New solutions for water supply management in a climate change context

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ABSTRACT

In the near future, drinking water services may undergo many changes (water scarcity, contamination peaks, growing water demand) and it is the role of water utilities to anticipate new water schemes and develop tools to secure drinking water production. The paper will discuss water portfolio management, the concept of managing multiple water resources from storm water to seawater and present the different tools developed by Veolia R&D as climate change adaptation solutions.

One of the most significant developments in water management in recent years has been the increasing focus on integrated water supply planning, including water recycling and demand management. This allows different sources of water to be compared side-by-side with traditional infrastructure solutions. Recognition of the full water cycle means that often-overlooked options, such as wastewater reuse, are given equal opportunity to be assessed on their merits. This advance blurs the traditional boundaries between the supply of water, wastewater and stormwater services to provide what is termed 'Integrated Water Cycle Management' or water portfolio management as a climate change adaptation solution.

In this context, water utilities need management tools to anticipate new situations in water resources availability and to secure drinking water production. Veolia Environnement R&D has engaged different research programs on decision support, water resource management and prediction tools. Existing tools are presented in this paper.

KEYWORDS

Water management, climate change, integrated water cycle management, water portfolio management

INTRODUCTION

In the near future, drinking water services may undergo many changes (water scarcity, contamination peaks, growing water demand) and it is the role of water utilities to anticipate new water schemes and develop tools to secure drinking water production. The paper will discuss water portfolio management, the concept of managing multiple water resources from stormwater to seawater and present the different tools developed by Veolia Environnement R&D as climate change adaptation solutions.

Indeed, over the past years, new information about climate change has emerged from the scientific community and especially from the UN's IPCC (Intergovernmental Panel on Climate Change) (IPCC 2001, IPCC 2007). It is also increasingly clear that climate change may have impacts on water resources, water and wastewater management, and affect the programs designed to protect the quality of the resources to be implemented across the European Union (EEA 2007) with the implementation of the Water Framework Directive (European Parliament and Council, 2000) or in the United States (US EPA, 2008) with the NPDES permits or the watershed protection programs for example.

Last April, the IPCC released a new technical paper on climate change and water. The report clearly quotes that "*Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences on human societies and ecosystems*" (IPCC, 2008). Several likely impacts are described in this paper, and among others:

- Projected precipitation increases in high latitudes and some tropical areas and decreases in some subtropical and lower mid-latitudes regions,
- Projected increase of the annual average river runoff and water availability at high latitudes and in some wet tropical areas and decrease over some dry regions at mid-latitudes and in some dry tropical areas,
- Projected increased precipitation intensity and variability causing risks of flooding and droughts in many areas,
- Projected higher water temperatures and changes in extremes, including floods and droughts, will likely affect water quality and exacerbate many form of water pollution.

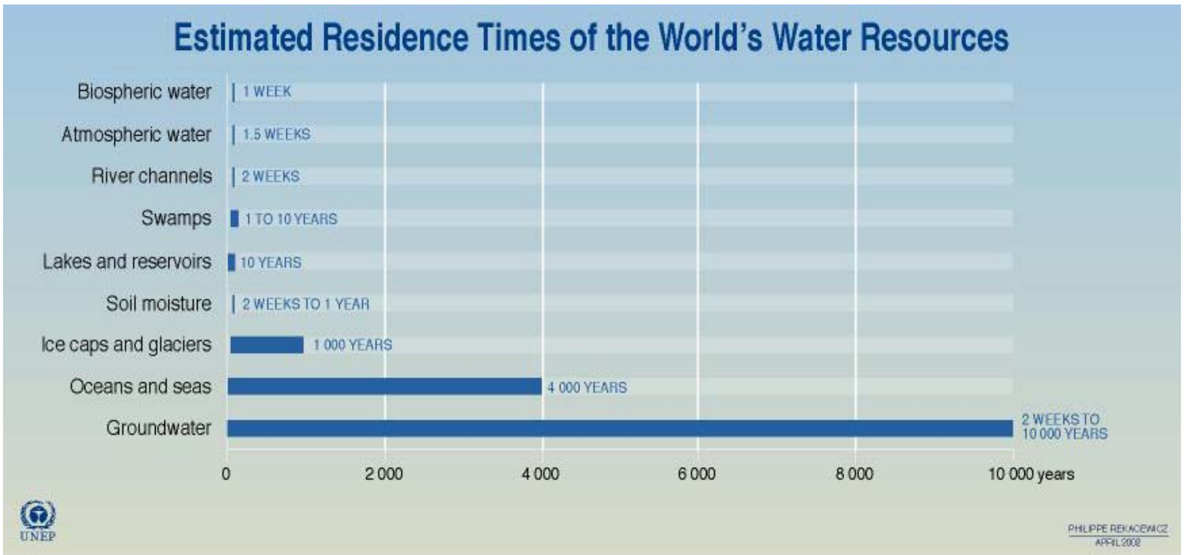
Globally, the IPCC states that the negative impacts of future climate change on freshwater are expected to outweigh the benefits. All these projections will have an effect on water management practices.

One of the most significant developments in water management in recent years has been the increasing focus on integrated water supply planning, including water recycling and demand management. This allows for different sources of water to be compared side-by-side with traditional infrastructure solutions. Recognition of the full water cycle means that often-overlooked options, such as wastewater reuse, are given equal opportunity to be assessed on their merits. This advance blurs the traditional boundaries between water supply, wastewater and stormwater services to provide what is termed 'Integrated Water Cycle Management' or water portfolio management as a climate change adaptation solution.

1. THE GLOBAL WATER CYCLE AND CLIMATE CHANGE

There is a finite amount of water on earth of which 2.5% is estimated to be freshwater and the remaining 97.5% is saltwater. Out of this total water stock, around 0.7% is freshwater located in groundwater, lakes and rivers. The global quantity of water does not change. What is important to focus on is the residence time of a molecule of water in different places such as aquifers, rivers, the sea, etc.

Figure 1 shows the estimated residence time of a water molecule in the atmosphere, in aquifers, in river channels, in oceans and seas, among others. It is important to recognize that freshwater entering the sea is lost to abstraction or beneficial use (whether potable or not). Indeed, freshwater discharging to the sea is no longer available without energy-intensive desalination technology for approximately four thousand years. Freshwater in rivers stays approximately two weeks before reaching the sea and freshwater in lakes and reservoirs has a residence time of approximately ten years. It is therefore important to maximize freshwater availability before it reaches the sea.



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999; Max Planck, Institute for Meteorology, Hamburg, 1994; Freeze, Allen, John, Cherry, *Groundwater*, Prentice-Hall: Engle wood Cliffs NJ, 1979.

Figure 1: World's water cycle - Residence time
Credit: P. Rekacewicz, UNEP/GRID-Arendal
http://maps.grida.no/go/graphic/world_s_water_cycle_schematic_and_residence_time

2. THE INTEGRATED WATER CYCLE MANAGEMENT APPROACH

The Integrated Water Cycle Management (IWCM) approach that has been adopted in Australia and China (Durham and al., 2005) is needed to avoid focusing separately on drinking water and wastewater management as if they were not part of the same local water management cycle. The IWCM approach must:

- Satisfy the appropriate quality standards and strive towards greater water security,
- Meet today's needs without jeopardizing the ability to meet the needs of future generations,
- Enable the development of the local economy and satisfy local requirements.

Northern China, for example, is a water stressed region and the Government has reviewed and adopted best practices on water reuse from international experience and has resulted in:

- The adoption of an integrated water cycle management approach,
- A reduction of the problems of overlapping institutions and regulation,
- The implementation of demonstration projects to prove benefits and build local experience,
- A new policy ensures that all types of wastewater treatment shall take reuse into consideration.

Another example has been shown by the Spanish government, through the A.G.U.A. (Actuaciones para la Gestión y la Utilización del Agua) program. Spain is indeed considering systematic water reuse for irrigation and mobilization of other types of resource like desalination of saltwater in order to meet the growing needs of coastal population and respond to the new impacts of climate change happening in its territory.

River basin water management has been used to balance withdrawals with demand. However, this is difficult to implement in arid regions where there are few rivers. The

Australian and Chinese Governments have been promoting Integrated Water Cycle Management which recognizes that water also recycles locally rather than just flowing down the river to the sea.

The same type of program is being proposed in a recent public review draft by the US EPA entitled National Water Program Strategy, Response to climate change (Office of Water, EPA, 2008). In this strategy, the US EPA established a goal which consists in adapting implementation of core water programs to maintain and improve program effectiveness in the context of a changing climate. Among other suggestions, experts from the EPA propose to assess fresh water body spatial changes due to climate change or implement a climate assessment tool in order to model the predicted changes on a watershed.

Finally, the European Union has established a Strategic Steering Group on water and climate change, in order to integrate this new variable into the implementation of the Water Framework Directive, the main piece of European legislation in this regard. The Member States should especially make sure the 'program of measures' (which consists in setting objectives and timing in order to comply with the requirements of the Water Framework Directive, i.e. mainly reach the good ecological status of water bodies in 2015) is climate resilient. For a water operator, this consists in taking into account the consequences of climate change from the raw water withdrawal for the production of drinking water to the treated wastewater discharge into the natural environment.

3. INTRODUCING THE CONCEPT OF WATER PORTFOLIO MANAGEMENT

With the consequences of climate change on water resources, coming from the forecasted impacts, best water management practices will now have to emphasize a diversity of water sources in a portfolio selected not simply on least cost and timing, but also on the reduction in the covariance between sources. This is the concept of managing multiple water resources from storm water to seawater. Each resource has different availabilities, quantities, qualities and locations and can be tailored for different applications ranging from ecological management, cooling water, irrigation or potable production. In areas where the pressure on traditional water resources are high and increasing, the implementation of water efficiency management plans are key and the first measure to adopt when facing possible shortages issues on a local scale is always to put demand-management measures in place, for the domestic as well as for the agriculture and the industrial sector.

Figure 2 represents the possibilities offered by the portfolio management of available resources. It is a concrete example of a simple matrix showing the options a catchment has at his disposal in order either to slow down or to boost the natural water cycle when facing climate tensions.

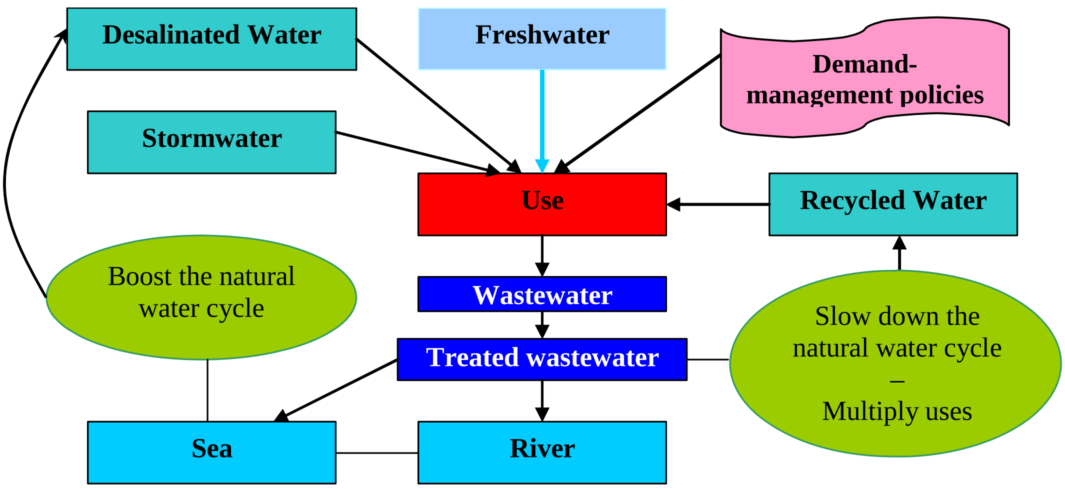


Figure 2: Portfolio management of water resources at local level

4. TOOLS FOR THE ADAPTATION TO CLIMATE CHANGE

Veolia Environnement R&D has been working since 2003 on different water resource management tools to support decision making, explore appropriate water supply solutions and optimize drinking water production. Concertation between operation and research lead to the design of three internal tools responding to present and short-term requirements. Existing tools are presented hereafter.

The climate change context has enhanced the need for such tools, along with water supply prevision tools. Future developments concern prediction tools to assess where and when water scarcity may become a real problem for drinking water production. New research programs have been launched.

4.1. Alternative resources assessment tool: Appr'eau

Presentation

Appr'eau was designed to explore different water supply solutions in relation to a specific context. The choice between traditional water resources (surface water and groundwater) and alternative solutions (desalination, stormwater or treated waste water reuse, aquifer recharge) is not an easy one. It depends on many criteria based on the technical, environmental, economical, political and regulatory context. A specific analysis of the supply area is necessary beforehand to assess the current situation and the different sustainable options.

Appr'eau is a methodological tool designed to analyze the local situation in regard to water supply and assess if the context is favorable to the implementation of alternative water resources. The objective is to help the user in the decision process with a large check-list of questions. At the end of the process, the user has gone through all the relevant questions on water supply in the study area and has all the keys to assess:

- Water supply challenges in the years to come (situation indicators, balance between availability and demand) in the study area,
- Economical, political and regulatory contexts,
- Relevant water supply solutions.

Appr'eau comes as an Intranet tool (see Figure 3).

Figure 3: Appr'eau intranet home page

The process leads the user through 4 steps and 250 questions:

① Context definition

→ Political context: who is the authority, which principles apply...?

→ Legislation and regulatory context: applicable regulations

→ Water management: organization, financial support

② Assessment of the water supply challenge

→ Signs of water shortages and water supply security

→ Indicators on water demand, withdrawals, population

→ Economical data: agriculture, industry…

→ Identification of water resources (traditional and alternative)

③ Are alternative resources needed and if yes, which ones?

→ Inciting factors for alternative resources

→ Obstacles and solutions

④ Summary

The online 'Help' provides information on the methodology, requested indicators (definition, significance…) and gives a framework for interpretation. Additionally, the tool has a well documented database with information on traditional water resources and alternative solutions.

Applications and benefits

Appr'eau was tested on four cases, two in France, one in Europe and one in Asia. It was approved as a valuable tool and check-list for assessing water supply challenges, especially in unfamiliar contexts, and a good help for organization and interpretation of different types of information. The tool itself does not draw any conclusion but assists the user in the assessment process.

The two French cases concluded the following:

	Case 1	**Case 2**
Water supply	One substantial surface water resource, but no substitute in case of a pollution incident	Many traditional resources left to explore (groundwater)
Alternative resources	Large volumes of treated waster water are produced and directly released to surface waters	Treated waste water reuse
Incentives	Local industries are seeking alternative water resources	Decision makers show a great interest
Obstacles	Lack of motivation of decision makers due to: - Surface water availability - Concern on water sale and purchase balance	No major obstacles
Conclusion	Not enough incentives	Need to identify users for reuse

Table 1: Appr'eau application cases in France

Appr'eau was applied to two other case studies, one in the initial phase of the water supply project scheme and one in the ending phase. The tool was very much appreciated for its exhaustive information check-list and train of thought which leads the user to assess the situation properly.

4.2. Resource allocation scenario simulator

Presentation

This tool's objective is to determine the best solution for water supply and resource allocation between multiple and interconnected water supply areas. It can be used from a regional to a more global scale to simulate annual water supply scenarios. The tool calculates drinking water balance and transfers and includes a GIS interface.

The user starts an initial work scenario with information on supply areas and their connections, current or future water demand, operational water resources and their contributions, hydrological conditions (normal or crisis situations). These initial results are shown on a map of the total area: water balance, shortage or surplus rates, self-sufficiency duration for each supply area and for the whole system (see Figure 4).

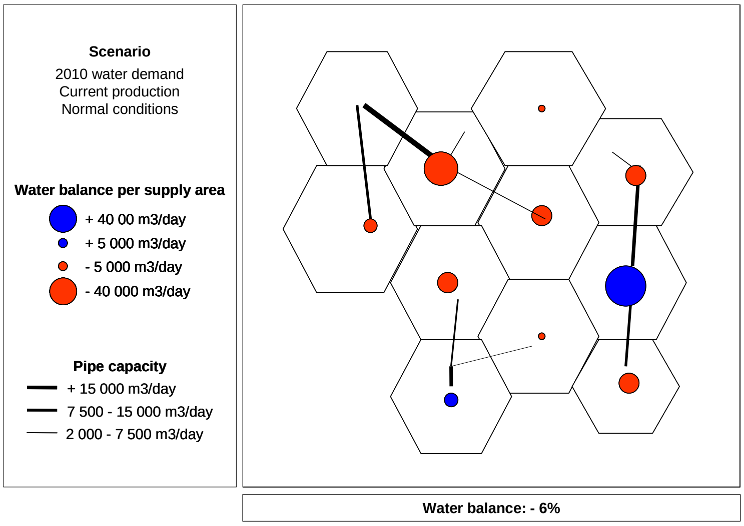


Figure 4: Water balance without supply area grouping

The user may allocate water volumes by transferring water from supply systems in surplus to systems with shortages. System grouping is built depending on pipe connection and distance. Grouping may be done several times (order 1, order 2…). The tool calculates new water balances, global allocation balance, water transfers and provides indicators on required treatment plants and pipes to achieve this new production and distribution scheme. Major results are shown on a map (see Figure 5 'Supply area grouping').

In this example, grouping according to available water volumes improves the water balance, but it remains negative (-4%). Three groups are deficient. The initial scenario may be changed anytime to test different solutions (new resources, new pipes…). If a treated waste water reuse project were to be implemented in group 1, the whole area would have a positive water balance (+2%) (see Figure 5 'Supply area grouping + reuse').

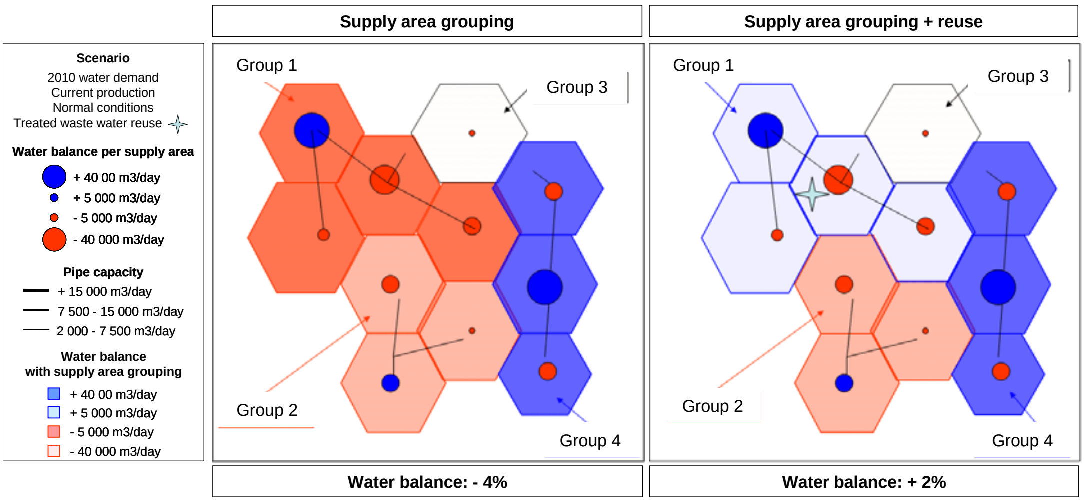


Figure 5: Water balance with order 1 supply area grouping and effect of a reuse project

Applications and benefits

The 'Resource allocation scenario simulator' was applied to a single case in France. Results were compared to the more conventional study performed for the watershed drinking water plan. Simulations proved to be easy and quick to run. They provided a good overview of the situation on the study area with a classification of its supply systems, prioritization of needs, and definition of appropriate transfers or new resources. Interactions between supply areas were more effectively assessed than with the traditional approach. Maps were clearly an added value.

Finally, the method is a global quantitative approach of a situation and its potential solutions. A feasibility study on the technical and economic aspects would be useful to complete the assessment.

4.3. Multi-resource management tool

Presentation

Supply areas with interconnected water resources are complex systems that are very effective for dealing with drinking water production, especially when water quantity and/or quality limitations occur. However, ensuring water supply and water production balance may be difficult.

A management tool was developed to optimize year round production for supply area with multiple and interconnected water resources. Its objectives are to:

- Simulate up to 3 years of monthly water production for demand and export,
- Optimize production site interconnexion,
- Predict operation under normal and dry conditions and ponder management solutions,
- Anticipate future operation under growing water demand.

Calculations are based on historical data. The tool evaluates the predictive monthly balance between incoming water volumes and withdrawals for 6 to 36 months ahead. Reservoir operation is represented with volume evolution and alert thresholds (see Figure 6). This information can be used to anticipate water shortages or manage system failures by altering production sites.

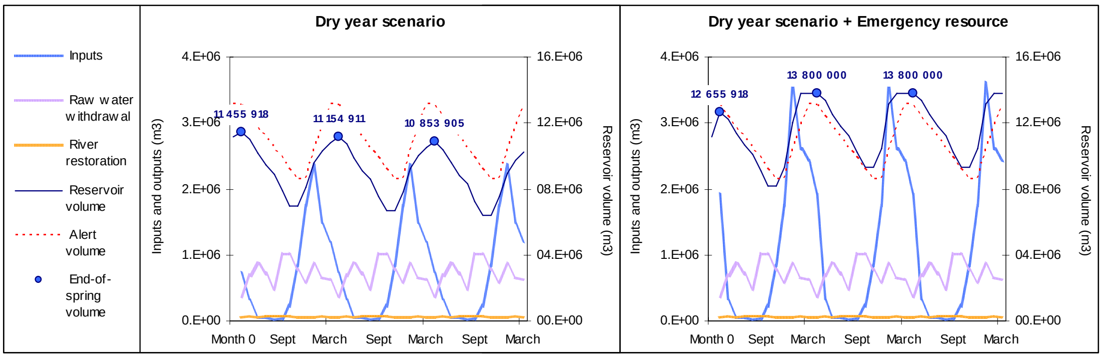


Figure 6: Example of reservoir predictive operation over 3 years

Applications and benefits

The 'Multi-resource management tool' was developed for a specific supply area in France and is being adapted to a second one in the United States. This adaptation allows for specific issues to be included (seasonal aspects of contamination, pumping constraints, etc.). Evaporation was not considered in these case studies, but it could be added in future developments if relevant.

Some perspective on historical data is necessary to have proper simulations. Once the data are compiled, the tool is quick and easy to run. Simulations were ran to predict the impact of reservoir variations or low river inputs over the next months to make sure water supply and water production were balanced or to anticipate water shortages. The management tool proved to be a good support to ponder withdrawal solutions so that water production remains optimal.

5. CONCLUSION AND PERSPECTIVES

The science of climate change has made a lot of progress in recent years. A lot more consequences of climate change on water systems have also been studied recently. This paper tried to show that applying the principles of ‘Integrated Water Cycle Management’ at the local level introduces a new prospective in explaining that availability of global water resources depends mainly on the appropriate treatment of wastewater and the development of alternative resources to increase water availability. These practices are even truer in a global climate change context where pressures on local water resources are exacerbated. Several examples show that although river basin water management is being used to balance withdrawals with demand, it is difficult to implement regular water strategies in regions already impacted by water stress or where there are few rivers.

Veolia Environnement R&D has been working since 2003 on different water resource management tools to support decision making, explore appropriate water supply solutions and optimize drinking water production. These tools may be a big help for complex systems from present management to a long-term perspective:

- Present: current needs and exports, dealing with dry periods or occurrence of contamination
- Future: growing water demand, water resources scarcity, etc.

Current climate change forecasts enhanced the need for such tools, along with the requirement for water supply prevision tools. Future developments concern prediction tools to assess where and when water scarcity may become a real problem for drinking water production.

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