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THE SOURCES DAMS IN ALGERIA
A FORGOTTEN HERITAGE

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ABSTRACT

This paper evokes for the first time a hydraulic heritage. Forgotten and never taken into consideration, it is indeed the spring dams. The study was started since the year 2000 after the accidental discovery of a spring dam on the River Tiout (Naama Algeria). No note was written on this subject, a bibliography on the subject almost nonexistent; this pushed us to approach this work by traveling to the rivers of the northern Sahara. This first spring dam opened the way for us to understand the functioning of this type of hydro-agricultural development. The results obtained by this modest work are considered very satisfactory and allowed us to discover a part of these ancestral hydraulic structures. The system of spring dams as we have nicknamed it is composed of one or two dams intended to store spring water discharged by resurgences distributed along the river. The surplus water is transported by the frontal seguias to the palm groves located on the major beds of both banks of the river. Although the number is unknown, these spring dams have given rise to hundreds of oases along the rivers. Thousands of date palms have been cultivated on farmland developed on the major beds of the rivers. Irrigated continuously by spring water (very good quality) and temporarily by water laden with flash floods. These are the roles played by these hydraulic structures. No one can say how many spring dams have been built. However, this modest work has allowed us to have an idea of the distribution of these structures built across all the rivers of the northern Sahara.

Keywords: Spring dam, Sahara, Oasis, Resurgence, Seguia.

NOMENCLATURE

Ain: Water source

Ksar: Peasant city

Seguia: Open-air canal

Dachra: Peasant city

Khottara of Mzab: Animal-drawn well

Khottara of Saoura: Balance-arm well

Seguia Gharbia: Right bank canal

Seguia Cherkia: Left bank canal

Foukani Dam: Upper dam

Tahtani Dam: Lower dam

Ghout: Cratered palm grove

INTRODUCTION

The Sahara, the largest desert on planet Earth. Despite an arid climate that is even hostile to life in certain regions of this vast territory, the Sahara is the richest region in water in all of Africa. Its subsoil is full of fresh water; four aquifer systems with a capacity of several billion m^3 of water occupying a territory of more than 8 million km^2 (Remini, 2025; Remini, 2021a; Remini, 2021b). In the Algerian Sahara there are hundreds of open aquifers that are rechargeable and 3 large closed aquifers that are not very rechargeable; These are the aquifer systems of the Northern Sahara (SASS), the Taoudéni-Tanezrouft-Iulleden aquifer system (SATTI) and the Mourzouk basin with a volume of 80,000 billion m^3 occupying an area of 4 million km^2 (Remini, 2025). On the ground of the Algerian Sahara, water coming from the sky in the form of precipitation is rare, but water coming from the subsoil through resurgences in the form of water sources is very abundant. Saharan floods occur sporadically, thus draining considerable quantities of water. The wadis of the Sahara carry significant quantities of water and sediment brought by flash floods once or twice a year. In several places in the Sahara, despite the absence of rainfall, water flows into the wadis even in summer, but this water does not come directly from rainfall, but comes from underground through resurgences and cracks in the rocks. Under pressure, good quality water flows out through thousands of openings distributed in the beds and banks of the rivers; these are the spring waters. Flash and rapid floods drain large quantities of water that often mix with spring waters. It is these two types of water: underground and surface that gave life to the Sahara. Man settles in the four corners of the Sahara and its stability is directly linked to the existence of a water source. Thanks to the oasis genius and its know-how, the peasant has invented water capture techniques that adapt to the topography and hydrogeology of each environment. This is how foggaras were dug in the oases of Touat, Gourara and Tidikelt, Ahaggar and in the Saoura (Remini, 2024a; Remini, 2024b). In the Souf valley, farmers opted for a hydro-agricultural development that is original to the region and unique, which consists of planting palm trees in craters created in the middle of the dunes of the Grand Erg Oriental (Remini and Miloudi, 2021). Such a technique requires continuous irrigation since the roots of these palm trees will remain soaked in the water table. In the Mzab valley, it is the khottara, an animal-drawn well that draws water from the water table. This natural reservoir is recharged with each flood that occurs in the Mzab wadi by adequate development of the watercourse equipped with thresholds (Remini, 2020; Remini, 2018). In the oases of the Saoura, such as Kerzaz, Igli and Beni Abbes, it is the original balancing well (Khottara de la Saoura) of the region with a depth exceeding 6 m and is equipped with 3 to 4 balances in a single well (Remini and Rezoug, 2017) It is interesting to highlight the diversity and richness of water collection techniques in Algeria. However, the hydraulic process of foggaras is the most successful, since it exists in 52 countries around the world (Remini et al, 2014). Iran is the first country in the world with the highest number of qanats. In 2020, Iran recorded approximately 40,000 qanats draining a flow of 4.7 billion m3 (Mansouri Daneshvar et al, 2023). The Sultanate of Oman, according to the 1998 inventory, gave a number of 4,117 falaj that were dug, only 3,017 remain in operation (Tayara, 2015). Today, the census of Aflaj carried out in the Sultanate of Oman gave 4,000 falaj, of which approximately 3,000 are still in operation. A similar number of falaj contributes 30% of water resources, intended for irrigation and domestic uses (Semhi et al, 2024). Intended for the irrigation of 450 ha of agricultural land in Tunisian arid zones, the flow of the 800 foggaras (mkayels in Tunisia) has been declining since 1900, which was equal to 1 m^3/s, to fall to 0 m^3/s in 2011. In Afghanistan, 170,000 ha of land are irrigated by 7,000 foggaras (Karez in Afghanistan) (Khan et al., 2015; Himat and Dogan, 2017). This hydraulic system irrigates 15% of the agricultural land area of the whole of Afghanistan. (Himat and Dogan, 2017). Today, out of a total of 5,887 Karez recorded in Afghanistan, only 11% are in operation and the rest (89%) are considered inactive (Himat and Dogan, 2019; Stinson et al, 2016). Of the 6,741 karezes recorded in 1978 in Afghanistan, 3,406 karezes were dried up following long droughts (Azami et al, 2020). These are just a few Figures that demonstrate the success of a hydraulic system on a global scale. Unlike other countries that only have hourly foggara, only Algeria has two types of foggaras: hourly and volumetric. The latter is based on a sharing of water per unit of volume. It has a lot of genius compared to the hourly foggara, the sharing is done per unit of time (Remini, 2024; Remini and Achour, 2017).

In this article we study for the first time an original hydro-agricultural development that has never been the subject of a serious study on this subject. It is indeed a low-height dam made of gypsum which consists of storing spring waters which come from resurgences distributed on the beds and banks of the wadis. Equipped with two seguias (East and West) of several kilometers which are intended to transport these spring waters to the gardens located on major beds of the river and downstream of the dam. The hydro-agricultural development is called Dams of the Sources as it was mentioned by its title of this modest article: "The dams of the sources in Algeria, a forgotten hydraulic heritage".

STUDY REGION AND WORKING METHODOLOGY

Located in the north of the African continent, Algeria, this beautiful country with an area of 2.382 million km^2, shares its land borders with Tunisia to the northeast, Libya to the east, Niger and Mali to the south, Mauritania and the territory of Western Sahara to the southwest, and Morocco to the west (Fig. 1).

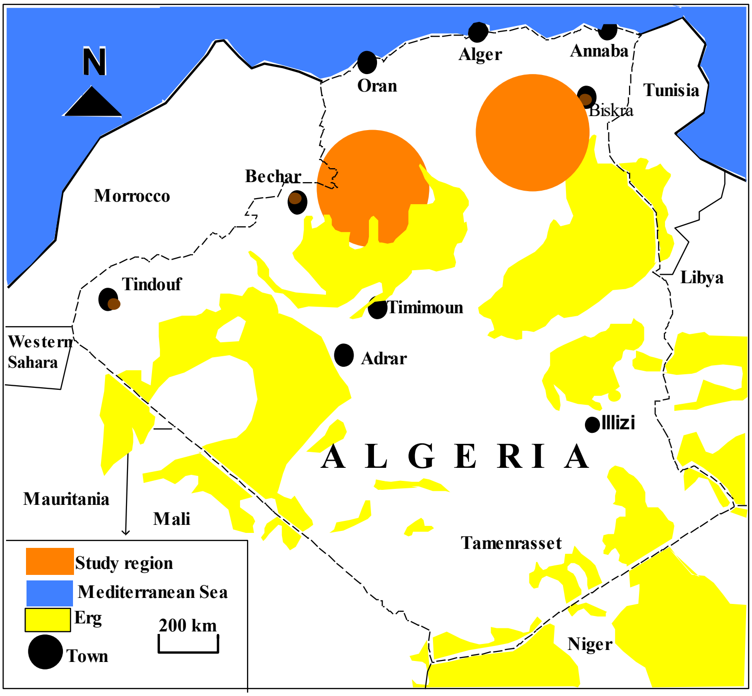

Figure 1: Situation of the study region (Remini, 2025)

A large country, Algeria has a varied relief that is composed of 3 main parts. These are the Tell in the north, a coastal strip 1,600 km long and 100 to 200 km wide. It is delimited to the south by a mountain range, more or less parallel to the coastline, and which extends from the region of Tlemcen in the west, to the Tunisian border in the east. This group is made up of fertile plains and valleys and the Tell Atlas which regularly exceeds 2,000 m in the east. The high plateaus and the Saharan Atlas in the center of Algeria which are made up of semi-arid plains and high plateaus. This group is delimited to the south by a mountain barrier (the Saharan Atlas). From west to east follow the mountains of Ksour, Ouled-Naïl, Ziban and Aurès. At the foot of these mountains are the oases synonymous with the beginning of the Sahara. This desert expanse is the most beautiful desert on the planet, covering approximately 85% of the Algerian territory and part of the largest desert on the planet, encompassing 11 countries in North Africa. These are Algeria, Tunisia, Libya, Mali, Mauritania, Niger, Egypt, Sudan, Chad, Nigeria, Morocco, and Western Sahara (Remini, 2021b). Covering an area of more than 8.5 million km^2, the Sahara is occupied by Ergs, plateaus, Regs, and Hamadas, lakes, wadis, rocky massifs, Sebkhas, Chott, and Gueltas. In addition, the Sahara contains hundreds of oases and oases that are wetlands within a dry environment. The sand or dune area formed by the Ergs represents only 1.7 million km^2, or 20% of the entire surface area of the Sahara.

The rocky massifs occupy an area of 820 km^2, or 10% of the surface area of the Sahara (Remini, 2021a. Remini, 2021b). While the majority of the Sahara Desert is made up of Regs; a flat and stony space. The Algerian Sahara is the most beautiful and the largest part of the Sahara Desert whose surface area is around 2 million km^2 (Fig. 2).

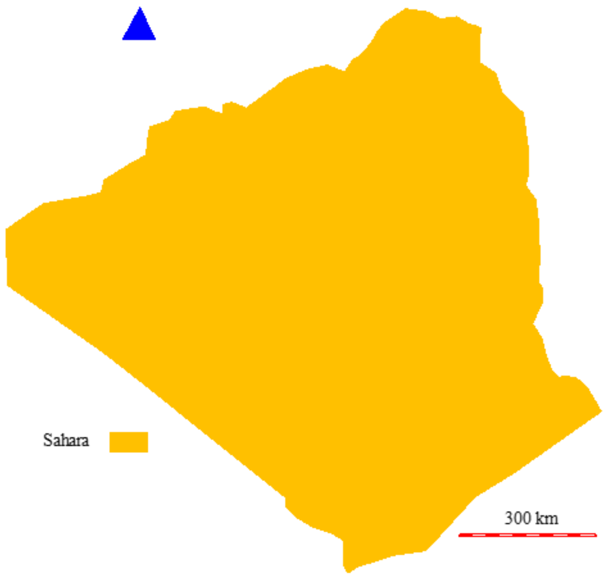

Figure 2: Territory of the Algerian Sahara (Remini, 2025)

Working Methodology

In the early 1990s, we began serious work on the subject of ancestral water harvesting techniques in the Algerian Sahara. While we considered such a delicate mission, it was a duty and an obligation for us, since it is our heritage. We knew at the beginning of this fascinating study that this heritage would one day disappear, but the written records would remain. Our objective, in the first phase, was to preserve and protect this hydraulic heritage and, in the second phase, to leave written records on these hydraulic techniques for future generations. Given the rapid deterioration of this cultural heritage, written records (books and articles) remain an essential avenue. The first hydro-agricultural development on our agenda is the foggara system. The first field mission was carried out in the oases of Touat, Gourara, Tidikelt, and Tamanrasset, followed by several missions in the oases of the Saoura Valley. The objective of these field trips is to first discover the secrets of Algerian foggara.

In a second step, establish the inventory of foggaras and the creation of a distribution map of foggaras in the Algerian Sahara (Remini, 2023). The second project we have started is the rainwater sharing system in the Mzab valley (Remini, 2020, 2018). The Souf valley; the third project which concerns the development of the Ghouts; the palm groves of the craters which consists of planting palm trees in a hole 100 meters in diameter whose water table level must be 1 meter from the bottom (Remini and Miloudi, 2021). The fourth project concerns the Saoura wells which are unique balance wells in the world (Remini and Rezoug, 2017). In 2019, we discovered by chance a small dam on the Tiout wadi in the wilaya of Naama during a mission to the oases of the northwest of the Algerian Sahara such as Boussemghoun, Moghrar, Tiout, Sfissifa in search of hourly foggaras. A study was launched on this hydro-agricultural development to understand its functioning and which was materialized by the publication of an article (Remini, 2019). This new line of research on these small dams that store spring water does not stop at the Tiout dam alone, but our investigations have gone beyond the borders of the wilaya of Naama. Today, our study extends across the entire Algerian Sahara in search of spring dams. We set out at our own expense to study this transfer of oasis engineering and spring dam know-how on several wadis of the Sahara. The long journey in search of small dams across hundreds of oases of the Sahara during the period 1990-2025, allowed us to discover a dozen ancestral dams. It should be remembered that the first non-degraded dam is that of Tiout discovered in 2006. It is a small dam made of gypsum and built on the Tiout wadi is intended to store spring water from more than 50 resurgences according to the testimony of the population of the Tiout ksar. After an unsuccessful bibliographic search and a total absence of information and data on this hydraulic heritage, we were forced to focus our research on investigations and surveys among the oasis population and old farmers. It is thanks to these interviews that we obtained information on the location of a second dam on the Tiout wadi 200 m downstream. This research work in this beautiful oasis took us a long time to understand the functioning of this hydro-agricultural development. Thanks to the local population, we discovered two dams in the oasis of Boussemghoun 40 km from Tiout. Two other dams were discovered in the oases of Chellala Gueblia (Naama) and Boualem (Bayadh). It took 3 years of work to publish the first article in 2019 entitled: cascade dams (Remini, 2019). For us, this was a unique discovery for this type of irrigation project. We were certain that the know-how of this heritage had been exported to other wilayas. This prompted us to head to the oases of the eastern part of the northern Sahara to search for possible spring dams.

RESULTS AND DISCUSSIONS

River Oases

Oases, a wetland in a dry region (Sahara), what a paradox! The oasis, the work of human ingenuity, consists of a residential area for farmers called a ksar or dachra. A palm grove sheltering gardens for the population to ensure food security in the oasis. A water source in sufficient quantity and quality is essential to ensure water security in the oasis. The Algerian Sahara contains oases in 20 wilayas. These are In Salah, Timimoun, Khenchela, Bousaada, Batna, Biskra, El Oued, Tébessa, Ouargla, Djelfa, Laghouat, Ghardaïa, Naâma, El Bayadh, Béchar, Adrar, Illizi, Tindouf, Tamanrasset, and Djanet. The water source determines the type of oasis. In the Algerian Sahara, there are four types of oasis, depending on the water supply method (Fig. 3):

- Foggara oasis
- Khottara oasis (dipper well)
- Ghout oasis or Erg oasis
- Wadi oasis

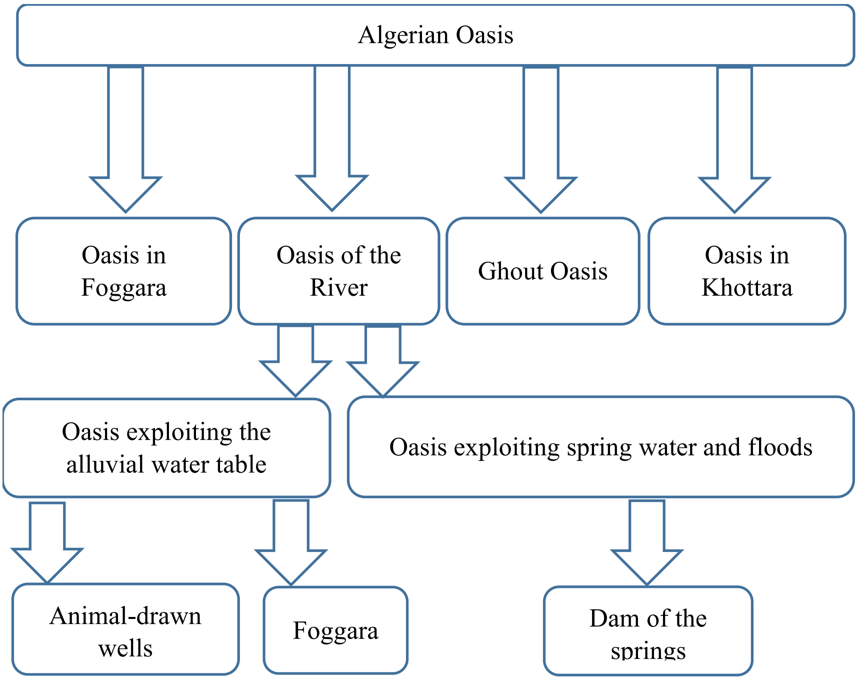

Figure 3: Types of foggara in the Algerian Sahara according to the water collection technique (Remini, 2025)

Regarding the River oasis, there are two types of oases (Figs. 4 and 5):

- Wadi oasis, which exploits the alluvial aquifer of the river (Khottara: animal-drawn wells).

For this type of oasis, this is the case of the Mzab oasis, which exploits the alluvial aquifer of the Mzab River using animal-drawn wells called Khottara. Thanks to this hydraulic system, water security has been ensured for more than seven centuries in an arid climate. Thanks to the floodwater sharing system, gardens are temporarily flooded by nutrient-laden waters. This is a natural fertilizer for the soil of the floodplain of the Mzab River. Food security has been ensured thanks to highly developed agriculture. Other oases such as Sfissifa and Tindouf exploit the alluvial water table using foggara (Remini and Abidi Saad, 2022).

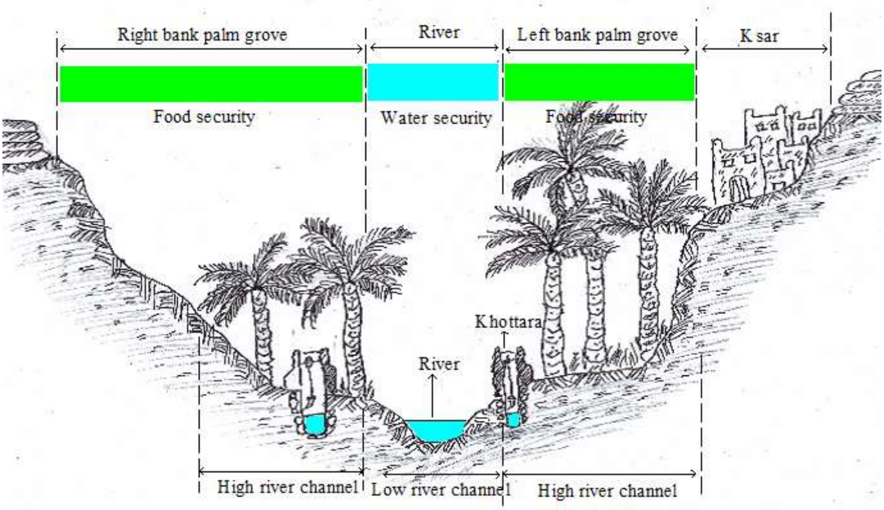

Figure 4: Synoptic diagram of a River oasis exploiting the alluvial water table (Diagram Remini, 2025)

- Oasis of the wadi which exploits the waters of the resurgences of the river (spring water) (spring dam). For this case of oasis which is found on the Rivers of Tiout, Boussemghoun, Chellala Gueblia, El Hay, Abid, Labiod, the spring dams ensured the water and food security of the oases located along the major wadi beds were irrigated by spring waters in a continuous way. The sporadic flood waters loaded with nutrients flood the gardens through the seguias of the spring dam.

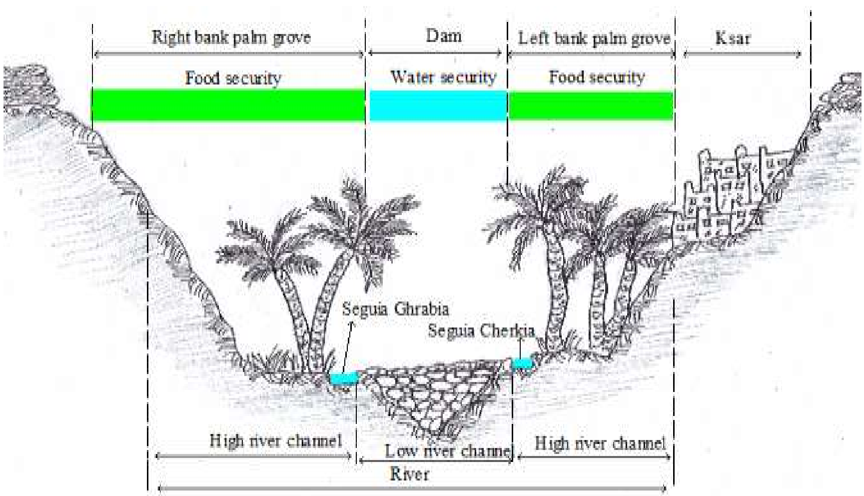

Figure 5: Synoptic diagram of a River oasis exploiting spring water evacuated by the resurgences distributed along the wadi bed (Diagram Remini, 2025)

The Role of the Spring Dam in Ensuring Water Security in the Oasis

Among water storage dams, the technical literature identifies two types of dams: the conventional dam, which stores surface water, and the subsurface dam, which stores water from the alluvial aquifer. However, there is a third dam, which stores water from springs emanating from resurgences distributed along the river floor (Fig. 6). Unfortunately, this third type of dam has not been studied, and consequently, there is a lack of publications concerning this type of dam. It is the flow rate of the springs emanating from the resurgences that determines the size of the spring dam (Figs. 7 and 8).

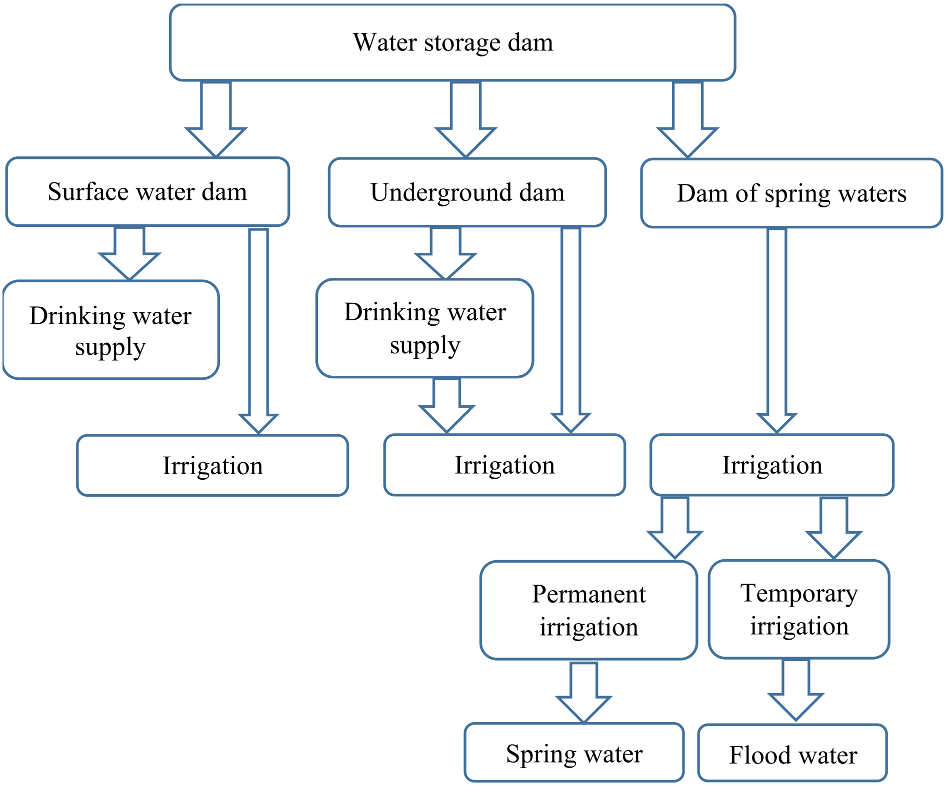

Figure 6: Types of water storage dams in Algeria (Remini, 2025)

Figure 7: Resurgences on the bottom of the Tiout wadi (Photo. Remini, 2018)

Figure 8: Spring waters in the Boussemghoun dam reservoir

This type of dam is intended exclusively for the irrigation of palm groves. For this type of dam, spring water flows continuously and without stopping and consequently the water level rises. Equipped with two seguias (Gharbia and Cherkia) which are made at the same level of the flood spillway. Therefore, the surplus spring water is transported continuously and without stopping by the seguias to the gardens (Figs. 9 and 10). In addition, flash floods draining excessively charged water are transported by these channels to flood the gardens; an operation of watering water full of nutrients to amend the soil during floods.

Figure 9: Synoptic diagram of the spring dam system (Diagram Remini, 2025)

Figure 10: Tasrift springs dam (Menaa) with the two seguias (Photo. Remini, 2025)

For several centuries, regions were very rich in spring water that comes from resurgences distributed on the bottoms of Rivers and cracks in rocks. Quantities of very good quality water are lost in nature, a large part of which evaporates and returns to where it originally came from, that is, it returns to the sky. However, the collection and storage of a portion of this resurgence water can lead to the socioeconomic development of an entire region. This is what has been done by the population of the Sahara for centuries. Everything has been combined to develop hectares of palm groves, namely good quality and appreciable quantity. Very good land suitable for successful agriculture. It is only a matter of storing this water in a reservoir and then it is transported by seguias to the agricultural lands. For this type of oasis called River oasis, it is the lands of the major bed of the river that are valued to shelter the palm groves.

The spring dam system, a hydro-agricultural development project

The term spring dam system is more commonly used than spring dam. Collecting, storing, transporting, and distributing spring water are the functions of this ancestral hydraulic system. This hydro-agricultural development project consists of one to two cascading dams, one to two seguias of several kilometers, built in parallel on both banks (right and left) of the river. Unfortunately, no study of this hydraulic heritage has been conducted. Difficulties have been encountered in finding data and information on this type of hydraulic structure. The only option left to us is to travel to River sites in search of these small dams. In the early 2000s, we accidentally discovered a small gypsum dam in the beautiful Tiout oasis. It was a discovery for us, and from that moment on, we began working on these dams. In a first step and after several work missions in the Tiout oasis, we learned that the filling of this dam is carried out with spring waters emanating from around fifty resurgences distributed on the bottom of the Tiout wadi (Fig. 11). Surface water fills the dam but only during flood periods.

Figure 11: A view of the Tiout springs dam (Photo. Remini, 2006)

In a second stage, after investigations and visits to the site and the surroundings of the dam, we discovered a second dam upstream of the first dam. Finally, this hydro-agricultural development on the Tiout River, consisting of two cascading dams with a height of 2 m and a seguia with a length of 2 km, functions as a single entity (Fig. 12).

Figure 12: A view of the second dam of the Tiout springs (Photo. Remini, 2008)

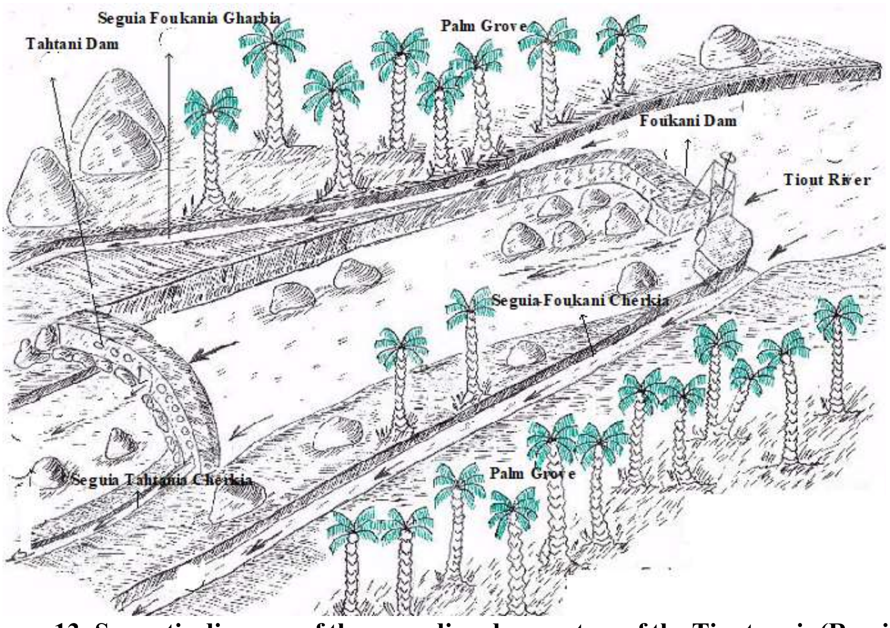

Figure 13: Synoptic diagram of the cascading dam system of the Tiout oasis (Remini, 2019)

This hydro-agricultural development, composed of two cascading dams, is intended to store spring water from more than 50 resurgences, which are intended for the irrigation of a palm grove covering an area of 40 ha. The two dams are separated by a freshwater lake 370 m long. The first dam is equipped with a 2 km long Cherkia seguia. On the other hand, the second dam is equipped with two seguias (Cherkia and Gharbia) each 1400 m long. The Tiout hydro-agricultural development consists of two spring water reservoirs. Three seguias in total are intended to transport spring water to the gardens located downstream of the dams (Fig. 13) (Remini, 2019).

After this discovery, we conducted research on the oases surrounding this hydro-agricultural development for about ten years and allowed us to discover other dams in the oasis of Boussemghoun. These are 3 dams that have been in operation for several centuries on the Boussemghoun wadi (Fig. 14). No information on the number of water sources in this region has been provided. Only today there remain 3 sources with an appreciable flow. These good quality waters fill the dam in a first phase, then in a second phase, the surplus water is evacuated by the two seguias towards the gardens.

Figure 14: First dam of the Boussemghoun springs (Photo. Remini, 2017)

A very interesting particular case that demonstrates the magnitude of the flow rates of water sources. In the Boussemghoun wadi, a single spring was sufficient for around ten gardens thanks to a single water source. To store and share the flow of this source, a small dam equipped with a seguia was built to supply the gardens (Fig. 15).

After the oases of Tiout and Boussemghoun, we expanded our research to neighboring oases such as Chellala Gueblia, Boualem, Asla, Ghassoul, Ain Ouarka, Stitten, Brezina, Les Arbaouts, El Abiodh Sidi Cheikh, Sfissifa and Moghrar. Over the years, we have visited all these oases several times and have concluded that, indeed, all these oases form a water source environment. However, the exploitation techniques for these water sources are shared between the spring dam and the spring foggaras. For example, the oasis of

Moghrar uses two foggaras to exploit spring water (Remini, and Achour, 2017). On the other hand, the oases of Chellala Gueblia and Boualem use spring dams. Today, the dam of the Boualem oasis has deteriorated and is no longer functioning. On the other hand, the Chellala Gueblia dam is in good condition and continues to operate despite the 2008 flood which occurred in the region (Fig. 16).

Figure 15: A small spring dam in the Boussemghoun oasis (Photo. Remini, 2019)

Figure 16: Spring dam in the Chellala oasis (Photo. Remini, 2019)

Given the interesting results obtained in the western region of the Northern Sahara with the discovery of spring dams, we decided to head towards the eastern part of the Northern Sahara. The choice was made on the Ziban region known for the importance of these water sources in terms of number of resurgences and the quantity of water. The Rivers Labiod, Abdi, El Hay, Biskra, Djedi have been the subject of repeated visits in recent years. What we noticed is above all the number of dams built and significantly higher than in the western region. Throughout the wilaya going up to the borders of the wilayas of Batna and Khenchela, we encountered traces and remains of dams and seguias, proof of the construction of spring dams (Figs. 17 to 23). For a first approach, the Labiod wadi, with a length of 120 km, is the one that has the most spring dams built and consequently the most developed land on the major beds of the wadi. According to the testimonies of farmers in the oases of Mchounech and Ghoufi, about thirty dams have been built on this watercourse over many centuries. In total, about twenty dams have been discovered since the year 2000. In a first estimate, the number of dams that have been built in the northern Sahara greatly exceeds the number of 100 dams. Not to mention that we must take into account the dams that have been washed away by flash floods that have occurred in the wadis of the northern Sahara.

Figure 17: First spring dam on the Abdi wadi (Photo. Remini, 2025)

Figure 18: Second Spring Dam on the Abdi Wadi (Photo. Remini, 2025)

a) Upstream of the dam **b) Downstream of the dam**

Figure 19: Lahbal springs dam on the River Labiod (Photo. Remini, 2025)

a) Upstream of the dam **b) The crest of the dam**

Figure 20: Branis springs dam on the River Abdi (Photo. Remini, 2025)

Figure 21: Spring dam on the River El Hay (Photo. Remini, 2016)

Figure 22: Spring dam (Photo. Remini, 2025)

Figure 23: Mchounech springs dam on the River Labiod (Photo. Remini, 2025)

All the dams we have supervised, even the remains of the disappeared dams, were built with materials carried by the rivers. The mortar used in the construction of the dikes consists of sand and gravel as well as gypsum. To withstand flash floods which are characterized by a significant tractive force, the height of the dam plays a major role in the stability of the dam. Thus, the height of the dike is directly linked to the flow of the sum of the number of resurgences. The height is calculated based on the flow of the springs. In the case where this theoretical height exceeds the limit of 2.5 m, a second dam will be built upstream of the first dam while keeping a height of the dike below 2.5 m. The stability of the dike according to the farmers does not stop at the limited height of the dam and the material used but the shape of the dike plays a major role in stability. This is how we observed aerodynamic shapes without pressure losses to facilitate the discharge of the water blade and consequently to avoid the overturning of the dike (Fig. 24).

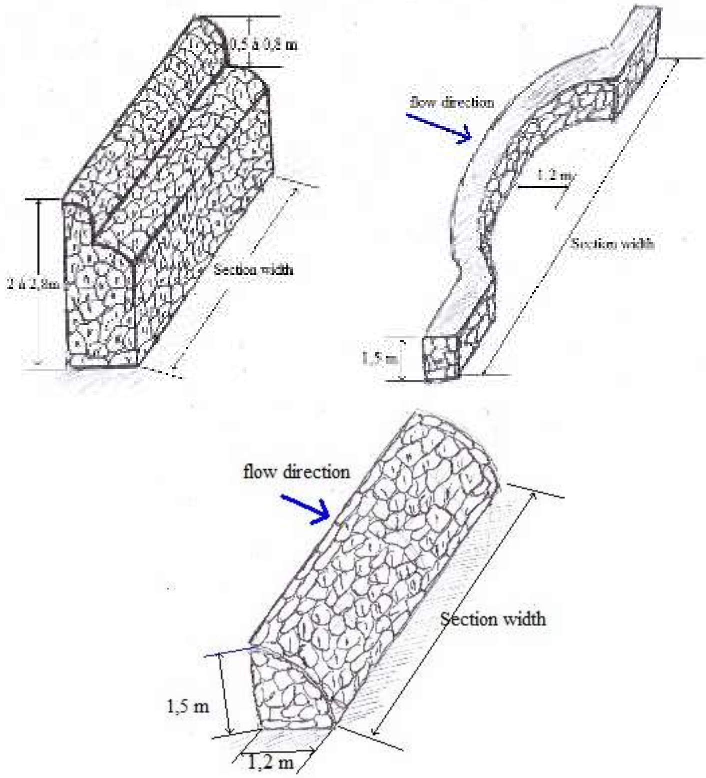

Figure 24: Shapes used in the construction of dams (Diagram Remini, 2025)

The essential element in the construction of the springs dam is undoubtedly the dike that we have just discussed. But ancillary works were added, such as an opening in the dike that acts as a bottom valve. It is closed with rocks and clay. In some dams, a sliding metal door has replaced the rocks and clay. One or two rectangular seguias extend from the dike towards the gardens (Fig. 25). The seguias are well-sized economically since the width is twice the height of the rectangular section. The seguias were made with gypsum, sand, and gravel mortar. In several places, sections of the seguia were carved into the limestone rocks.

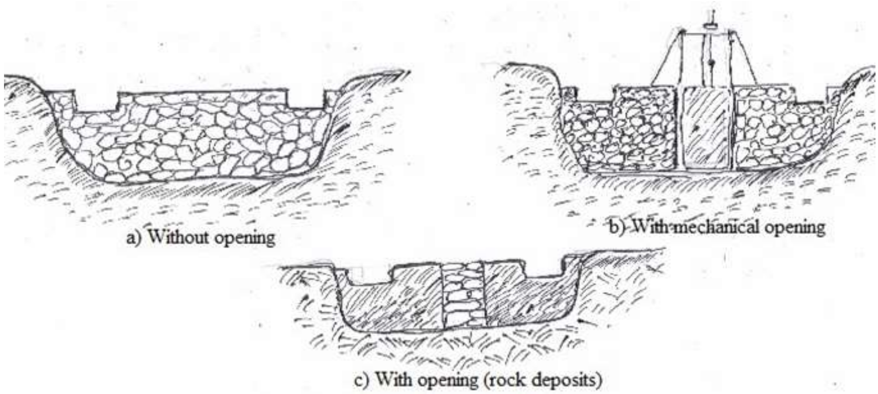

Figure 25: Diagrams of some types of dikes built (Diagram Remini, 2025)

Spring Dams and Climatic Hazards

Today, many dams have disappeared, leaving only vestiges and traces of the existence of dikes and seguias. Other dams still function, but they are covered in alluvial deposits. Other dams were washed away by flash floods. A large part of them were abandoned due to a lack of fresh water following the drying up of several springs due to a lowering of the water table caused by prolonged droughts. The majority of palm groves are now irrigated by motor-driven wells or boreholes. These hydro-agricultural developments were built in areas where water is abundant; the pressurized water flows through springs and cracks from the subsoil to the ground surface. However, temporary flash floods have posed a threat to these structures since the construction of the first dam. With each flood, one or two dams were swept away by the flow. Rebuilding the structure with other innovative ideas allowed the dike to withstand the overturning and thrusting caused by flash floods. Over time, farmers developed essential expertise in the field of dams and canals.

The role of seguias in conveying water to the palm groves

Without the open channels called seguias that connect the dam to the palm grove, the water will not be able to reach the plants. The construction of the seguias is a much larger project than the construction of the dam itself. All the seguias we supervised have a rectangular cross-section. The construction of a seguia is directly linked to the slope and the flow carried. The slope must be gentle to maintain river flow and, consequently, to maintain a permanent flow between the surplus spring water and the water carried by the seguia (Fig. 26).

In addition to the difficulties related to the slope, the determination of the economic section of the seguia was established, since we observed that in most cases the width of the section is equal to twice the water height. It should also be noted that these seguias also carry loaded water drained by flash floods to the palm groves to flood the gardens (Fig. 27). The development of new lands of the palm grove requires a new quantity of water to meet the irrigation demand. The addition of a superimposed seguia can solve the problem (Fig. 28).

Figure 26: Seguia Cherkia emanating from the Mchounech dam on the River Labiod (Photo. Remini, 2025)

Figure 27: Seguia Gharbia in the River Labiod. After an irrigation operation by flooding the entire palm grove with flood waters, the seguia must be cleaned of sediment deposits (Photo. Remini, 2025)

Figure 28: Two superimposed seguias emanating from the Branis dam on the Abdi wadi (Photo. Remini, 2025)

Figure 29: The section of a section of a Gharbi seguia emanating from the dam on the El Hay wadi was carved into the limestone rock (Photo. Remini, 2010)

Moreover, the construction of these hydraulic structures for water transport is not an easy task. Kilometers of seguias are built with gypsum mortar and gravel from the wadi. Sections of seguias had to be carved into the limestone rocks, taking into account the slope of the canal and the dimensions of the canal section (Fig. 29).

So, we can classify the spring dam system as a mega ancestral project. It can be divided into two major projects: the dam and the seguias. The water transport canal system presents 5 models. In the first case, the palm groves are located on both banks of the wadi and they are fed by two cascading dams, so in this case, 4 seguias in total are needed to transport spring water as well as flood water (Figs. 30, 31 and 32).

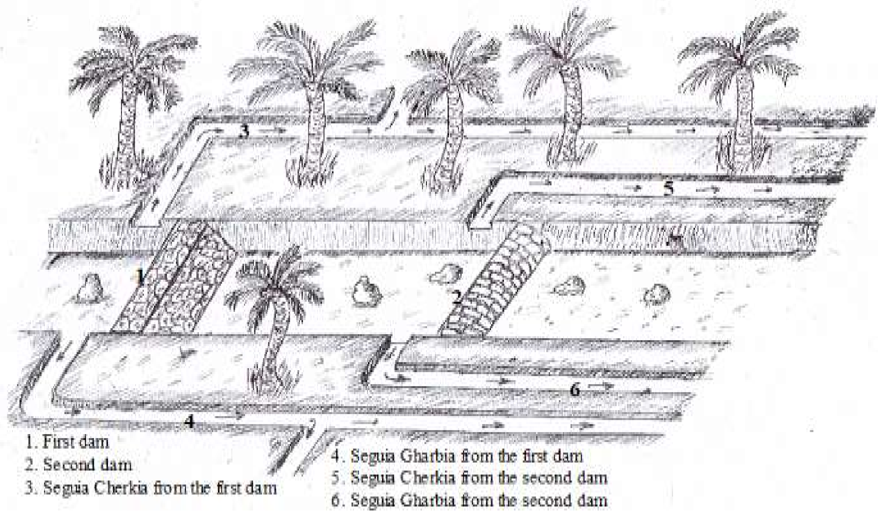

Figure 30: Synoptic diagram of a hydro-agricultural development model composed of 2 dams and 4 seguias (Diagram Remini, 2025).

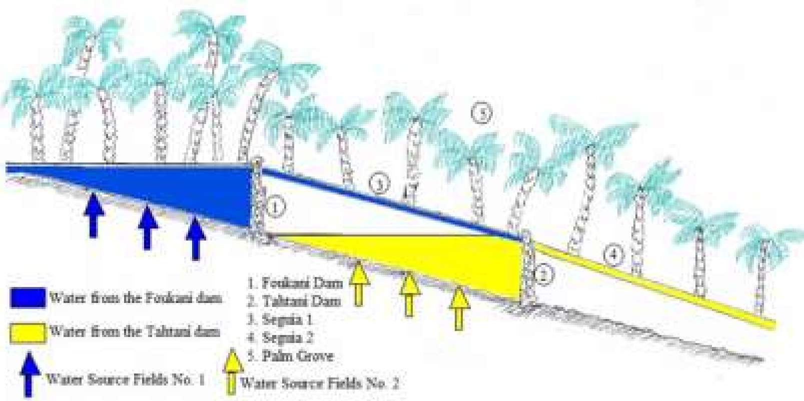

Figure 31: Diagram of a longitudinal section Synoptic diagram of a hydro-agricultural development composed of 2 dams and 4 seguias or 3 seguias (Diagram Remini, 2025).

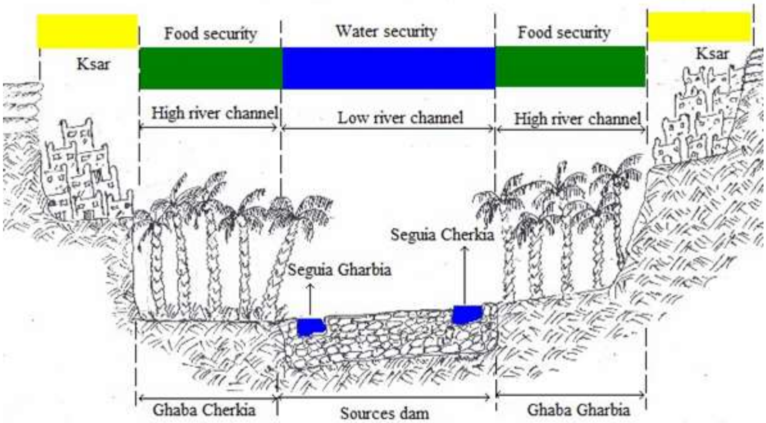

Figure 32: Diagram of a cross-section of a two-seguias spring dam (Diagram Remini, 2025)

The second model consists of two cascading dams that supply two palm groves located on both banks of the wadi. Assuming that one palm grove is small compared to the other (fewer palm trees), in this case it is sufficient to have three seguias to supply these two palm groves, only the large palm grove is supplied by two superimposed seguias emanating from the two dams (Figs. 32 and 33).

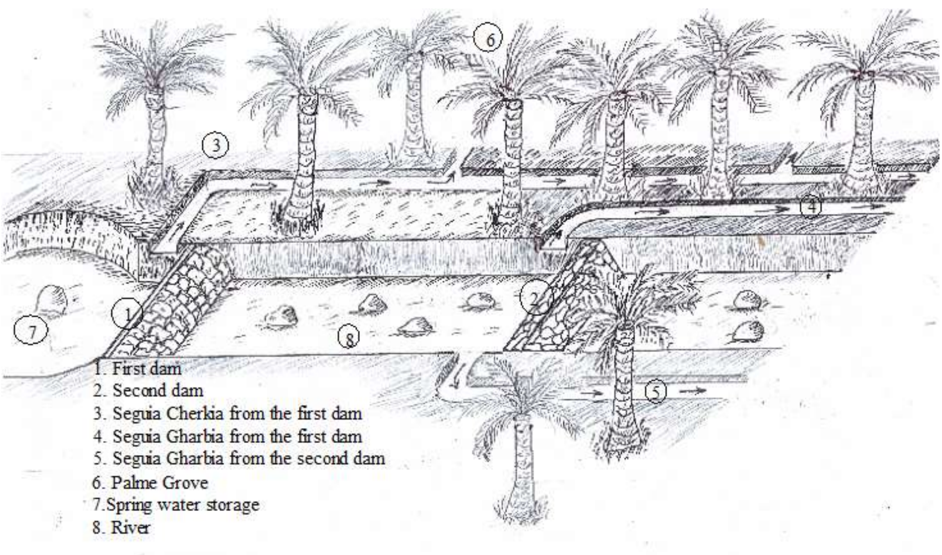

Figure 33: Synoptic diagram of a hydro-agricultural development model composed of 2 dams and 3 seguias (Diagram Remini, 2025).

Figure 34: A system of 3 seguias emanating from the system of two Mchounech dams on the River Labiod (Photo. Remini, 2025)

In the third case, a single dam irrigates two palm groves of the same size on both banks. In this case, two seguias are sufficient to transport water from the dam to the two palm groves (Figs. 35, 36 and 37).

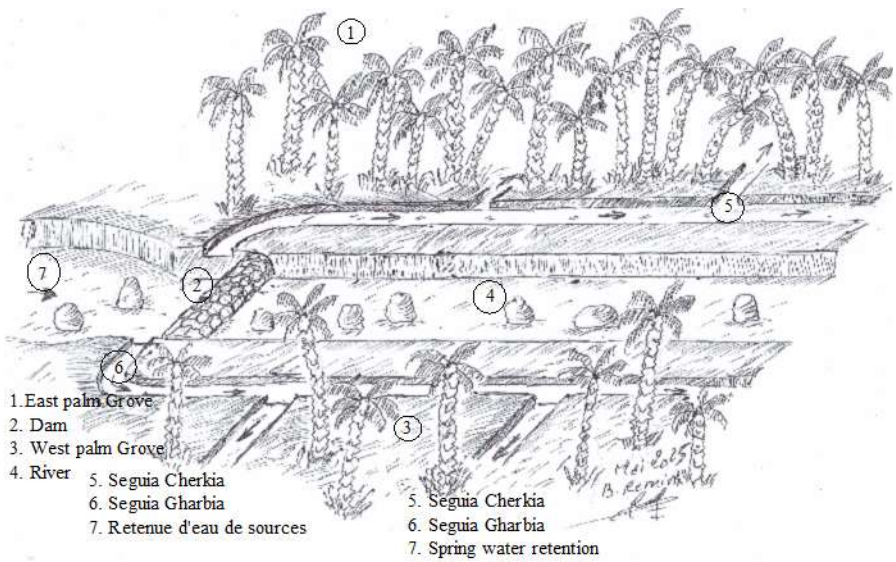

Figure 35: Synoptic diagram of a hydro-agricultural development model composed of a single dam (Diagram Remini, 2025)

Figure 36: The parallel seguias of the Branis dam on Wadi Abdi (Photo. Remini, 2025)

Figure 37: The parallel seguias on River Labiod (Photo. Remini, 2025)

For a fifth case, a palm grove located either on the major bed of the right bank, or on the major bed of the left bank. In this case, a single seguia connects the dam to the palm grove (Figs. 38 and 39).

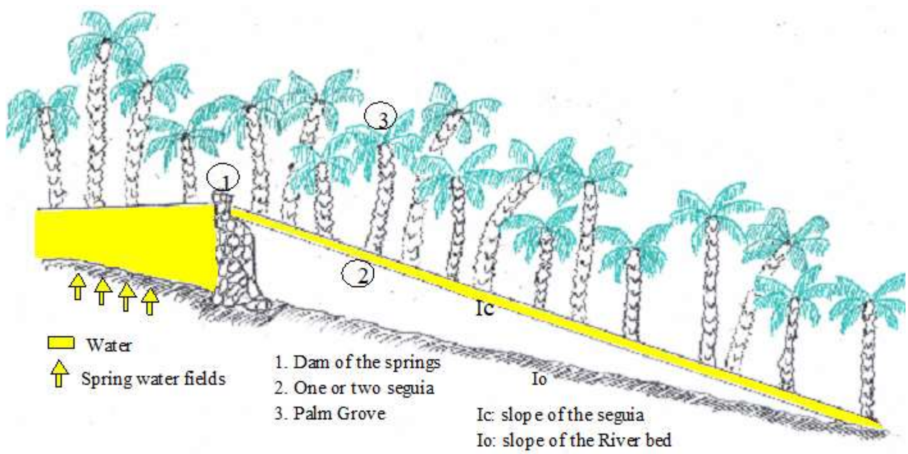

Figure 38: Diagram of a longitudinal section of a hydro-agricultural development composed of a single dam and 2 seguias or one. (Diagram Remini, 2025)

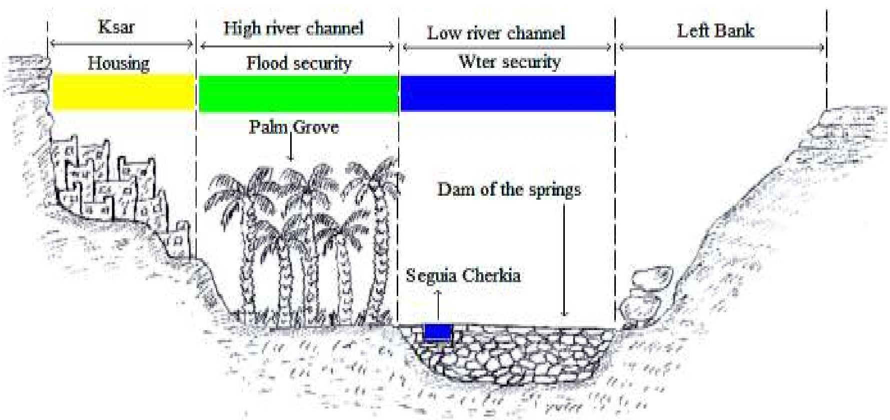

Figure 39: Diagram of a cross-section of a single-seguia spring dam (Diagram Remini, 2025)

Calculate the Dam Height

Knowing the location of the spring dam, located at a distance L from the palm grove, determine the height (h) of the spring dam, given that the spring water flow rate is Qs (Fig. 40).

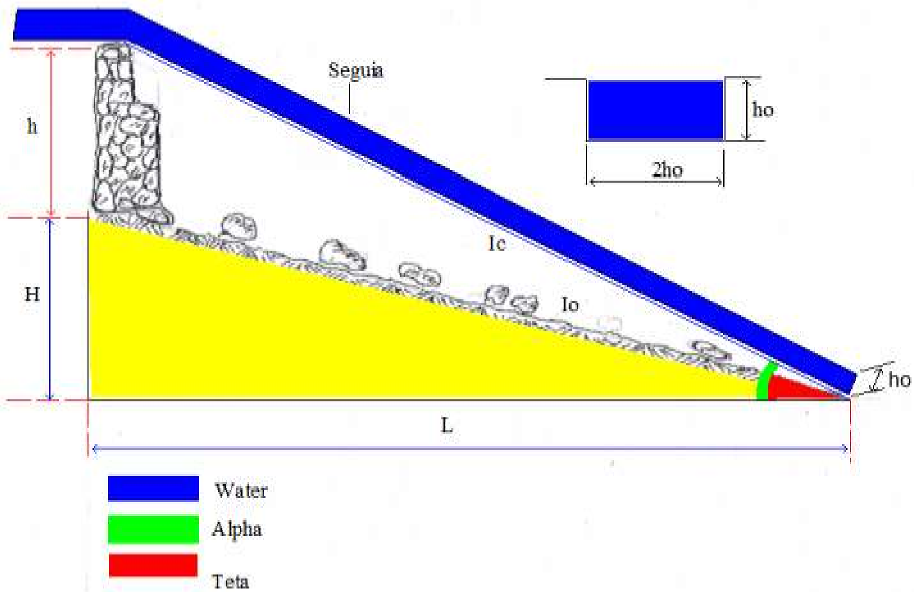

Figure 40: Diagram for calculating the slope of a seguia of the springs dam (Diagram Remini, 2025)

We give C, the Chézy coefficient, I_O, the slope of the wadi bed, Ic the slope of the seguia. To have a permanent flow, it is necessary that the flow of the water sources evacuated by all the resurgences distributed on the bottom and the banks of the reservoir formed by the dam is equal to the flow evacuated by the seguia or the two seguias.

We set

Q_s: Flow rate of spring water

Q_c: Flow rate of water evacuated by the seguiasc

Starting from the equation:

$$tan \propto = \frac{H+h}{L} = I_c \quad an \quad tan\, \theta = \frac{H}{L} = I_o$$

From these two equations, we determine:

$$h = L(I_c - I_o)$$

Thus

$$I_c = I_o + \frac{h}{L} \qquad (1)$$

The continuity equation Q_s=Q_c

With Q_c = V. S_m or V: average flow velocity, S_m: wetted section

$S_m = 2h_o^2$: economic section of the channel.

The average flow in the seguia is given by the Chezy relation:

$$V = C\sqrt{Rh.\ Ic}$$

With:

$$Rh = \frac{S_m}{P_m} = \frac{2h_o x h_o}{4h_o} = \frac{h_o}{2}$$

$$Q_s = C\sqrt{\frac{h_o I_c}{2}}\, 2h_o.h_o$$

$$h_o = \left(\frac{Q_S^2}{2C^2 I_c}\right)^{1/5} \qquad (2)$$

With Eqs. (1) and (2), we can resign the seguia (the slope, the width and the height of the section) by fixing from the beginning the height h of the dam.

DISCUSSION

This fieldwork showed us the symbiotic relationship between man and nature. An educational lesson in human adaptation to the desert climate. A daily struggle in search of water; the source of life. Man has invented hydraulic techniques and developments adapted to his environment. What to do with the water sources that appear in the rocks or on the wadi beds? Transporting a quantity of water from the spring to the garden individually is a delicate and arduous operation. Building a spring dam to collect all the water sources scattered along the river bed and then sharing and transporting this water to the gardens is a challenge. The land, generally located on the banks and meanders of the wadi, is a veritable repository for silt and silt, as well as nutrients drained and brought back by flash floods that occur in the wadis. Natural fertilizer, these vases are very rich in phosphorus, nitrogen and potassium are very useful for the development of palm groves. A soil very rich in nutrients such as phosphorus, nitrogen and potassium irrigated by a very good quality source then in this case what result should we obtain? A quality agricultural product? After several visits during 25 years of work in the wadis and oases, we noted that mega ancestral projects were carried out along the wadis either to ensure their water security or to ensure their food security. Real hydraulic developments consisting of spring dams and kilometers of seguias to transport water from the dam to the gardens. In each palm grove, a branched network of seguias of different sections was built so that each plant receives its desired amount of water. In parallel, real agricultural developments were carried out over many centuries. When we talk about the bed of the river, we mean a place where a double dynamic reigns: sedimentary and hydraulic. From the point of view of sedimentary dynamics, with each flash flood, the bottom of the wadi becomes mobile, blocks, pebbles and gravel compose their symphony which depends on the tractive force of the flow generated by the flash flood. The quantities of aggregates moved by the hands of the farmers tirelessly to make way for the palm trees. The recovered aggregates, a construction material, are used to build dams, seguias, and retaining walls to maintain and stabilize garden soils and River banks against flash floods. In addition, farmers benefit from their environment of Rivers and rocky massifs. These two natural sites constitute veritable deposits of raw materials. The river will provide blocks, gravel, and sand, and the Rocky Mountains will provide gypsum. Obviously, the rocks from the neighboring mountains, once in the kiln lit at very high temperatures, will pass directly into gypsum. The mortar obtained with gypsum. And the aggregates of the rivers (sand and gravel) widely used in the construction field in the oases of Mzab, the oases of Tiout, the oases of Moghrar, the oases of Boussemghoun and the oases of Chellala El Gueblia. As for the city of the dwellings of these peasants, called Ksar or Dachra is built on the heights for security reasons and more particularly to avoid flooding caused by flash floods. The choice of the site for the implantation of the dwellings depends on the existence of a water source and to be protected from flooding. In this case, we speak of a wadi oasis which is composed of a water source, a residential city (ksar) and a palm grove. For this modest paper which is focused on the hydro-agricultural development based on the collection and storage of water in a first phase. Through the seguias, the water is conveyed directly to the palm grove in a second phase. In reality, there are not two phases, but only one, the dam serves to create a level of fresh water that is evacuated by the resurgences in a continuous way. Built at a level lower than the lower level of the crest, the seguias which played the role of evacuator of the excess water (overflow) continuously transport the water to the gardens of the palm grove. We are witnessing an original system of capture and irrigation. It is very similar to the foggaras systems which is nothing other than a large-scale water source coming from the water table which flows towards the Madjen through a slightly inclined underground gallery. The difference between the two systems lies in the location of the water storage reservoir.

For the hourly foggara, the water is stored at the entrance on the highest point of the palm grove in order to obtain a gravity element going from Madjen to the gardens located below. On the other hand, for the dam system, the spring water is stored directly in the reservoir of the dam located far from the palm grove. Except that the oasis of the wadi is much more interesting than the foggara oasis since it benefits from the flash flood waters drained by the wadi. Sporadically one or two floods occur in the wadis of the Sahara, except in the case of a dry tongue. These flash floods are known for their waters too loaded with fine particles and nutrients. Part of this water flows directly over the dam dike and thus continues its path to reach its drop point. On the other hand, the other part of this water flows directly through the seguias to flood all the gardens of the palm grove. The branched seguias network is fully open on the day of the flood to ensure complete flooding. This is the updating of the soil, giving it new life thanks to the quantities of silt and nutrients drained by the floods to fertilize the soil. With each flood, everything is washed and renewed, the green color of the palms becomes lighter and the aggregates of the wadi washed by the waters become brighter. The question we have been asking for several years is why did this system of water source dams spread across the wadis of the northern Sahara? It is quite simply its success that led to its exploitation from one wadi to another. Unfortunately, many questions have not been answered, notably the lack of documentation and data-t-on these ancestral dams, unlike the foggaras, which have never been raised during symposia or study days on heritage. Today, many dams have disappeared, leaving vestiges and traces of the existence of dikes and seguias. Other dams still function but they are covered in alluvium. Other dams have been washed away by flash floods. A large part was abandoned due to lack of fresh water following the drying up of several resurgences as a result of a drawdown of the water table caused by long-term droughts. The majority of palm groves are irrigated today by motor-driven pump wells or boreholes. These hydro-agricultural developments took place in places where water is abundant, the pressurized water flows through resurgences and cracks from the subsoil to the ground surface. However, temporary flash floods have posed a danger to these structures since the construction of the first dam. During each flood, one or two dams were swept away by the flow. Rebuild the structure with other innovative ideas to allow the dike to resist the overturning and thrusting induced by flash floods. Over time, farmers have developed essential know-how in the field of dams and canals. This is how we found that the structures are made of gypsum with a height that does not exceed 2.5 m and a rounded crest to minimize overturning and facilitate the evacuation of the flood water. It should also be noted that the height of the dike is directly linked to the slope of the canal. Quite simply, it is the height of the dam that determines the slope of the seguias and therefore the speed of the flow. It should be noted that the slope of the seguia must not exceed the threshold of 1 m/s to maintain a slow flow. Everything depends on the height of the dike (h) and taking into account the length of the palm grove (L) to create the main seguia that starts from the dike to the end of the palm grove of a length (L). But great care must be taken with the height of the dike, which must not exceed 2.5 m. On the ten or so dams we visited, the height of the dikes varies between 1 m and 2.5 km. Only beyond a threshold of 2.5 m is the dam at risk of being swept away by a flash flood. In addition, a flash flood can drain the equivalent of six months of rainfall in 48 hours (Remini, 2023b). A powerful tractive force generated by the flood causes a very powerful thrust that can displace large boulders. With each flood, the dam is filled with pebbles and gravel, requiring cleanup operations by the population. In other wadis, such as Tiout, silting poses problems for dams. Thus, tons of sand are removed after each flood that occurs in River Tiout. Each dam is equipped with one or two seguias, depending on the presence of one or two palm groves. The seguias are rectangular in section and made of gypsum. When they encounter a limestone rock, a rectangular channel is carved while maintaining the same cross-sectional dimensions. The most beautiful thing is that most of these seguias the width of the section is equal to twice the height, that is to say the wetted section is equal to $Sm = 2h \times h = 2ho^2$. In this case, we are talking about the economic section of the canal. Is it a coincidence or simply the farmers mastered the calculation of the economic section well. These two seguias are mounted in parallel along the two banks, right and left and which are placed at the normal level of the reservoir, that is to say the seguias are at the same level of a flood spillway.

CONCLUSION

Spring dams, as we have called them. They store water hidden in the rocks and underground, released by resurgences. Forgotten or abandoned in nature, since their locations are located in the wadis of the northern Sahara. Long droughts have plagued the sites of these hydraulic structures over the years, resulting in the total depletion of their stored water. The water table has fallen farther from the ground level, and consequently, the springs have dried up. After the droughts, flash floods sweep away and destroy everything built by the hands of farmers. Discovered by chance, there is no information on the date of creation or the number of these dams built in the northern Sahara. One thing is certain, thanks to these hydro-agricultural developments, which have given rise to several hectares of palm groves and thousands of palm trees cultivated in the floodplains of the wadis, they have even ensured the water and food security of the oases. These hydraulic systems have provided the oases with water in quantity and quality over the centuries. What genius, the hydro-agricultural development of spring dams supplies the palm groves with spring water and floodwater loaded with nutrients. Permanent irrigation by spring water and temporary irrigation by floodwater. During periods of drought, continuous irrigation by seguias carries spring water from the dam to the gardens. During floods, irrigation with charged water floods the gardens to improve the soil.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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