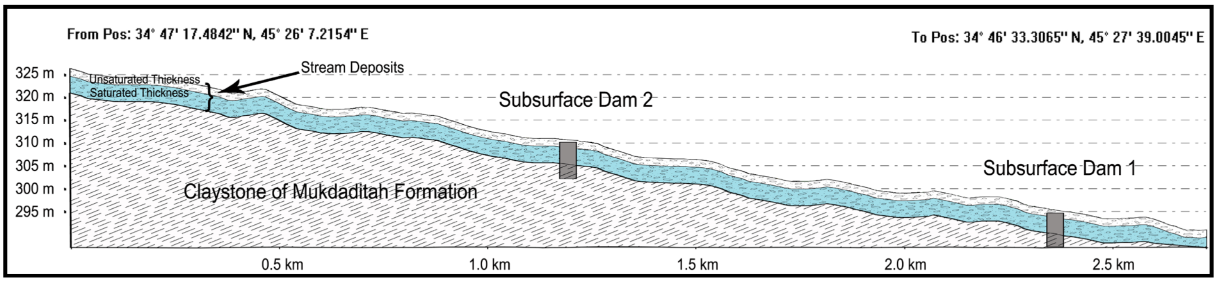

Figure 11. Longitudinal section along Isayi stream, illustrating location of the suggested subsurface dams with the stream deposits.

Table 5. Measured characteristics of stream deposits and assumed storage capacity of the subsurface dam.

Subsurface Dam NO.	Dam Height (m)	Average Saturated Thickness (m)	Upstream area of the stream deposits (m^2)	Porosity of the stream deposit [11] [20]	Storage Capacity (m^3)
1	4 - 10	4.5	434,330	20% - 35%	390,897 - 684,070
2	4 - 10	4.5	400,920	20% - 35%	360,828 - 631,449
Total	-	-	835,250	20% - 35%	751,725 - 1,315,519

Table 6. Water resource measurement within Isayi watershed.

Months	Rainfall (mm)	Rainfall (m^3) based on watershed upstream the projects	Surface Flow (m^3)	Surface Flow (%)	Subsurface Flow (m^3)	Surface & Subsurface Flow (m^3)	Surface & Subsurface Flow %
Sep.	0	0	0	0.00	19175.77	19175.77	Base Flow
Oct.	0	0	0	0.00	19978.72	19978.72	Base Flow
Nov.	3.50	507,500	0	0.00	20205.87	20205.87	Base Flow
Dec.	7.40	1,073,000	14257.78	0.18	20879.4	35137.18	0.42
Jan.	22.70	3,291,500	195932	2.43	20879.4	216811.4	2.61
Feb.	39.50	5,727,500	3625344	44.93	18985.59	3644329.59	43.84
Mar.	53.50	7,757,500	3555783	44.07	21165.98	3576948.98	43.03
Apr.	27.30	3,958,500	659021.2	8.17	20364.35	679385.55	8.17
May	11.50	1,667,500	18752.78	0.23	20879.4	39632.18	0.48
Jun.	5.30	768,500	63.05	0.00	20126.63	20189.68	Base Flow
Jul.	0	0	0	0.00	20633.76	20633.76	Base Flow
Aug.	0	0	0	0.00	20142.48	20142.48	Base Flow
Total	170.70	24,751,500	8069153.81	100	243417.35	8312571.16	100

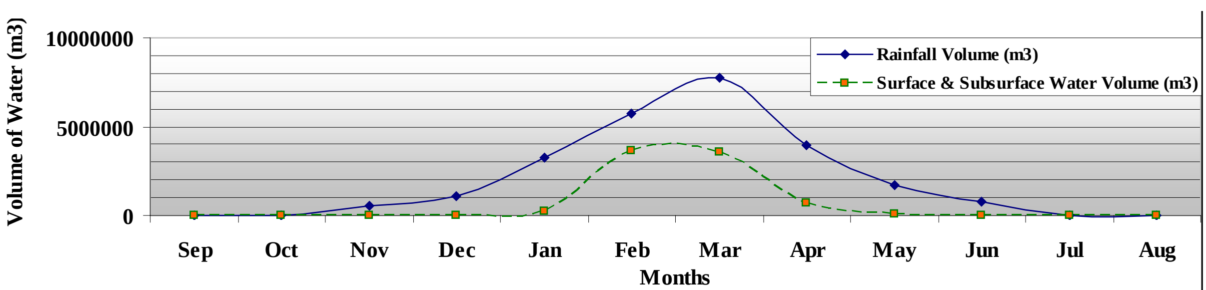

Figure 12. Available water resources in Isayi watershed.

from the rainfall only but also it has been recharged with water from base flow which originated from the neighboring and nearby aquifer especially Bai Hassan and Quaternary aquifer. The best time to undertake construction is at the dry season, because the lowest possible water table level is reached so that maximum water

Table 7. Groundwater compared to drinking water standards.

Parameters	Range of Water samples			Drinking Water Standard		Groundwater Samples Suitability
	DW1	DW2	DW3	(WHO, 2008)	Iraqi Standard (2000)	
Temp. (˚C)	26	26	26.1	25-Aug		Suitable
pH	7.26	7.3	7.55	6.5 - 8.5		Suitable
Ca^{2+}	90.63	90.8019	111.785	75	50	Suitable
Mg^{2+}	17.244	17.562	19.959	125	50	Suitable
Na^{+}	1.342	1.373	3.964	200	200	Suitable
K^{+}	1.4	1.34	1.5	12	-	Suitable
HCO_3^-	323.3	298.9	421.6	-	-	Suitable
SO_2^{-4}	76	78	86	250	250	Suitable
Cl^-	27	26	30	250	250	Suitable
NO_2^{-3}	15.52	14.16	0	50	50	Suitable
TH	297.275	299.009	361.294	-	500	Suitable
TDS	552.436	528.1369	674.808	1000	1000	Suitable
Coliform	0	0	0	0	50	Suitable

Table 8. Water samples classification depending on EC [23].

Level	EC (µS/cm)	Hazard and limitations
C1	<250	Low hazard; no detrimental effects on plants, and no soil buildup expected.
C2	250 - 750	Sensitive plants may show stress; moderate leaching prevents salt accumulation in soil.
C3	750 - 2250	Salinity will adversely affect most plants; requires selection of salt-tolerant plants, careful irrigation, good drainage, and leaching.
C4	>2250	Generally unacceptable for irrigation, except for very salt tolerant plants, excellent drainage, frequent leaching, and intensive management.

Table 9. Recommended TDS concentration limits for livestock consumption [24].

Stock	Hazard and limitations (ppm)
Poultry	2860
Horses	6435
Cattle (Diary)	7150
Cattle (Beef)	10,100
Sheep	12,900

reserve is acquired and water logging during construction is minimized and intermediate work pauses are curbed so that the activity is completed on time.

According to the meteorological data, the peak of dry season is the end of summer and beginning of autumn seasons at the studied area, whereas on the basis of groundwater level observation information, the maximum lowering down level of groundwater for 2012 was the end of autumn season (end of November). Hence the best time to be chosen for construction of the subsurface dam is during the autumn season from September to November.

12. Conclusions

Garmiyan area suffers from water shortage problems such as poor absence of surface water resources and groundwater in many places as well as low rainfall rate. To overcome this problem subsurface water dams are to be suggested to serve as strategic water supply storage. The results suggested:

- The selected site location for the proposed subsurface dam within Isayi watershed is suitable lithologically because the bed of stream deposit is surrounded by claystone. In addition to that the geological and structural situations provide suitable condition for subsurface dam construction.

- The GPR survey results revealed that no evidences of faults and cavities were recorded beneath the whole area under consideration.
- The geomorphologic investigations revealed that outlet of Isayi watershed collect high amount of surface and subsurface water; the stream deposits are perfect landform for water conservation that is surrounded by claystone preventing irregular water bypaths and leakage; and the slope is level to very gentle which is within the recommended range.
- The hydrogeologic surveys indicated that the selected site location for the project is suitable. This is due to the very low fluctuation of groundwater level in the boreholes, the pumping test revealed high productivity of stream deposits and the result of packer test indicated that the lower claystone layer is able to retain water and prevent seepage.
- Analyzed water samples suggest that it is suitable for domestic, irrigation and livestock purposes.
- The best time to be chosen for the construction of the proposed subsurface dam is during autumn *i.e.* from September to November.

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