3.2.2 RIFF

Introduction

Scope of prototype

Water resource management in the Seine river catchment and Adour-Garonne river catchment implies decision-making processes of great importance. Essential public infrastructures and economic sectors are potentially affected: e.g. for the Seine river, fresh water supply for more than 6 million people, cooling for 1 Nuclear and 2 Thermal power stations, economical loss estimation of severe flooding in Paris reaching up to 6.5 billion Euros and for the Adour-Garone river low flow support potentially leading to buy water from external providers. The prototype intends to help the EPTB Seine Grands-Lacs (Seine) and DREAL Midi-Pyrénées (Adour-Garonne) in their current decisions making to:

- anticipate drought and maintain minimum rivers flows in summer;
- ensure the refilling of reservoirs at the end of the winter;
- especially for EPTB Seine Grands-Lacs, adapt the management in Winter to damp possible flooding events at Spring while ensuring efficient low flows support in summer and autumn.

Behind these decisions, the major stakes concern fresh water supply (contribution of the river flow from 50% to 80% in summer) and flood control over the Paris metropolitan area for the EPTB Grands Lacs and irrigation for agriculture over the Adour Garonne river catchment for DREAL Midi-Pyrénées (this region ranking first in France for farming). The stakeholders are already using models to monitor their reservoir dams. They use a range of possible situations issued from their historical records (over more than one hundred years) to make their water volume prediction. The benefits of using seasonal forecasts are real if they allow reducing the range of possible scenarios. The overall value to our stakeholders of the prototype is promising since, as demonstrated, using seasonal forecasting brings more skill than using climatology as they used to do.

Scope of vulnerability analysis

Water management problems comprise many different tasks and aspects covering diverse sectors. The number of critical situations caused or influenced by climate is therefore manifold and probably difficult to identify and analyse completely. Thus, the scope of this vulnerability analysis will be focusing on the problem of water supply management which is within the scope of local authorities and related organizations. This implies decisions on reservoir management controlling rates of water inflow and release considering diverse interests, safety issues and user needs. The focus will also be on the Seine catchment with the EPTB Grands-Lacs as decision-maker.

System of concern

The river basins are the logical physical boundaries of the system. Nevertheless, some hazards may affect larger area. As an example, drought could persist over months or years; it can affect large areas and may have serious environmental, social and economic impacts (Horion et al. 2012). For the prototype this comprises the catchments of the Seine River. The French water policy is defined and coordinated at the national level by the Ministry of Ecology, Energy, Sustainable Development and the Sea. But water management occurs decentralized on the level of river basins considering geographical boundaries instead of political. In France there are 13 river basin districts in accordance with the European Water Framework Directive (WFD) which is implemented in accordance with the national water policy on basin level (Master Plan for Water Development and Management [SDAGE]) (Noel 2009). For the Seine catchment it is the EPTP Grand-Lacs who is responsible for the regional water management issues.

The *Seine Normandy basin* drains an area of about 97,000km^2 which comprises a river network of 66,000km among which the Seine has a length of 776km and a mean discharge of 460m^3/s draining a catchment of 64,500km^2. The climate is oceanic with an average rainfall of 750mm (varying between 300 and 1600mm depending on the area) and a mean evapotranspiration of 500mm with a maximum in summer (90 mm/month). Average temperatures range from 2.5°C (January) to 24.6°C (August) (AESN 2003, Dorchiesa, Thirelb et al. 2014). 17.500 million people live in the Seine Normandy basin which is 30% of the French population. Respectively, the main purpose of water use is for drinking water. 100% of the population receives their drinking water from the river network. About 40% of surface waters and 60% of ground waters are used which is around 1.5 million m^3 per year or 190l per inhabitant per day. Four dams with a total capacity of 800 million cubic meters and water towers with a total capacity of 880 million cubic meters are available to manage variable water needs. Besides the provision of drinking water, the dam reservoirs provide water for industry and agriculture, to protect urban areas from flooding and offer leisure activities on the local scale (AESN 2003, MEDDE 2006).

Critical situation

The general task of water managers is to provide water supply to cover respective demand of different stakeholders and users within a specific basin. This relative straightforward task is complicated by the plurality and diversity of users like industry, energy production, agriculture, inland waterway transport, tourism and especially municipal use of water (drinking water and wastewater) which all have individual needs especially with respect to volume, purpose of use and timing (Noel 2009). Since 2000 in the context of the Water Framework Directive management does not only imply the managing of available water supplies (quantity) and its related hazards like droughts and floods but also the preservation of flow rates, quality and feedbacks from affected systems (Atwi and Arrojo 2007). To predict future water availability in a reasonable way water managers require a firm understanding of the natural water cycle and the variability of water resources at different scales within a catchment. A common critical method of managing hydrological variability is the use of dam reservoirs. Reservoirs provide a significant although limited opportunity to control water supplies by storing water at times where water availability is greater than the demand for seasons with potential water scarcity. Reservoir design is tightly related and based on historical streamflow, current water needs and projections for future water needs as well as future water availability. Thus, assuming stationarity, prevalent water supply systems do meet the need of current and near future water use. Challenges may occur with respect to the reliability (buffering of variability) and the sustainability (future reliability) of such systems (Brown, Baroang et al. 2010).

Hazard: A major problem is the major water consumption which causes low river flows. In summer drying the rivers upstream from Paris which has serious consequences on water supply, ecological conditions and especially water quality (AESN 2003, Dorchiesa, Thirelb et al. 2014).Flooding is a further major concern for the area especially since large parts of the basin rendered impermeable and thus increased surface runoff. Floods are prevalent in spring season (January-April) and have the potential to inundate urban areas and also mobilize wastewater causing severe health problems. The role of dams to control floods is important but limited because of their distance from the large urban areas and their limited capacity compared to the volumes of major floods (800 million m^3 vs. 4 billion m^3 in 1910) (AESN 2003, Dorchiesa, Thirelb et al. 2014). In the context of this analysis the hazard of flooding will only be considered secondarily since the focus is on water supply management and flooding comprises different decision-making processes.

To determine thresholds for high- and low-flows relevant for decision-making it needs to be considered that the critical aspect is the reservoir management and not the final consequences. Since the water management system is aligned or rather based on historical hydrological respective extreme events are also relevant for water managers.

Decision-making processes: the main purpose of the four dam reservoirs in the Seine catchment is to provide sufficient high water supply during the summer season (for irrigation and drinking water) when natural water availability is low and to prevent flooding in urban areas downstream of the reservoirs. Thus, the focus of reservoir management is to reach maximum volume shortly before the beginning of the dry season (July-October) considering the provision of sufficient buffer capacity to damp flood events during the filling period. Each of the four dams is operated independently following a filling curve (FC) which determines the reservoir volume for each day within a year. The curves are designed using the information from the analysis of historical hydrological regimes (Ficchi, Raso et al. 2014).The main filling periods in France are thus during the rainy periods between autumn and early summer (November - June). The emptying period lasts from July to October and can be extended until December in case of low-flows. Thresholds are determined for a minimum flow during the filling period to preserve aquatic life downstream of the dam and a maximum flow during the emptying period to avoid unexpected high flows. A desired storage volume at the end of the filling period is determined considering a respective buffer to damp flood events and a “reserve tranche” is defined determining a minimum storage volume for the release period (Dorchiesa, Thirelb et al. 2014, pers. com. Viel).

Decisions related to reservoir management in the Seine basin occur within the technical committee or user meeting (COTECO) which takes place around three times per year according to the three main periods of decision-making: (i) in June the low-flow for the coming dry season is projected to adapt the safety reserve threshold; (ii) in September at the end of the low-flow period projections until December are made to extend the release period if necessary and decisions about under-filling measures are made to prevent future flooding; (iii) in February at the end of the filling period projections of the coming summer conditions are made to review and adjust the refilling of the reservoir (pers.com. Viel).

Critical situation: the critical situations related to decision-making processes for reservoir management in the context of balancing supply and demand are twofold:

A critical situation arises by a high variable discharge regime during the rainy season (October-June) challenging the balance of maximizing the reservoir capacity until June and buffering unexpected flood events prevalent between January-April.

Buffer system characteristics

For water management issues in context of reservoir management the availability of water in form of discharge is the attribute of concern. Water managers and users get a problem when there is a "prolonged period with below-normal water availability in rivers and streams, and lakes or groundwater bodies due to natural causes" (VanLanen, Wanders et al. 2013 p.1716) thus, a hydrological drought. Hydrological droughts evolve slowly and are due to periods of low precipitation combined with high evaporation losses which causes soil moisture deficits and subsequently reduces groundwater recharge and head and eventually lowers stream flows (Maybank, Bonsal et al. 1995). The area affected by droughts is primarily climate driven whereas local variability is influenced by characteristics of the terrestrial system. Hydrological storage or a combination of catchment characteristics which relate to catchment storage and release (e.g. land use and geology) is the most important factor controlling drought propagation and causing lag times between a meteorological drought and hydrological drought and its spatial characteristics (Tallaksen, Hisdal et al. 2009, VanLoon and Laaha 2014). The monitoring of hydrological reservoirs within a catchment is also a central element of the Spanish Drought Management Plan (Monreal and Amelin 2008).

In contrast, the occurrence of flood events is much more sensitive to changes in hydrological reservoirs. For flash floods the soil do not even need to be saturated. High magnitude rainfall events may exceed the infiltration rate of the soil, causing surface runoff and thus provoke local flooding despite rather dry soil conditions. Also snowmelt floods and rain-on-snow floods are often dominated by temperature which controls the activation and the draining of the respective hydrological storage (Merz and Blöschl 2003).

Dams and reservoirs can also be considered as hydrological storages and thus as an additional buffers. However, these storages should be considered as different buffer systems, since this storage type is controllable and stored water is available at discretion. The infilling of these storage types is dependent on the discharge of the catchment draining the area uphill of the reservoir but the release rate can be controlled by decision-makers.

Critical climate conditions and climate information

Critical climate conditions

The relation between discharge and rainfall is strongly dependent on catchment characteristics especially the state of hydrological reservoirs. The development of hydrological droughts is a slow process and not only dependent on periods of low rainfall but also on temperatures and evapotranspiration potentials. Required time-scales over which precipitation events need to be below average or even lacking to provoke hydrological droughts are in general seasonal for fast responding catchments and may be inter-annual in catchments with large hydrological storages (vanLanen and Tallaksen 2007).

For the Seine basin little information could be found on typical climate conditions responsible for drought events. However, the Seine basin possesses large geological aquifers and thus a large natural storage capacity conferring a long hydrological memory. Compared to other regions in France drought events in the Seine basin do have a lower frequency but are of longer duration and typically start in autumn or winter (Vidal, Martin et al. 2010). Consequently, longer lead times of below-average precipitation are expected to create a drought. The study of Hannaford et al. (2011) confirms this hypothesis and fond a correlation of RDI/RSPI (Regional Deficit Index / Regional Standardized Precipitation Index) which is best for a time scale of 12 months for the Seine basin.

In contrast, flood events occur due to much shorter reaction times of the catchment: flash floods or short-rain floods which happen on the local scale due to saturated soil conditions or high magnitude rain events which exceed the infiltration rate are at the time scale of less than 1 day. But even long-rain floods which cause floods on a larger spatial scale are in the temporal scale of several days to maximum weeks. Floods due to snow melt are often even independent of rain but rather related to temperature (Merz and Blöschl 2003).In the Seine basin floods typically occur in the winter time and last around 20 days. Simple floods are caused by high magnitude rainfall events of 2-3 days and double floods require rain spells separated by around 4-6 days rainfall. Multiple floods are caused by a succession of rainfall events during a few weeks (Rousset, Habets et al. 2004).

Critical climate conditions are below-average precipitation during the year combined with above-average temperatures. Furthermore, extreme high rainfall events during and especially at the end of the rainy season.

Climate information

To assess the potential inflow in dam reservoirs information on total rainfall and temperature means for the infill-season (October-February) is required. Thus the demand is for a 6 month-forecast available at beginning of October. In June another 4-6 month forecast would be required to recheck the water availability and demand of the dry season to adapt the safety reserve in the reservoirs.

To assess flood events during winter information on total water availability is sufficient however information on the distribution (magnitude-frequency) would be desired to be able to cope with individual events especially at the end of the filling season when reservoirs are rather full.

Vulnerability attributes

Criticality of the problem: water availability in a drought-prone region is basically a very critical factor and thus related decision-making processes are of general criticality. But, no information is available about risk preferences of the EPTB Grands Lacs. However, decision-makers in Spain appear to be risk-averse an attitude that could also be prevalent within RIFF: uncertainties on water availability are countered by worst-case hypotheses to avoid risky (irreversible) decisions of users (e.g. farmers) (CHE 2014). Thus, the decision to exhaust the storage capacity of reservoirs within a catchment is a robust (low risk) decision with respect to water availability. In this context floods do constitute greater risk since they don’t allow exhausting the total storage capacity due to dam safety reasons (CHE 2014).

Usability of S2D climate forecast information: decision-making of water managers refers to the fill-level of the reservoir which is aimed to be exhausted at the end of the rainfall season but requires considerations for in-seasonal release rates due to a number of issues including flood-protection and the protection of ecosystem. Thus, decision-makers are interested in total water available at the end of the rainy season. Discharge rates during the season and thus the timing of high- and low-flow events are of minor importance with respect to this goal. This interest is systemically and technically supported by the buffer effect of the catchment and dam reservoirs. Consequently, information on mean temperature and effective rainfall over a certain period is general desired and usable due to the systemic buffering of rainfall and evapotranspiration rates by the catchment and reservoir system. Furthermore, since temporal scales of the critical climate conditions is much longer than the temporal scale of decision-making seasonal climate forecasts must not cover the entire time-scale. At the time of decision-making a great deal can be covered by using climatology.

Timing is however an issue for the coping of flood events. Especially when approaching the end of the rainy season when the reservoir tend to be close to maximum capacity and the timing of high-magnitude flood events becomes a critical information. Thus, climate information with higher temporal resolution would be desired to reduce uncertainty of such events.

River catchments do not only aggregate rainfall events on a temporal dimension but also on a spatial dimension. Compared to problems of other sectors the need for high ***spatial resolution*** is limited and thus the tolerance to lower spatial resolution is expected to be higher. Furthermore, since water resource planning is traditionally made by the use of historical climate (discharge) data, the overall catchment water management system is aligned to climatology and thresholds of low- and high flows relevant for decision-making are also related to the local hydrology. The ***timing*** of decision-making processes is also aligned to the hydrological year. Thus, forecasts periods do match periods of climate information needs no complicating demands are set for the seasonal climate forecasts. Referring to the relative risk-averse decision-making forecasts are supposed to have very little uncertainty to cause any change in decision-making.