Extracted from Achievements of the custodian of the two holy mosques in water sector, PSIPW, 2004, Riyadh, Ch 5, achievements in water resources development using dams, by Prof. Abdulaziz A. Alhamid,

Dams in KSA

Saudi government, represented in the Ministry of Agriculture and Water previously the Ministry of Water and Electricity now, has given the surface water issue a great importance to increase the benefit from the seasonal rainfall and increase rainfall harvesting. This has been achieved through the construction of hydraulic structures like dams and other structures for detention of runoff and floods. By the end of the year 1424H, the number of constructed dams reached to 215 dams in different regions of the kingdom and the storage capacity of these dams exceeds 833 millions cubic meters. King Fahad's dam on Wadi Bishahh is the largest constructed dam in the kingdom with 103 meter high and 325 million cubic meters maximum storage capacity.

The annual surface water quantity has increased about three times in the previous decades, where it was estimated at 1140 million cubic meter per year in 1400 H and reached to 3000 million cubic meter per year in 1420 H (Ministry of Planning: the development plans).

In this chapter, we will shed the light on the dams in the kingdom and the role it do in the exploitation of the seasonal rainwater for the development of surface water. Also this chapter will focus the light on the great achievements in the construction of the large dams to secure water for different purposes.

Purposes and types in KSA

Concrete and embankment dams of different types were constructed in the kingdom as the case in the rest of the world. Embankment dams are predominant in the kingdom, where about 58.5 % of the total number of constructed dams are embankment dams and the rest are concrete dams. Table (5-1) gives the number and types of dams in the kingdom till the end of 1424 H, and the expected number after the new dams construction is completed. Previous table shows that the concrete dams detain about 78 % of the total storage capacity of the dams in the kingdom in the present time and this will increase to more than 81 % in 1429H.

In the kingdom, dams were built for single definite purpose and later on dams are used for multipurpose, and among the most aims which dams built for in the kingdom are the following -

-Flood control and protection of the cities; in the kingdom there are 57 dams built for this purpose and among these are Al-Madiq dam in Najran which have a storage capacity of 86 million cubic meter and Ka'a Hazuzah dam in Al Madinah Al-Munawara with storage capacity of 40 million cubic meters. Also, there are six dams for flood control under execution with the largest is Wadi Hali dam with a storage capacity of 250 million cubic meters.

-Recharge of groundwater aquifers; there are 140 dams for this purpose with a total storage capacity of 503 million cubic meter and the largest dam constructed for this purpose is King Fahad 's dam on Wadi Bishah. There are also 8 dams under execution for this purpose.

Table (5-1) Types of dams and its storage capacity in the Kingdom.

Dam Type	Constructed dams				Under construction dams	
	No.	%	Storage Capacity ×1000 m^3	%	No.	Storage Capacity ×1000 m^3
Embankment dams						
-Earthfill	87	40.47	141895	17.04	10	93435
-Rockfill	39	18.14	42228	5.07	2	20000
Concrete Dams						
-Gravity	84	39.07	455785	56.05	5	668335
-Buttress	2	0.93	53130	6.379		
-Arch	1	0.465	86000	10.33		
-Underground	2	0.93	42800	5.139		
Total	215	100	832838	100	17	781770

-Drinking water in which potable water are obtained from rainfall water retained behind surface dams or through pumping the detained waters behind underground dams. In the kingdom there are 14 surface dams and two underground dams constructed for securing potable water. These dams were constructed during the last tow decades except Abha dam. The total storage capacity of dams used for drinking water purpose is about 71 million cubic meters, and Table (5-2) gives a list of the largest dams for securing potable waters and its geometric specifications. Also, there are three dams under construction for securing potable waters with a total capacity exceed 20 million cubic meters.

-Storage of rainfall water and distribution for irrigation of agricultural regions like Jizan dam with a storage capacity exceeds 50 million cubic meters and irrigate an area of 6 thousands hectares.

-Multipurpose dams which includes all of the above in addition to entertainment and tourist attraction as in the case of Abha dam. Multipurpose dams are a new trend in dam's construction in the world and the kingdom has started in increase the benefit from the dams by adding other activities on it. For example, King Fahad's dam was constructed for groundwater recharge and later on part of the detained water used for securing potable water to Bishah city and a treatment plant amended to the dam with daily production rate of 40 thousand cubic meters.

Table (5-2) Largest dams in the kingdom for drinking water.

No.	Dam's Name	Location	Type	Height m	Storage Capacity ×1000 m^3	Execution year
1	Al Aqiq	Al Baha	Gravity	30	22500	1408 H
2	Aridah	Taif	Underground	24	21000	1404 H
3	Turabah	Taif	Underground	15	21800	1404 H
4	Itwad	Asir	Rockfill	39	10000	U/construction
5	Maraba	Asir	Rockfill	38	10000	U/construction
6	Abha	Abha	Gravity	33	2130	1394 H

Growth in number of dams and the storage capacity

The kingdom started long time ago benefiting from the seasonal rainfall and runoff quantities through the construction of dams which started in 1376 H. Ekremah dam is the oldest dam in the Kingdom which was built in Taif upstream of wadi Almathnah, at 1376 H with a maximum storage capacity of half a million cubic meter. The number of dams grows up year after year until its reach to 37 dams at the beginning of this century (1400H). During the last 25 years the number of dams reaches 215 dams distributed over the kingdom regions, and it's expected that the number of dams grow up to 250 dams before the end of the third decade of this Hijri century. There are 17 dam underconstruction and about 20 dams in the biding process. Figure (5-1) shows the number of the constructed dams each year, and Figure (5-2) shows the accumulative constructed dams in the kingdom till the end of 1424 H. This fast development in the number of constructed dams indicates clearly the enthusiasm of the government, represented in the Ministry of Water and Electricity, to the renewable water issue and the ways of its development.

Dams of different storage capacity were built in the kingdom such as small dams with a storage capacity less than 50 thousand cubic meters, medium dams with storage capacity up to 20 million cubic meters and large dams like King Fahad's dam with storage capacity of 325 million cubic meters. Figure (5-3) shows the accumulated storage capacity of the dams in the kingdom, where it can be seen from the figure that the dams storage capacity in the kingdom was 259 million cubic meters in the year of 1402 H and grows rapidly to reach about 833 million cubic meters at the end of year 1424 H. This means that the storage capacity of the dams increase more than three times through 22 years. When the new dams construction is completed at the beginning of 1429 H, the storage capacity will increases tremendously to become 1614 million cubic meters. These amazing increases in storage capacity are attributed to the construction of large dams like King Fahad's dam on Wadi Bishah, Wadi Hali dam, Wadi Baysh dam and Wadi Rabigh dam, in addition to medium size dams like Ka'a Hazuzah dam in Al Madinah Al- Munawara and Al Aqiq dam in Al Baha.

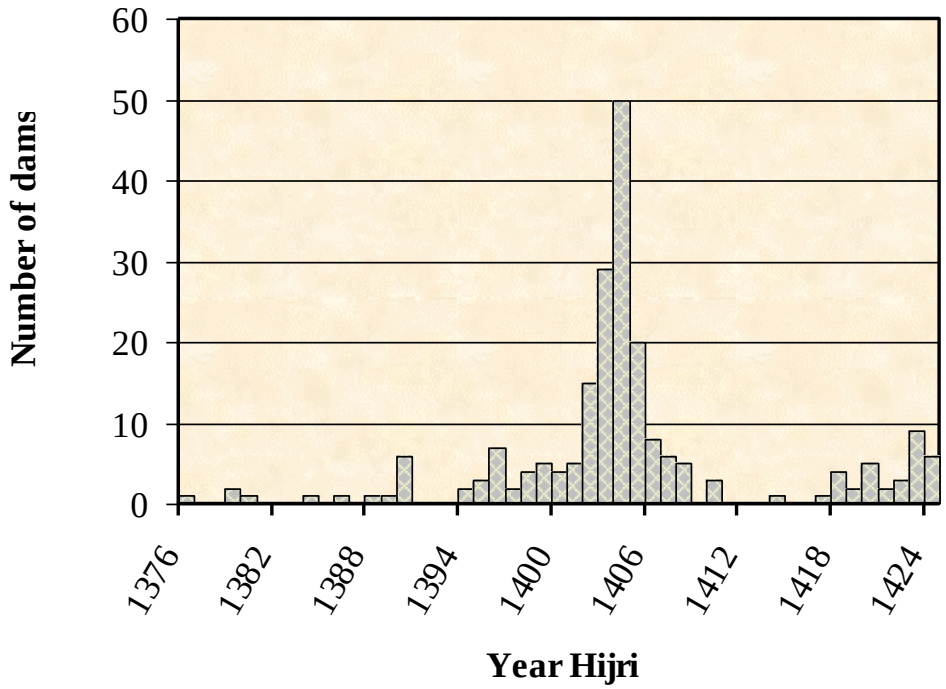


Figure (5-1). Number of constructed dams per year till the end of 1424H.

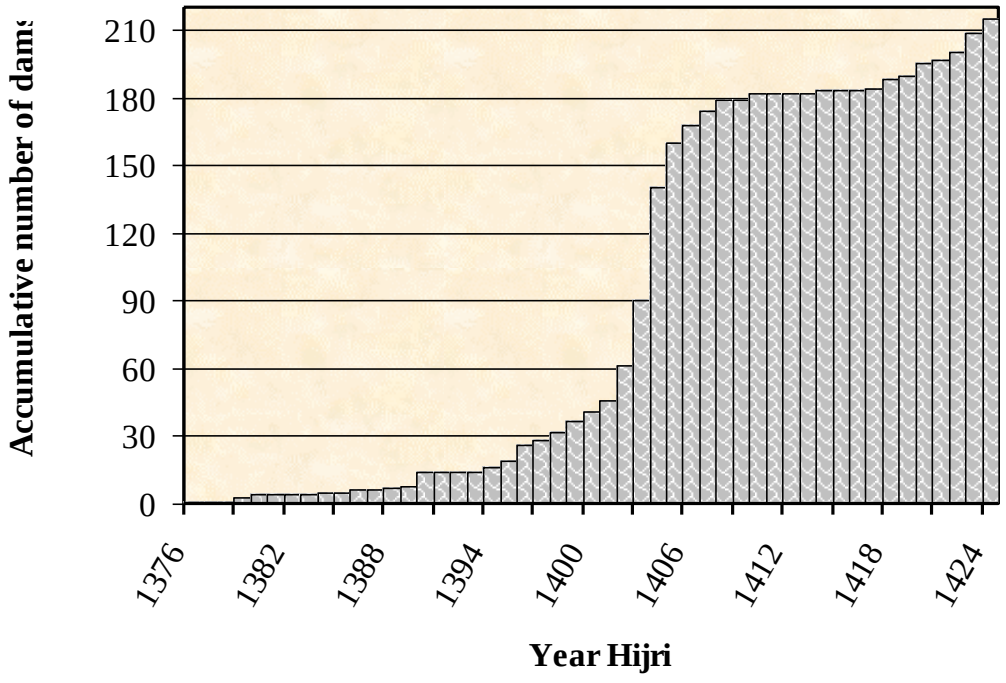


Figure (5-2). Accumulative number of dams till the end of 1424H.

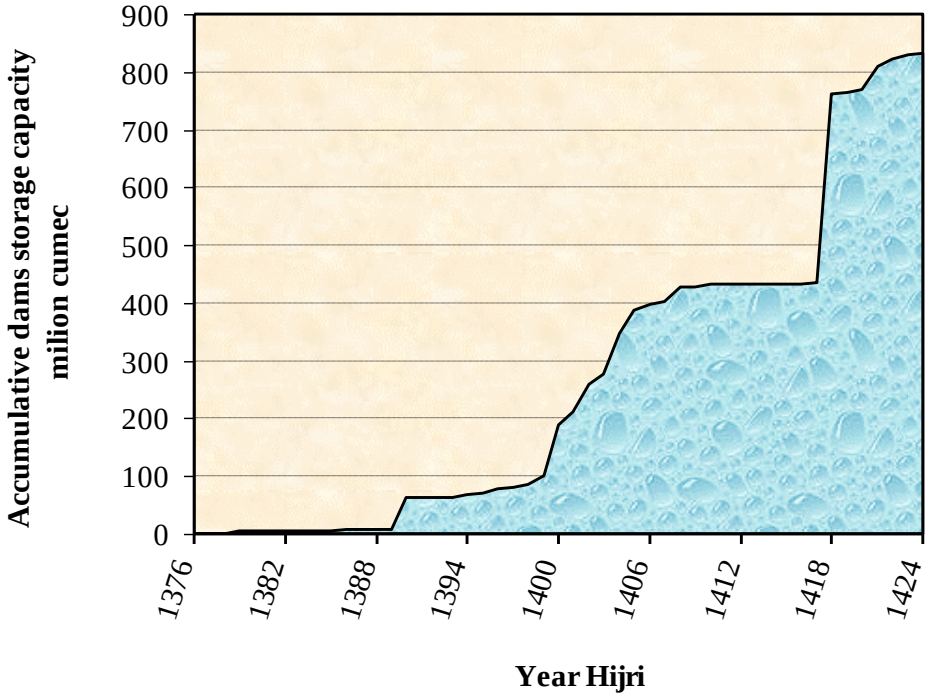


Figure (5-3). Accumulative storage capacity of dams till the end of 1424H.

Large Dams in KSA

In spite of the fast developments in communication technologies and easy contact and access of information, there is no accurate statistic in the number of dams in the world. Although it is believed that there are more than three hundred thousand dam in the world. The international commission on large dams (ICOLD) carries out the work of statistics of large dams in the world. Large dams are those having 15 m high or more or dams having height less than 15 meter but the storage capacity of the dam exceeds one million cubic meter or the flow rate in the valley is 2000 cubic meter per second or more. According to these definitions, there is about 45 thousand large dams in the world, and half of this number is in China. Kingdom of Saudi Arabia comes in the fourth rank in the Middle East after Turkey, Iran and Syria according to ICOLD register of dams in 1999. It is expected that the kingdom will be in an upper rank after the construction of the new large dams is completed in the beginning of 1429H. In the present time there are more than 88 dams in the kingdom with storage capacity of exceeding one million cubic meters, and this number will reach 97 dams at the beginning of 1429H. Also, there are 51 dams in the kingdom with more than 15 meter high, and this number will become 61 dams before the end of this decade.

King Fahad's dam on Wadi Bishah is the largest dam in the kingdom with respect to storage capacity, and Wadi Hali dam comes in the second rank, Table (5-3) gives a list of the largest dams in the kingdom with respect to storage capacity. Wadi Baysh dam in Jizan region is the Highest dam in the kingdom with 106 meter high, and King Fahad's dam comes in the second place with 103 meter high, Table (5-4) gives a list of the highest dams in the kingdom for both constructed and under construction ones. In the following sections a brief description of the largest dams for both constructed

and under construction ones will be presented. These dams reflect the pioneer achievements in the construction of large hydraulic structures and the dependence on the renewable water as an important source for the future.

Table (5-3). Largest storage capacity dams in the Kingdom.

No.	Name	Region	Storage Capacity (×1000 m^3)	Execution year
1	King Fahad	Bishah	325000	1418 H
2	Hali	Mekkah	249860	U/construction
3	Rabigh	Mekkah	220350	U/construction
4	Baysh	Jizan	193644	U/construction
5	Al Lith	Mekkah	88570	U/construction
6	Al Madiq	Nijran	86000	1400 H
7	Jazan	Jizan	51000	1390 H
8	Ka'a Huzuza	Al Madinah	40000	1421 H

Table (5-4) Highest dams in the Kingdom.

No.	Name	Region	Height (m)	Execution year
1	Baysh	Jizan	106	U/construction
2	King Fahad	Bishah	103	1418 H
3	Hali	Mekkah	95	U/construction
4	Rabigh	Mekkah	80.5	U/construction
5	Al Lith	Mekkah	79.5	U/construction
6	Al Madiq	Nijran	73	1400 H
7	Liah	Taif	40	1402 H

King Fahad's dam

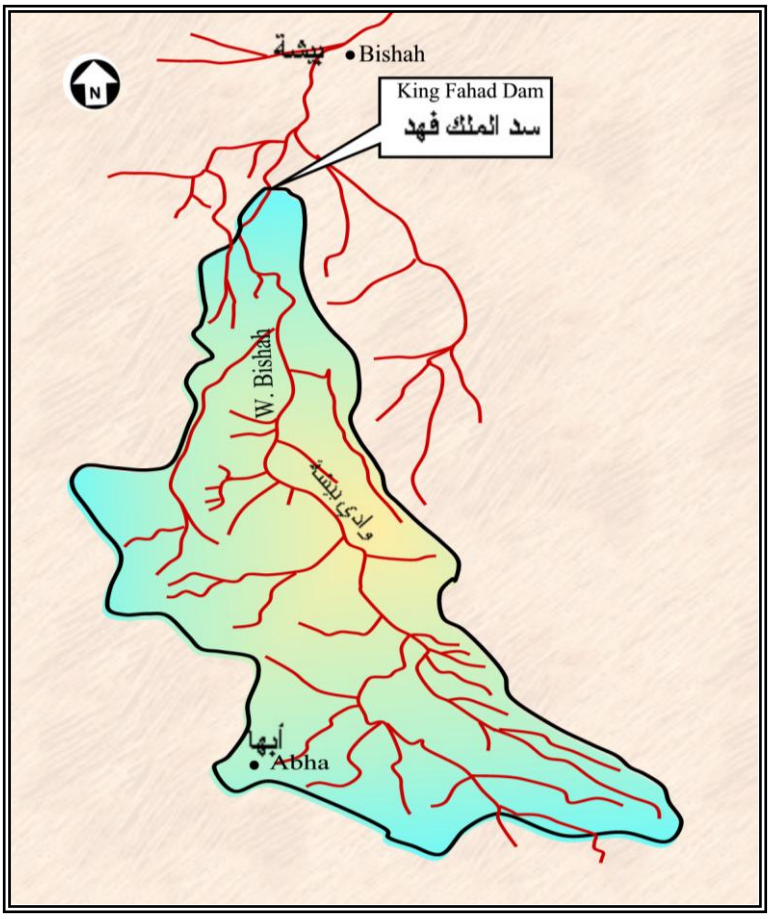
King Fahad's dam gets its importance from the storage capacity detained which represent about 39 % of the total storage capacity of constructed dams in the kingdom till the end of 1424H. Also the construction of King Fahad's dam is a mile stone in the construction of dams in general and large dams in particular. As large dams usually built on rivers rather than wadis.

King Fahad's dam is located on Wadi Bishah at a distance of 40 kilometres south of Bishah governorate. Wadi Bishah is consederd as one of the biggest valleys in the Arabian Peninsula where its length exceeds 250 km up to the dam site. It runs from Asir heights through Asir hill. Wadi Bishah collects its flow from more than 100 tributaries, among those are wadi Khamis Mshit, wadi Abha and others. Wadi Bishah continues after the dam towards the north along 200 kilometers where a number of tributaries flow into it, such as wadi hurgab, Turuj and Tabalah, till its meet with Wadi Tathleeth forming one stream known as Wadi Al-Dawaser which extends as far as 200 kilometres and ends in Rumeila in Rub' Al Khali. Dam catchment area is about 7600 km^2 extend from Sraat Ubaidah heights in the north to the dam site. Within the catchment area there are 14 climatological stations and 4 meteorological stations

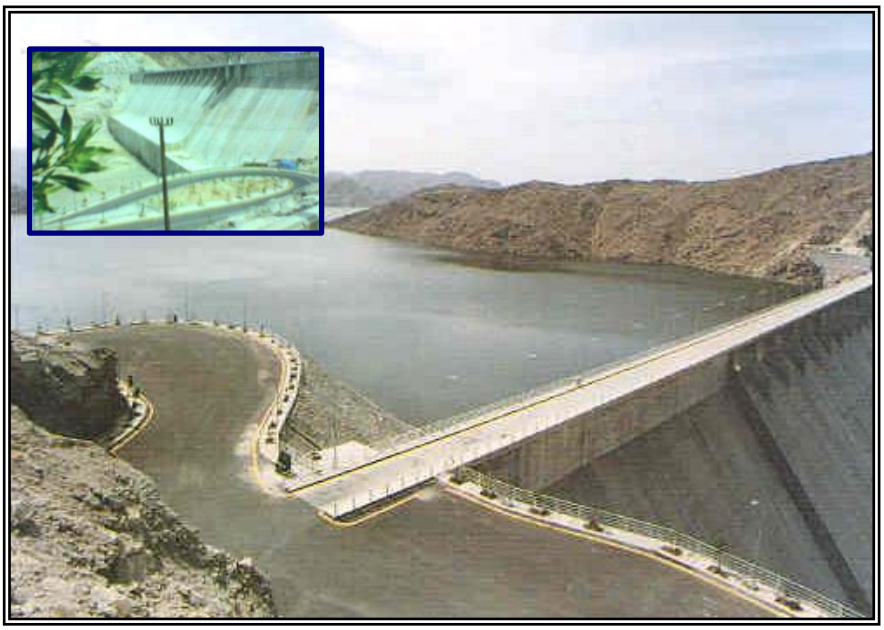
record the climatic changes and the rainfall quantity in the basin. Rainfall rate at the upper part of the wadi is about 600 mm and decreases to 270 mm in the middle of the wadi and does not exceed 120 mm in Bishah region. Map (5-1) shows the dam site, catchment area and Wadi Bishah, (Agricultural magazine, 1419 H).

Many studies were conducted before the construction of King Fahad's dam. These studies include the geological, hydrological, economical and topographical studies in order to select the proper location and type of dam. These studies completed in the year of 1402 H and a royal order was issued for the construction of this large dam on 21 / 7 / 1407 H. The construction works started with the construction of coffer dams in front of and behind the dam site and process of construction continued by excavation and provide the access road and so on. The project finished by 1418H and an official opening of the project took place under the auspices of HRH prince Abd Ullah bin Abdulaziz the Crown Prince and the National Guards president in Saturday, 13th of Muharram, 1419H. The total cost of this dam was about 246 million Saudi Riyals

King Fahad's dam is a concrete gravity dam with 80 meter base width and 8 meter width at the top from which 5 meters is a road. The dam is 103 meters high above the foundation and 68 meters from the wadi bed. The length of the dam at the top is 507 meters divided into 34 blocks 15 meter each, Picture (5-1).



Map (5-1). Location of King Fahad's dam and the catchment area.



Picture (5-1). King Fahad's dam on wadi Bishah.

In the construction of the dam more than 1.4 million cubic meter of concrete and 1380 tons of reinforcement steels were used. Also construction works included excavation of 1.79 million cubic meters, filling of 416 thousand cubic meters and 1560 tons of cement for grouting in the foundation curtain and dam body.

The maximum reservoir storage capacity is about 325 million cubic meters and the length of the reservoir lake is 18 kilometers. Dam is provided with a spillway having crest at 60.5 meter above wadi bed and its length is 225 meters with a design flood capacity of 5338 cubic meters per second. In the dam there are two outlets, in addition to the spillway, at different levels. The lower is at 4 metere from wadi bed level and consist of two pipes having a diameter of 282 mm with an upstream gate and downstream jet valve. The upper outlet is 20 m above the wadi bed and consists of two pipes having a diameter of 225 mm with an upstream gate and downstream jet valve.

Dam provided with six galleries on different levels with a total length of 3280 meters for the works of operation, maintenance and monitoring. Monitoring include horizontal and vertical dam movements, dam body temperature and uplift pressures. Monitoring instrumentation include 8 pendulums, 4 for the measurement of vertical movements and the others for the measurement of the horizontal movements, four temperature gauges for measurements of concrete temperature in the dam body and 6 piezometer for the measurement of uplift water pressure. Also dam is provided with two elevators connecting galleries for operation and maintenance works.

A special departments in the Ministry of Water and Electricity carries out the operation and the maintenance of the dam according to plans and the operating programs. These include operation of the dam through its gates, valves and monitoring instruments. Also monitoring the water quality and water levels in the wadi upstream and downstream the dam.

To increase the benefit from the dam, water treatment plant was installed to provide Bishah governorate with potable water with maximum daily capacity of 40 thousand cubic meters. Hence King Fahad's dam on Wadi Bishah is one of the integrated projects that utilize surface water in an ideal way. Iin addition of the protection of the region from the danger of the frequent floods, detained water are used for agriculture, groundwater recharge and potable water.

Wadi Hali dam

Wadi Hali dam is one of the under construction large dams in the kingdom. Its construction contract was signed in Safar, 1424 H and its expected to be completed at the beginning of year 1429H. After completion of its construction, it will be the second largest dam in the kingdom with respect to storage capacity after King Fahad's dam on Wadi Bishah. The dam is intended for flood control and protection, but it will participate in the recharge of groundwater and the provision of the necessary water for drinking and agriculture at wadi downstream.

Wadi Hali dam is located on Wadi Hali at a distance of 35 kilometers east of the Red Sea and about 18 kilometers east of Kiat town. Wadi Hali basin is located in the southwest of the kingdom and the catchment area is about 5600 km^2. Wadi Hali runs from Asir mountains north of Rejalalma and heads towards the south of Mahail city towards the west parallel to wadi Tih and flows into the Red Sea at a distance of 22 km southwest of Kiat town. Wadi Hali is one of the biggest valleys in the Kingdom of Saudi Arabia where its length to the dam site is 155 km, and collect runoff from wadi Qad, wadi Dufah and wadi Baqarah. Catchment area of Wadi Hali dam is about 4843 square kilometers, and within the catchment area there are one climatological station and 13 meteorological stations in addition to 4 climatological stations and 23 meteorological stations close to the basin of the dam. The annual average rainfall on Wadi Hali dam catchment area is about 375 mm with 500 mm on the top of the wadi and decreases to about 150 mm near the dam site, Map (5-2) shows the site of dam, catchment area and wadi Hali.

Wadi Hali dam is a concrete gravity dam with 71 meter base width at the foundation level and 8 meter width at the top from which a road of 4.5 meter width. The dam is 95 m high above the foundation and 57 m high from the wadi bed. The length of the dam at the top is 384 meters divided into 25 blocks, Figure (5-4). Volume of concrete needed for construction is about 690 thousand cubic meter, (Ministry of Water and Electricity, 1424 H).

The maximum reservoir storage capacity of Wadi Hali dam is 249.86 million cubic meters and the flood control reservoir volume is about 153 million cubic meters. The reservoir lake area is 15 square kilometers. The dam is provided by a spillway having a crest at 47 meter above wadi bed with a length of 179 meters divided into 12 openings separated by one meter width piers. The spillway is provided with sidewalls extends to the end of the spillway. Spillway ends in a ski jump bucket energy dissipator having a radius of 14 meter and its invert is 18.9 meters above the wadi bed. The spillway design flood is 9000 cubic meters per second. In the dam there are four outlets, in addition to the spillway, at different levels. The upper outlets consist of two steel pipes having a diameter of 160 mm each with two 1×1 m gates in the

downstream and the level of the upper at 22 meter above wadi bed. The lower outlets consist of two steel pipes having a diameter of 320 mm each with 2×2 m gates in the downstream and the level of the lower at 5 meter above wadi bed.

Dam will have six galleries on different levels for the works of operation, maintenance and monitoring. The project includes the installation of climatological station, runoff gauging station, four observation wells and dam monitoring instruments. Monitoring include horizontal and vertical dam movements, dam body temperature and uplift pressures. Also the project will be provided with 10 tons capacity overhead traveling crane for valve chamber and asphalt paved access road to the valve chamber from the crest of the dam, (Ministry of Water and Electricity, 1424 H).

Map (5-2). Location of Wadi Hali dam, catchment area and wadis flow into wadi Hal.

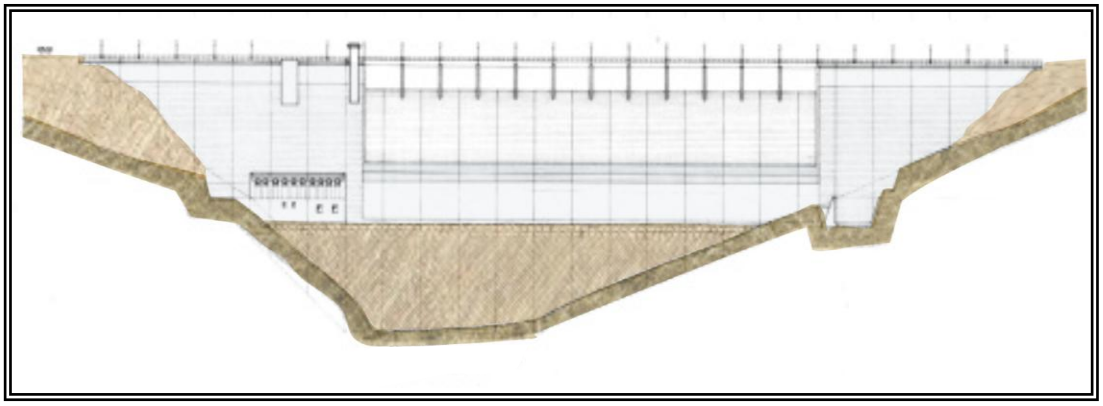


Figure (5-4). Cross-section of Wadi Hali dam showing dam profile and the spillway.

Wadi Baysh dam

Wadi Baysh dam is one of the under construction large dams in the kingdom. Its construction contract was signed in Safar, 1424 H and its expected to be completed within 60 months. After completion of its construction, it will be the highest dam in the kingdom with 106 meters above the foundation. The main purpose of Wadi Baysh dam is flood protection as will as securing necessary irrigation water for the downstream farms and recharge of groundwater aquifers.

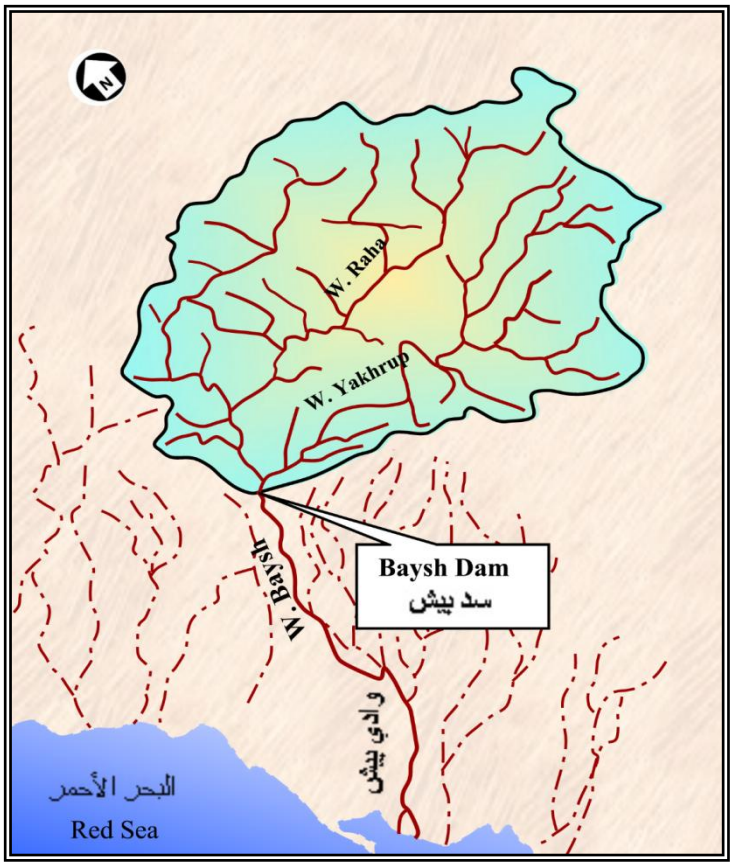
Wadi Baysh dam is located on Wadi Baysh at a distance of 33 kilometers southeast of Baysh town in Jizan province after the confluence of wadi yakhrup and wadi Baysh by about 500 meters. Wadi Baysh basin is located in the southwest of the kingdom and the catchment area is about 5000 km^2. Wadi Baysh runs from Asir mountains in the west of Dhran Aljenub towards northwest then turns towards southwest and flows into the Red Sea at a distance of 30 km northwest of Jizan city. The upstream part of wadi Baysh is mountainous and bare of vegetation. Therefore, catchment area converts rainfall to runoff in a short time. Downstream of wadi Baysh, after the dam site, is plain and suitable for agriculture. The length of wadi Baysh to the dam site is about 165 km. Wadi Baish collects runoff from several tributaries, amonge those are wadi Yakhrup, wadi Raha, wadi Qaha, wadi Atf and wadi Al-Awra. Catchment area of Wadi Baysh dam is about 4843 square kilometers, and within the catchment area there is one rainfall measurement station. Nearby the dam catchment area there are 31 meteorological stations and two climatological stations. In these stations rainfall quantity, temperatures, evaporation and other important climatological and hydrological elements are recorded. The annual average rainfall rate on the dam catchment area is about 391 mm with 600 mm on the heights and decreases to about 250 mm near the dam site, Map (5-3) shows the site of dam, the catchment area and wadis flow into Wadi Baysh.

Wadi Baysh dam is a concrete gravity dam with 79.5 meters base width at the foundation level. The dam is 106 meter high from the foundation level and 74 meters from the wadi bed. The length of the dam at the top is 340 meters, and construction required about 675 thousand cubic meter of concrete, Figure (5-2).

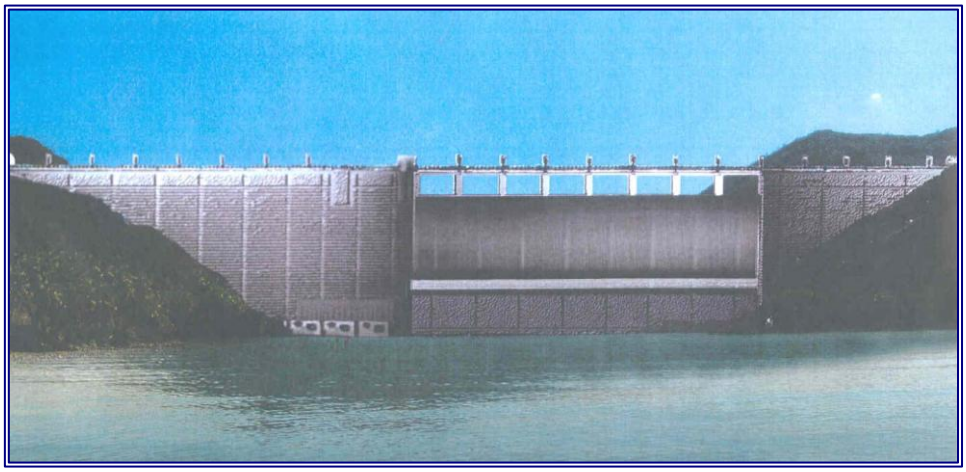
The maximum reservoir storage capacity is 192.75 million cubic meters and the flood control reservoir volume is 118 million cubic meters. The reservoir lake area reaches 8.09 square kilometers. The dam is provided by a spillway 62 meter above the wadi bed having total length of 112 meters, which divided into 8 openings separated by 1 meter width piers supporting the overhead bridge. The spillway is provided with sidewalls extends to the end of the spillway. Spillway ends in a ski jump bucket energy dissipator having a radius of 17 meter and its invert is 23.2 meters above the wadi bed. The spillway design flood is 8186 cubic meters per second. In the dam there are four outlets, in addition to the spillway, at different levels. The upper outlets consist of two steel pipes having a diameter of 160 mm each with two 1×1 m gates in the downstream. The lower outlets consist of two steel pipes having a diameter of 320 mm each with 2×2 m gates in the downstream.

Dam will have a number of galleries on different levels for the works of operation, maintenance and monitoring. The project includes the installation of climatological

station, runoff gauging station, four observation wells and dam monitoring instruments. Monitoring include horizontal and vertical dam movements, dam body temperature and uplift pressures. Also the project will be provided with 10 tons capacity overhead traveling crane for valve chamber and asphalt paved access road to the valve chamber from the crest of the dam, (Ministry of Water and Electricity, 1424 H).



Map (5-3). Location of Wadi Baysh dam, catchment area and wadis flow into wadi Baysh.



Picture (5-2). Expected look of Wadi Baysh dam after construction.

Wadi Rabigh dam

The importance of Wadi Rabigh dam comes from its storage capacity, which exceeds 220 million cubic meters, and after the completion of its construction it will be the third largest dam in the kingdom with respect to storage capacity. The purpose of Wadi Rabigh dam is flood control and protection and recharge of groundwater aquifer. Wadi Rabigh dam is one of the under construction large dams and its construction contract was signed in Safar, 1424 H and expected to be completed within 54 months.

Wadi Rabigh dam is located on wadi Marr the main tributaries of wadi Rabigh at about 5 km upstream of the confluence of wadi Haya and wadi Timayah with wadi Rabigh, and at a distance of 35 kilometers east of Rabigh town in Mekkah province. Wadi Rabigh basin is located in the west of the kingdom and its catchment area is 4800 km^2. Wadi Rabigh consists of three tributaries; these are wadi Marr, wadi Haya and wadi Timayah. It is called wadi Rabigh after the confluence of these tributaries and continues northwest till its flows into the Red Sea at a distance of 9 km northwest of Rabigh town. Also wadi Rabigh receives flows, from the north, from wadi Nwebah and wadi Khmas. The catchment area of Wadi Rabigh dam site is 3456 square kilometers. There are six meteorological stations and one climatological station nearby the dam catchment area. In these stations rainfall quantity, temperatures, evaporation and other important climatological and hydrological elements are recorded. The mean annual rainfall rate on the dam basin is 98 mm with 120 mm on the upper part of the basin and decreases to about 40 mm near the dam site, Map (5-4) shows the site of the dam, the catchment area and wadis discharging into wadi Rabigh.

Wadi Rabigh dam is a concrete gravity dam with 60 meter width at the foundation level and the top width of the dam is 5 meters from which 4.5 meter is a road. Wadi Rabigh dam is 80.5 meters high from the foundation and 59.5 meters from the wadi bed. The length of the dam at the top is 381 meters and the volume of concrete needed for the construction is about 585 thousand cubic meters, Figure (5-5).

The maximum reservoir storage capacity is 220.35 million cubic meters and the flood control reservoir volume is 140 million cubic meters. The reservoir lake area extended over 13.58 square kilometers. The dam is provided by a spillway 50.5 meter above the wadi bed having total length of 179 meters, which divided into 12 openings separated by 1 meter width piers supporting the overhead bridge. The spillway is provided with sidewalls extends to the end of the spillway. Spillway ends in a ski jump bucket energy dissipator having a radius of 15 meter and its invert is 19 meters above the wadi bed. The spillway design flood is 7856 cubic meters per second. In the dam there are four outlets, in addition to the spillway, at different levels. The upper outlets consist of two steel pipes having a diameter of 160 mm each with two 1×1 m gates in the downstream and the level of the upper at 30 meter above wadi bed. The lower outlets consist of two steel pipes having a diameter of 320 mm each with 2×2 m gates in the downstream and the level of the lower is at 5 meter above wadi bed, (Ministry of Water and Electricity, 1424 H).

Dam will have six galleries on different levels for the works of operation, maintenance and monitoring. The project includes the installation of climatological station, runoff gauging station, four observation wells and dam monitoring instruments. Monitoring include horizontal and vertical dam movements, dam body temperature and uplift pressures. Also the project will be provided with 10 tons capacity overhead traveling crane for valve chamber and asphalt paved access road to the valve chamber from the crest of the dam.

Map (5-4). Location of Wadi Rabigh dam, Catchment area and wadis flow into wadi Rabigh.

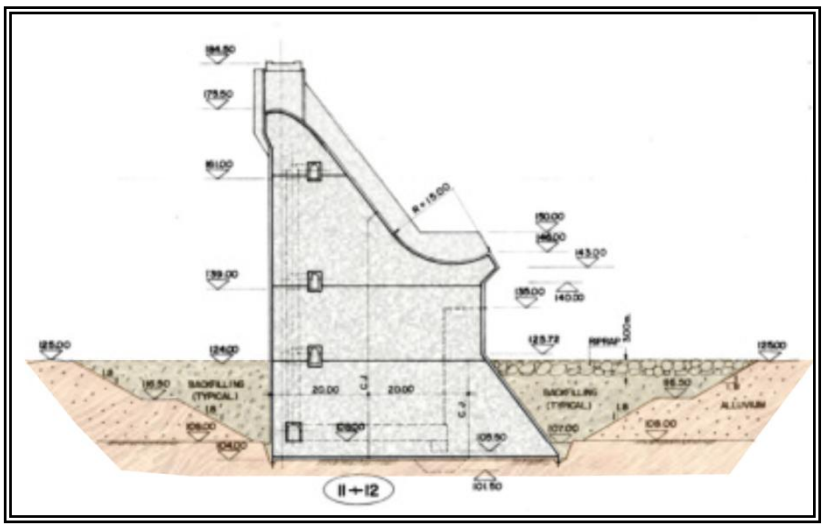


Figure (5-5). A cross section on Wadi Rabigh dam showing spillway and galleries.

Integrated Projects for Rain Harvesting

As a result of the increased demand on water resources and the unbalanced situation between demand and resources, man looks for more resources to fulfill the deficit of water resources from renewable sources and the term rain harvesting started and numerous techniques are adopted for this. Rain harvesting means the optimum exploitation of rainwater through its collection and usage in an organized way at the right time. Numerous techniques are available in the literature for rain harvesting and among these are underground tanks, terraces of different sizes and dams. In the kingdom rainfall harvesting started long time ago in which the first dam was constructed 50 years ago, and earth fill terraces having 70-120 cm high were used for rainfall detention and the total number of these terraces are more than 440 with a total length of 178 km (Al-Sharif, 1410 H). Also number of ponds was constructed on selected wadis to store rainfall water for drinking and agricultural uses.

Saudi government has exerted persistent efforts for providing water everywhere in the Kingdom and exploited all new techniques for this purpose, in order to provide an honorable life provision for citizen and resident in the kingdom,. The diversity of climate and topographies in the kingdom encouraged the use of many techniques for the exploitation of rainwater and floods, especially in the regions having high rainfall rates. In addition to the construction of large dams, the Kingdom adopted what can be named the integrated projects for rain harvesting through the construction of system of surface and underground dams on alluvial wadis with high permeability and rainfall rate to increase the efficiency of renewed water. Water then extracted through a number of wells and treated before pumping to beneficiaries for use in agriculture or drinking. This technique has been used on wadi Turabah project in Taif and it will be applied also on wadi Itwad project in Tihamat Asir. Hereafter a brief description of these integrated projects that represent the integrated water management through the development of renewable water.

Wadi Turabah projects in Taif

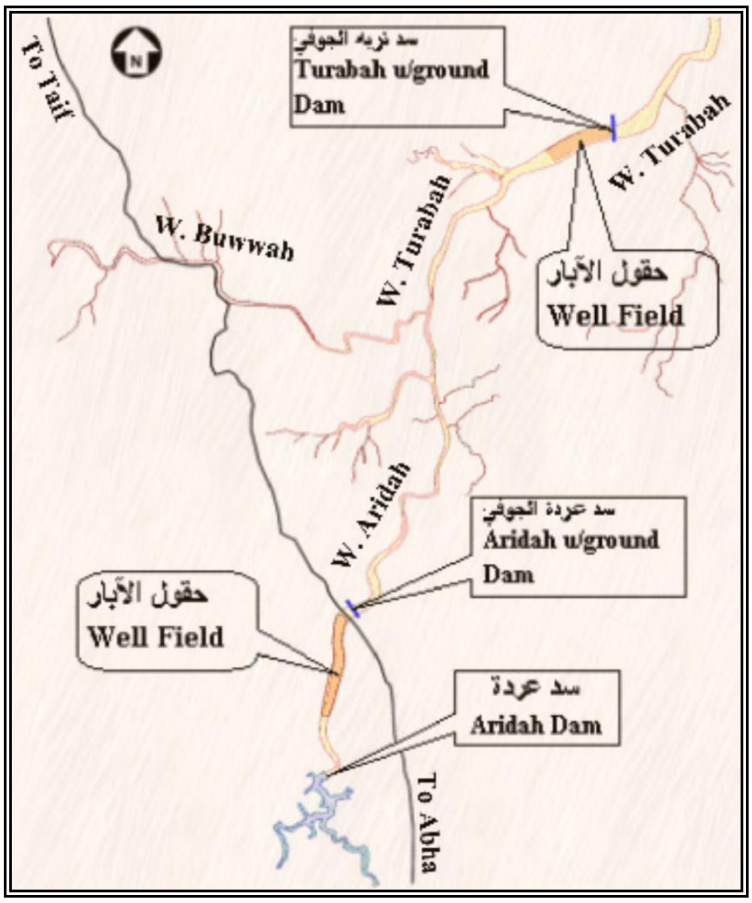
Wadi Turabah project is located on wadi Aridah which represents the eastern natural drain to rains falling on Alsroat mountains crest overlooking the Red Sea near Taif. Wadi Aridah runs northeastward and recives inflows from its main tributary wadi Shuqub and wadi Buwwah. After it confluence with the latter, it changes its name to wadi Turabah which receive inflows from wadi Bidah in the right bank, Map (5-5). Wadi Aridah and wadi Turabah basins represent the main two sources of potable water to Taif governorate. The annual rainfall rate on these basins ranges between 540 mm and 120 mm. Number of studies, hydrological and hydrogeological ones, were conducted to meet the water requirement of the city of Taif and securing irrigation water for wadi Turabah (Ministry of Agriculture and Water, 1980). These studies showed that, both wadi Aridah and wadi Turabah are the major part of these resources, as both have a thick permeable alluvial formation that can be recharged through a system of surface and undergroud dams. Underground dams will reduce natural flow through groundwater aquifer and surface dams carry out the recharge of these aquifers. The project started with the execution of two underground dams, one on wadi Aridah and the other on wadi Turabah. the length of wadi Aridah dam is 430 meter and its depth is 24 meters and its execution completed in 1404H, and its storage capacity is expected to be about 21 million cubic meters. Also, Turbah underground dam completed in the same year and the dam is 610 m in length, 15 m in depth and the storage capacity is expected to be about 21.8 million cubic meters. The construction of these two dams has provided about 7 million cubic meter per year of potable water for Taif governorate from the well fields in wadi Aridah and wadi Turabah. The second stage of this project will include the construction of surface dam on wadi Aridah, where designing is completed and execution is expected to starts very soon. Wadi Aridah surface dam is located at the top of Aridah valley at a distance of about 8 km south of the point where the Taif -Abha road crosses the wadi. Dam catchment area is about 1125 km^2 and its storage capacity is about 68 million cubic meters, Map (5-5), (Ministry of Agriculture and Water, 1980). The completion of the second stage will increase water quantity in the underground dams and hence provide extra water sources for both drinking and irrigation purposes for Taif governorate and Al-Bahah in the future.

Wadi Itwad project in Asir province

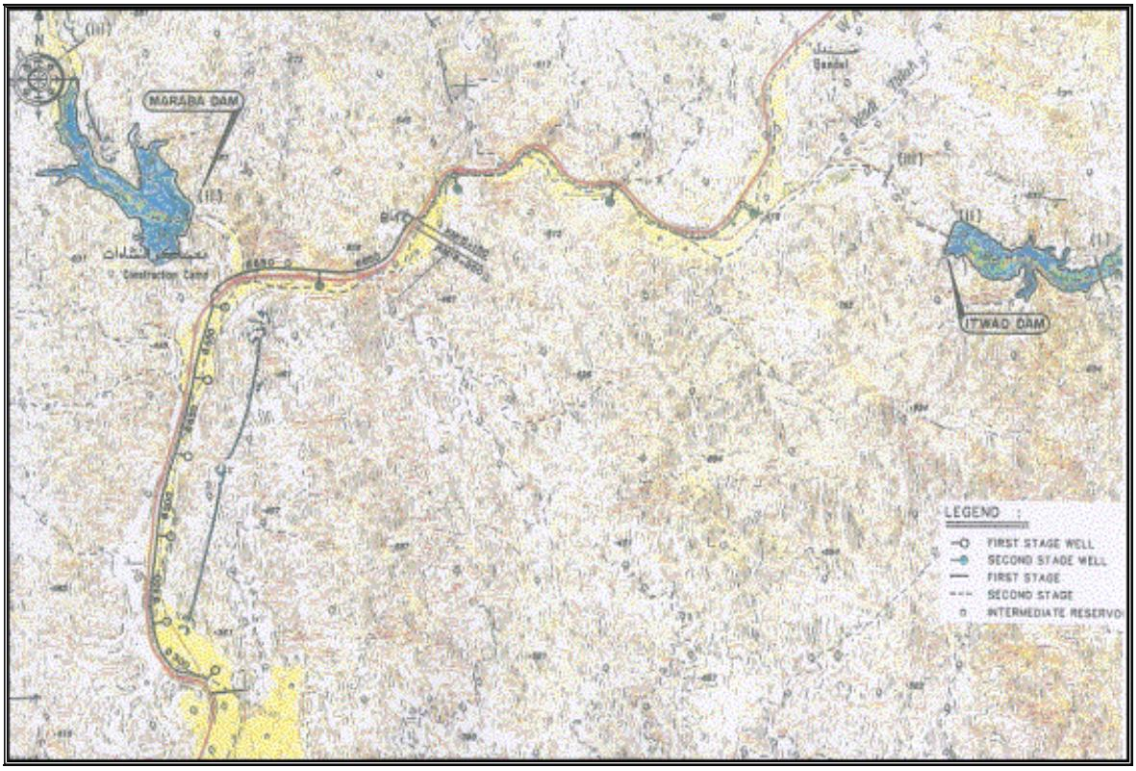
The project of wadi Itwad is located in Asir region southwest of the kingdom on Itwad valley. Wadi Itwad runs from Itwad Mountain towards the west and receive inflows, from the north bank, from wadi Ad-dilah and wadi Maraba before its deviates towards southwest and flows to the Red Sea, map (5-6).

This project is under construction and its first stage contract was signed in Shawal, 1424 H. The first stage consists of two surface dams, one on wadi Itwad and the other on wadi Maraba. Itwad dam is located on wadi Itwad and it is a geocomposit faced fill dam, 39 meter high with a maximum storage capacity of 10 million cubic meters and intended for potable water. The dam catchment area is 507 km^2 and the annual rate of rainfall is about 282 mm. The second dam in this project is Maraba dam located on wadi Maraba, a tributary of wadi Itwad. The annual rainfall rate on Maraba dam basin is about 332 mm and its catchment area is 482 km^2. Maraba dam is a geocomposite faced fill dam, 38 meter high with a maximum storage capacity of 10 million cubic meters and intended for potable water, (Ministry of Water and Electricity, 1424H).

In addition to the surface dams, the second stage of this project will include the construction of underground dam downstream of wadi Itwad after the meeting of wadi Maraba and wadi Itwad below Maraba town. The basin area of the underground dam is about 1429 km^2 and the rate of the annual rainfall rate on the basin is 276 mm. Dam will be 350 m long, 21 m deep and 1.2 m thick. Dam will retain the groundwater storage reserve in the aquifers and raise water table level upstream of underground dam, Map (5-6) shows sites of surface and underground dams. Project also includes the installation of ten wells for drawing water, water collection pipe network and treatment plant for water purification. After completion of this project, it will secure about 30 thousand cubic meters per day for the supply of Abha city by potable water, and the total production of this project is estimated therefore to be more than 10.5 million cubic meters per year.



Map (5-5). Wadi Turabah *project.*



Map (5-6). Location of surface and underground dams in Wadi Itwad project.