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Special Plan of Action in Situations of Warning and Eventual Droughts of the Tagus River Basin

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SUMMARY – In accordance with Article 27 of the Spanish Law 10/2001, where the National Hydrologic Plan is passed, the Spanish Tagus River Basin Water Organism devised, during the period of 2005-2007, the Special Plan of Action in Situations of Warning and Eventual Drought of the Tagus River Basin (Special Drought Plan-SDP). The main objective of this SDP of the Tagus Basin is the specification of measures of control, risk assessment, organization of decision making and implementation of mitigation measures which are required to minimize the frequency and intensity of water shortage conditions, and to reduce the environmental and socioeconomic effects of these extreme situations.

Key words: Drought, risk management, water resources management, hydrological planning.

Introduction

Drought is an extreme hydrological phenomenon that can be defined as a significant decrease of water resources availability during a sufficiently long period of time and concerning extensive areas. Unlike other natural phenomena, such as floods, droughts evolve slowly in such a way, that corrective measures are usually not applied until it is acknowledged that a region is in drought condition and the effects are already important. This reactive approach is clearly non optimal, since the effectiveness of the measures could be significantly enhanced if they are adopted earlier under objective criteria.

In order to solve this problem, the Spanish Law 10/2001, where the National Hydrologic Plan is passed, established new legal instruments for drought management in Spain. These actions are based on three main instruments: (i) a drought monitoring system based on drought indicators for each Basin Authority and for the entire country; (ii) Special Drought Plans for Basin Authorities; and (iii) Emergency Drought Plans for urban water supply systems supplying more than 20,000 inhabitants.

As a result, Spain has recently completed the process of drafting Special Drought Plans for all Basin Authorities. Special Drought Plans are mainly targeted to identify the conditions and schedule the establishment of specific measures to prevent or mitigate drought effects. The Special Drought Plan developed for the Tagus Basin is presented in this paper.

Objectives of the plan

The main objective of this Special Drought Plan of the Tagus basin (SDP) is the specification of measures of control, risk assessment, organization of decision making and implementation of mitigation measures which are required to minimize the frequency and intensity of water shortage conditions, and to reduce the environmental and socioeconomic effects of these extreme situations.

The specific objectives of the SDP are: (i) to guarantee water availability in order to assure population health; (ii) to prevent or minimize the negative effects of droughts on the ecological status of water bodies, especially on the regime of minimum flows, avoiding, in any case, negative permanent effects on the status; (iii) to minimize the negative effects of droughts on urban supply; and (iv) to minimize the negative effects of droughts on economic activities, according to the priority of uses established in the water legislation and in the Tagus basin Hydrological Plan.

There are also instrumental objectives, such as: (i) definition of mechanisms to detect and forecast drought situations; (ii) establishment of thresholds to identify the progressive severity of drought conditions; (iii) definition of adequate measures to achieve the specific objectives in every drought episode; and (iv) guarantee of transparency and public participation within the elaboration process and implementation of the Plan.

Water resources and droughts in the Tagus Basin

The Tagus Basin is located in the central part of the Iberian Peninsula (Fig. 1). The main river runs on East-West direction, with a contributing area of 83,678 km^2, of which 55,870 km^2 are located in Spain and the rest in Portugal. The administrative body responsible for providing public service regarding water management in the basin is the Basin Authority, Confederación Hidrográfica del Tajo which is in charge of inland water and groundwater. The Confederación Hidrográfica del Tajo (CHT) is an autonomous public organization, which is dependant on the Ministry of the Environment.

Fig. 1. Location of the Tagus Basin.

Water resources in the Tagus Basin are dominated by irregularities of the hydrologic regime. This drifts in frequent and severe drought episodes.

There is a long experience of water use in this basin, were 12 main water supply systems have been defined. They are equipped with well-developed infrastructure of regulation, transportation and distribution of water resources (Table 1). In some of these systems, water demand is a large fraction of average resources.

Table 1. Main average values of hydrologic zones in the Tagus Basin

System	Area (km^2)	Precipitation (mm/yr)	Evapo-transpiration (mm/yr)	Runoff (x10^6 m^3/yr)
Cabecera	7418	649	633	1191
Tajo intermedio	2781	470	753	118
Tajuña	2608	535	679	132
Henares	4136	584	676	518
Sorbe	4802	640	688	992
Madrid	1709	531	738	162
Alberche	4109	668	758	823
Margen Izquierda	7590	461	764	537
Tiétar	4459	1012	797	2155
Alagón	4405	942	787	1996
Árrago	1020	949	784	430
Tajo inferior	5949	661	818	1329
Almonte	2463	635	779	501
Salor	5492	570	753	1105

The Tagus Basin in recent years, has suffered several historical droughts. The last most important ones correspond to the years, 1943-45, 1979-83, 1990-95 and 2004-07. The average duration of the hydrological droughts in the Tagus Basin is in the order of two years, with an average reduction of runoff with respect the average of the historical series of 45%. The average frequency of dry cycles is approximately 7 to 10 years. Due to the imbalance between water availability and demand in drought years, there is an extensive experience in hydrological management, but recent drought events have questioned the capacity of some systems to meet increasing demands with the available water resources, since droughts had impacts of different intensity in all water resources systems in the basin. Until now, drought management was mostly based on reactive measures, including special legislation to mitigate drought impacts and promotion of emergency infrastructure.

Activation of drought management actions

Drought indicator system

Any drought management plan needs a robust drought indicator system in order to identify and diagnose anomalies in water availability, as it has to provide a basis for early detection of drought episodes. Drought characterization in highly regulated systems, is complex and calls for multiple indicators. A comprehensive study of hydro-meteorological time series and drought indices in the basin was carried out to define a drought indicator system. The methodology used was based on the analysis of water demand units. For each of them, a list of variables was selected in order to describe the evolution of available water resources. The indicators adopted for each demand unit are shown in Table 2.

Historic time series compiled for each variable were normalized on a scale from 0 to 1, with 0 corresponding to the minimum historic value, 1 to the maximum and 0.5 to normal conditions. The functions to relate variables and indicators were chosen to characterize the risk of water shortages and were validated through the analysis of historic values and drought episodes. Individual demands were grouped in water resources systems, obtaining average values of the indicators which are representative of the global situation of each system. A weighted average was selected as the averaging procedure, with weights proportional to the relative importance of each demand unit.

The system of indicators is in continuous revision, taking into consideration the availability of new information and the progress in knowledge of the hydrologic behaviour of the basins.

Drought management actions

The basin drought policy is summarized as a list of possible actions to be taken in case of drought. Drought management actions can be classified into three main groups: strategic, tactical and emergency measures. Strategic measures are long-term actions of institutional character and infrastructural nature, which are contemplated in long-term hydrological planning (demand management, regulation and arrangement of uses, infrastructure for storage or transportation. Due to their very nature, they are out of the scope of any drought management plan, as they need long term implementation, expensive budgets, political negotiation, social acceptance and eventually legislative modifications. Tactical measures are short-term actions planned and validated beforehand in the framework of the drought management plan. These types of measures are designed from experience, considering historical drought situations and are activated if the system of indicators identifies drought conditions. Finally, emergency measures are adopted once the drought has already originated significant impacts and their nature depends on the intensity, magnitude and extension of the affectation to the basin.

The catalogue of possible actions included in the Special Drought Plan is restricted by the legal competences that are attributed to the Confederación Hidrográfica del Tajo, but the resulting list includes a great number of actions of very diverse nature, such as: (i) supply enhancement – development of complementary resources, interconnection of systems, additional groundwater resources, etc.; (ii) demand management – revision of rules for the operation of infrastructure, information dissemination and user involvement, promotion or enforcement of water savings, prohibition of certain uses, etc.; (iii) legal – official declaration of emergency due to drought, contracts

for water use exchange, palliative measures with different objectives: subsidy, restrictions, emergency works, etc.; (iv) environmental control – maintenance of acceptable water quality, environmental indicators, enhancement of monitoring of environmental parameters, etc.; (v) monitoring and management; and (vi) mitigation and recovery.

Table 2. Drought indicators in water resources systems in the Tagus basin

System	Indicator	Main demands	Value $x10^6$ m^3/yr
Cabecera	Inflow to Entrepeñas + Buendía reservoir	Cooling C.N. Trillo	45.00
	Volume in Entrepeñas + Buendía reservoir	Tagus demands	-
Tajuña	Volume in La Tajera reservoir	Supply Almoguera	2.95
		Other urban supplies	2.75
		Private irrigation	25.46
Sorbe	Volume in Beleña reservoir	Supply Sorbe	56.66
Henares	Volume in Alcorlo + Pálmaces reservoir	Bornova I.D.†	14.91
		Canal del Henares I.D.†	55.38
Madrid	Volume in CYII reservoirs	Supply Canal de Isabel II	682.21
Alberche	Volume in Burguillo + San Juan reservoir	Supply Talavera	11.11
		Supply Torrijos	5.86
		Supply Sagra Baja	4.24
		Supply Sagra Alta	6.43
		Canal del Alberche I.D.†	75.00
Tajo intermedio	Flow in Tagus river	Required flow in Aranjuez	186.60
Toledo	Volume in El Torcón + Guajaraz reservoir	Supply Toledo	10.54
		Supply Torcón	1.32
Tiétar	Inflow to Rosarito reservoir	Supply Rosarito-Caraba	1.06
	Volume in Navalcán + Rosarito res.	Supply Oropesa	1.10
		Tiétar I.D.†	108.62
Alagón	Volume in Navamuño reservoir	Supply Béjar	4.04
	Volume in Jerte reservoir	Supply Jerte	4.62
		Irrigation Jerte	1.39
	Volume in Baños reservoir	Ambroz I.D.†	34.50
	Volume in Gabriel y Galán reservoir	Alagón I.D.†	391.00
Árrago	Volume in Borbollón + Riv. Gata res.	Supply Rivera de Gata	3.38
		Árrago I.D.†	90.00
Bajo Tajo	Vol. In Alcántara + Valdecañas reservoir	Cooling Almaraz	583.42
		Valdecañas I.D.†	29.40
		Alcolea I.D.†	25.90
Cáceres	Volume in Guadiloba reservoir	Supply Cáceres	10.50
Trujillo	Volume in Santa Lucía reservoir	Supply Trujillo	1.81
Salor	Volume in Salor reservoir	Supply Salor	2.10
		Salor I.D.†	5.78

† I.D.: Irrigation District.

Activation thresholds

The operational effectiveness of the SDP is greatly enhanced if the selected measures for every system are grouped together to be applied under certain drought conditions. In the Tagus Special Drought Plan, three thresholds were defined for drought indicators: pre-alert, alert and emergency, which delimit four situations associated to different levels of drought severity.

In normal condition, drought indicator values are above the pre-alert threshold and there is no need for the adoption of specific drought measures. In pre-alert condition indicator values are between the thresholds for pre-alert and alert and there is already need for the implementation of preventive measures for control intensification and user awareness. In alert condition indicator values are between the thresholds for alert and emergency, and there is need for the application of measures of demand management, resource conservation and mobilization of complementary resources to maintain the situation. In emergency condition indicator values are already lower than the emergency threshold, and exceptional measures are unavoidable to guarantee the urban supply; minimum environmental conditions, supply to nuclear power plants and, if possible, keep tree orchards alive.

The model *Simrisk* was used to determine the drought severity thresholds in each indicator based on risk analysis. *Simrisk* evaluates the risk of failure in a water resources system with a certain strategy of management in a given time horizon. The model is used in a repeated way, with historical inflows to the reservoirs, to determine the values of the drought indicators that exceed a given risk threshold. Model parameters are: time horizon of the analysis, required level of demand supply and acceptable risk. Parameter values depend on the kind of system analyzed: urban water supply or irrigation. An example is shown in Fig. 2, where the time evolution of the normalized value of the indicator (volume stored in two reservoirs) is shown compared to the activation thresholds for the pre-alert, alert and emergency conditions.

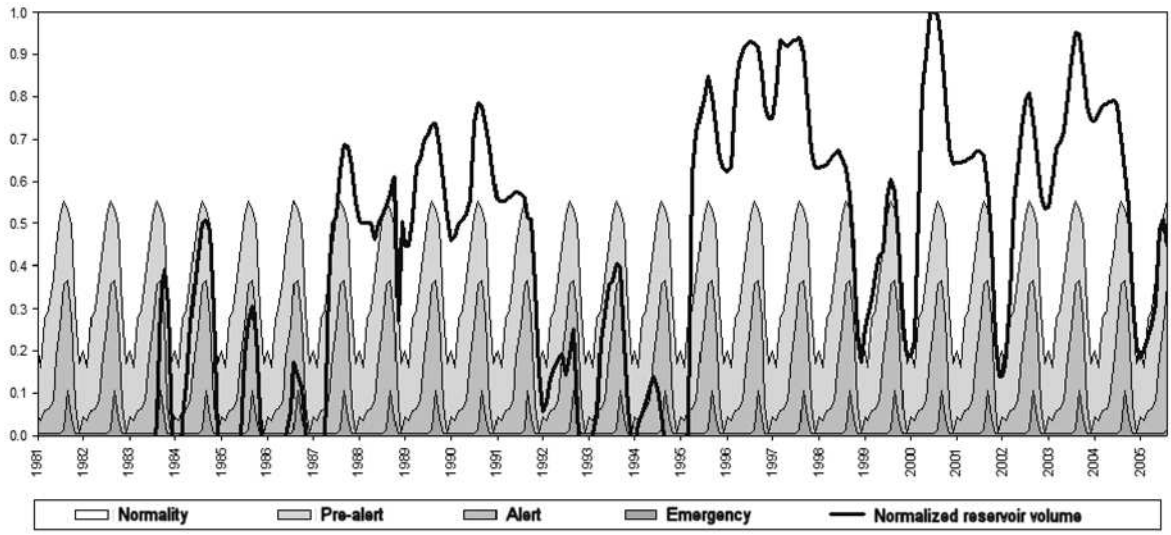

Fig. 2. Time series of normalized drought indicator for the Henares Irrigation District. The indicator corresponds to volume stored in Pálmaces and Alcorlo reservoirs.

In every condition, a set of measures is activated to prevent or mitigate drought effects, with increasing impact on water resources systems as drought severity increases. These measures could be focused on water resources, on demands or on the administrative and legal framework. This scheme allows the application of quantitative criteria to establish thresholds for the activation of drought management measures, and which facilitates the process of public participation and plan revision.

Operational implementation

The Special Drought Plan is framed within the Basin Hydrological Plan. The CHT is responsible for the elaboration, management and enforcement of the SDP. Therefore, it is foreseen that the operation of the drought indicator system and the enforcement of drought management actions will be carried out with its resources.

The official declaration of drought conditions will be made by the Presidency advised by the Office of Hydrological Planning, the Technical Direction and the Water Commissariat of the CHT. For each drought condition, a detailed scheme of responsibilities has been drafted, assigning the implementation of major actions to a specific unit of the organization or to specific committees appointed to manage the drought situation.

A follow-up system has also been established, to verify the accomplishment of the objectives of the Special Drought Plan, to identify the magnitude, causes and possible solutions of all deviations from the Plan provisions, and to propose possible revisions of specific aspects of the Plan. A follow-up report will be produced after every episode in which there has been a formal drought declaration, including the values of hydrological variables, the impacts identified, the actions implemented and the effectiveness of the measures.

A system of indicators has been established to monitor the implementation of the Plan. It includes indicators for progress, effects and efficiency for each of the groups of management actions. As environmental authority, the Ministry of the Environment will be informed of the plan progress. Finally, the plan also contemplates mechanisms for updates and revisions, including the minimum conditions that will be required for updates or revisions, and formal procedures for approval.

Conclusions

The Tagus basin has recently approved it Special Drought Management Plan. It is an instrument for proactive drought risk management, based on a set of normalized drought indicators, a collection of drought management actions and an objective procedure for the official declaration of drought and the activation of measures. The Plan has undergone a process of Strategic Environmental Assessment, a Public Participation procedure and its implementation is being supervised by the Ministry of the Environment.

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