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Analysis of immersed geological formations for Bekhmeh dam reservoir/ Erbil

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ABSTRACT

Geological formations areas measurements for immersion level have been got for the Bekhmeh dam reservoir depending on the digital elevation model (DEM) with resolution (10 m) and Global Mapper-GIS software, which deal with the spatial analysis and get the spatial data of the landforms. The immersed area of each geological formation was determined separately for all levels, from the minimum level (380m) to the maximum one (600m) above the sea level, with (1 m) interval
According to these measurements, Aqra-Bekhme and Shiranish formations have the highest value of the immersed areas, with immersion area (46386) m2 and (33183) m2, respectively, which form (19.6%) and (14.01%) respectively of the total immersed area of the reservoir. These two formations were immersed at most of the immersion levels. Those formations consist of hard rocks with low solubility.The lowest value of the immersed area was for (Naopardan and Chile Formation) with an area (79) m^2, which forms (0.03%) of the total immersed area; followed by Chia Gara, Barsarin, and Nokelekan formations with an immersed area of (164) m^2, which form (0.07%) of the total immersed area .Those formations were immersed at the last three immersion levels (570-600m). The soluble and friable unit, which cause an engineering problems, has low value of the immersed area. That unit represented by Fat'ha Formation, which has an immersed area of (16399) m^2, and forms (6.92 %) of the total immersed area. In addition, it is far away from the dam body with (1472) m. These characteristics qualifies this location for reconstruction the dam.

Introduction

The main area of scientific studies includes the landforms and its formation processes along the time scale. The present study concludes(immersion level)by geological formations The nature of the processes that prevailed and led to the formation of forms, which will enable us to know the nature of the prevailing processes which will lead us to know the shapes expected to be formed later as well as the most important problems and risks which will result. As the field of interest of landform concentrated in the surface included in natural forms and processes. It will explain the nature of the interaction between the Earth's surface and the surrounding environment. Such as Atmosphere and hydrosphere and biosphere and lithosphere. This is made for applied landforms relevant relations with other sciences. which distinguishes our current study to clarify the measurements of areas of exposed geological formations' and indicate the extent to which its structure is affected and rock formation through levels different reservoirs[1].

The theme of immersion areas of geological formations that exposed at reservoirs body is very important, adding to the necessary requirements needed by the designer, executive and decision-making and the effect has determines the location, position and reservoirs of the dam, which is complemented with the rest of the other scientific disciplines (engineering and hydrological) that apply and contribute to the operation and establishment of

the dam reservoirs project. To complete this study (immersion areas) at each level, an important and accurate sources. These sources includes a satellite data technologies (Digital Radar Elevation Model) with high distinction resolution. which were not used in other projects in Iraq because it was not available at establishment time. These high resolution satellite images are important for determination the type and area of geological exposed so as to determine whether there are geometric problems that will occur because of the presence of friable geological formations and a position on the site of the dam and its reservoir, especially containing high proportions of gypsum such as the Fat'ha formation. In addition, they will help to identify and document the data and preliminary information for weakness levels, vulnerability and strengths such as the structures (fault, cracks and joints) and geological formations that will influence the establishment of the project structure, as well as knowledge of risks (erosion and dissolve), which will faces the dam position and its environmental impacts in the future.In addition to determining the type and features of water which will be stored in the future[2]. after the construction of the dam and after knowing the area of each immersed geological formation at the water levels of the dam reservoir.

The study Problem:

Many dam sites suffer of problems and dangers of collapse especially in Iraq, because the rock beds on which these dam were built are unsuitable such as (Mosul and Badush) Dams.This leads to the statement of what are the most important reasons that led to these risks?

- ❖ Lack of geological studies for the project.
- ❖ Neglecting and not relying on the initial geological reports in establishing the project.
- ❖ Low quality of geological studies, especially the immersion of the reservoir from each level, as well as the location of the dam body, whether exposed or subsurface.
- ❖ Neglecting the formations and their areas located near to the dam body and located within the immersion levels of the dam reservoir.

Study hypothesis:

- ❖ Conducting many geological studies and on-site geological investigations for the dam's body and its water reservoir will give the main determinant of whether or not the dam was built.
- ❖ The study will achieve the determination of the immersion areas of the geological formations of the water reservoir, using the practical methods of the software which based on the high-accuracy remote sensing data**.**

Study Approach:

The study is organized with its ideas and the way it deals with the spatial variables of the subject by using:

The barometric Approach: which specializes in using the digit language by applying a series of different statistical calculations and analyzes to reach accuracy in the language of expressing spatial variables.

- ❖ Land appearance Approach: which will lead to achieving a comprehensive geomorphological and geological assessment of the dam reservoir.

Study Justifications:

High-risky and geometric problems dams were constructed in Iraq, including the Mosul dam, continuous treatment processing (injection) costed too much money. As these errors persist, such as the starting the build Paddoush and Makhul Dams, where those sites were selected. The dams and reservoirs on an invalid land (gypsum) making them a continuing threat and must hold ongoing processors and maintain them, which affects the economic return after building it. So our current study was to indicate, statement and clarification a good ground to build the dam , as well as the impact of the reservoirs floor (rock formations) when each water level will immersion the dam reservoirs to reach the result of the consequence and validity of the dam site, as well as the water quality of the reservoirs and the extent of the contribution and impact of fragile and vulnerable formation on the endurance strength of the dam, economic value and to avoid risks after the filling the reservoirs.

Objectives of the study:

The study aims to get and analyze the immersion areas for each geological formation at Bakhmeh dam reservoirs to determine its hydrological and hydraulic relationship with the reservoir, and the geometry of the dam body. The immersed area of each formation was calculated at each water level in the dam reservoir, it will be an Important and basic database can the designer rely on it to develop designs for the dam's body and its location, and the optimum level of the reservoir, which gives economic benefit and good project management of the project and avoid the risks and problems that the dam will be faced after or operation.

Sources of data and information:

The study relied on previous available reports and studies especially those related to the geology, geomorphology, topographical maps, climate data and digital data covering the study area, as well as data taken from field visits, some pictures illustrating the field study.

Picture (1), taken by the researcher, showing the location of the Bakhme Dam

Picture (2-3) Shows some areas of immersion inside the reservoir Bakhme Dam

Picture (4-5) showing the Bekhmeh formation and the reservoir of the dam

Programs used in the study:

- ❖ Programs Arc GIs 10.6.1.
- ❖ Programs Global Mapper 13

Study area:

The study area, represented by The area of the dam reservoir (Bakhmeh) is located, was determined between longitude (20 ″44° 27′ 30″ - 43° 41′) E, and latitude (37° 22′ 50″ - 36° 32′ 80″) N shown in Fig (1). with area about (236853) m^2, and extends with the Upper Zab River stream in parallel direction. The direction of the axes of the folds in the region isNE-SW for a distance of (83.5) km long east of Bakhmeh gorge. Its area overlaps between the adjacent administrative borders of three governorates: Dohuk, Erbil and Nineweh. It is bounded on the west by the Aqrah district ,from west and east by Merka Sur, and in the south and southwestern side by Khalivan and Shaqlawa. As for the site of the Bakhme Dam located near the district of Aqrah in the Bahdinan area, near the village of (Bakhma) at the southern plung of Berat anticline along the Upper Zab River. The suspended sediments in the Upper Zab River is about (19) million tons of deposits per year, in addition to gravel and sand with higher quantities [4].

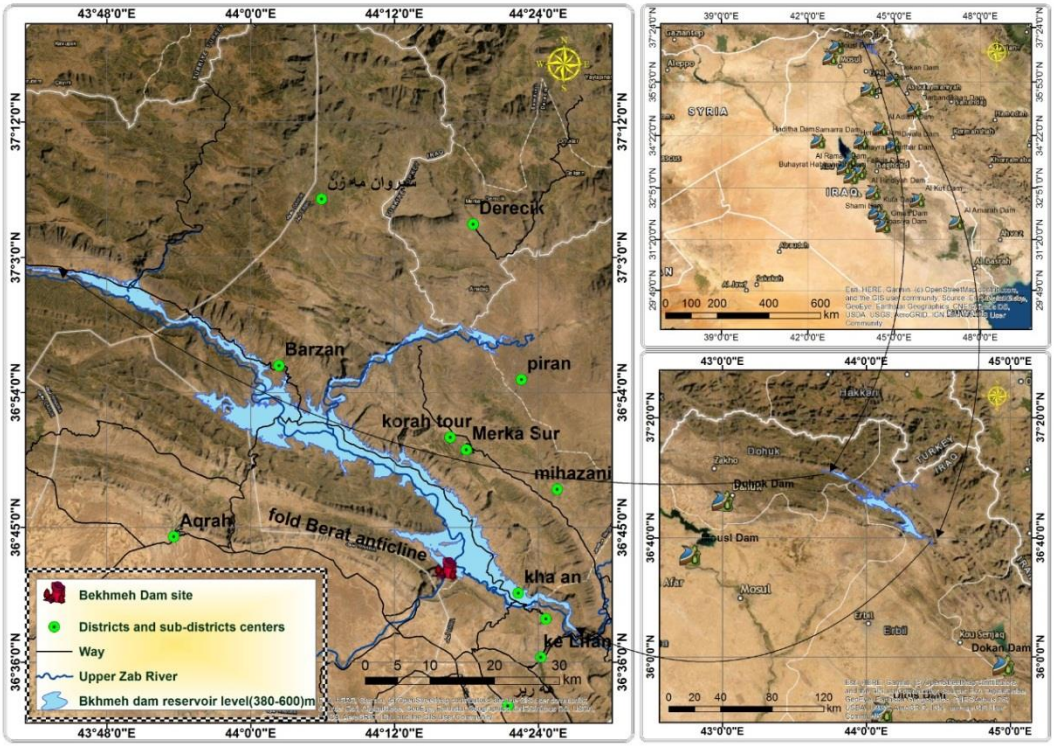

Fig. 1: showing the location of the study area (a reservoir and Bakhme Dam)

Previous studies of the design and implementation of the Bakhme dam project:

Investigation of the geological structures for dams and reservoirs is of greatly important by companies and researchers specialized projects (dams) before starting and establishing the site and position of the dam and a water reservoir, especially in recent years because the need for water and to control the rivers drainage, as well as its scarcity and to prevent the dangers of flooding and its importance in the development of human life and its sustainability, achieving water and food security; lack of local studies of immersion levels of the geological formations of the Bakhme dam reservoir with the exception of studies that were held at the site of the dam only by foreign companies as well as some of the undergraduate researchers. We include some of these studies: -

- ❖ In 1938, the geologicalist, Mister (Copens) conducted a geological examination of the site. He two visited the site two times, and he concluded that a site for the construction of the dam on the Great River was at the entrance to the Bkhmeh Strait.
- ❖ F During the period (1945-1948), a geological study was carried out by the geological expert (Dr. Hijn) and submitted his report in 1949. He has made the investigations for two northern and southern sites Bkhmeh Strait. The first site was elected as the most suitable for the construction of the dam.
- ❖ The Great Irrigation Projects Authority, headed by Heck, conducted a detailed study between the years (1946-1949) about the Bakhme Dam project In addition to several other projects. It provided detailed hydraulic geological site surveys, The study mentioned the details of the rock beds at the site of the dam. It was chosen because of its geological suitability, it also mentioned the importance of the dam to control and reduce the flooding of the Tigris River [3].
- ❖ In 1979, a Japanese company (E.P.D.C) to conduct new geological investigations and prepare detailed designs. The final design was a high dam

with a height of (230) m at the entrance to the Bekhmeh Strait, to store about (10) billion m3.

❖ Study Azealdeen Al-Jawadi-(2018) (Evaluation of the Rock Mass At The Bekhme Dam Site North East Iraq.

Structure, geology and geomorphology of the study area:

The geology and geomorphology of the area are one of the most prominent natural ingredients in the planning of the dam body structure and reservoirs, which are linked to the grounds and engineering studies that precede and determine the place for the dam project and its reservoirs. After construction the dam, it may be exposed to collapse or failure if these elements are neglected, so must follow and establish several preparatory studies associated with the process of planning, implementation, dams and reservoir construction.

The study area is located in the Northeast edge - Nubio Arabian Platform within the Unstable Shelf in the high folded Zone according to the tectonic divisions of Iraq (Jassim and Goff, 2006), and reflects the development of a series of high and narrow folds with northwest -southeast trend. They were formed due to Alpine orogeny as a result of the collision between the Arabian shield with the Iranian and Turkish shields. The location of the study area is at Pirat foldin the Zab River Valley, which is restricted between Merka Sur and Aqrah folds.. look figure (2)[4].

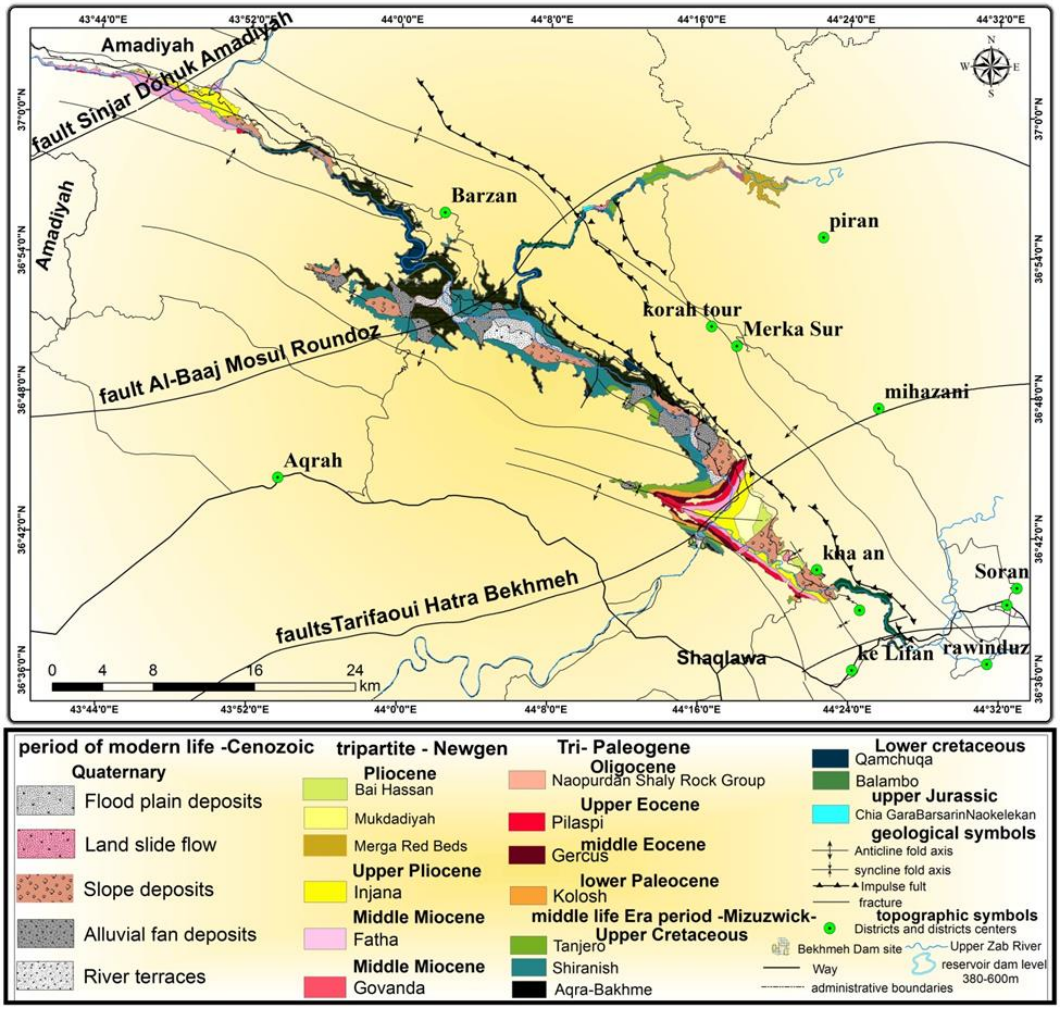

Fig. 2: represents the exposed geological formations of the Bakhme Dam reservoir (after [6])

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Geological formations exposed at the dam reservoir:

The importance of studying geological formations and their impact on the hydraulic characteristics for layers, its hydrological nature, hydrochemistry of the water in valleys towards the reservoir vertically or horizontally. Rock units of the study area are of Mesozoic and Cenozoic ages. The Mesozoic successions represented by the Upper Jurassic formations (Chia Gara, Barsarin, Naokelekan), the Lower Cretaceous formations (Balambo-Qamchuqa), and the Upper Cretaceous formations (Aqra-Bakhme and Tanjero). The Cenozoic successions represented by the Paleogene Kolosh Formation, the middle Eocene Gercus Formation, the Upper Eocene Pilaspi Formation, the Oligocene (Naopurdan Shaly Rock Group Formation, the Middle Miocene Govanda and Fat'ha formations, the Upper Miocene Injana Formation, the Pliocene Merga Red Beds – Mukdadiyah, and Bai Hassan formations. Exposed

geological deposits have ended by Quaternary sediments that stretched from the Pleistocene to the Holocene and included the river terraces, alluvial fan deposits, slope deposits, and flood plain deposits Table (1) [5].

Table (1) represents the exposed geological formations of the Bakhme Dam reservoir, its age and its lithological description. [6]

s	Formation name	age			rocky description
1	Flood plain deposits	period of modern life -Cenozoic	Quaternary	Holocene	siltstone and sandstone with lenses of clystone and Conglomerate
2	Land slide flow			Pleistocene-Holocene	A heterogeneous mixture of rock fragments
3	Slope deposits			Pleistocene-Holocene	Rock fragments, with fine clastics
4	Alluvial fan deposits			Pleistocene	Rock fragments, locally gravelly, covered by thin mantle of soil
5	River terraces			Pleistocene	Conglomerate with lenses of sandstone and siltstone
6	Bai Hassan		tripartite - Newgen	Pliocene	Conglomerate, sandstone and clystone
7	Mukdadiyah			Pliocene - Miocene	Pebbly sandstone, siltstone and clystone
8	Merga Red Beds			Upper Pliocene	Pebbly sandstone, red marl, shale and conglomerate
9	Injana			Upper Pliocene	sandstone, siltstone and clystone
10	Fatha			Middle Miocene	Gypsum,Marl, limestone, red claystone and siltstone
11	Govanda			Middle Miocene	Mainly limestone
12	Naopurdan Shaly Rock Group		Tri-Paleogene	Oligocene	Grey Shale,coralline limestone- Tuffaceous slates-Felsitic volcanics – Basic conglomerate ,Grey wacke
13	Pilaspi			Upper Eocene	Mainly well bedded limestone's
14	Gercus			middle Eocene	Red sandstone, siltstone and claystone
15	Kolosh			lower Paleocene	Black Claystone, siltstone and sandstone
16	Tanjero	middle- life Era period - Mizuzwick-	Upper Cretaceous		Khaki sandstone and clystone, with Conglomerate
17	Shiranish				Well bedded to limestone's and blue marl
18	Aqra-Bakhme				Mainly Well bedded massive limestone's(MARLY limestone's
19	Qamchuqa		Lower cretaceous		Mainly massive limestone's and dolomites
20	Balambo				Marly limestone, marl, bedded to limestone's and dolomite
21	Chia Gara, Barsarin, Naokelekan		upper Jurassic		Mainly bedded to massive dolomites, limestone's and marl

Geomorphology of the study area:

The study area (reservoir Bakhmehe) is located in the eastern border of the high Folded Zone, which represents the simple folding belt. It is the transitional area towards the Foothill Zone area. The reservoir rises between (380-600) meters above sea level, which has been selected and cut its limits from Satellite (DEM). It has by longitudinal and transversal valleys. The reservoir is confined to a long and highly simple fold of the east – west direction. It deviates at Bakhme Dam to a northwest-southeast direction, including a Merkasur and Bradust folds, east and northeast of the reservoir, in addition to Kara and Sherine folds north of Zebar, northeast of the reservoir. It is also limited by the north-western folds (Berts, Pierce, and Aqra), which runs parallel to the western and northwestern borders of the reservoir passing through the city of Aqrah until it crosses the Upper Zab River at Bakhme gorge (site of the dam). At the city of Rawanduz, the southern and southeastern borders of the reservoir, it is very sinuosity as a result of fracture effect which cuts its axis vertically. The syncline folds represents the narrow low topography of the reservoir which forms the course of the Zab River in the middle of the reservoir. Many of valleys cut these folds orthogonally towards its axes, especially the anticline. Some of these valleys are tributaries which meet with the Upper Zab River within the border of the reservoir which was formed by vertical cracks and faults on the axis of the folds, causing structural weaknesses represented by valleys such as (Tarifaoui-Hatra-Bekhmeh) and Al-Baaj-Mosul-Roundoz faults [7].

The factors and geomorphological processes led to the modification and formation of varied landforms in the reservoir area, including a destructional and constructional landforms, which reflected the activity of these processes and the dominant type (Internal Movements - weathering erosion – collapse-landslide). All kinds of water erosion predominate because of the rugged surface and the intensity of the slopes. Physical weathering processes due to low temperatures and snowfalls. These processes led to formation of various geomorphologic forms. Some of them are of structural origin, such as mountains, folds, faults, andstructural ridges especially at a high folds at the most resistant rocks for erosion and with

steep slope. (previousely mentioned folds), as well as the hogback, at the fold limbs, the furrows and brook erosion is predominant. The landforms with fluvial and depositional origin, including flood plain, are distributed at some neighboring areas of the Upper Zab River inside the reservoir, especially in the areas of river bends at the beginning of the reservoir and near the dam area. These are consists of sand, alluvial and clay deposits, as well as the alluvial fan and slope sadiments at the base of the the slopes. These sediments are made by rivers and valleys descend from the highlands to the lowlands. River terraces was also formed on the right side of the Upper Zab River southeast of the village of Barzan. It consists of a different size gravel , from fine to coarse; and silt and clay. They are between (30-60) meters above the river level [8].

Climate Region:

Rains is a main source of feeding the Tigris River and its tributaries, in addition to the snow and groundwater in north and northeastern Iraq (mountainous area) with an area of 15% of Iraq, with its annual rates between (300 - 1000) mm in those areas and up to more than (1200) mm inside Turkey in the highest side of the upper Zab River. Low rainfall rates in dry and fluctuated years in the catchment area countries (Iraq - Turkey - Iran) to about (389.8) mm compared to the base rate of (502.2) mm In the feeding basin of the river, and most of Iraq, dry and semi-dry climate is predominat, which increases annual evaporation rates, reaching to 2737 mm. caused by extremely high temperatures from the basic rates (13.3)° to (14.9)°, with difference (+1.6) ^{o}C (14). This is due to the effects of climate change during some time periods, which leads to acceleration in geomorphological processes, including (weathering and erosion), especially in areas consisting of fragile and weak formations. All those climate variables contribute an effective decrease and increased annual revenue rate for the Tigris River in Iraq, according to the increase and decrease of each to be in the rainy years. The total general discharge of the Tigris River into Iraq in (2010) (33) billion ^{m3}, while in drought intervals, it is (19) billion ^{m3}. On the other hand, the contribution of the basin countries, Turkey, Iraq and Iran, at an annual discharge rate of (56-32–12) billion, respectively [9].

Choosing the closest weather station for meteorological monitoring to represent the climate data for the study area, which is the Mirka Sour station in the Erbil governorate, located to the northeast of the reservoir at a distance of (6) km. Table (2) shows the annual and monthly average values of a number of climatic elements recorded over a period of time (18) year in the meteorological station, which is the period recorded since the establishment of the approved station.

Table 2: Annual and monthly averages of a number of climatic elements for the study area

climatic element	average yearly	Highest monthly average	Lowest monthly average
Temperatures (°C)	18	30 - July and August	2.2 - January
Rainfall (mm)	675	200 - January	0- July, August, September
relative humidity (%)	65	75.3 - January	28 - August, September
wind speed (m/s)	1.9	2.8 - April	1.7 - September
evaporation (mm)	1.6	6.3 - July	0.7 - January

Acquisition the immersed area of the geological formations in reservoir:

The exposed geological formations were calculated for the Bakhmeh dam reservoir from the digital elevation model with resolution (10 meters). It was calculated from the level (380-600) m above sea level per meter for (220) levels using spatial analysis software which processes spatial data and converts it into numbers representing the measurements of land form (2D-3D). The boundaries of the water reservoir were cut from the dam body site at the top level, to (600) m. Then cut off for watch level and exported form with shapefile after converting it from formula (Raster) to (Features -Vector) using the (GLOBAL MAPPER) program. Then performed a cut off program (GIS) for each level from the map of the exposed geological formations. After that, the calculating the area of each formation at each level was carried out with 1 meter interval and exporting the data to the Tables format, which represent databases for level of exposed geological formation for each reservoirs level as in tables (3-4). The spaces of immersed formations are taken for each level (10)m to reflect the immersion models of the reservoir, as well as the table of percentages (5-6) and calculate percentage of the immersed area for each formation and represented in graphical forms. Areal coding process was also carried out for the exposed geological formations as in shapes.

Table 3: The immersion area(m2) for each geological exposed and the level interval (10) m for the reservoir

Water Level /m	Flood plain deposits	Land slide flow	Slope deposits	Alluvial fan deposits	River terraces	Bai Hassan	Mukdadiyah	Merga Red Beds	Injana	Fatha	Govanda
400									295	246	
410	64	44	149		0	0	213		2534	904	
420	794	63	868	226	0	0	650		3439	1470	
430	1411	90	2556	1015	0	0	1490		4343	1845	
440	2383	129	3942	1524	0	0	1961		4937	2169	
450	3474	166	5204	1993	0	0	2359		5416	2533	
460	4154	197	6781	4343	2	11	2808		5913	2827	
470	6070	227	8509	6109	13	33	3275		6519	3108	
480	7205	259	10485	7328	86	98	3836		7338	3371	
490	8079	296	12725	8318	187	214	4326		7668	3662	
500	8686	336	14110	9976	477	391	4805		7964	3914	
510	9025	376	15627	11435	1009	576	5122		8226	4226	
520	9238	415	18043	13125	3230	869	5331		8443	4530	
530	9266	451	20488	14346	4401	1170	5475		8611	4796	
540	9269	487	22680	15097	4435	1415	5610		9096	5186	
550	9269	537	24544	15831	4439	1644	5761		9597	6001	
560	9269	596	26114	16617	4439	1880	5882		10955	8158	
570	9269	645	27513	17678	4439	2089	6031		12421	10763	
580	9269	703	28874	18614	4439	2378	6185		13640	13027	
590	9269	748	29949	19600	4439	2554	6386		14716	14831	
600	9269	1046	30601	20016	4439	2761	6221	**4432**	14883	16399	**658**

Table 4: The immersion area(m2) for each geological exposed and the level interval (10) m for the reservoir

Water Level /m	Naopurdan Shaly Rock Group	Pilaspi	Gercus	Kolosh	Tanjero	Shiranish	Aqra-Bakhme	Qamchuqa	Balambo	Chia Gara, Barsarin, Naokelekan
380					**35**	**10**				
390				**14**	**71**	**28**	**3**	**3**		
400		**66**	**28**	**51**	**125**	**102**	**37**	**15**		
410		**227**	**245**	**102**	**150**	**160**	**57**	**24**		
420		**299**	**397**	**457**	**279**	**881**	**71**	**30**		
430		**387**	**487**	**587**	**506**	**1176**	**578**	**35**		
440		**514**	**561**	**687**	**707**	**1986**	**893**	**36**		
450		**690**	**636**	**770**	**875**	**3231**	**1203**	**41**		
460		**898**	**731**	**989**	**1185**	**5103**	**1856**	**49**		
470		**1153**	**888**	**1333**	**1499**	**7821**	**2615**	**53**		
480		**1370**	**1158**	**1568**	**1717**	**9665**	**4471**	**581**	**268**	
490		**1623**	**1489**	**1765**	**1963**	**11577**	**5707**	**860**	**328**	
500		**1879**	**1779**	**2006**	**2213**	**13763**	**7427**	**1656**	**391**	
510		**2140**	**2106**	**2253**	**2451**	**15695**	**9344**	**2676**	**639**	
520		**2394**	**2438**	**2498**	**2765**	**17625**	**13625**	**4667**	**752**	
530		**2711**	**2732**	**2726**	**3070**	**19699**	**16535**	**5314**	**931**	
540		**3075**	**3060**	**2894**	**3443**	**21440**	**22193**	**6197**	**2032**	
550		**3562**	**3504**	**3058**	**3930**	**22956**	**24970**	**6812**	**2656**	
560		**4829**	**4567**	**3213**	**4421**	**24502**	**28099**	**7426**	**3852**	
570		**5246**	**4871**	**3382**	**4884**	**26089**	**31679**	**8021**	**4346**	
580		**5748**	**5212**	**3496**	**5378**	**27928**	**35321**	**8601**	**4867**	
590		**6758**	**5914**	**3620**	**5945**	**29921**	**40195**	**9353**	**5583**	
600	**79**	**7575**	**6136**	**5092**	**10154**	**33183**	**46386**	**10518**	**6827**	**164**

Table 5: The Percentages immersion area (m2) for each geological exposed and the level interval (10) m for the reservoir

Water Level/m	Flood plain deposits	Land slide flow	Slope deposits	Alluvial fan deposits	River terraces	Bai Hassan	Mukdadiyah	Merga Red Beds	Injana	Fatha	Govanda
400									0.12	0.10	
410	0.03	0.02	0.06	0.00			0.09		1.07	0.38	
420	0.34	0.03	0.37	0.10			0.27		1.45	0.62	
430	0.60	0.04	1.08	0.43			0.63		1.83	0.78	
440	1.01	0.05	1.66	0.64			0.83		2.08	0.92	
450	1.47	0.07	2.20	0.84			1.00		2.29	1.07	
460	1.75	0.08	2.86	1.83			1.19		2.50	1.19	
470	2.56	0.10	3.59	2.58	0.01	0.01	1.38		2.75	1.31	
480	3.04	0.11	4.43	3.09	0.04	0.04	1.62		3.10	1.42	
490	3.41	0.13	5.37	3.51	0.08	0.09	1.83		3.24	1.55	
500	3.67	0.14	5.96	4.21	0.20	0.16	2.03		3.36	1.65	
510	3.81	0.16	6.60	4.83	0.43	0.24	2.16		3.47	1.78	
520	3.90	0.18	7.62	5.54	1.36	0.37	2.25		3.56	1.91	
530	3.91	0.19	8.65	6.06	1.86	0.49	2.31		3.64	2.02	
540	3.91	0.21	9.58	6.37	1.87	0.60	2.37		3.84	2.19	
550	3.91	0.23	10.36	6.68	1.87	0.69	2.43		4.05	2.53	
560	3.91	0.25	11.03	7.02	1.87	0.79	2.48		4.63	3.44	
570	3.91	0.27	11.62	7.46	1.87	0.88	2.55		5.24	4.54	
580	3.91	0.30	12.19	7.86	1.87	1.00	2.61		5.76	5.50	
590	3.91	0.32	12.65	8.28	1.87	1.08	2.70		6.21	6.26	
600	3.91	0.44	12.92	8.45	1.87	1.17	2.63	1.87	6.28	6.92	0.28

Table 6: The Percentages immersion area(m2) for each geological exposed and the level interval (10) m for the reservoir

Water Level m	Naopurdan Shaly Rock Group	Pilaspi	Gercus	Kolosh	Tanjero	Shiranish	Aqra-Bakhme	Qamchuqa	Balambo	Chia Gara, Barsarin, Naokelekan
380					0.01	0.004				
390				0.01	0.03	0.01	0.001	0.001		
400		0.03	0.01	0.02	0.05	0.04	0.02	0.01		
410		0.10	0.10	0.04	0.06	0.07	0.02	0.01		
420		0.13	0.17	0.19	0.12	0.37	0.03	0.01		
430		0.16	0.21	0.25	0.21	0.50	0.24	0.01		
440		0.22	0.24	0.29	0.30	0.84	0.38	0.02		
450		0.29	0.27	0.33	0.37	1.36	0.51	0.02		
460		0.38	0.31	0.42	0.50	2.15	0.78	0.02		
470		0.49	0.38	0.56	0.63	3.30	1.10	0.02		
480		0.58	0.49	0.66	0.73	4.08	1.89	0.25	0.11	
490		0.69	0.63	0.75	0.83	4.89	2.41	0.36	0.14	
500		0.79	0.75	0.85	0.93	5.81	3.14	0.70	0.17	
510		0.90	0.89	0.95	1.03	6.63	3.95	1.13	0.27	
520		1.01	1.03	1.05	1.17	7.44	5.75	1.97	0.32	
530		1.14	1.15	1.15	1.30	8.32	6.98	2.24	0.39	
540		1.30	1.29	1.22	1.45	9.05	9.37	2.62	0.86	
550		1.50	1.48	1.29	1.66	9.69	10.54	2.88	1.12	
560		2.04	1.93	1.36	1.87	10.35	11.86	3.14	1.63	
570		2.22	2.06	1.43	2.06	11.02	13.38	3.39	1.84	
580		2.43	2.20	1.48	2.27	11.79	14.91	3.63	2.06	
590		2.85	2.50	1.53	2.51	12.63	16.97	3.95	2.36	
600	0.03	3.20	2.59	2.15	4.29	14.01	19.59	4.44	2.88	0.07

Analysis and discussion of immersion geological formations:

The results of the immersed areas of the geological formations varies with different levels. The immersed area of some of these formations still to rise, and the other stops, (that it does not appear at that level). As a result, the total area of exposed formations increases with increasing immersion level, finishing with the final immersion level of the reservoir at (600) m above sea level. The immersion levels have been partition into formations for each (50) m for possible scenarios for the preferential selection of the level that will be adopted by the relevant authorities, if the dam is rebuilt.

Immersion levels (380-450) m:

According to the tables of the immersed areas of the geological formations (3-4-5-6) , the first immersed formations are (Shiranish - Tanjero) at the level of (380 m) above sea level. This level is represent the site of the dam. The immersed areas of these two formations are (35 m2) and (10 m2) for the Tanjero and Shiranish formations, respectively .At the level of (390m), the immersed area rises to (71-28) m^2 respectively. At this level, the immersed area of Kolosh Formation is (14)m^2 and for Aqra-Bakhme and Qamchuqa formations is (3) m^2 each. The characteristics of those formations are suitable to establish the body of the dam in terms of the rigidity and the hydraulic strength. Generally, there are no engineering problems in the these formation outcrops. The rising of the immersion level will leads to immerse the river valley near areas of the dam and to the confluence region (Rawinduz River) down the reservoirs (south) with Zab River flowing from from The highest area of the reservoirs (north). In addition to previously immersed formations, Gercus –Pilasp – Fatha - Injana formations will be immersed and as a shown in table(5). Appearance of of Fatha - Injana outcrops begins at the level of (399 m) and as shown in the level (400 m). The immersed area of The Injana and Fat'ha formations is (295) $^{m\ 2}$ and (246 m^2), respectively. These areas form (0.12-0.10)% respectively of the total immersed areas at this level

The closest outcrops of Fat'ha Formation , which is one of the most dangerous formations for the body and reservoir of the dam, is about (1472 m) from the dam site. Fat'ha Formation contains some of thin and thick beds of gypsum, which they are water soluble and may cause engineering problem in the future s. These water-soluble gypsum beds increase infiltration problems and increase salinity in the reservoirs water, especially at the first stages of the storage. Fat'ha Formation crops out in northwest-southeast direction with the Branch (Roandoz) valley, which occupies the biggest area (Fig.2). ,At the immersion level of (410) m level, in addition to the previously immersd formation, other formations will also immerse. The beginning with the Mukdadiyah Formation- Alluvial fan deposits - Slope deposits - land slide flow – and Flood plain deposits, with variable immersed areas. Then the increase of the immersed areas of these units till to rise significantly at the level of (420) m to the level of (450) m to be the largest area of immersed areas is for Injana Formation - Slope deposits - Flood plain deposits - Shiranish Fat'ha -Al-Mukdadiyah, respectively; with an area of more than(2,300) ^{m2} to (5416) m^2 to Injana Formation, as explain in Figures)., The immersed areas at this level extends with the river valley from the western region (Rizan), north of the reservoir, to the south of the reservoirs (Kha an). Generally, the immersion of the geological formations immersed does not reflect the presence of engineering problems at these levels, except for the Fat'ha Formation.

The immersion of the geological formations do not reflect presence of engineering problems at the suggested immersion levels, except for Fat'ha Formation. In addition, the immersion of the recent sediments; which they have high filteration rate; will leads to leak the water downward to the groundwater, which, in turn, will lead to rise the groundwater level. But the leakage will decrease systematically with time as a results of the accumulation of the fine sediments; which will envelope the reservoir, decreasing the permeability and the dead storage of the dam [10].

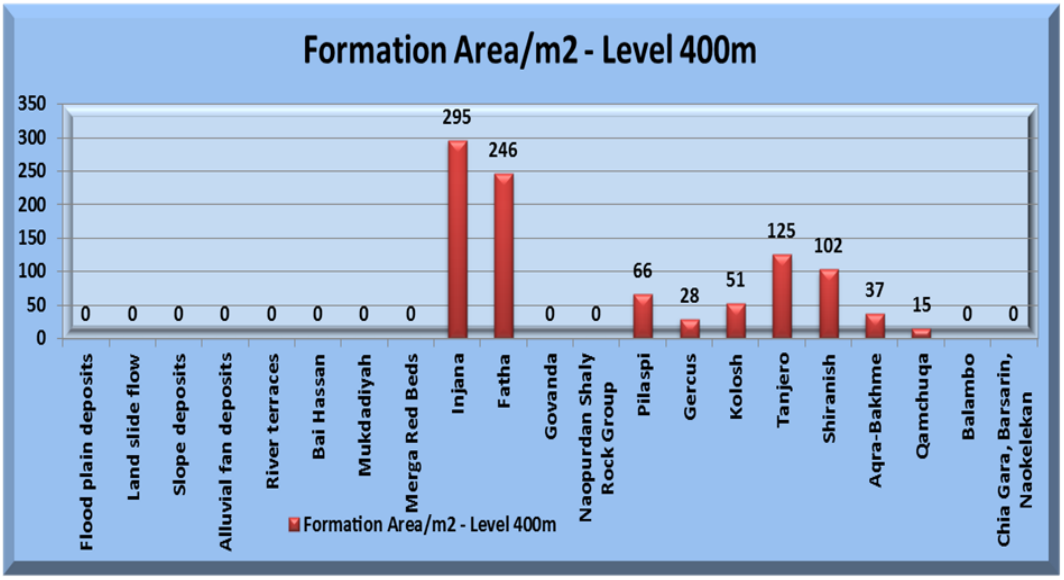

Fig. 3: Diagram showing the geological immersion area for the level (400) m

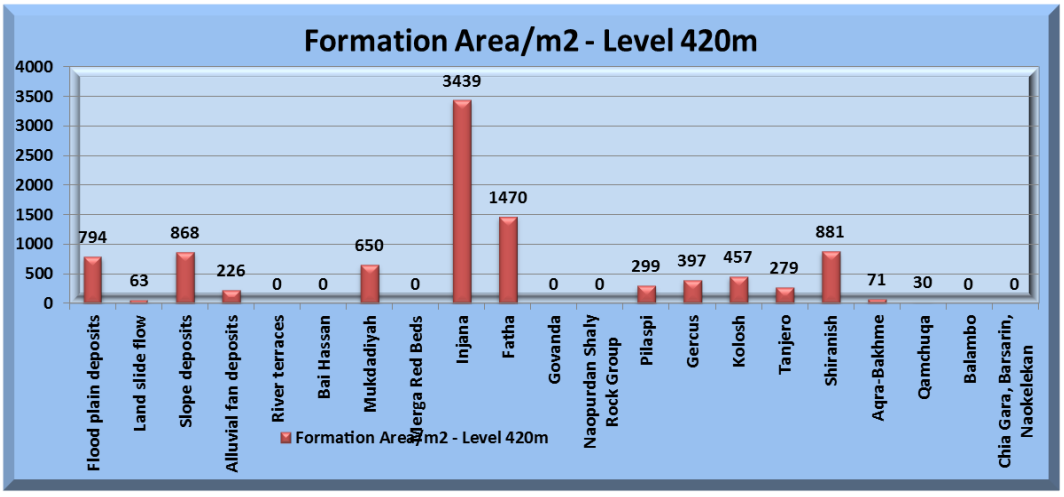

Fig. 4: Diagram showing the geological immersion area for the level (420) m

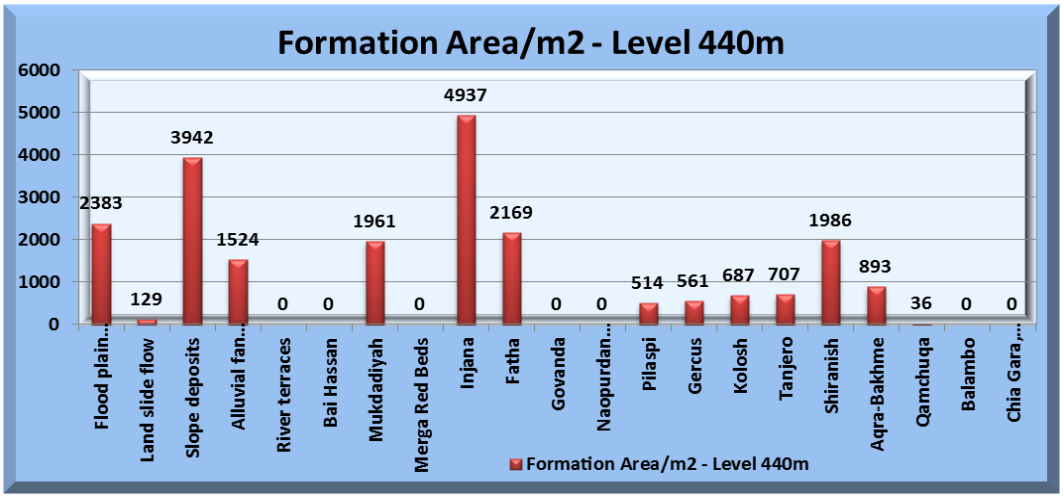

Fig. 5: Diagram showing the geological immersion area for the level (440) m

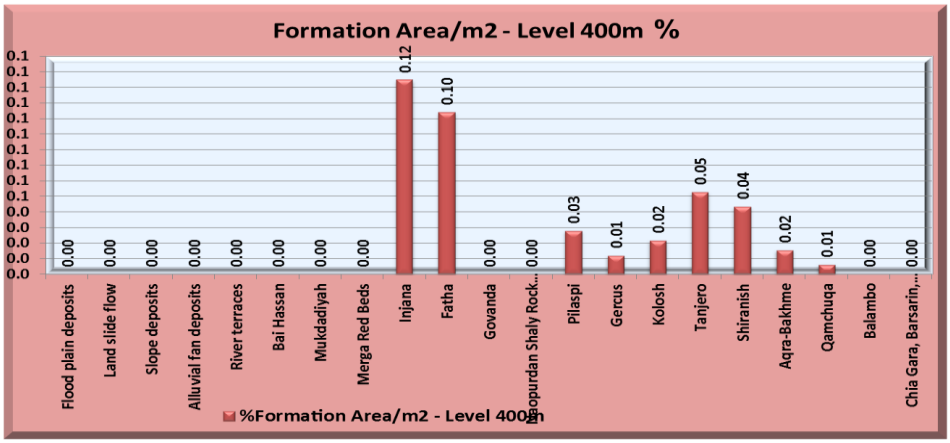

Fig. 6: Diagram showing the% geological immersion area for the level (400) m

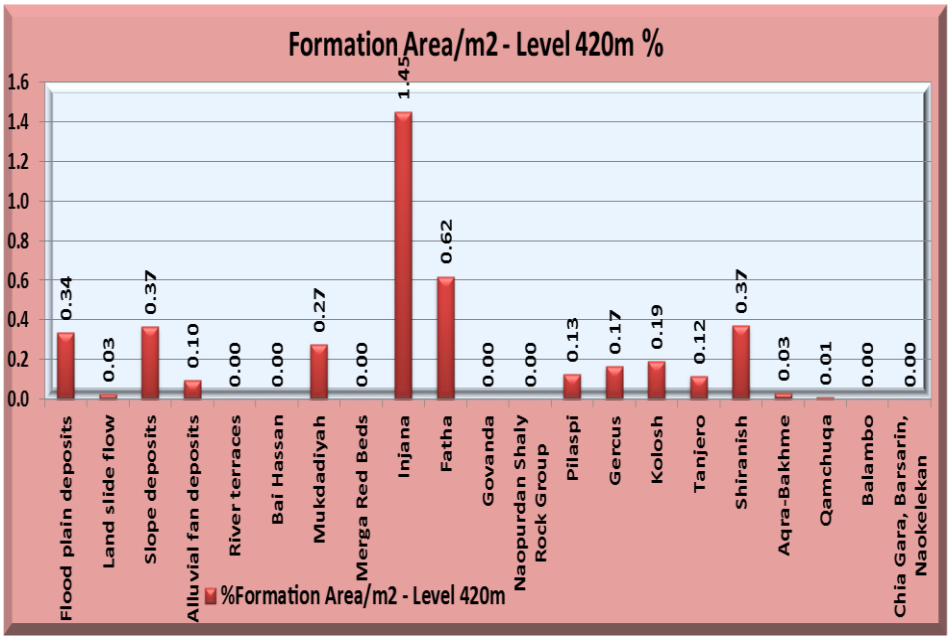

Fig. 7: Diagram showing the% geological immersion area for the level (420) m

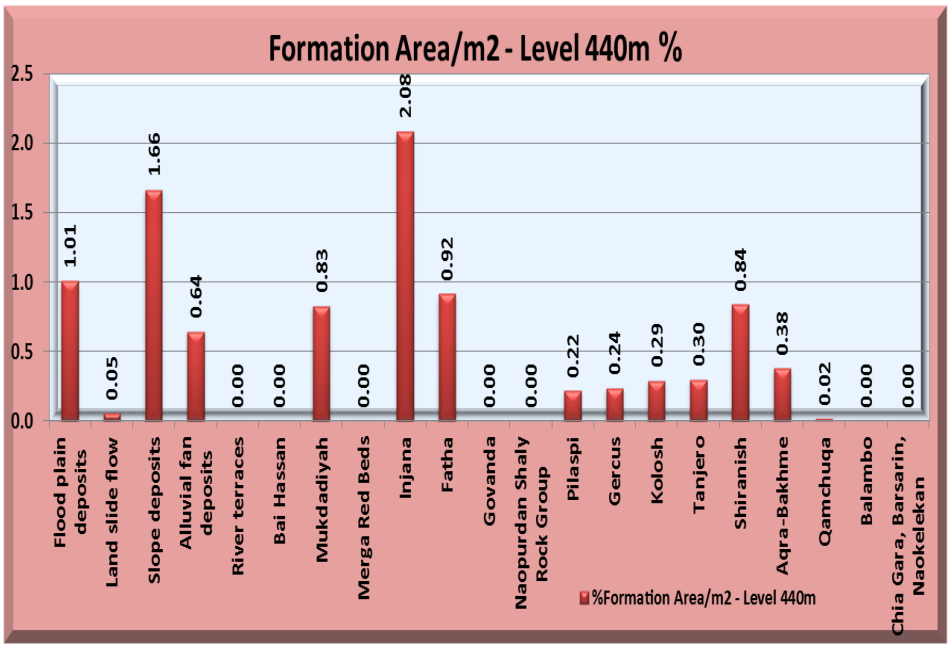

Fig. 8: Diagram showing the% geological immersion area for the level (440) m

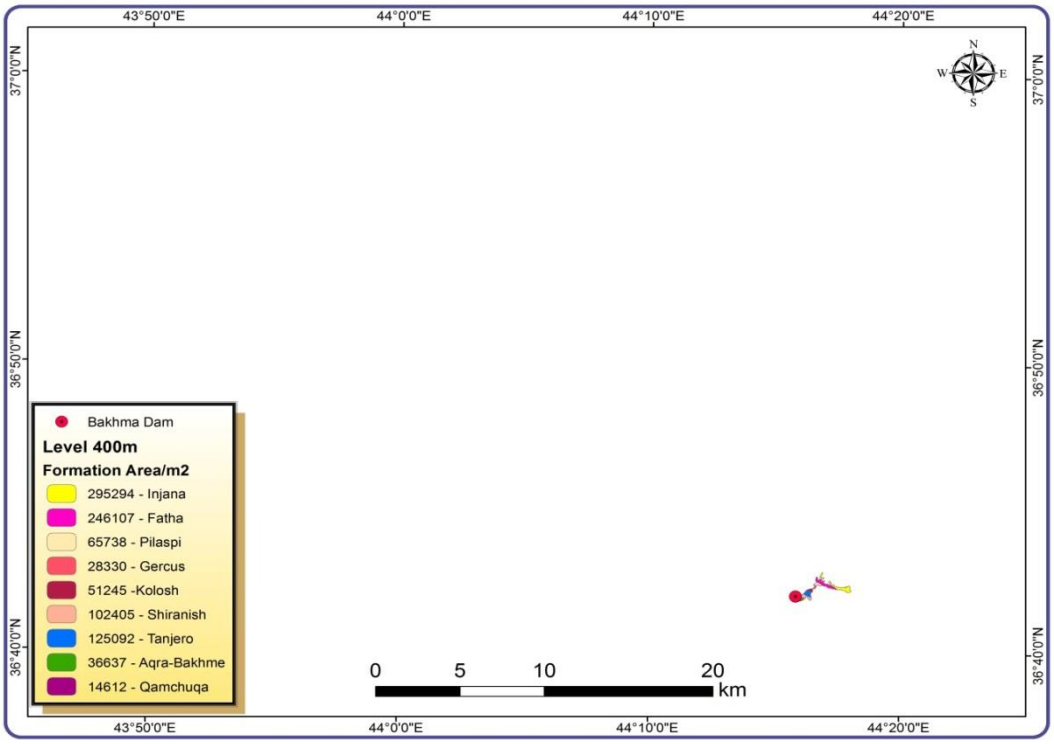

Fig. 9: Map distribution immersion area of the geological formations of the reservoir at level (400)m

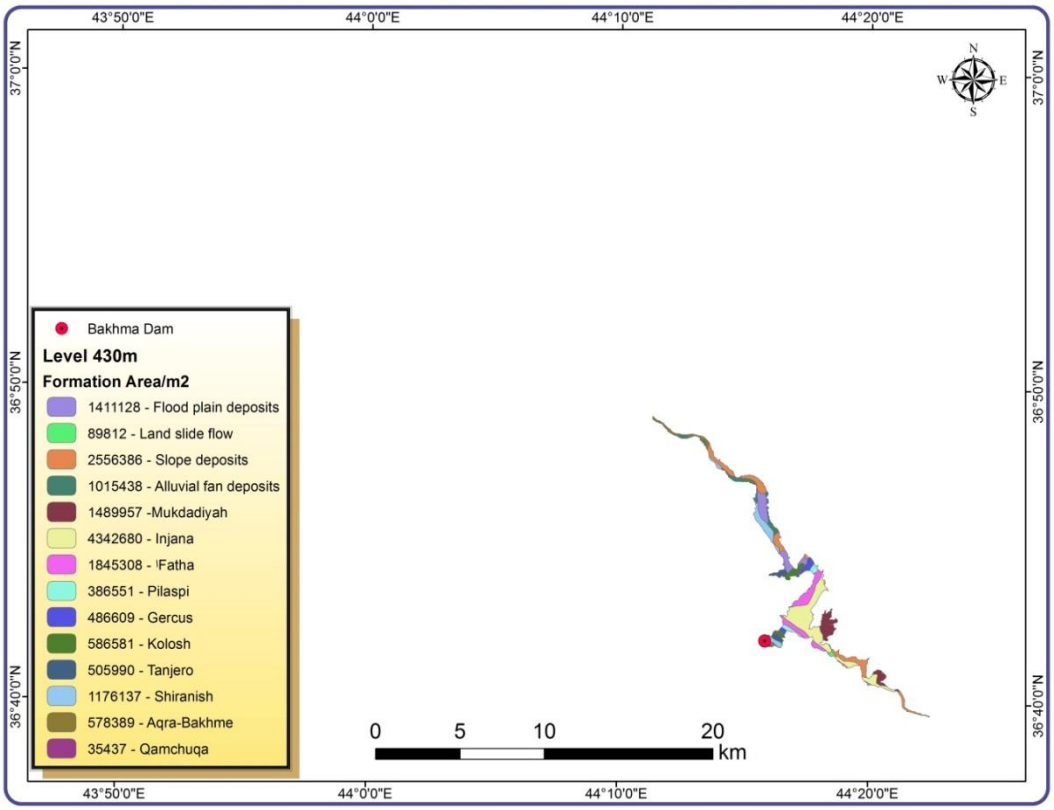

Fig. 10: Map distribution immersion area of the geological formations of the reservoir at level (430) m

Immersion levels 460-500m:

The immersed area begins at the level (460)m. in addition to the previousely immersed formations, Bai Hassan Formation and river terraces deposits also were immersed with an immersed area about (11) m^2 and 2 m^2, respectively. The immersed areas of the other formations and increased with variable values. Alluvial fan deposits has the highest immersed area at this immersion level, with increase about (2349) m^2 to (4343) m^2; followed by Shiranish Formation, with increase (1872) m^2 to, slope deposits with increase (1577) m^2 to (6781- 5103) m2 compared to the

previous level (450). The immersed areas of these formations form(2.86, 2.15, and 1.83%,) respectively of the total immersed areas at this level. At level(470)m, the highest increase of the immersed area was for Shiranish Formation, with (2718) m^2, followed by flood plain deposits (1916 m2), alluvial fan deposits (1766 m2), slope deposits (1728 m2). The immersed areas of these formations form (3.59, 2.58, 2.56, and 3.3 %) , respectively of the total immersed areas at this level. At level (480)m, in addition to the previously immersed formations, Mesozoic Balambo Formation will also be immersed, with (286) m^2. The highest increase of the immersed area was for the slope deposits (1976 m2), followed by Aqra and Shiranish formations (1856 and 1844 m2, respectively), compared to the previous level (470 m). The immersed areas of these formations form (4.08, 1.89, and 4.43%,) respectively of the total immersed areas at this level.

The immersed areas of the geological formations were increased in the following order: slope deposits (2241m^2), Shiranish Formation (1912 m^2), compared to the level 480m. The immersed areas of these formations form 4.89 and 5.37%, respectively, relative to the total areas of these formations. At level 500m, the geological formations were increased in the following order: Shranish Formation (2286 m^2), Aqra-Bekhme Formation (1721 m^2), alluvial fan deposits (1658 m^2), slope deposist (1385 m^2) compared to the level 490 m. The immersed areas of these formations form (5.96, 4.21, 3.14 and 5.81%,) respectively, relative to the total areas of these formations. Other formations and deposits were slightly increased, as shown in the Figures(11-12-13-14-15-16) and Table(5-6).

The immersed areas of the geological formations at level 500m extent along the river valley from south of (Barzan) area, north of the reservoir, to the north of Khulaifan area, south of the reservoir.

Generally, the immersed areas of the geological formation at the level (460-500)m do not reflect presence of engineering problems at that levels, except for Fat'ha Formation and the recent sediments, where their immersion will increase the water leakage downward to the groundwater, which, in turn, will lead to rise the groundwater level. In addition, the immersion of Fat'ha Formation will leads to rise the salinity of the reservoir water.

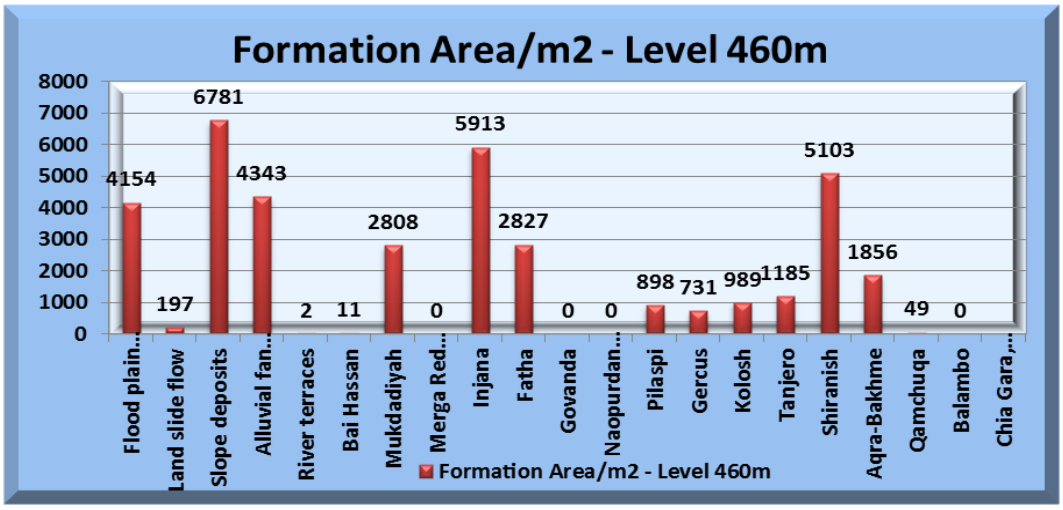

Fig. 11: Diagram showing the geological immersion area for the level (460) m

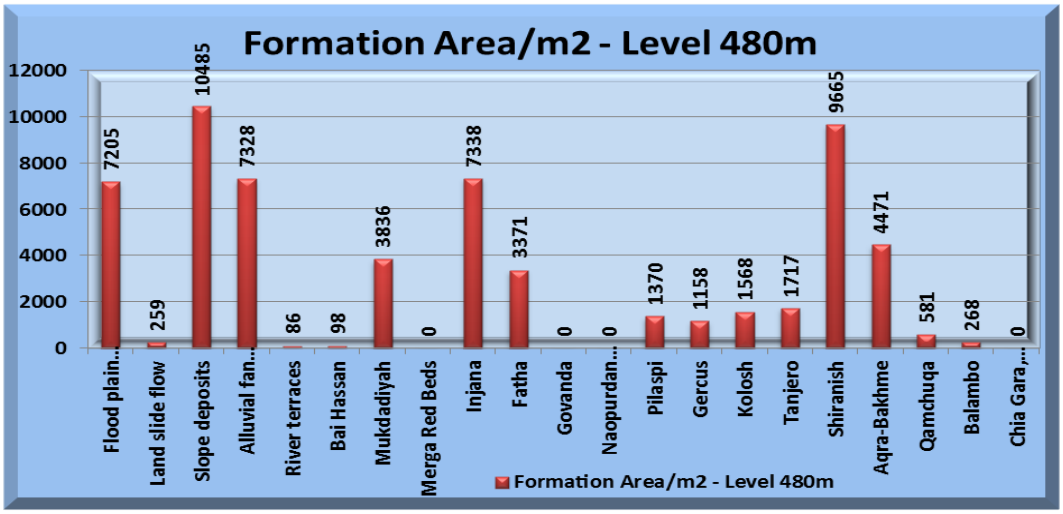

Fig. 12: Diagram showing the geological immersion area for the level (480) m

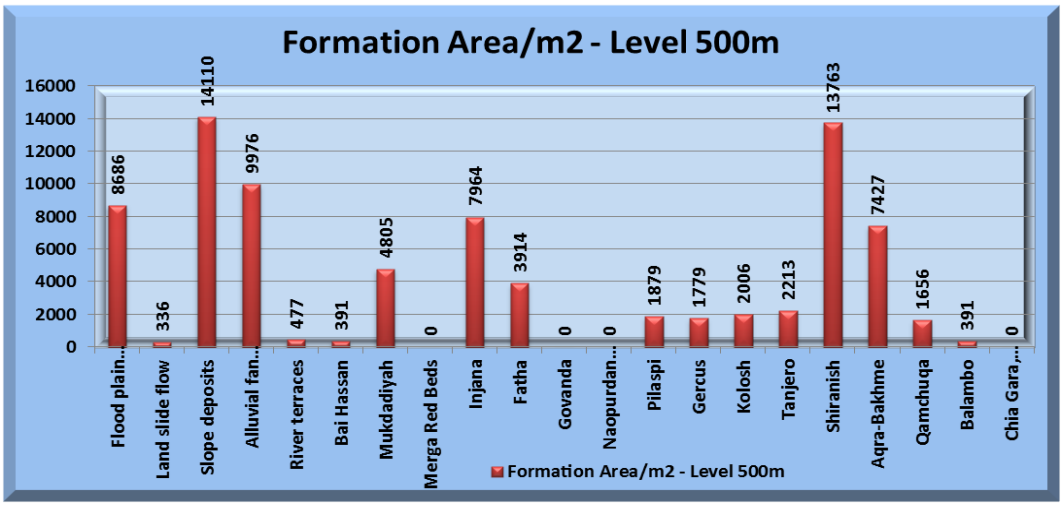

Fig. 13: Diagram showing the geological immersion area for the level (500) m

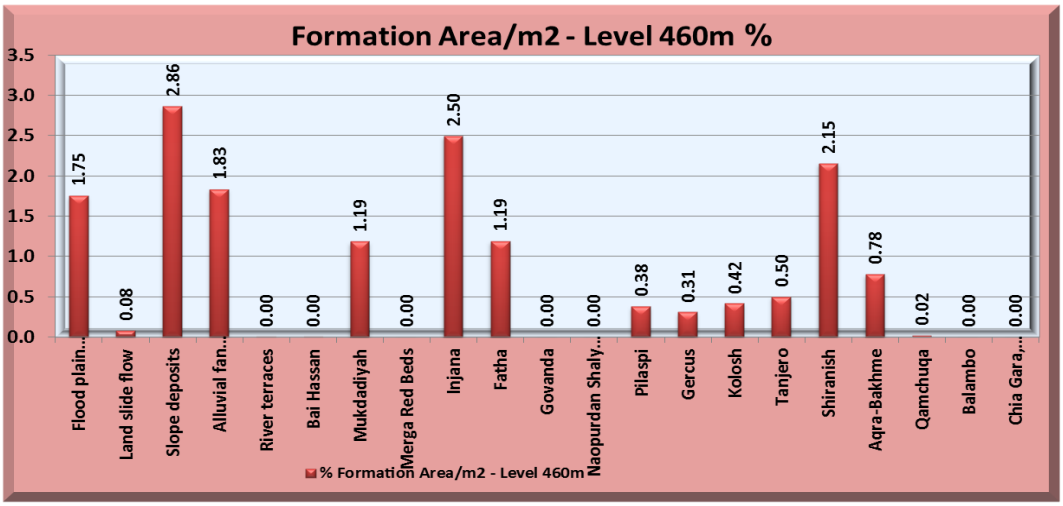

Fig. 14: Diagram showing the% geological immersion area for the level (460) m

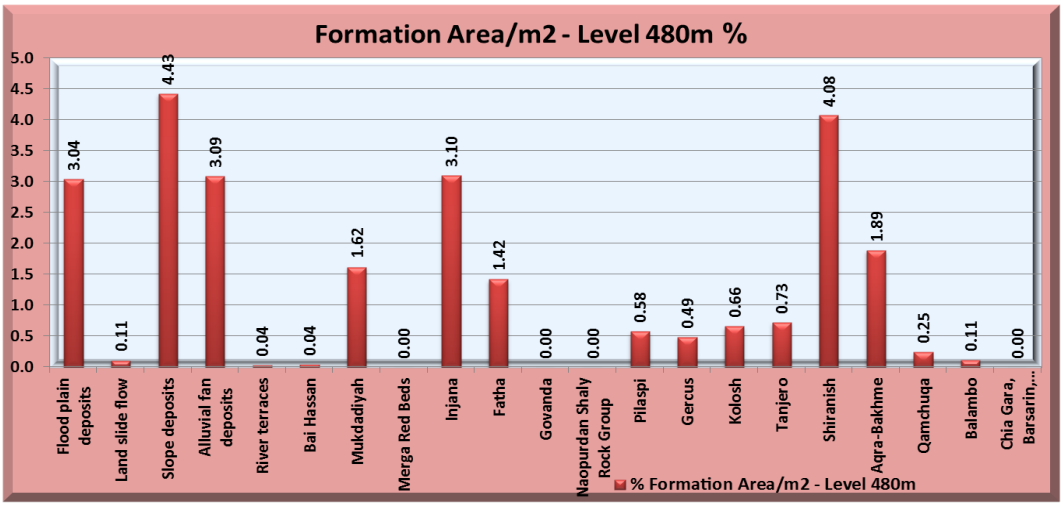

Fig. 15: Diagram showing the% geological immersion area for the level (480) m

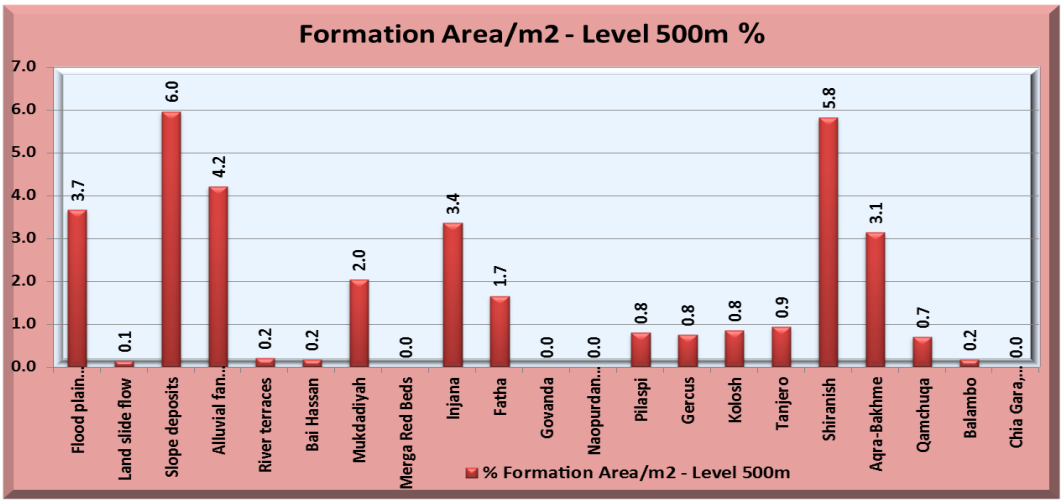

Fig. 16: Diagram showing the% geological immersion area for the level (500) m

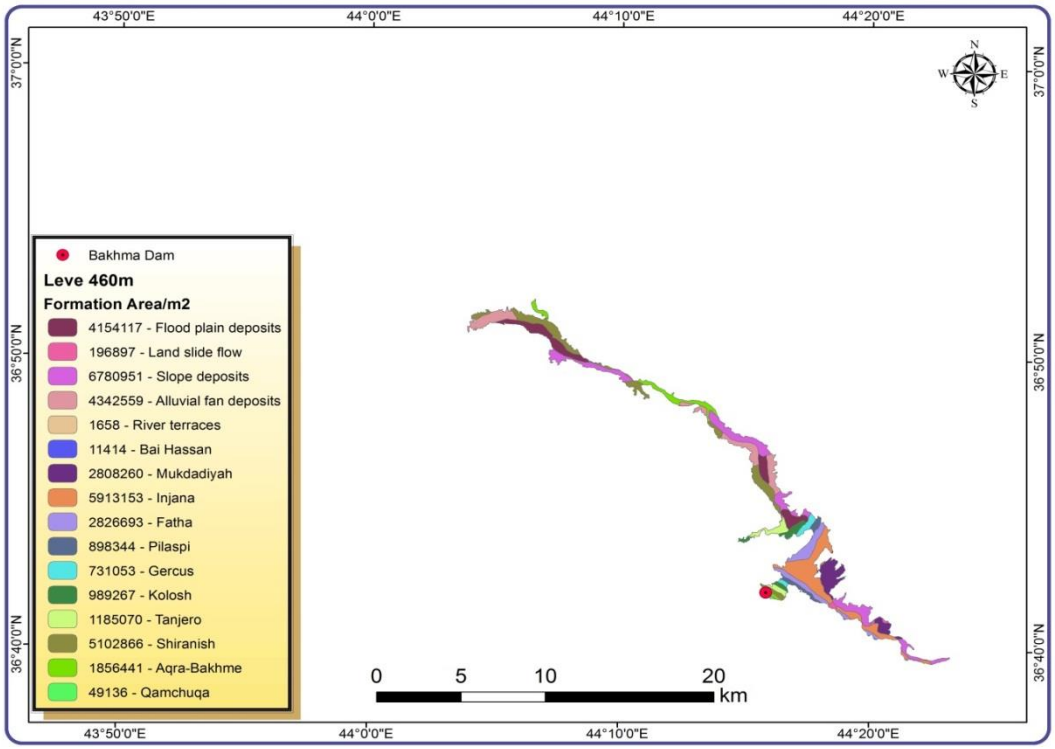

Fig. 17: Map distribution immersion area of the geological formations of the reservoir at level (460) m

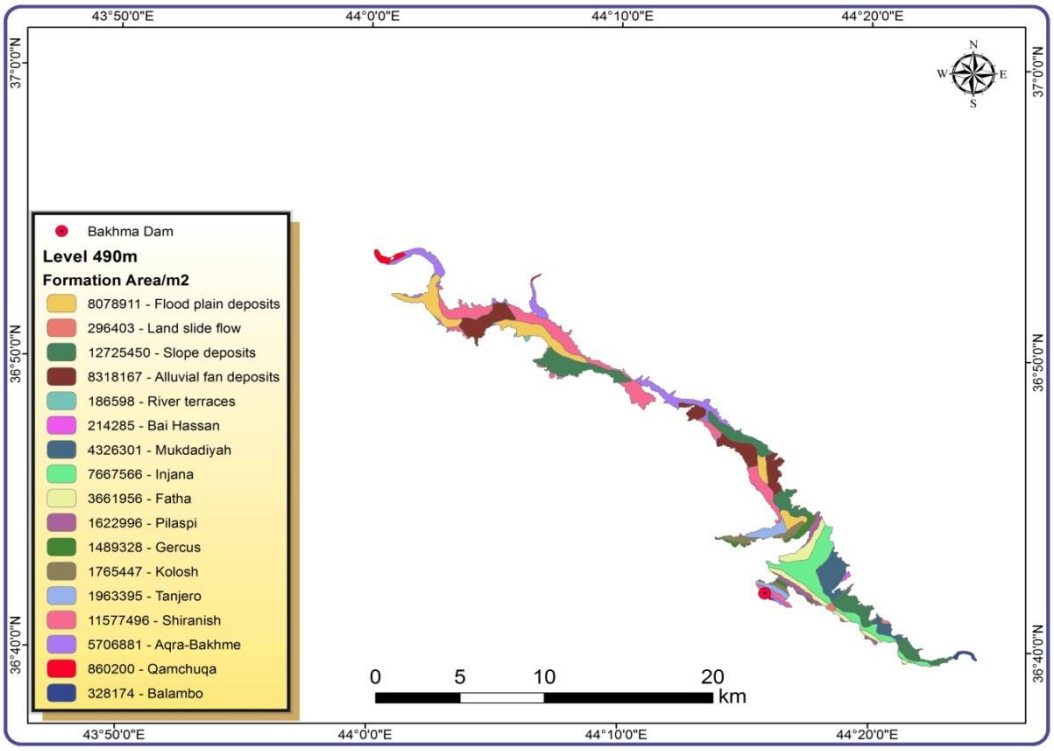

Fig. 18: Map distribution immersion area of the geological formations of the reservoir at level (490) m

Immersion levels 510-550 m:

The immersed geological formations at this level are similar to those at the previous level. At level(510)m, the immersed areas of the geological formations were increased, compared to the previous level the following order: Shranish Formation (1932 m^2), Aqra-Bekhme Formation (1916 m^2), slope deposits (1517 m^2), alluvial fan deposits (1459 m^2), and Qamchuqa Formation (1019 m^2). The immersed areas of these formations form (1.13, 4.83, 6.6,3.95, and 6.63%), respectively, relative to the total areas of these formations. At level (520m), the geological formations were increased in the following order:, Aqra-Bekhme Formation (4281 m^2), slope deposits (2416 m^2) Shranish Formation (1930 m^2), and alluvial fan deposits (1690 m^2) compared to the previous level. The immersed areas of these formations form (5.**54**, 7.44, 7.62 and 5.75%), respectively, relative to the total areas of these formations. At level (530), the immersed areas of four geological formations were significantly increased compared to the previous level. The increased immersed areas of these formations were in the following order: Aqra-Bekhme (2909 m^2), slope deposits (2445 m^2), Shiranish Formation (2074 m^2), and alluvial fan deposits (1222 m^2). The immersed areas of these formations form (6.06, 8.32, 8.65 and 6.98%), respectively, of the total areas of these formations.

At level (530), the immersed areas of four geological formations were also significantly increased compared to the previous level. The increased immersed areas of these formations were in the following order: Aqra-Bekhme (which its immersed area continue to increase for three level) (5658 m^2), slope deposits (2192 m^2), Shiranish Formation (1741 m^2), and Balambo Formation (1101 m^2). The immersed areas of these formations form (0.86, 9.05, 9.58 and 9.37%), respectively, of the total areas of these formations.

At the last level (550m), the immersed areas of three geological formations were highly increased compared to the previous level. The increased immersed areas of these formations were in the following order: Aqra-Bekhme; which its immersed area continue to increase for the four time at the levels (520-550)m; (2777 m^2), slope deposits (1864 m^2), and Shiranish Formation (1516 m^2). The immersed areas of these formations form (9.69, 10.36, and 10.54%), respectively, of the total areas of these formations. Other formations were slightly increased, as shown in Figure, and table. From Figure(19-20-21-22), it is evident that the immersed areas at level (550) are extent along the river valley from southeast Deralok, (17) km north the reservoir, southward to the north of Khulaifan area, south of the reservoir.

The immersion of the geological formations do not reflect presence of engineering problems at these immersion levels, except for Fat'ha Formation, which has constant immersed area at these levels, and the recent sediments, especially the slope deposits and the alluvial fan deposits. Most of these sediments and conglomerates composed of limestone and igneous rock particles which transported from higher levels.

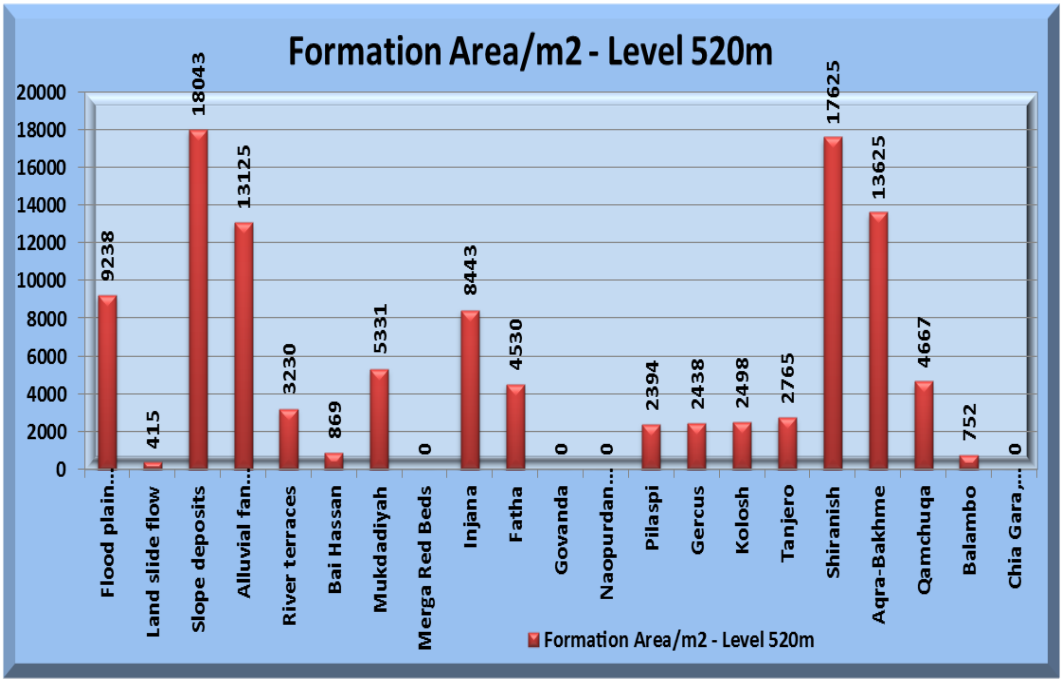

Fig. 19: Diagram showing the geological immersion area for the level (520) m

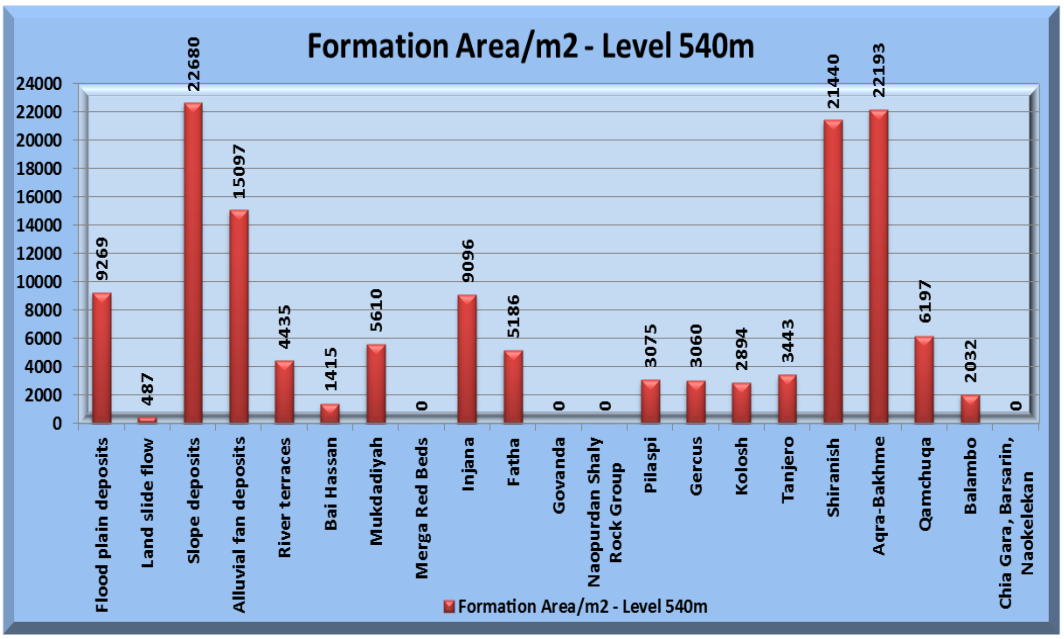

Fig. [20] Diagram showing the geological immersion area for the level (540) m

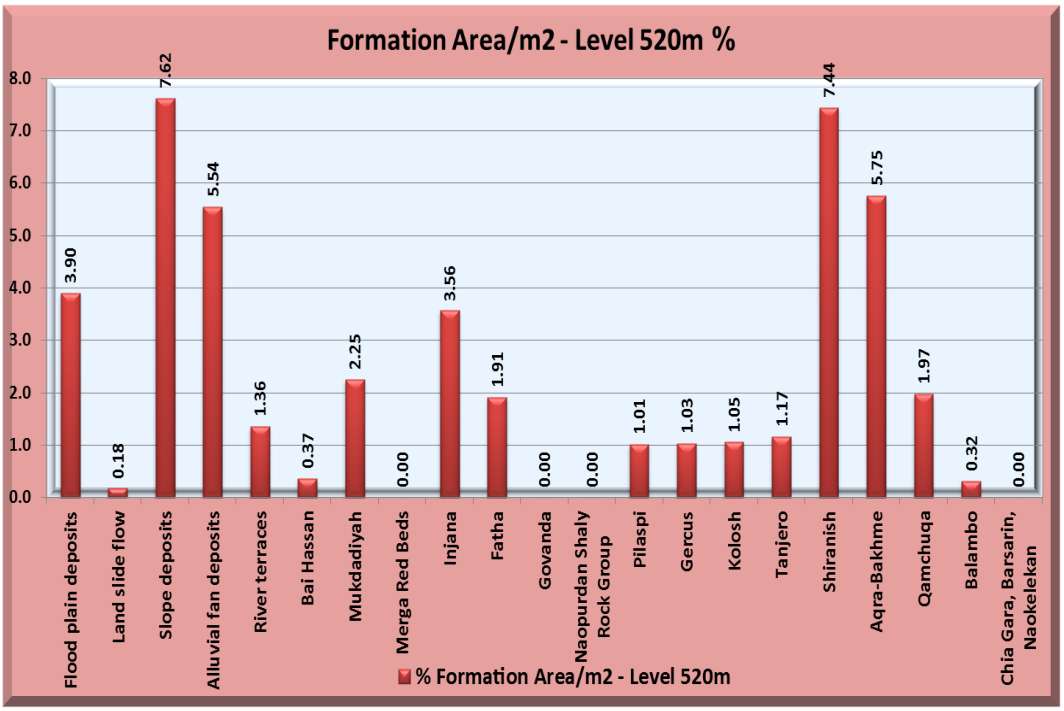

Fig. 21: Diagram showing the% geological immersion area for the level (520) m

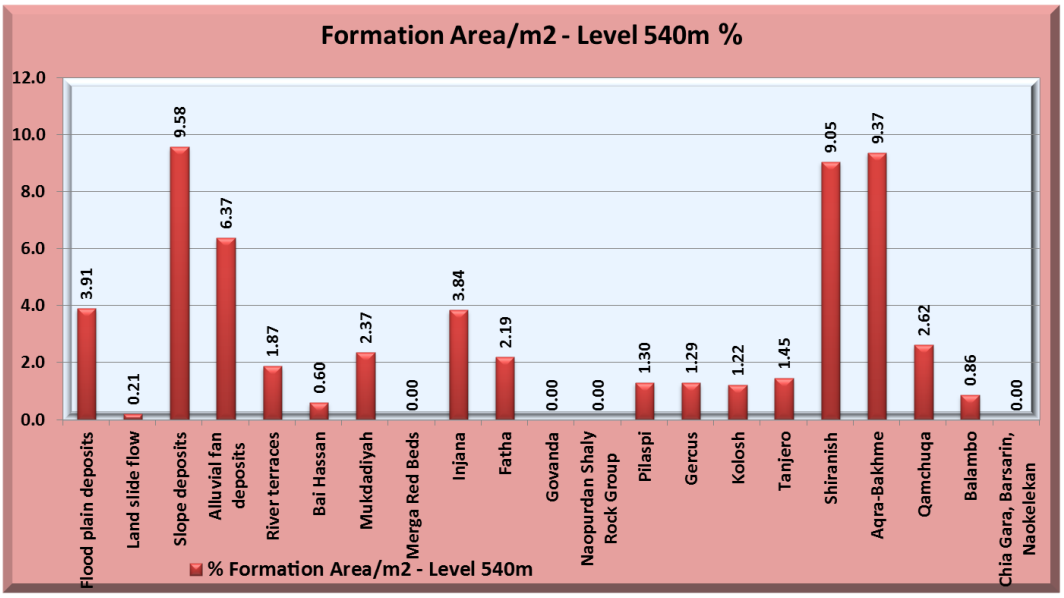

Fig. 22: Diagram showing the% geological immersion area for the level (540) m

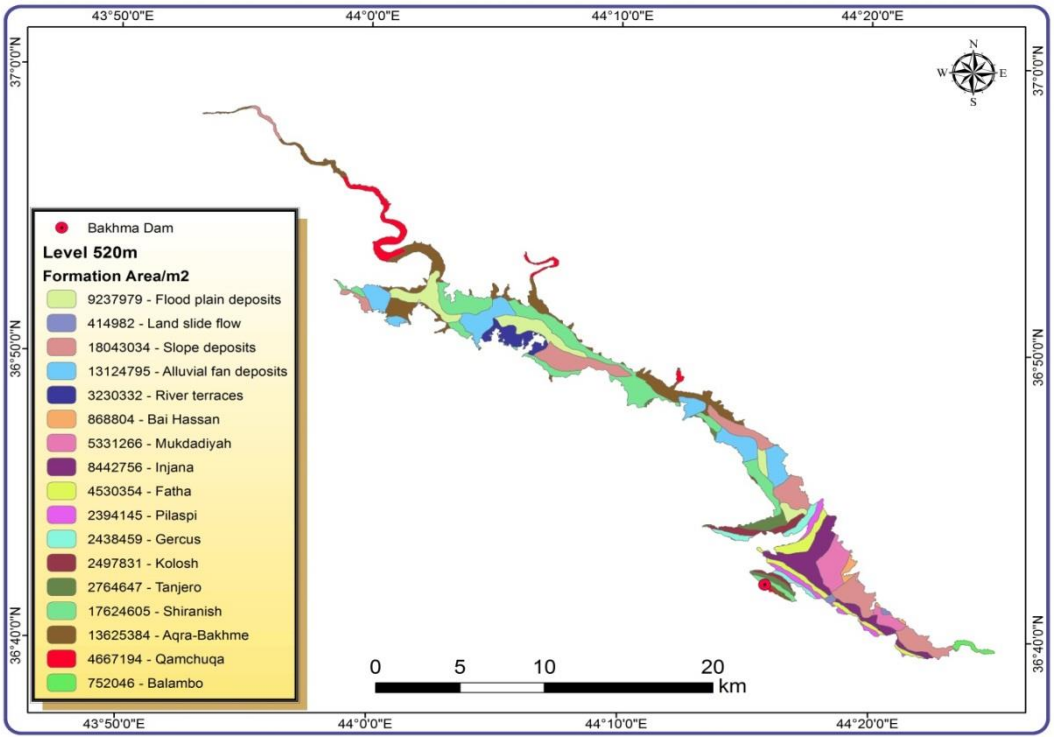

Fig. 23:Map distribution immersion area of the geological formations of the reservoir at level (520) m

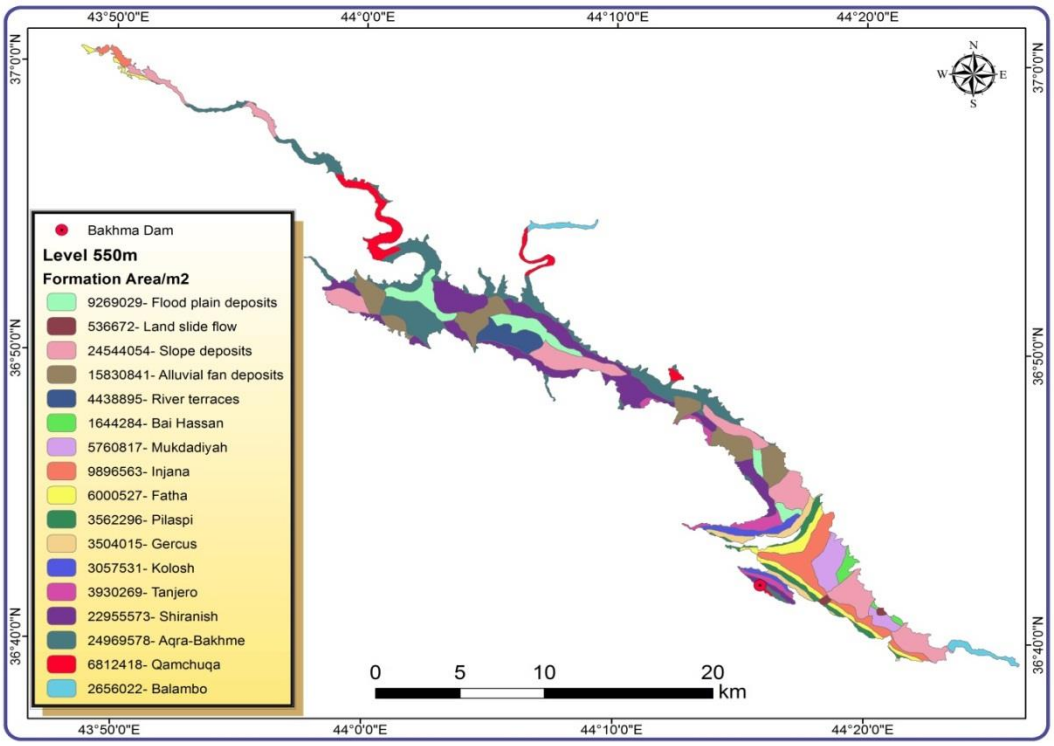

Fig. 24: Map distribution immersion area of the geological formations of the reservoir at level (550) m

Immersion levels between 560-600 m:

The immersed area of the geological formations at level (560) are highly differ from those of the previous levels, it has higher number of the immersed geological formations which up to 8 formations with this level. Aqra-Bekhme Formation still has the highest immersed areas, with increase (3130) m^2 compared to the previous level, followed by Fat'ha Formation (2157 m2), slope deposits (1570 m2), Shiranish Formation (1546 m2), Injana Formation (1358 m2), Pilaspi Formation (1267 m2), Balambo Formation (1196 m2), and Gercus Formation (1036 m2). The immersed area of these formations form (1.93, 1.63, 10.35, 4.63, 2.04, 11.03, 3.44, 11.86%), respectively, of the total area of the formations at this level.

At level (570) m, the immersed areas of six formations were significantly increased. The (Aqra-Bekhme) Formation has highest immersed areas (3579 m2), followed by Fat'ha Formation (2605 m2), this increase is close to the previous level, Shiranish Formation (1587 m2), Injana Formation (1466 m2), slope deposits (1399 m2), and alluvial fan deposits (1061 m2). The immersed area of these formations forms(13.38 - 4.54 - 11.02 - 5.24 - 11.62 - 7.46, %) respectively, of the total area of these formations at this level.

The highest increase of the immersed area were recorded at level (580) for six formations. The (Aqra-Bekhme) Formation still has the highest increase of the immersed areas (3642 m2), followed by Fat'ha Formation (2265 m2), this increase is close to the previous level (570 m), Shiranish Formation (1839 m2), slope deposits (1361 m2), Injana Formation (1219 m2), and alluvial fan deposits (937 m2). The immersed area of these formations forms
(7.86 - 5.76 - 12.19 - 11.79 - 5.5 - 14.91
)%respectively, of the total area of these formations at this level. At level (590) m, the immersed area of the six geological formations was increased constantly, and Aqra-Bekhme Formation still has the highest increase (4873 m^2), followed by Shiranish Formation, Fat'ha Formation, Injana Formation, slope deposits, Pilaspi Formation, and alluvial fan deposits, which their immersed areas were increased
(985 -1010 -1074 -1076 -1803 -1994)m^2,
respectively. The immersed area of these formations forms (-2.85 -12.65 -6.21 - 6.26 - 12.63 - 16.97 8.28)%, respectively, of the total area of these formations at this level.

The highest level of the Bekhme dam reservoir is (600) m. At this level, the increase of the immersed areas for some geological formations are significantly changed from the previous levels. At this level, new formations were also immersed; to become the number immersed formations is eight. Again, aqra-Bekhme Formation still has the high increase of the immersed area (6191 m2), followed by Tanjero Formation (4209 m2), Shiranish Formation (3262 m2), Fat'ha Formation (1569 m2), Kolosh Formation (1472), Balambo Formation (1245 m2), Qamchuqa Formation (1165), and Pilaspi Formation (817 m2). The new formations which immersed for the first time represented by Naopardang Group (164 m2) and Chia Gara, Barsarin, and Naoklelekan formations (658 m2). The immersed area of these formations forms
(3.2 -4.44 - 2.88 - 2.15 - 6.92 - 14.01 - 4.29 - 19.59)
%, respectively, of the total area of these formations at this level.

The immersed areas of the other formations still increase but with low rate, as shown in table and figures. The immersed areas at this level extent along the river valley from south of Derlock area,(5) km north of the Bekme dam reservoir, to east of Khulaifan area, south of the reservoir .

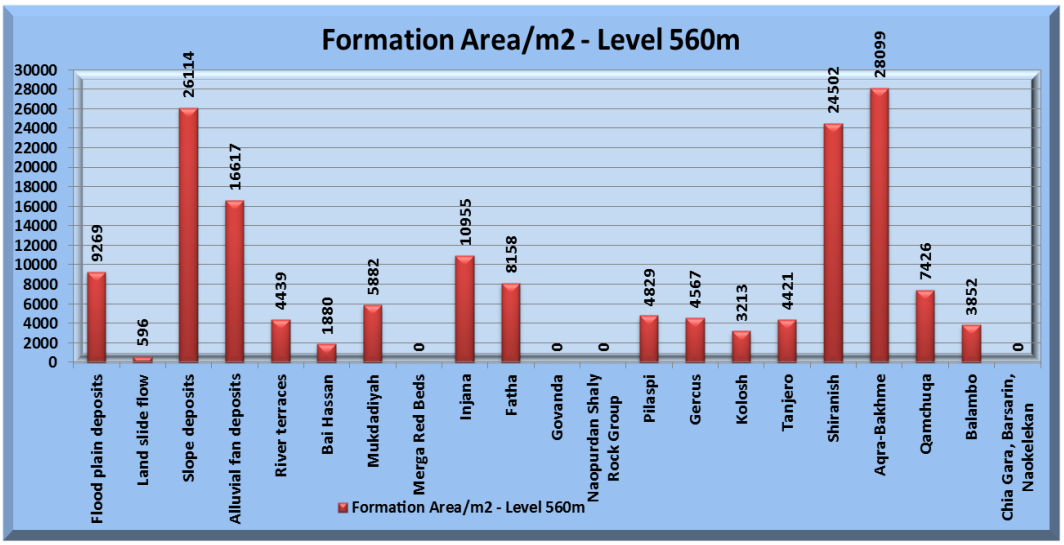

Fig. 25: Diagram showing the geological immersion area for the level (560) m

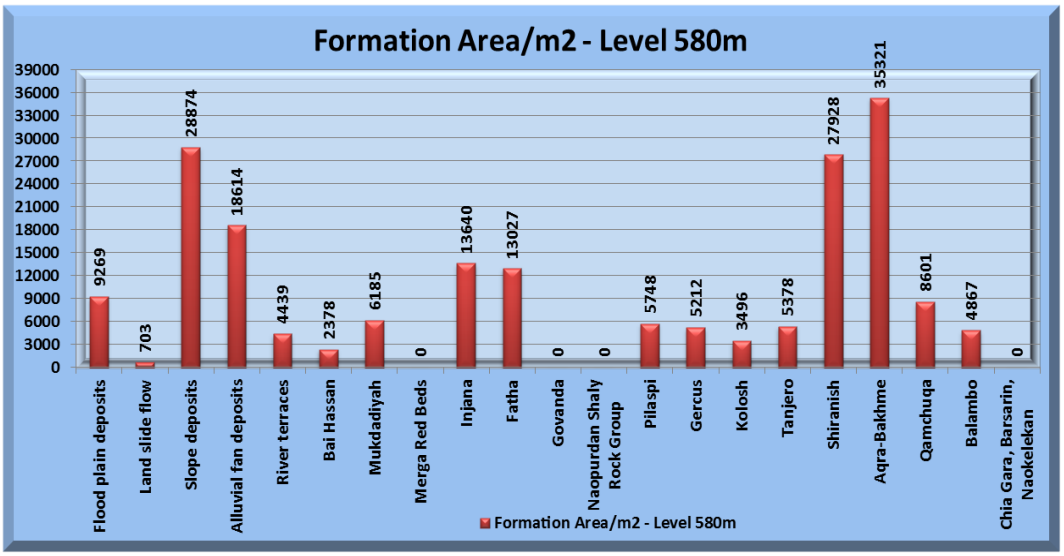

Fig. 26: Diagram showing the geological immersion area for the level (580) m

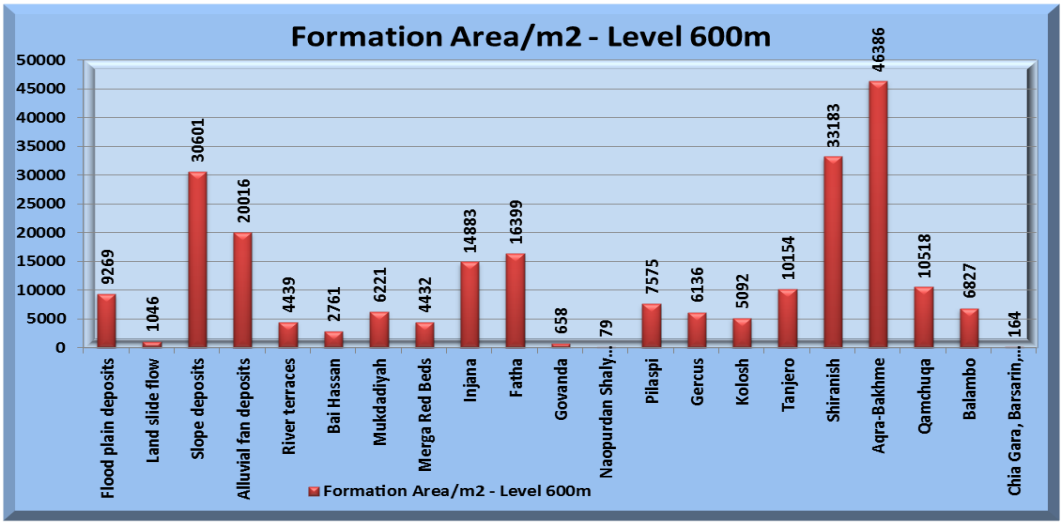

Fig. 27: Diagram showing the geological immersion area for the level (600) m

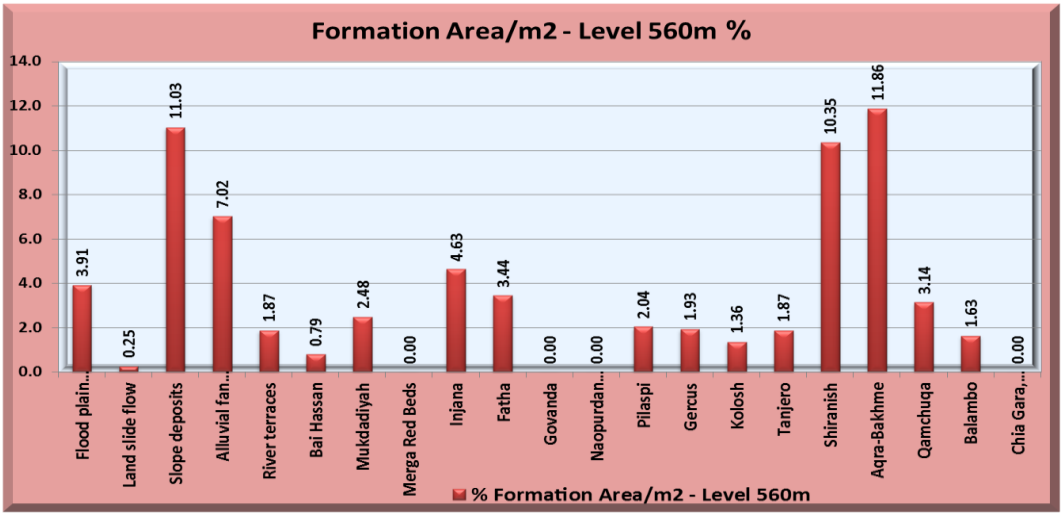

Fig. 28: Diagram showing the% geological immersion area for the level (560) m

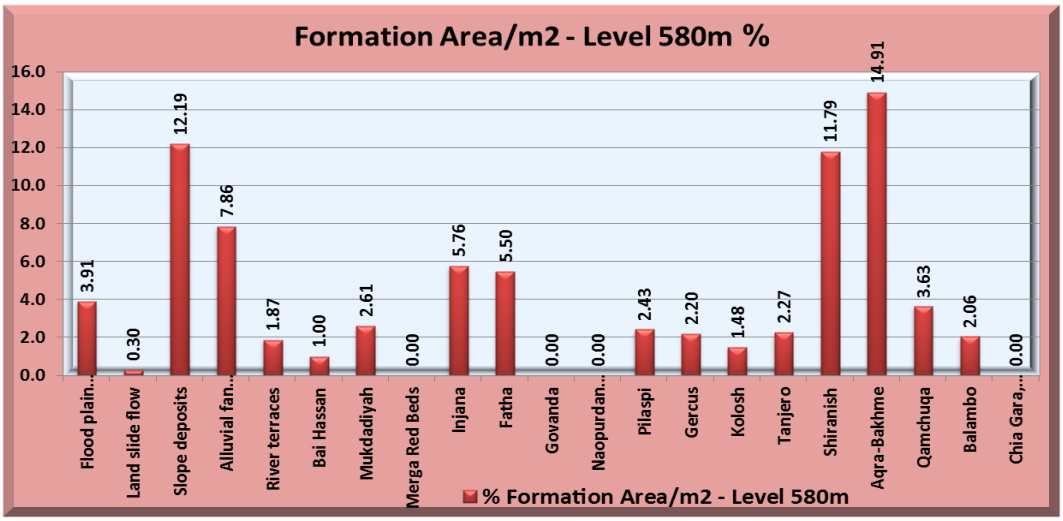

Fig. 29: Diagram showing the% geological immersion area for the level (580) m

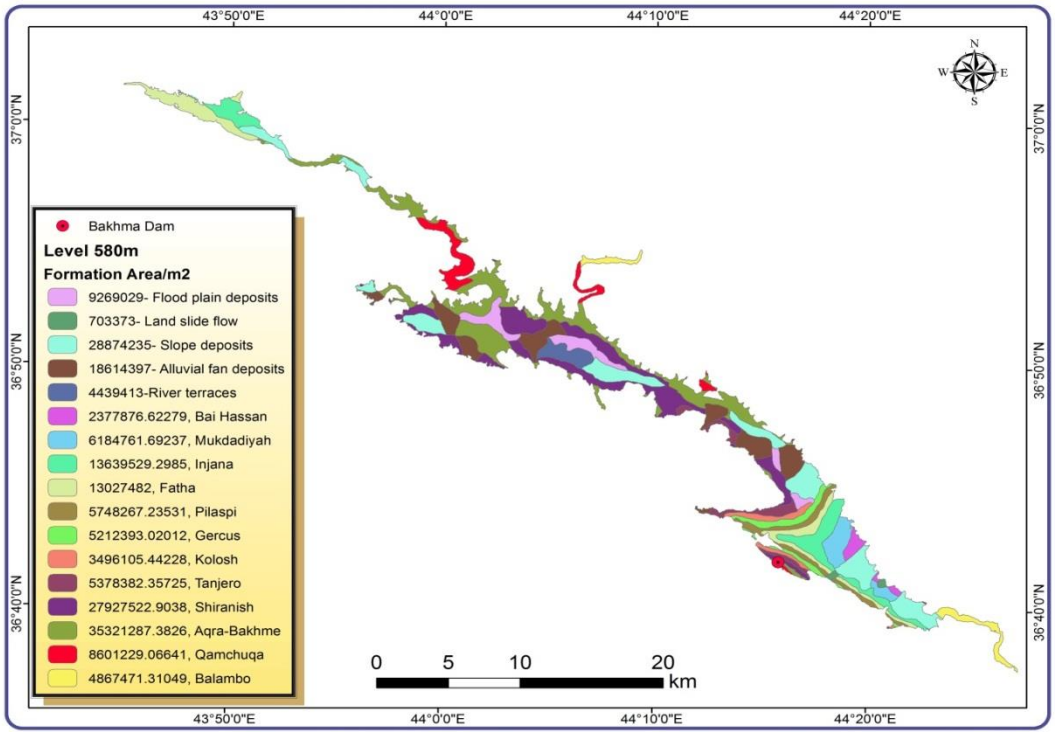

Fig. 30: Map distribution immersion area of the geological formations of the reservoir at level (580) m

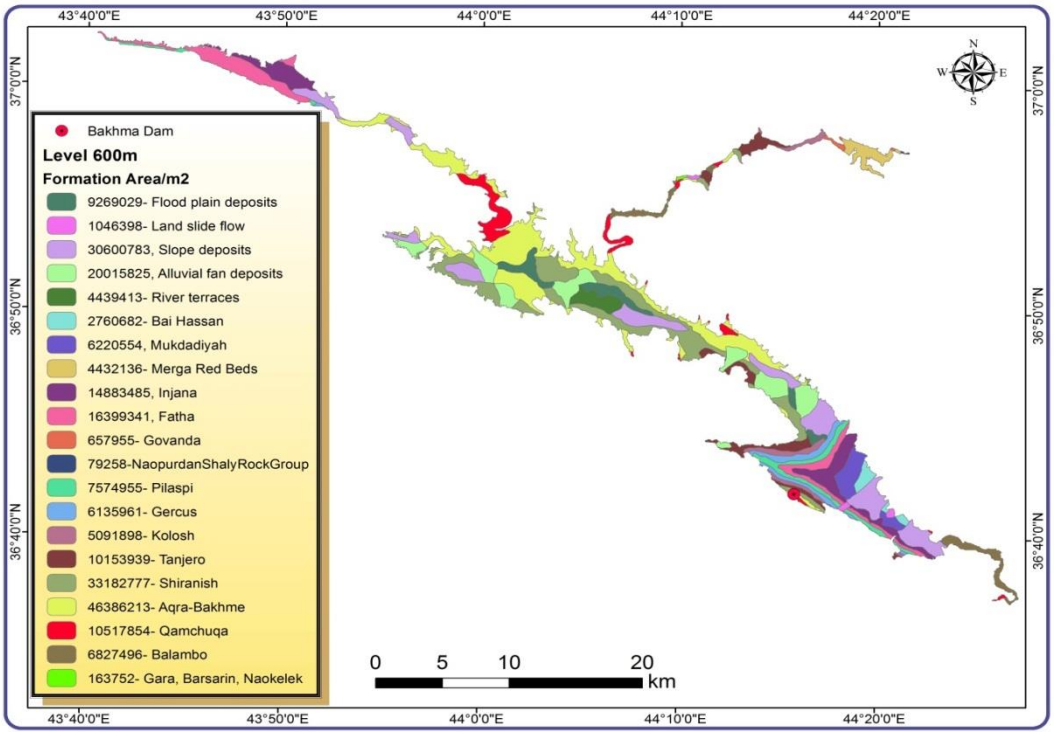

Fig. 31: Map distribution immersion area of the geological formations of the reservoir at level (600) m

Analysis of immersed areas of some geological formations at the maximum level (600m):

The immersed area percentage of the geological formations for the reservoir were calculated according to the difference between the minimum level at the dam body (380 m) and the maximum level (600 m) above the sea level. The previous geometric study concluded that the volume of the water storage is (19) billion m3 . The immersed areas percent of each formation at each level are in table (5-6) and figure(32). From the analysis of the immersed areas at the maximum level (600 m), it can be concluded that the Aqra-Bekhme Formation had the higher value of the immersed areas, with an area reached (46386) m2, which forms (19.59)%. This value is high compared to the number of the immersed geological formations in the reservoir, which is (21) formations. The Aqra-Bekhme Formation starting to immerse at level (390) m and rises, with low rate to the level (460) m. Then the immersed area increases with higher rate after the level (470) m, and still to rise until the level (520)m, thereafter, it become stable until the maximum level 600m (Table).

Aqra-Bekhme Formation consists of hard limestone and dolostone with thickness up to 320 m at the dam area, which is the type section and from which the dam takes its name. The hard nature of these rocks is suitable for dam construction and water storage, therefore, the water lose will be minimum.

The second higher immersed formation at the maximum level is Shiranish Formation, with an area reached (33183) m2, which forms (14.01%) of the immersed formations. This formation starting to immerse at the first immersion (380 m), in addition to Tanjero Formation, then the immersed area increase gradually until the level (450) m. The immersion rate will rise especially after the level (460), then it still to rise until the level (570), thereafter, the immersion rate become stable until the maximum level (600 m) (Table and Figure). Shiranish Formation consists of well-bedded marl and marly limestone. These rocks are resistant to weathering.

The third highest immersed geological units is the slope deposits, which formed (12.92)% of the immersed formations at the maximum level (600) m, with an immersed area (30601) m^2. These deposits starting to immerse at the level (410) m, and the immersion rate rises at the level (430) m, and become stable until the maximum level (600 m) (Table and Figure). These deposits were formed as a results of the weathering of the higher areas surrounding the reservoir. The higher areas have steep slopes toward the Upper Zab river valley. These deposits have different grain size (from fine to coarse) according to the slope degree. The composition of these sediments is reflection of the older formations which forms the fold bodies, from which, these deposited were transported. Therefore, most of these deposits are composed of limestone, dolomite, and clay grains produced from Bekhme, Shiranish, and Tanjero formations.

The fourth highest immersed geological units is the alluvial fans deposits, which formed (8.45%) of the immersed formations at the maximum level (600) m, with an immersed area 20016 m^2. These deposits starting to immerse at the level (420) m, and the immersion rate rises at the level (460) m, and become stable until the maximum level (600 m) (Table and Figure). These deposits were formed as a results of

the erosion and transportation by streams, then the slope change between the higher areas (folds) and the low areas (reservoir) leads to deposition of the load . These compositions of these deposits depends on the source rocks from which they transported, and on the weathering intensity. Generally, they consist of non-consolidated clay, sand, pebble sizes of limestone grains, with some chert and gypsum. Most of these grains are rounded, oval, and platy shapes.

The fifth highest immersed geological units at the maximum level (600) m is the Fat'ha and Injana formations which they have similar immersed areas reached (6.92 and 6.28%) of the immersed formations, with an immersed area (16399 and 14883) m^2, respectively. These formations starting to immerse at the level 400 m. Fat'ha Formation starting to immerse with low at, then the immersion rate rises gradually until the level (550) m, thereafter, the immersion rate will rise at the level (560), then it became stable until the maximum level (600 m). While the immersion of injana Formation starting with low rate, then the immersion rate rises gradually until the maximum level (600 m) (Table and Figure).

These two formations are of Cenozoic age. Fat'ha Formation consist of alternations of claystone, evaporites, and limestones; but in the study area, the evaporites are absent, whereas the clastic rocks are the dominant, which indicate that the study area is far away from the basin center. Generally, the evaporite rocks decrease and clastic rocks, and limetone to lesser extent, increase toward the north and northeast of Iraq. Injana formation consists of sandstone, siltsone, and clystone successions.

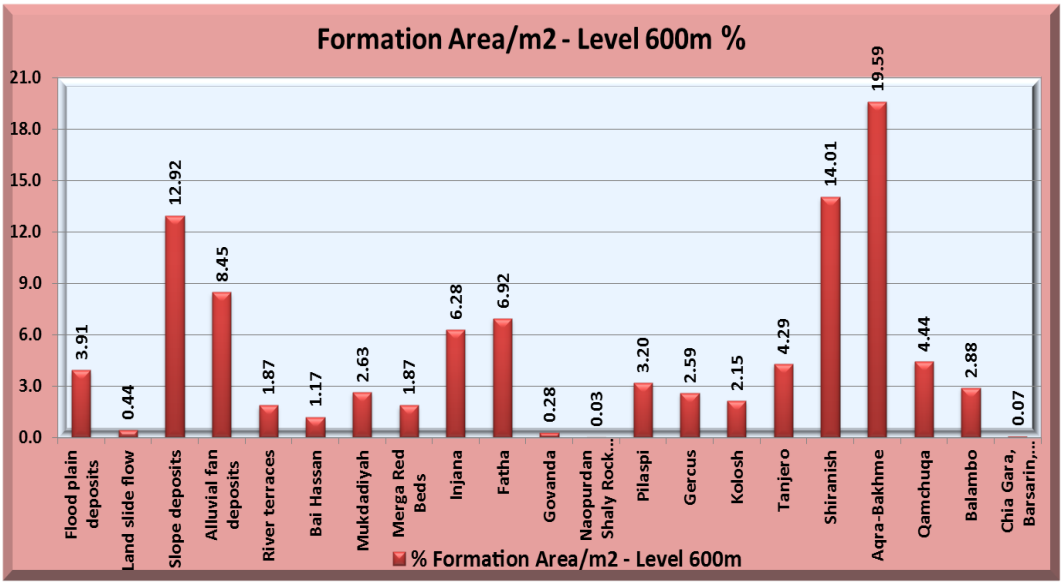

Fig. 32: Diagram showing the% geological immersion area for the level (600) m

Conclusions

1. The immersion of the geological formations do not reflect presence of engineering problems at the suggested immersion levels, except for Fat'ha Formation. In addition, the immersion of the recent sediments; which they have high penetration rate; will leads to leak the water downward to the groundwater, which, in turn, will lead to rise the groundwater level. But the leakage will decrease systematically with time as a results of the accumulation of the fine sediments; which will envelope the reservoir, decreasing the permeability and the dead storage of the dam.
2. The attributes and characteristics of the geological formations are reflected on the reservoirs floor constituent in addition to the external boundary areas of the reservoirs. Its influence increasing of geomorphological processes (carving -erosion - weathering - landslides) the fragile and vulnerable rock formations leads to acceleration of those processes. As a result, as risk affects the dam reservoirs and the dam body.
3. The characteristics of the immersed geological formations in the dam body are suitable for construction of the dam. Therefore, there are no future engineering problems in the outcrops of these formations.
4. The geomorphological processes have high influence in the ground surface formation. These formations are controlled the shape, size, and topography of the reservoir.
5. The geologic structure has high influence on the shape of the reservoir floor. This influence is reflected in the immersion ratio at each level, determination the size and type of the reservoir, validity of the reservoir floor for water storage for long time.
6. The calculations showed that the highest value of the immersed area was for Aqra, Bekhme, and Shiranish formations, which reached to about 35% of the immersed geological formations. The immersed areas of these three formations were at most of the reservoir levels. Rock beds of these formations have high hardness and low solubility.

7. The friable and high soluble immersed geological units were at low values, and these units were distributed in the moderate levels. The first outcrop for these units is about 1472 m from the dam body. These units include Fat'ha Formation, which forms about 6.92% of the Bekhme dam area. This low value of the soluble units reduces the hazards and qualifies this location for the dam reconstruction.

Recommendations

1) The study recommends the need to implement this study model and adopt high-resolution space data on any project Toms Toms to establish, as well as its application for the current reservoirs to stand on the most important problems and future symptoms to be faced, and to be avoided and planned plans.

2) The geological formations surrounding the dams (reservoirs parties), especially severely regression, reflect many risks in the case of their move (its collapse). The land of the river outside the reservoirs will result in the closure of the river and then the risk of being a lake before him and then the collapse and a sudden flood, will increase the size of the storage for the dam and thus increased pressure on the body of the dam and its collapse, so the study recommends the study of the ground reservoirs During the study of slopes of slopes surrounding the reservoir (stability of the slopes), which are located in the highest river valley, to determine the hazardous areas exposed to collapse.

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تحليل التكوينات الجيولوجية المنغمرة لخزان سد بخمه /اربيل

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الملخص

استخلصت قياسات مساحات التكوينات الجيولوجية لمناسيب الاغمار لخزان سد بخمه من خلال الاعتماد على نموذج الارتفاع الرقمي (DEM) ذو القدرة التميزية (10) م، وباستخدام برنامجي (GLOBAL MAPPER-GIS) التي تعالج التحليل المكاني وتستخلص البيانات والمعلومات المكانية للمعالم الارضية ،حيث استخرجت مساحات كل منغمر جيولوجي على حدة ابتداء من منسوب (380) م عند موقع السد وحتى ارتفاع منسوب (600) م فوق مستوى سطح البحر بفاصلة (1) م.

،بينت القياسات ان اعلى نسبة مساحة للمنغمرات الجيولوجية كانت تشمل تكوينات(عقره بخمة)بمساحة (46386)م2 وبنسبة مئوية بلغت (19.6)% من المساحة الكلية للخزان ،تلاه تكوين (شرانش) بمساحة (33183) م2 وبنسبة مئوية بلغت (14.01)% من مجموع مساحة خزان(بخمه) وقد توزعت مساحتهما بغالبية مناسيب الخزان وهي تكوينات تتسم صخورها بالصلابة وتحملها جيد لعمليات الاذابة ،بينما اقل مساحة منغمرات للتكوينات الجيولوجية شملت تكوين (مجموعة صخور ناوبوردان وشيلي) بمساحة بلغت (79) م2 وبنسبة مئوية بلغت (0.03)% ،تلاه تكوين (جياكارا– بارسيان–ناوكلكان) بمساحة بلغت (164) م2 وبنسبة مئوية بلغت (0.07)% من مجموع مساحات الخزان وقد توزعت في المناسيب الثلاثة العليا من مناسيب الخزان ،بينما بلغت مساحة التكوينات الهشة والتي تمتاز بانخفاض مقاومتها لعمليات الاذابة وتسبب مشاكل ومخاطر (السد) نسب منخفض وتوزعت في المناسيب المتوسطة من الخزان ويبعد اقرب منكشف له عن موقع السد بمسافة(1472)م وشمل منها تكوين (الفتحة) بمساحة (16399)م2 وبنسبة مئوية بلغت (6.92)% من مجموع مساحة خزان بخمه، الامر الذي يؤهل موقع وخزان (بخمه) من حيث الخزن والجدوى الاقتصادية وقلة المشاكل والمخاطر في حال اعيد بناءه .