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Modeling of underground dams Application to planning in the semi arid areas (Biskra, Algeria)

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Abstract

In arid and semi-arid areas where desertification is progressing, exploitation of water resources is focused on surface water and groundwater who pose sustainability problem. The exploitation of surface water uses «surface dam» heavily exposed to evaporation and cannot perform the function of "dam-reservoir" in the dry season.
We envision the use of groundwater by the underground dams, designed to contain groundwater and accumulate water.

Compared with conventional dam, underground dams have the advantage of not overwhelm the land, offer particularly low evaporation losses and preserve the environment.
A DEM and the river network of the study area were obtained by ArcGIS software The results obtained were injected into Modflow to extract the discharge. The dam body stability has been verified and validated using a model of the fluid-structure interaction under the platform "COMSOL Multiphysics".

A significant gain in water volume is found by storing away the long intense sunshine and evaporation. COMSOL allows us to have an optimal design of the dam body.The development of the region requires necessary a control of water resources.

Keywords: subsurface dam,;fluid-structure interaction; groundwater flow, COMSOL Multiphysics, Biskra

1. Introduction

In the region, the date palm cultivation is the main economic activity seconded by livestock. These activities are mainly due to the presence of groundwater and / or highly productive aquifers, shallow, in which the operation goes back more than a century. During the 50, resource management has emerged. Indeed, the development of urban centers, especially the city of Biskra posed the problem of drinking water. Thus, it was decided to build a first dam «Foum-El-Ghorza " on the Oued El-Abiod. The silting of the dam and over_exploitation of groundwater raised again the problem of acute

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water which leads to build a second dam, "Fountains of Gazelles" in El Oued Hai, the annual mean input of wadis crossed is estimated at 41. 106 m3 (21. 106 m3 and 20. 106 m3), therefore the potential for groundwater recharge are reduced and limited to contributions of the third river (less than 15,106 m3). The surfaces of retained of the two dams at the average rating for Foum el Ghorza Gazelle and Fountains are respectively 2.1 and 5 km2 km2. Evaporation measured at both sites is evaluated annually to 2383mm and 2200mm, which is equivalent to an evaporation loss, equal to 5106 m3for the first and 9106 m3 for the second. Due to the drying for halogen soil, the stored water is slightly saline. Evaporation indicated only increases salinity.

The incompatibility between politics of agriculture in the region and the politic of water has given rise to a non-rational management. The hydraulic developments thus projected, can not satisfy to development in the region of Ziban who's characterized by the expansion, diversification and rationalization of economic activities. It is necessary to rethink because water is the limiting factor of development, and especially of agriculture [1,2]

To address this problem, we envisage the possibility to exploit the "groundwater" by the "underground dams". Compared with the dam surface, subsurface dam has the advantage of not involving submersion of land and be protected of risk of rupture and offers low losses by evaporation of the reservoir. Our thinking is inspired by different works made in the arid and semi-arid in Algeria and around the world [3], [4] and the treaty of fight against desertification who was adopted in 1994 by the General Assembly.

2. Study area

Ziban region is located at the foot of the southern flank of Aures. It forms the northern boundary of the Sahara (gateway to the desert). Its flat topography is mainly due to Quaternary formations originating from the degradation of flank that stack on a thickness of between 200 and 300 m. These formations of high porosity and a large storage capacity constitute the water table. Given the low rainfall of the region (145mm), the slick is mainly powered by the input of Wadi El Hai, El Abiod, Bouzina who drain the southern flank and lead to the plain. [1,2,]

2.1 Geographical and physical context

The region of Biskra (fig.1) constitutes a transition zone between the domains atlas, which reaches 2300m above sea level while the outlets are only at 150m and the Sahara to the south, the plain Saharan extending approximately over 400km². From the morphological point of view, it is as a piedmont without marked relief that connects by a gently sloping, channels Atlas to the southe expanses Saharian . generally, topography is characterized by the development of a vast plain cut by the beds wadis flowing from the Atlas Mountains and disappear into the Great Depression closed of Chott Melrhir.

Fig.1. Region of Biskra

The study area constitutes one of the largest palm in Algeria (more of 10000 ha). Its status has imposed a rapid pace of development leading resulting a sharp increase in water needs. La average annual rainfall is less than 200 mm. Only the north constituting the southern flank of the Aures receives relatively high rainfall (300 to 800mm). The annual average values are low but interannual variations are very strong. [5,6,7]

2.2 Geological Setting:

The region of Ziban represents a country of structural transition and sedimentary. In the north, it is a mountainous region. At south, It is a region slumped that is part of northern Sahara. The transition between these two distinct domains is made through a set of flexure Saharian. This developed during the uplift of the Aures Nord. As happened the raising of the atlas and aurassiennes areas, it created a sagging south "south aurassien the groove" where the products dismantling reliefs emerging are deposited. Thus we find the highest point north of the Atlas (2326 m) and south of the deepest depression of Algeria (chott Melrhir -33 m) where the quaternary are widespread and form large units which are the alluvial aquifers siege of medium depth.

2.3 The drainage and individualization of watersheds

Movements delayed, cuts relative erosion deposits and soft coverage have played, with climatic oscillations an important role in the development and evolution of the river system. Wadis cross the southern slopes of the Aures northeast to the southwest and in the compartmentalization are geographical structures. They are all designed to get lost in the saline lakes of the south. Few wadis are tailored to the structure. All along their course most cross relief "Y" digging grooves. There are three valleys.

- The valley of the “Oued el Abiod” whose drainage is by the gorge of Tighanimine superimposed. The river is formed by the merger of several rivers flowing parallel or perpendicular to the folds Tighanimine. To the north, the river flows over Cenomanian marls to the south it drains the surface formed mainly of clay gypsum. From Foum el Gherza, dam site, it opens into the plain of Biskra.
- The valley of the Oued Bouzina narrowly squeezed between two parallel chains, the wadi flows over foundations limestone marl to the town of Mena. The middle valley describes meanders, further downstream, the Wadi crosses the valley gorge periclinal termination of the anticline. In the valley, the river flows on its own post-Pliocene infilling where it joins Wadi El Hai upstream of the city of Biskra.
- The valley of the Oued El Hai, the birthplace of El Kantara syncline, drains the northwestern part of the corridor formed by Aures Batna-Ain Touta. The sub-basin of Wadi El-Hai, belongs to the large pool of Chott Melrhir. It spreads over an area of 1660 km2.

It is bounded on the north by the Batna Daira, that of Merouana, to the south by the Wilaya of Biskra, west of the Daira N'gaous and Tamarins and Barika, to the east by Tazoult, Arris and Mena . It starts in the Batna Mountains and flows into the plain of Outaya through a drainage network formed mainly by Oued El-Hai, feeding the dam of the fountains of Gazelles (Fig.2)

The total annual flow has gaps of 50 to 100% in both directions compared to the average annual flows. The extreme monthly flows have a maximum in March and a minimum in July, corresponding to one twentieth of the average annual flows.

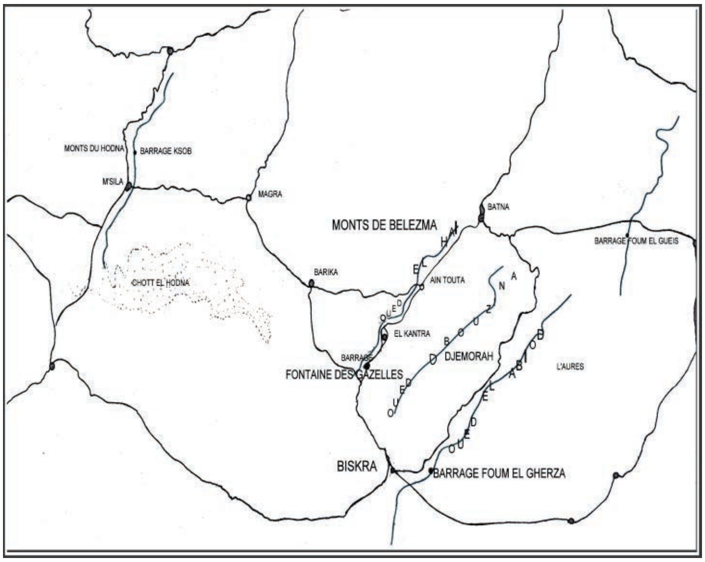

Fig.2.Drainage network and valley

The following table summarizes the hydrological data of 3 basins

Table 1. Data of basins

caractéristique	BV oued El Abiod	BV oued Bouzina	BV oued el Hai
Area	1300	900	1600
Perimeter	200	113	182
Principal Thalweg length	90	71	82
Capacity	1.55		1.3
Means altitude	1170		1060
Means annual Precipitation	355	355	360
Annual inflow(Mm3)	22.210	15	208
Specific Degradation T/km²/an	870	800	800

2.4 Sediment transport

The alternation of winter rains, usually highly contrasted and warm periods, almost dry, leading to an erosion more violent because of the poor vegetation cover and the chemical decomposition attached to the mechanical disintegration is preparing an enormous burden that cause flooding.

The hydrological regime of the wadis is characterized by great irregularity annual and interannual and a coefficient of torrential strong enough, the watersheds of the southern flank of the Aures undergo specific degradation exceeding 800 t / km ² / year, which amounts to a loss enormous capacity of dams. The example of Foum el Gherza dam is eloquent indeed, the dam with an initial capacity equal to 45,106 m3 (impoundment in 1950) and a capacity of 31,106 m3 in 1966. "Oued El Hai" knows the contents of highest suspended material, the turbidity exceeding 160 g / l [8]

3. Subsurface dam

The choice of site is difficult subsurface dam [3,9] in contrast to the dam surface. The site where the dam was built surface of the Wadi el Hai, meets the requirements required for such construction, the presence of groundwater, the presence of porous formations (aquifers) capable of forming a reservoir, the presence of low permeability fields that close the tank (bottom and side) a favorable topography. The total yearly flow of Wadi el hai has gaps of 50 to 100% in both directions compared to the average annual flows. The extreme monthly flows have a maximum in March and a minimum in July, corresponding to one twentieth of the average annual flows. In view of this irregularity, we project the subsurface dam upstream of the dam surface to form a single system that works as a complement.

3.1Methodological approach

The processing chain leading to the chosen model consists of the stages of treatment and control. Their logical sequence is shown schematically in the flowchart

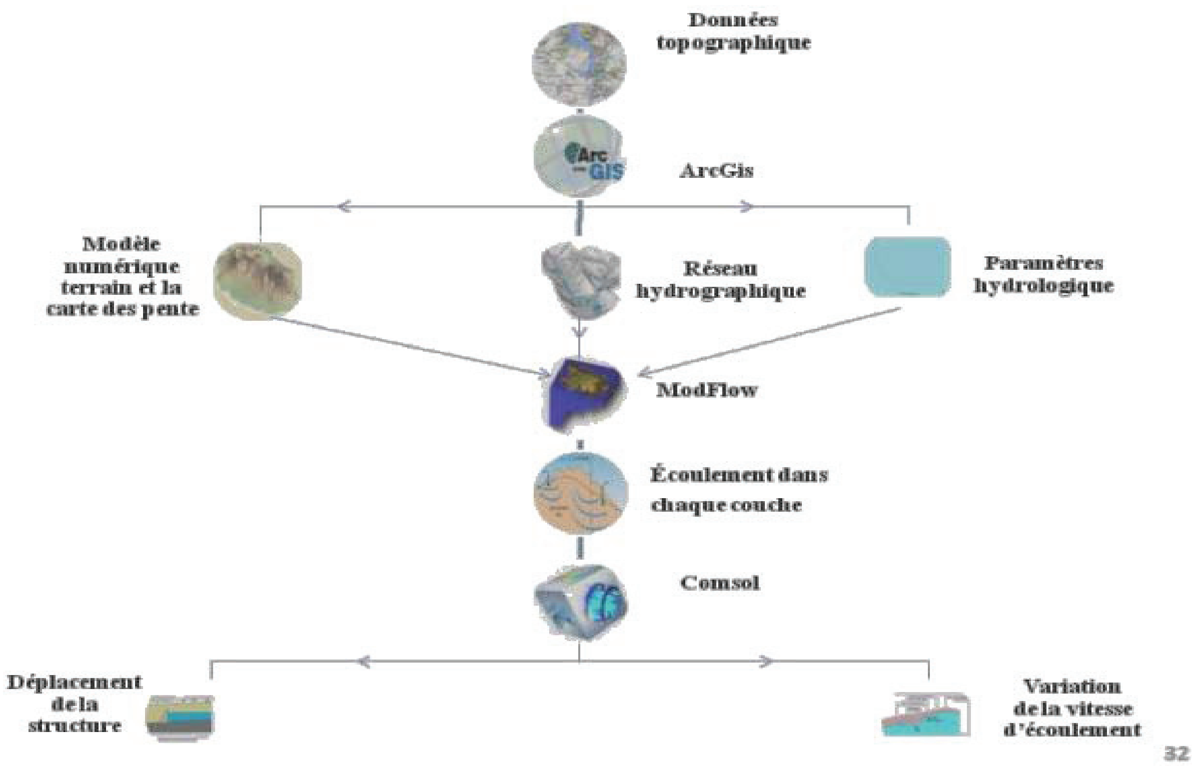

Fig.3 Flowchart of the processing steps

These steps are mainly based on a set of spatial environmental data involving several sources of geographic information, topographic data set the number of 33 cards (fig.4), satellite image and external data. The methodology used demonstrates the importance of the different phases of conceptual modeling first, then physical. The various data were analyzed, processed and stacked in layers of independent information in raster mode. These criteria were combined and crossed in GIS using "Arc GIS 9.3," which allowed us to obtain different maps sub-basin hypsometric curve "Oued El Hai", DEM, slope map, drainage, (Figure 5)

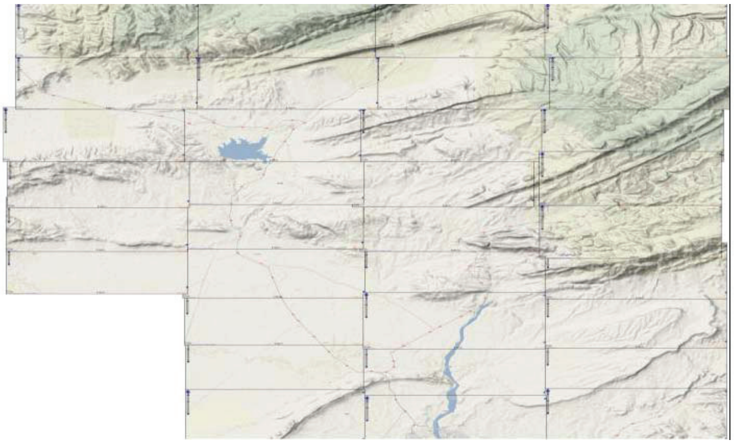

Fig.4. Mosaic of topographic cards

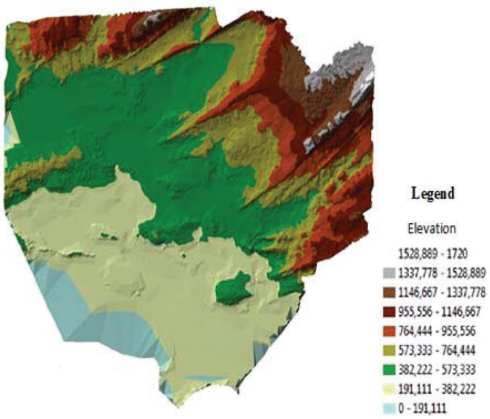

Fig.5a. DEM

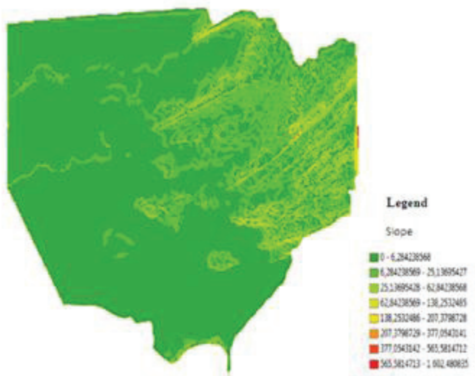

Fig.5 b. Slop map

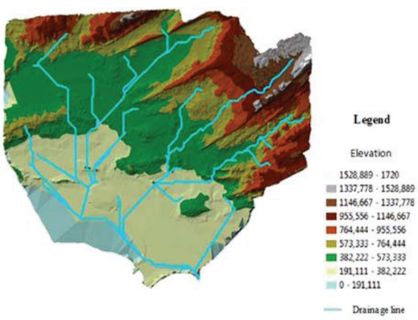

Fig.5c.Drainage map

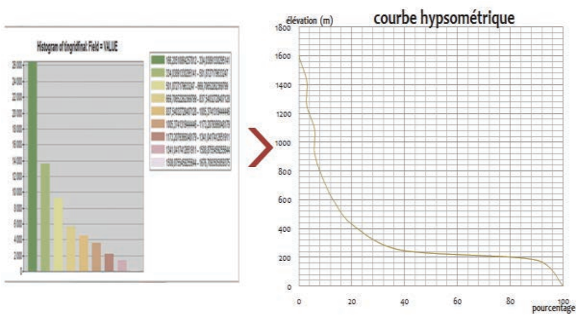

Fig.5d .Sub-basin hypsometric curve

Fig.5 Different maps of Oued El Hai

These steps are mainly based on a set of spatial environmental data involving several sources of geographic information. The methodology used demonstrates the importance of the different phases of conceptual modeling first, then physics as "Arc GIS 9.3," which allowed us to obtain different maps (DEM, slope map, drainage network) and under hydrodynamic "Modflow "and" GMS "for modeling groundwater flow on the basis of geological parameters in order to extract the flow of the different layers and the flow velocity

3.1 Geological Description:

The dam of the Fountain of gazelles, which is part of the sub-basin of Oued El-Hai is located 37km from the city of Biskra (latitude 35 ° 03'00"N, longitude 5 ° 38'00"E) . The geological formations outcropping vary widely. We meet from calcareous sedimentary rocks more or less hard sometimes dolomitic marl rocks strongly altered surface mainly because of the harsh climate of the region the different geological units that meet spread of Quaternary to Triassic. The geology of the sub-basin has to show the water potential of the region. So much of the Quaternary formations and limestone, are permeable, allowing the creation of alluvial and possible karst aquifers. While the rest of marl and clay formations have low permeability thus playing the role of substratum impermeable to runoff of surface waters. These courses provide the plain sediments rich in limestone, marl and sand and sometimes drain into the waters of the water solution rich in Ca + +, Mg + +, CO3 -, HCO3 .fig.

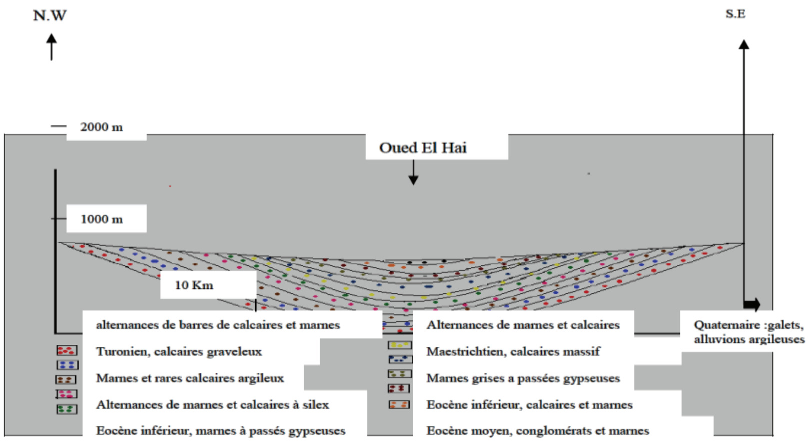

Fig.6- Geological formation of Oued El Hai

In the basin of Oued El Hai, one can see three types of rocks:

- Impermeable formations: composed of marl, marly limestone and clay soils. Infiltration in these areas is less than 10% of the precipitation. These formations dominate 38% of the total area is 1059km ² of the basin, they spread over the plain of El Outaya, and Djebel El Kantara Mahmel.

- The means permeability formations: Made up of limestone formations and the upper Cenomanian dolomite and marl of Miocene. They are seen near Dechra Tilatou which is at the northern end of Jebel Metlili, the valley of Wadi Fedhala, It is of limestone and biodetrital sublithographiques Cretaceous, calcareous algae or Miocene, or the grainy dolomite, these rocks are very compact, contains rare pockets of ferruginous mineralization more or less hollow, only able to increase local permeability.

- The high permeability formation is in the lower detrital formation, training marrno-Turonian limestone, but also in the Quaternary. These lands have a relatively high porosity 45 %, occupies 28% of the total area of the basin is 780 km ². Table.1 shows the parameters of Oued el Hai..

Table 1. Parameters of Oued el Hai

Parameter	Symbole	Valeurs	Unité
Perimetr	P	200.30	Km
area	S	1504.06	km²
compactness index	K	1.46	.
equivalent length of the rectangle	L	60.09	km
maximum altitude	H max	1720.00	m
minimum altitude	H min	120.00	m
altitude moyenne	H moy	920.00	m
la hauteur qui correspond a 5% de la surface	H5%	1080.00	m
la hauteur qui correspond a 95% de la surface	H95%	178.00	m
Dénivelé	D	902.00	m
Indice de ponte global	Ig	15.01	m/kg
Longueur du talweg principal	Lp	109.73	m
Temps de concentration	Tc	10	H
longueur du cours d'eau	Lc	845.82	km
densité de drainage total	Ddt	0.5623579	km/km²

3.2 hydrodynamic modeling

The area modeled includes the dam site fountains gazelles and the site chosen for the subsurface dam. It is representative of the basin Oued el Hai, in terms of hydrology, geology and hydrogeology. (Fig.7)

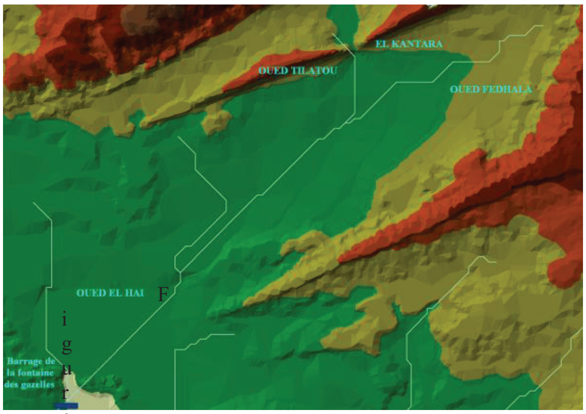

Fig. 7. Area modeled

To construct the hydrodynamic model of the region and we used Modflow2000 and GMS. It is constructed from the results taken from ArcGIS and geological data (Table.2) and the initial hydraulic head and recharge of river. Table 3 summarizes the parameters obtained after simulation. The annual volume is 2 million [m³] and the flow velocity is 0035 [cm / s]

Table 2. The parameters used in geological

Paramètre	symbole	1er couche	2e couche	3e couche	unité
conductivité hydraulique horizontal	KH	10	8.64E-02	8.64E+00	m/j
conductivité hydraulique vertical	KV	1	8.64E-03	8.64E-01	m/j
porosité efficace	φ	30	10	45	%
coefficient de stockage	S	(5:10)φ	(5:10)φ	(5:10)φ	%

Table 3. Flow in each layer

LAYER 1			
Flow term	IN	OUT	IN-OUT
Storage	3.32E+07	8.28E+06	2.49E+07
Exchange lower	5.78E-01	1.03E-01	4.74E-01
Drain	0.00E+00	3.67E+07	-3.67E+07
River leakage	7.54E+06	0.00E+00	7.54E+06
Sum of the layer	4.07E+07	4.50E+07	-4.24E+06
Layer 2			
Flow term	IN	OUT	IN-OUT
Storage	9.06E+04	9.09E+04	-3.00E+02
Exchange upper	5.96E+00	9.34E+00	-3.38E+00
Exchange lower	4.64E+02	5.26E+02	-6.21E+01
Sum of the layer	9.10E+04	9.14E+04	-3.65E+02
Layer 3			
Flow term	IN	OUT	IN-OUT
Storage	5.89E+06	5.78E+06	1.09E+05
Exchange upper	5.26E+02	4.64E+02	6.21E+01
Sum of the layer	5.89E+06	5.88E+06	5.46E+03

The 3D model was treated with GSM for a better geological representation (Fig.8), the hydraulic initial (fig.9)and after simulation (fig.10) and the various states and nature of the cells(fig.11) of the study site

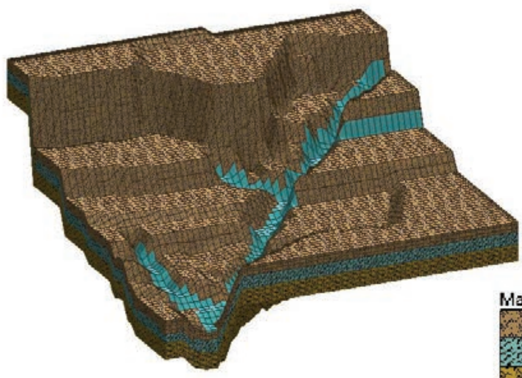

Fig8 3D Geological section of the study area"

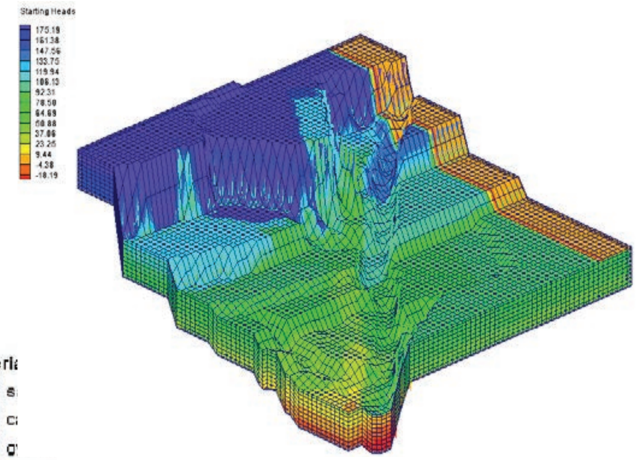

Fig.9 Initial hydraulic head of the study area

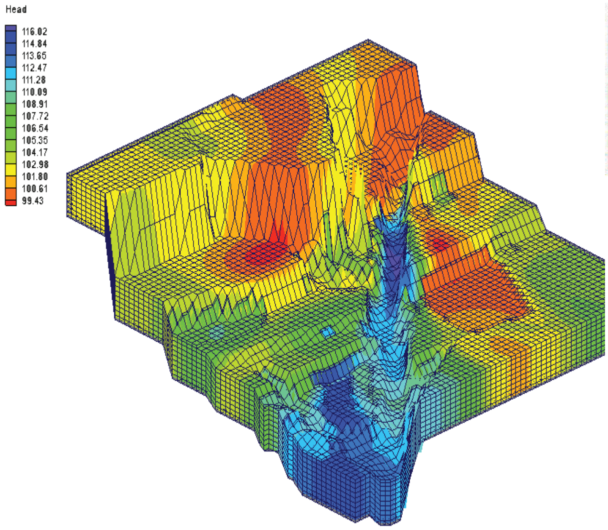

Fig.10- Hydraulic head

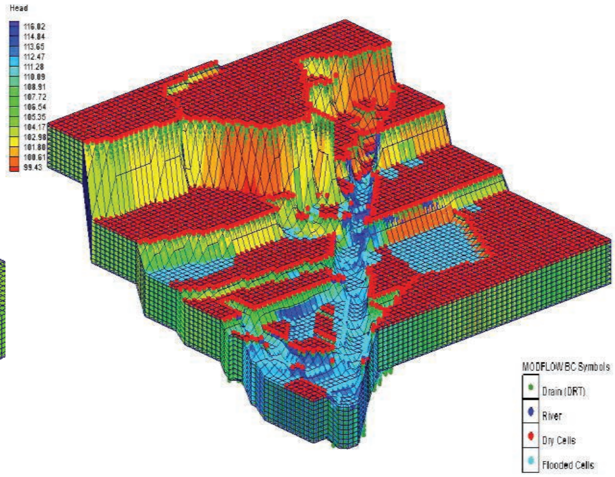

Fig.11 State and Nature of each cell

3.3 Study the feasibility of subsurface dam.

To study the feasibility of the work, we simulated the behavior of the dam body when interacting with COMSOL Multiphysics. Underground dams are usually built into the ground. For a first approach we have simplified the study by the choice of concrete materials whose characteristics are shown in Table 4. Hydraulic parameters are given obtained by MODFLOW

Table 4. The characteristics of materials

Element	Matériaux	Masse volumique Kg/m^3	Viscosite Dynamique Pa.S	Module de young (Pa)	Coefficient de poisson
Corps du barrage	Béton	2300	-	2.5E+10	0.33
Remblais	Sol	1.00E+03	1	-	-
Fondation	Roche	1.00E+03	1.02E+3	-	-

We were able to obtain the flow simulation, the direction and speed at each location of the mesh (figure 10) Figure 11 shows the initial state and critical of the dam.

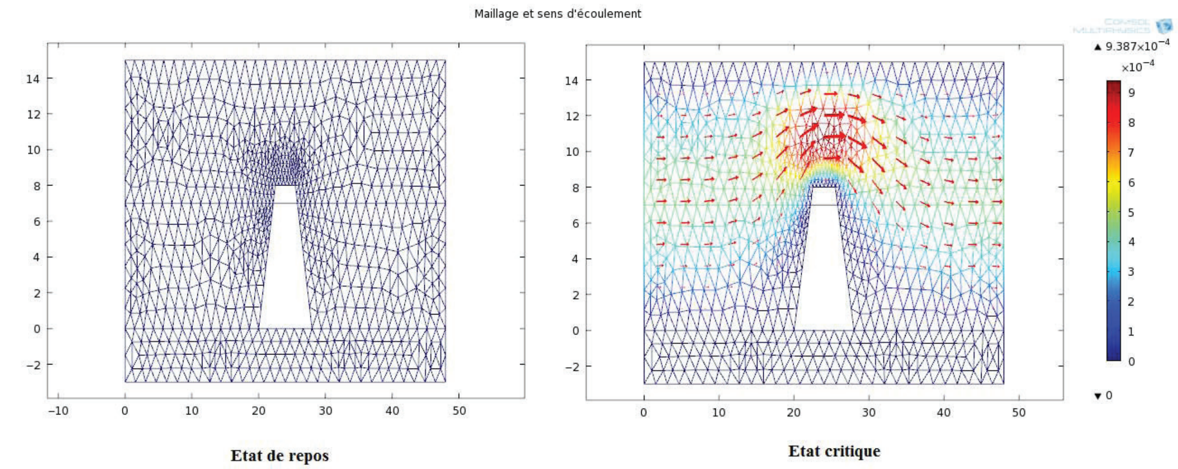

Fig. 12. Change the speed and direction of flow

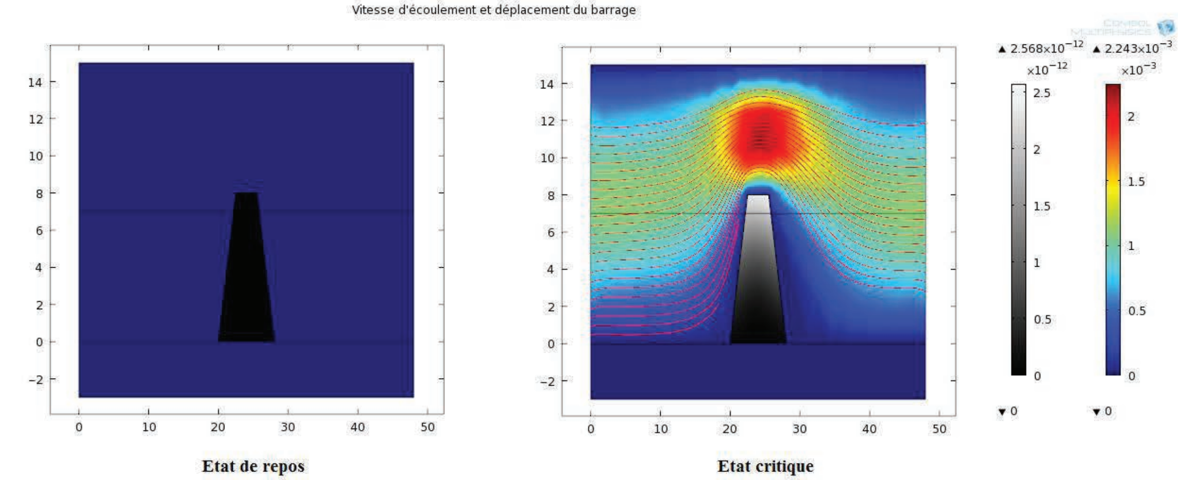

Fig. 13. Moving the body of the dam according to the flow velocity

4. Conclusion :

We believe that the dam construction area in the arid and semi-arid poses more problems than it solves. Thus, we believe that only an integrated development that takes account of environmental constraints is able to resolve the problem by preserving the environment. We can estimate that such work is feasible and will need a better hydraulic operation of the system obtained

The simulations also allowed a better understanding of the complexity of the mechanisms inducing spatial and temporal variations of fluid-structure interaction

According to the observations made above the underground dams, conveniently located is the best solution

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