Improving water storage into reservoirs of "second generation", an example of a preliminary condition for a precipitation enhancement program to be accepted".

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Abstract: Precipitation enhancement could become an efficient way to provide more resource of water. We consider that this technique is economically profitable only during already efficient rain processes. This means increasing environmental and social risks. A partnership with all the people concerned by the problem is a necessary and valuable step. In our context this approach has yield to the concept of storage into lakes of "second generation".

1. Introduction

The natural variability of rain produces, in most countries, regular difficulties in providing fresh water to an increasing population. The social and economic costs of droughts force the populations to look for solutions to get through as best as possible these natural events.

Prevention against droughts means developing the water resource. Most of the time the first solution is to increase the volume of storage to keep water during runoff events. The first dams are known since 3500 years BC in Jordan (Jawa). Rome, in 150 AC, was able to deliver each day one meter cube of water per person to more than 1 200 000 people. During the last century, many artificial lakes were built to provide water in many places of the world where periods of drought are frequent. If the question of **quantity** has been answered, most of the time, the question of **quality** remains. In fact, in most European countries, ecologists and representatives of the Civil Society, such as fishermen, disapprove of the development of such solution and storage in the shallow aquifers is not always possible.

This paper presents the results of a multi partnership program held in a small zone of the South-West of France to better prepare for the next drought, where Social, Environmental and Economic (SEE) aspects were approached.

2. Hypothesis

In the near future needs for more fresh water will increase economic and social impacts in most countries. New approaches including precipitation enhancement (PE) will be encouraged but may provoke new social difficulties.

We consider (Berthoumieu-2001) that our level of understanding and knowledge on precipitation allows proposing PE during already natural efficient rain processes, as with hygroscopic seeding of convective storms (Mather-1997, Bruinjjes-1999), or with icing agents in snow and frontal rain situations with cloud bases at negative temperature. **This means increasing water runoff in already possible critical situations**.

Therefore, to be accepted through SEE aspects, PE has to be able to provide volumes of water in a secure way. Measures to reduce the negative impacts of runoffs (eventually floods) have hence to be put in place before starting any PE program.

3. What does the past teach us?

The past (-5000 BC to 1200 AC) shows that most of the prosperous cities or kingdoms around the Mediterranean Basin were able to maintain strong and powerful societies as long as they could master the natural variability of their river flows and provide enough water to citizens and farmers. Archaeologists are confirming how water has always been a strategic tool (Violet-2000). We can still visit the remains of a very old dam in Jordan (Jawa), built around 3500 BC. The Queen of Saba (Yemen) was able to irrigate 10 000 Km^2 of fertile soils thanks to a dam of more than 600 m in length, capable of storing the rare but powerful rains.

In 150 AC, Rome with a population of 1.2 millions, was receiving, each day, $1m^3$ of water per inhabitant. That is 100 times greater than what was delivered in Paris around 1890! In all these

places, big lakes, dams, derivations, canals, aqueducts and siphons were in place, allowing production of food on fertile soils and providing water for the cities.

After the middle ages and the return of enough stability, we observe in most of the European and Mediterranean countries, a renewed interest in rebuilding dams. In France this was primarily to provide water for transportation until the XXth century, when the necessity for pure, fresh and abundant water became again a societal request.

Parallel to this demand, water is becoming a powerful means to produce energy, to clean cities and industrial zones, to produce food, to carry loads and, on a larger scale, to maintain life diversity.

The industrial countries situated in places where droughts are frequent, started to build dams and lakes to satisfy these new needs. These constructions provoked negative reactions among a minor but influential segment of the population. "Water is a gift of the sky and has not to be monopolized by few!!" Ecological and political parties built part of their program on this fear, getting support from those who want to preserve the natural diversity of life in the rivers.

New legislations about water management were discussed after each severe drought (1964, 1992) and are now relayed by European directives. The debates are presenting good indicators of the difference of culture about water between the north and the south of Europe. For the north, there is no need to store water; their experience shows that the soil has enough capacity to provide the needed water. For them, the solutions are: to save water, to reduce irrigation and to share the naturally available water with all the users.

In the south, the populations are used to seeing river beds completely dry during most summers; they know that storages are essential as drought periods can last many weeks or months. For them, agriculture cannot exist without irrigation.

Regularly, since the 70th, disputes between the different users of water emerge, especially during droughts. To try to solve these local conflicts, a national project called "*Irri-Mieux" (Irri-better)* started in 1998 (ANDA-2000).

In our zone of the South-West of France, this same type of scenario has opposed farmers to fishermen and ecologists. Farmers want more lakes with more rain during summer (seeding with hygroscopic flares is carried out in the zone for hail prevention knowing it is also a PE technique). Ecologists are against that sort of project and fishermen are on their side because they find that the natural equilibrium of the rivers is not provided by the water coming from these lakes.

This multi partner program (Irri-Mieux: 1998-2002) offered the possibility to discuss and to share with all the water users of a hydrological basin (Pays de Serres, north of Agen) this type of question. We propose to resume here the principal questions and propositions issued from this local project (ACMG-2002). It has to be taken as an example of what could be done to better include the Social, Environmental and Economical (SEE) aspects in a precipitation enhancement (PE) program.

4. Why a lake of second generation?

Knowing the natural variability of rain, varying annually from 400 to 1000 mm, and the impacts of a drought on agriculture, natural life and social bonds, a round table was organized with representatives from the different users of water. 0nce all grievances were declared (more than once) we were able to start to talk about different solutions, to be better prepared for the next drought.

Ecologists are for a limitation of water use, mainly for corn production, and they propose a sort of intelligent adaptation of the needs to what is naturally available. Fishermen are very close to this point of view except when a drought situation (appearing every 13/15 years) provokes death of most of the fishes in the small rivers. Tourism wishes sites with sun, water, green fields and no rain, therefore they are closer to the farmers and water suppliers who propose, for economical reasons, to continue to store water during rainy periods for use in drier months.

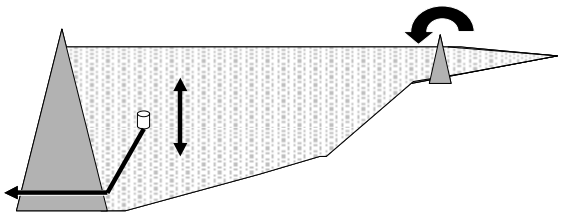
The principal grievances against the storage solution are: 1) the natural cycle of water in the river is modified and has a negative impact on the ecosystem, providing a new equilibrium with new species of insects and fishes that are not vernacular; 2) the quality of the water released by the lakes (generally dams with 1 to 3 millions of m^3) is bad for life with higher temperature and no oxygen in summer, lots of silt, and allowing fishes

from the lakes to propagate downstream into the river; 3) during summer the volume of water decreases and bare soil appears, degrading the land appearance for tourists and 4) it drowns land and pushes away local population and animals.

Having exchanged and observed the different positions, constructive meetings started with the idea of finding and testing solutions acceptable by all.

The first decision was to make the list of the different needs for water with aspects of volumes, periods of needs, quality and, if possible, the economical impacts if that water came to be unavailable. Hence the idea of a management "charter" emerged. This lead to building a management model based on: the needs for water variable with time, the rain amount during the last 30 days in the basin, the forecast for the next 5 days and the actual volume of water in the lake. This model includes the principles for protecting the downstream river from floods and maintaining a sufficient stream flow, able to preserve life during droughts. It has been tested and validated with more than 50 years of real rainfall recorded in the zone.

The second decision was to reduce the negative impacts of a lake. Two modifications were proposed and implemented in a new lake in construction in the zone:
1) a decanter built at the entrance of the lake (surface 2Ha) capable of reducing the river speed, allowing sand, sediment and silt to deposit before entering the main lake;
2) a system able to deliver to the river the water from the lake that has the best quality (See illustration below).



The decanter is supposed to be cleaned easily every two or three years or after a big storm. Its main goal is to reduce the speed of silting in the main lake that, otherwise, reduces the storage by 0.5 to 1.2 % every year. We found that it also reduces the nitrate contents by 50%.

This system, able to get the best water, is simple and robust. It allows choosing the height where the water has to be collected, hence reducing at the minimum the impact on the river below. The flow is variable from 15 to 800 m^3/h. During winter time, as the vertical gradients disappear due to convection, the flow can be taken from the bottom until the thermal gradient rebuilds in spring.

5. Results

Social:

The charter should be signed between the different users in 2003. After a very dry period (September 2001 till March 2002 with 50% deficit) the following summer was mainly wet and the water stored in the lake permitted maintaining a good flow in the river while in adjacent rivers, the flow became nil during few weeks. This maintained a relative peace between the ecologists and the farmers while fishermen are discovering the advantages of the lake equipped with the system delivering the best water. On their side, the Medias informed their readers about the first results.

No questions about PE produced by hygroscopic seeding came up, allowing continuation of hail prevention in good conditions in a nearby area.

Environmental:

The principle of a lake of second generation works well and two years of observations and data collection are confirming all that was expected and more. We still need two or three more years before we are sure that the river returns at the same level of diversity (or better) than before the construction of the lake.

The better quality of water taken at a depth of 2 to 3 m (see below) allows good conditions for life of many insects, such as macro invertebrates.

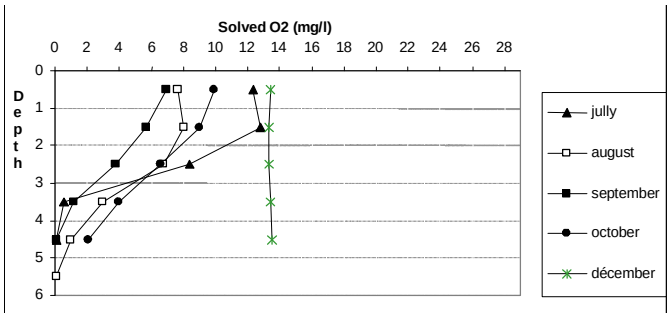


FIG: Evolution of the vertical stratification of dissolved oxygen at the level of the dam (2001).

There still remain, in small holes supposed good places for reproduction, some silts and sediments produced during the construction and that no new high flows can carry away as the lake reduces this type of event. An artificial flood will be tested next spring during a rainy period to try to clean out some of these depressions. It will help to refine the Charter, which may include some artificial increase of water level at determined periods to stimulate life.

It is also demonstrated that during and just after the building of the dam, the fishes living in the river below decreased by 50% in mass and also in diversity. Now, two years after the filling of the lake, 80% of the previous mass of fish is back and the natural species of fish are returning while in a nearby river, taken as a reference, no variation of population is seen.

The principle of the decanter is also confirmed in our climate, soil and vegetation cover situations. The sediments are of good enough quality to put them back into the adjacent fields where they can increase the organic matter of the soil. This can be done during summer when the entrance flow is at the lowest. To reduce the flow of mud removed by erosion, any action has to be encouraged, such as planting hedges in the above water drainage basin.

Economical:

12O Ha can now be irrigated along the river below the lake. It is mostly for fruits, vegetables and seeds and not for corn as feared by ecologists.

The presence of fishes allows the local Fish Association to open this river for fishing. Tourists have a new river to walk along with a beautiful lake surrounded by forests. Some projects to upgrade the site and make some profits are in preparation.

In raining summers, as the quality of water is controlled, it is possible to use, after standard treatment, about 200 000 m^3 for drinking water that the farmers don't need. That would permit saving water taken from deep, non- renewable, aquifers.

The extra costs required to modify a classic lake into a second generation type are less than 10% of the total (75 000 € in this case). On an old lake it will cost a little more and it will be necessary to empty the entire volume, during, for example a decennial inspection.

6. Conclusions

Water is, and will stay, a subject of conflicts and discussions as long as one of the different potential users will feel put at a disadvantage.

7000 years of humankind teaches us that Societies last in a satisfied way only when plenty of water is available for the citizen and the farmers. The actual changes observed around the Mediterranean countries and many others (more population, temperature increase, pollutions…) are forcing considering of new ways to satisfy the actual and future needs for water. Precipitation Enhancement will be one of the available tools if these projects are decided and controlled by all the representatives from the Civil Society or, at the very least, by the water users themselves.

In this project we have made the demonstration that a partnership with all the people concerned by the problem is a necessary and valuable step. The desires of all have to be taken in account and a common vocabulary to be found. The question of water is not only a question of quantity; it is now a matter of quality and share.

In our zone, the idea of a lake of second generation emerged as good solution for all. In other places this same approach of a partnership looking at the Social, Environmental and Economical aspects, could lead to different answers better adapted to the particular context.

Acknowledgements:

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