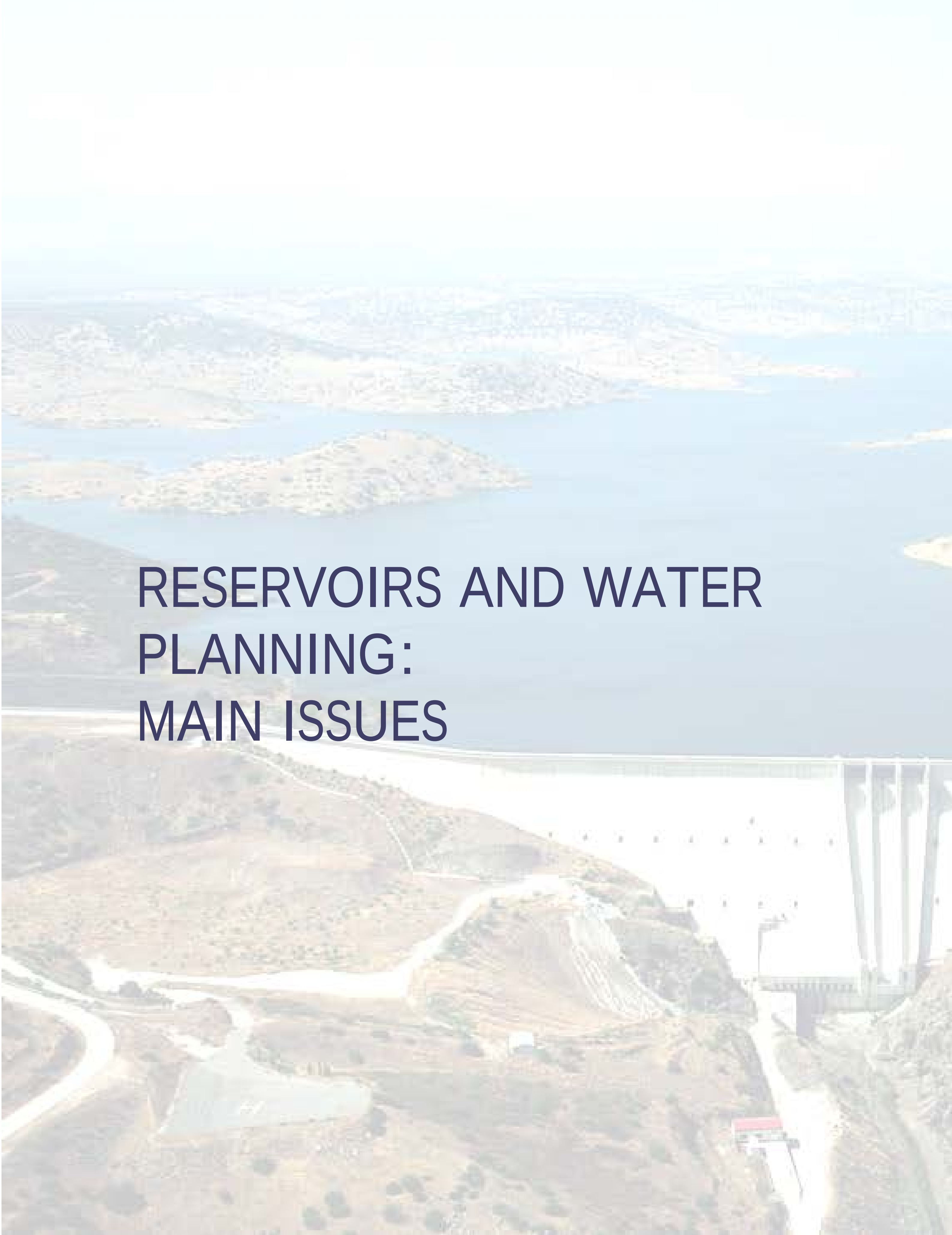

RESERVOIRS AND WATER PLANNING: MAIN ISSUES

Technical Committee "Engineering activity in planning"

Reservoirs and Water Planning: Main Issues

TABLE OF CONTENTS

1. INTRODUCTION: BACKGROUND AND OBJECTIVES

Water is a vital element for human beings and ecosystems. As such, it must meet all the sufficient quality and quantity requirements. It is also a production factor, which is extremely important in agriculture and in producing electricity, carrying out numerous industrial processes and providing tourism and environmental services. In some regions of the world, life and economic development are at risk due to the balance between water demand and the resources available.

Meeting the demand requires flows by means of natural channels (rivers) and artificial channels (pipelines), as well as natural storage (lakes and aquifer) and artificial storage (reservoirs and urban storage). It is also possible to increase the availability of resources using industrial processes, such as the desalination of sea water or the regeneration and reuse of treated wastewater. Any of those activities that involve human intervention may require significant investment and have an important economic, environmental and social impact. Thus, a suitable definition and control of demand must be a main factor in estimating water supply requirements.

The assessment of any activity in the area of water resources, and particularly in building reservoirs, must also include consideration of its environmental, social and economic effects. In the past, the assessment of environmental impacts was not always appropriately dealt with when constructing dams. When it was, however, impact estimations and the calculating of environmental costs did not meet clearly defined methods. Furthermore, as the alternatives were not sufficiently detailed, neither was the cost-benefit analysis. Moreover, the planning processes of these infrastructures have frequently been carried out on a local scale, using a cost-benefit analysis on all projects in a limited geographical area. Today, it is generally accepted that infrastructures relating to water resources should be analysed under the framework of the river basin management plan, with adequate public participation, which is undertaken on addressing each particular project.

In fact, the planning and management of water resources must be carried out based on river basin levels, as established under Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, better known as the Water Framework Directive. This approach had already been adopted in Spain with the creation of the Hydrographic Confederations [*Confederaciones Hidrográficas*] in the 1920s and 1930s, and was established in water planning regulations in the Water Law of 1985 [*Ley de Aguas*]. It created the River Basin Management Plan [*Plan Hidrológico de Cuenca*], which was adopted with Royal Decree status, and the Spanish National Hydrological Plan [*Plan Hidrológico Nacional*], with legislative status. As is subsequently mentioned, the framework directive has entailed the incorporation of new elements in traditional water planning, which are geared towards increasing water supply.

Currently, sustainability objectives now more than ever encourage medium- and long-term consideration in the assessment of effects and in the use of resources, with the aim of ensuring their continuance for future generations. On the other hand, adaptation to climate change is largely a temporary decision issue, as it entails trying to reduce damage associated with the long-term impacts of climate change by undertaking short-term actions.

The Committee on Engineering Activities in Water Resource Planning [*Comité de Actividades del ingeniero en planificación de recursos hidráulicos*] of the Spanish Committee on Large Dams [*Comité Nacional de Grandes Presas*], seeks to make progress on and improve the analysis of reservoirs, which includes the corresponding dams as elements in water planning, without hindering the exclusive aspects of project and construction phases. Therefore, the aim of this document is to explain and analyse this issue with a comprehensive approach, considering a series of technical, economic, social and environmental matters on the role of reservoirs and related dams in water planning in Spain. It not only takes into account new reservoirs, but also the adaptation and, where appropriate, the decommissioning of those currently used.

2. WATER AND RECENT GLOBAL CRISES

There is no doubt that water is a key issue on the current political agenda of the most senior leaders and institutions. This is due to:

a) The food crisis: The ever-increasing demand for agricultural products to meet the needs of a growing population is still the biggest factor behind water usage. Strong economic development and advancement in lifestyles, not least in emerging markets, have led to a demand for a more varied diet, putting additional pressure on water resources. Even in recent years, the so-called "food crisis" has occurred, a warning of what lies ahead if action is not taken. According to WWDR3[1], worldwide irrigated agriculture required the extraction of 2,700 km^3 of water in 2000 and approximately 3,100 km^3 in 2010, representing 71% of the total yearly water extraction. Thus, the challenge regarding water is closely related to the provision of food and its trade.

In this context, approaches such as the water footprint gain importance. This approach estimates that the global water footprint is 10,000 km^3/year, equivalent to 1,385 m^3/person/year, 75% of which is green water consumption[2]. The majority is due to food and other agricultural products and, of the total water consumption of countries, 19% is earmarked for international trade. In Spain, livestock and agriculture represent around 80% of the total water footprint (2/3 with national water and 1/3 with imported virtual water). Spain and the EU are major "net importers" of virtual water contained in agricultural products, although we should not ignore that some Spanish basins export virtual water.

b) The energy crisis: Energy is needed for water (making the quantity and quality available at the time and place required) and water is needed for energy (for production and regulation). The need can be direct, such as in hydroelectric power, including the use of reversible pumping, or indirect, whether for cooling nuclear or

[1] The United Nations World Water Development Report, Report 3, *Water in a changing World*, published in English in 2009 by UN-Water (the UN inter-agency that coordinates its diverse bodies relating to freshwater), prepared under the leadership of UNESCO in the framework of WWAP (World Water Assessment Programme).
Here we look to the 2009 report, *Charting our Water Future*, drawn up by the 2030 Water Resources Group, a consortium of companies -largely private- from diverse and important sectors in the world economy.
[2] Makonnen and Hoekstra, 2011.

thermal (coal and fuel) power stations or for biofuel production. Recently, the forecasted decline in fossil fuel reserves has led to a notable increase in energy prices.

Hydroelectric power production, along with other sources of renewable energy, is expected to increase by 60% from 2000 to 2030. Even though that would only cover a small part of the total energy demand, it could have a big impact on water resources. The future development of hydroelectric power will be mainly limited by two factors: geographical and spatial capability for new production facilities –already extremely reduced in certain areas such as in the US, Western Europe and Australia, where the most suitable locations are already being used- and the economic ability to finance it, which will be the main obstacle in developing countries, including in the majority of Africa.

c) Climate change and natural disasters: Climate change affects all regions, albeit in different ways. While some face rising sea levels, others face drought. In view of climate change, if mitigation implies acting on energy production, then adaptation is the action to be applied to water. Climate change accentuates all the issues previously referred to and may also noticeably increase the risk of damage associated with floods and droughts, causing a set back to the progress and economic development achieved in many parts of the world, including in those less developed (the most vulnerable). The operating resource systems with greater regulating ability are less vulnerable to the impact of climate change on water resources.

d) Pressure on the environment (due to water stress), going beyond the point of no return in some places: The fresh water available on the earth is limited and its distribution varies considerably, largely depending on frost-thaw cycles and fluctuations in rainfall, runoffs and levels of evapotranspiration. This natural situation has been modified by human activity, which has become a main factor in causing the pressures affecting the water systems on our planet. The pressures, in turn, are the result of 5 groups of external factors: demographic, economic, technological, social and governmental, and are further accentuated by climate change. Those in the water sector, agents and users, have little ability to influence such factors.

3. TECHNICAL ASPECTS

Integrated management of water resources

The integrated management of water resources is the practice of decision-making and the carrying out of actions while considering various perspectives on how to manage water, thereby balancing environmental objectives with meeting demand.

The competition between the different uses for the limited water resources is restricting certain development activities in water-scarce areas. As economies grow, the competition for the resource intensifies, as do the conflicts among water users. A planned and sustainable water management, while ensuring environmental protection, is currently one of the main goals of European countries.

The growing political and social awareness and the lack of adequate member state policies, led the European Union to enact legislation with clear quality and environmental protection objectives, which includes the Water Framework Directive (WFD) as the main lynchpin. As such, the EU member states, which include Spain, are integrating traditional supply approaches, based on the foundations of large water infrastructures, and management strategies on demand, preservation and restoration of water resources, as well as their continental ecosystems, coastal and transitional, in the search for greater environmental sustainability. All of that, taking into account the main principles of cost recovery for water services and the "he who contaminates, pays" principle, is especially considered in the cases in which water is a production factor, compared with others of public or environmental use.

Spain has a long tradition of water resource planning. This has led to the construction of large water infrastructures, such as regulating dams, making it possible to increase the available resource to meet current demand, and flood control dams, reducing the risks related to flooding. The most frequent is the creation of regulating reservoirs, which also collaborate on flood abatement with particular protection.

Regulating dams include those for consumptive use, mainly urban irrigation and supply, and those for non-consumptive use, the most well known of which is hydroelectric power production. The most common situation is that reservoirs provide for several different water uses, although there are cases of exclusive use. For example, dams that are exclusively used to create falls for energy production.

Lastly, it is worth mentioning the reservoirs with reversible hydroelectric use, of which some are not in the river network, given that their importance as renewable energy regulators, rather than hydraulic, could gradually increase. As such, these sources could contribute to better integration in the production of electricity.

The task of making resources available and meeting demand and environmental requirements is especially complex and difficult to achieve in regions with greater shortfalls in resources and more significant droughts. In these regions, the environmental flows in water management entail an additional challenge for years to come. The majority of current river basin management plans, of which the content and drafting method was regulated under the Water Law of 1985, were approved in 1998. The aim of the plans is to assign available resources to water demands, order the use of the resource and to fulfil the quality water objectives, which were fundamentally established in accordance with end water use, from a physicochemical perspective. Water plans are currently been reviewed and extended to also include as their objectives the requirements of quality, from an ecological perspective, and water body protection, originating from the Water Framework Directive.

Managing extreme events: droughts and floods

Water is a strategic resource in the economic, social and environmental development of a territory. However, water scarcity and droughts are factors that determine that development, as reflected in the international water policies, and particularly in the European and national ones. Furthermore, both factors can be made worse by the effects of climate change, which involve additional pressure on the areas with greater water stress. The role of dams and reservoirs is key if water availability in those regions is required to be increased. However, the analysis of their impact on the environment, aquatic ecosystems and corresponding territories is also important.

A European Commission communication in 2007 to the European Parliament and Council called *Addressing the Challenge of Water Scarcity and Droughts in the European Union,* regarding the issues relating to water scarcity and droughts, has given rise to different technical and political initiatives aimed at mitigating their impacts. This communication states that saving water must become a priority. It also lists possible measures to address water scarcity and droughts, and recommended moving from a crisis management approach, to one of planned management. How to sustainably produce more with less water is one of the biggest challenges we face. It stresses the need to establish regulatory mechanisms of supply and demand to reassign available resources and to foster more efficient use and fairer access.

As mentioned in the previous section, the management approach integrated with that used in the river basin plan, considering resources, environmental objectives and demands, will give rise to alternative proposals and to the selection of measure that will help to achieve environmental objectives, while maintaining an adequate level of demand fulfilment. The availability of new reservoirs, the adaptation of current ones and the construction of new interconnected infrastructures, as well as those that help to optimise their operating, are elements to be considered in establishing alternatives which must be analysed under the framework of the river basin plan.

This general level of planning must be complemented with another more detailed one in the plan of management, which envisages how to detect a drought and how to manage the infrastructures set out in the river basin plan in such extreme situations. This level comprises two special action plans in alert situations and temporary drought, already drawn up for all inter-community boundaries in Spain.

Floods are an extreme natural phenomenon that can cause major disasters throughout the world while rejuvenating ecosystems, acting as biodiversity controllers. In

Mediterranean regions, and particularly in Spain, the proportion between the maximum daily rainfall and the yearly average has become greater than one, which points to a high degree of temporary rainfall concentration and leads to the relation between extraordinary and ordinary river flow being much greater than in other European regions. The effect that reservoirs have on the abatement of flood flows is important in those territories where the pressure for land use is extremely high.

The current policy on flood management in the EU is established in the European Directive on floods. Its main aim is to reduce the risk of damage and the negative consequences arising from floods on health, human life, the environment, cultural heritage, economic activity and infrastructures. The flood risk management plans form an essential instrument in meeting those objectives.

This type of plans has traditionally used structural measures that involve construction works, including flood control dams, and work on training and flood propagation mechanisms. The floods directive establishes that programmes of measures of flood risk management plans will include the structural measures put forward and the cost-benefit studies that justify them.

In recent years, other measures, known as non-structural measures, have also been used. These measures do not act on floods per se, rather on reducing or easing the damage they cause by means of a policy of management and not construction. Flood prevention and alert systems such as SAIH (Automatic Hydrological Information System), which have been developed in Spain since the late 1980s, complement those measures and appear rather interesting. Those systems provide information on diverse elements, including on flood control dams, which transmit information in real-time through different sensors, facilitating the analysis of the effects of the particular management of its spillways on flood flows. The joint application of both structural and management measures is a big challenge, especially in countries such as Spain where the risks of damage due to floods are extremely significant.

Managing risk and uncertainties: preventive and precautionary principles

The increase in the greenhouse gas concentrations in the atmosphere, as a consequence of industrialisation and deforestation, and the subsequent effects in atmospheric variability are not comparable with the historical dynamics of climate variability. Climate change brings unknown risks in temporary periods and unprecedented uncertainty.

Environmental policies, whether of international or nation scope, are guided by the prevention principle; in other words, pay the costs to avoid environmental contamination and deterioration, taking action ex ante to reduce environmental damage. This principle has been bolstered by Directive 2004/35/EC of the European Parliament and Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage, transposed into Spanish Law on Environmental Liability [*Ley de Responsabilidad Medioambiental*], which compels the return of damaged natural resources to the state they were in originally and the settling of costs relating to prevention or remedy actions.

Furthermore, society faces an ever-increasing number of very different unpredictable and incalculable risks, capable of causing catastrophic damage. The Precautionary Principle is the approach that helps to incorporate the most profound uncertainties into risk assessment and management. Precaution refers to the aim of protecting human health and the natural environment from those potentially dangerous damages, including in cases in which scientific evidence is uncertain or inconclusive. For that reason, the majority of international agreements on food security, health and the environment -including the United Nations Framework Convention on Climate Change - recommend it be included in decision-making.

With regard to dams and reservoirs, it is now worth considering the consistency analysis of the current designs and those expected in the future, taking into account aspects such as the hypothetical change in contributions arising from climate change, as well as the analysis on demand sustainability.

The estimation of risks relating to the security of dams is especially significant. Identifying tolerable risk levels and establishing comprehensive security management programmes is crucial.

Research, development and innovation

Reservoirs have traditionally been considered as waterworks for resource regulating and flood abatement. With the incorporation of new environmental objectives into European legislation, reservoirs are also identified as bodies of water that must have good status or ecological potential. Furthermore, they must not cause effects that lead to a deterioration in the status of such water bodies.

The growing complexity of problems relating to water requires an ever-greater need for research in this field. Research programmes, both national and international, comprise questions relating to the integrated management of water resources, water planning, pressures and impacts on bodies of water, etc. It is worth highlighting, from a general perspective, the need to progress in the development of models that help to integrate the water issues of resource assessment and system simulations regarding operation, which have practically been resolved, with those of physicochemical and biological quality (efficiency assessment of the measures) and economic (cost of the likely applied measures, which includes dam construction), along with the power to select measures that lead to the most effective fulfilment possible of the established objectives.

In particular, with regard to dams and reservoirs under the water planning framework, it is worth mentioning the following lines of research, development and innovation: the assessment of dam and reservoir risks; task of dams in systems of alert and flood prediction; analysis of the possible barrier effect on the migration of fish species;

retention analysis of reservoir deposits and their impact on the corresponding river, coastal and transnational waters; proliferation of invasive species; effect of dams on the hydromorphological and ecological status of water bodies; adaptation of security regulations; and the recovery of action-related costs, etc.

4. ECONOMIC ASPECTS

There are two fundamental factors:

a) Water for development: The economy influences water planning and management to the extent that it becomes a scarce resource requiring investment to make it available to users and to maintain the quality. As such, the type of investment that should be undertaken (cost-benefit analysis), who should finance it, who should contribute to the recovery of such investment and how, must all be considered.

b) Efficiency in the use of water: Up until a few decades ago, water was considered an unlimited natural resource in which economic science played no part. However, as water use has increased and its scarcity pondered, economic instruments are being seen as a way of fostering the efficient and responsible use of water by users.

The need for supply and sanitation is still extremely important in the world, requiring major investment in order to be carried out. It is essential that the analysis of this investment is not limited to direct benefit; seeing the avoidance of damage in developing countries, especially regarding social and health issues, as a benefit, is indispensable.

The fact that water (wholesale) requires large-scale investment, which subsequently meets different objectives and affects numerous users, must be borne in mind. However, the cost of wholesale water (regulation and transport) represents a small percentage compared with the total cost of water services for different uses.

We can also consider two big groups of water usage. Firstly, public service uses (urban supply, environmental services, etc.) and secondly, uses of water for production purposes and those that generate economic benefits, arising from the private use of a common good.

Society can opt to maintain water as a free common good in any territory and situation[3]. In this case, the State, as representative of all citizens, must take charge of investment and the fixed and variable costs of the water system, dividing among all citizens the finance and cost requirements.

Therefore, this solution is possible, albeit with many issues. It evident that if water is provided free of charge, without any transparency as regards incurred costs, it is very difficult for an adequate resource management system to exist, which is solely motivated by the desire to better control public spending. It would surely lead to an over-use of the resource, giving rise to new investment and cost demands.

As such, the logical thinking of a microeconomy deems that the efficient use of water entails the recovery of costs incurred from the production, transport, storage, transformation, distribution and return, as well as the possible external costs associated with those activities. In this case, it seems that the idea that water provided by nature has no cost whatsoever, as it only involves recuperating the additional costs needed to efficiently reach consumers, companies, public authorities and homes, is still held.

The financial sustainability of water infrastructures, and dams in particular, must be a fundamental factor in the new cycle of planning, not just in rationalising and prioritising new investment, but also in the maintenance needs of the current facilities.

In the particular case that we are addressing, and under the concept of sustainable development that has to be pursued regarding the purposes of dams and reservoirs

[3] Echoing professor Emilio Fontela (2000): "*Economic science in light of water issues" [La ciencia económica ante la problemática del agua*]. A paper presented at the 6th International Water Economy Conference: Towards a better management of water resources, held in Valencia.

(the management of current ones and those in the life cycle of new initiatives), we will have to bear in mind a number of issues that will now be looked at.

The role of reservoirs in Spanish economic activity

Regarding jobs in Spain, set out in the White Paper on Water (MMA, 2000), only a small fraction of total natural resources (110,000 Hm^3/year), around 7%, could be used in meeting the different water needs if the natural system is not artificially altered. As a result of the regulatory infrastructure constructed in Spain during the twentieth century, and particularly in the latter half, a significant increase in useable volumes, which now sits at around 36% of natural contributions compared with the aforementioned 7%, has occurred.

This change evidently favours the development of the country's economic activity. However, conducting an analysis that quantifies and assesses said contribution in terms of the GDP is still pending.

Although some global figures are starting to emerge, a thorough assessment and calculation of the value of water assets in Spain is still pending. This would also help to adjust an estimation of the investment required to maintain them. The need to improve knowledge in this field and to accordingly apply the necessary economic resources to keep this service, which is of utmost importance to our country, is clear.

Financing and investment in the water cycle

Water is one of the factors in economic growth, along with energy, materials, capital, employment and technical progress. In numerous macroeconomic models, the role of energy in economic growth has been identified and quantitatively estimated, but that has not been the case with water. This is probably due to the lack of aggregated information on the production factor or that it has been considered as non-economic property.

However, a simple examination of the economic reality in our time is sufficient to detect the importance of water in growth processes: the richest countries on the planet have an abundance of available water and they use it; while many poor countries suffer from shortfalls in drinking water and witness desertification processes.

All the activities relating to water, whether from a structural perspective (water infrastructures) or otherwise (planning, obtaining data, legislation and regulations, education and training, etc.), require money in order to be carried out and finished. Having sufficient funds and the willingness to invest in water management and infrastructures have become one of the main determining factors in making the sufficient quality and quantities of water available. Although it may appear that there are many options available for financing the development of water resources, governments still have only three basic financing methods: rates, taxes and help from international cooperation and philanthropic donations.

Investments in the water sector are frequently characterised by not aligning economic and financial sustainability. This is because there is no big time-lapse between the application of funds and the recovery of profits, despite the fact that economic profitability is guaranteed, which makes financing difficult, especially with a short-term vision.

Investment in waterworks can contribute to averting future crises. Making water available to meet the human right of access to water, improving its availability and fostering sustainable development are essential. On the one hand, an increase in the availability of the resource (thanks to its storage, treatment, piping, desalination, reuse and regeneration) and, on the other hand, the efficient guarantying of its use and return in a sufficient condition to protect the quality of the resource via sanitation and purification are required.

Furthermore, society increasingly demands greater safety, which is reflected in laws and regulations, entailing further costs to reduce the risks of dam malfunction and failure, and affect both new and current infrastructures. Awareness of the cost of those safety actions, the space-time prioritisation and the method of user recuperation, are extremely relevant issues that must be considered in water planning and management in the forthcoming years.

In light of those considerations and of the experience acquired, investment in dams may be considered one of the investments that yield significant medium- and long-term returns, given their extensive life span and the resource availability they guarantee. However, economic resources currently used for dams fall very short of those needed, in both developed (where maintenance and renovation of water assets, which are very old, have been neglected) and developing countries (in which growth will be determined by the availability of water for primary, secondary and tertiary processes).

Financial investment and collaboration mechanisms between the public and private sector must be considered and initiated. This may, under public control and with a trustworthy and stable framework, provide management efficiency and capability, as well as resources and means that reduce deadlines in which to overcome problems.

Cost-benefit analysis of a general scope

Economic considerations regarding dams, including any other infrastructure, are of utmost importance in a context in which the competition for the application of economic resources is becoming increasingly greater. As regards dams, there are two individual circumstances: firstly, the high initial investment that is often required and that involves an extremely long life span, usually exceeding 50 years, normally considered in analyses. Secondly, in many cases, the lack of beneficiary perception regarding the service that the corresponding infrastructure provides (for instance, residents in a city know they have a supply to their home, but they rarely relate it to the existence of one or more dams, whose regulating sees to it that they receive the supply in an adequate and guaranteed condition). This circumstance does not occur in other infrastructures of which ordinary citizens are the direct users, for example, transport infrastructures.

There is still a long way to go as regards the economic calculations of water. The cost-benefit analysis requires an increasingly holistic perspective, in which there are currently issues that we can perfectly quantify with others, such as the economic value of an ecosystem, which are still not sufficiently impartial and with developing economic models that still lack sufficient verification, which cannot be considered of general application. The most expensive water is that which is not available when needed, which must give rise to assessing the cost of "no service".

The need of analysing the viability of infrastructure construction with economic rigour is obvious. To do so, a classic tool is available: the cost-benefit analysis. It has been used with diligence in recent decades and has helped to assess projects through objective indicators, such as the Net Present Value (NPV) and the Internal Rate of Return (IIR). These indicators comprise an unquestionably useful element in valuating rationality in a specific project from an economic perspective, as well as in prioritising different projects.

The difficulty of cost-benefit analysis lies in the fact that all the elements of cost and benefit must be considered, which means translating them into economic quantitatives, a task in which there is no current agreement, albeit there are case studies in which this issue has been addressed[4]. The difficulty is in the need to carry out a global cost-benefit analysis, which exceeds the initial approaches that only considered investment and maintenance costs, as well as the easily assessable direct

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[4] Some relevant references:
Louise Korsgaard & Jesper S. Schou (2010): Economic valuation of aquatic ecosystem services in developing countries. Water Policy 12 (2010) 20–31; Allen Blackman & Richard T. Woodward (2009): User Financing in a National Payments for Environmental Services Program Costa Rican Hydropower. In: Resources for the Future - RFF DP 09-04; Marvin Feldman with John Loomis & Water Resource Consultants (1999): A Cost-Benefit Analysis of Flow Alternatives associated with Pacific Gas & Electric's Rock Creek-Cresta Project Relicencing; Jared Hardner, Somony Thay & Heng Chhunhy (2002): Living with the Mekong River Flood: Economic Perspectives. Report for WWF; E.J. Leguía, B. Locatelli, P. Imbach, C.J. Pérez, & R. Vignola (2008): Servicios ecosistémicos e hidroenergía en Costa Rica. In: Ecosistemas 17 (1): 16-23. January 2008; Charles Gowan, Kurt Stephenson & Leonard Shabman (2006): The role of ecosystem valuation in environmental decision-making: Hydropower relicensing and dam removal on the Elwha River. In: Ecological Economics 56 (2006) 508– 523.

and indirect benefits. Costs regarding investment, operating, maintenance, replacement, as well as those associated to the construction of the infrastructure as regards third-party implications and to the environment, may be taken into account. Benefits deriving from the existence of reservoirs and those generated by the implementation of recreational activities associated with them, as well as environmental benefits from the creation of wet areas, and benefits that may lead to the creation of an activity that provides for population settlement in the territory, may also be considered.

Likewise, in the context of atmospheric emissions control, it is advisable to take into account the analysis of the life cycle relating to this concept, linking with it the cost-benefit analysis. In other words, the emissions necessary to construct a dam and the emissions avoided must be quantified.

The application of the cost-effectiveness analysis over the cost-benefit analysis has been proposed in recent years, perhaps as a result of the provisions under the Water Framework Directive. The cost-effectiveness analysis is undoubtedly a tool of great value for finding the combination of actions that helps to achieve set objectives with less cost. However, it should be borne in mind that this fact does not ensure economic viability. In that event, verification on whether the costs are acceptable or disproportionate would need to be carried out. This would mean, to an extent, carrying out a cost-benefit analysis on said actions. In other words, they are complementary and not replacement tools.

In Europe, new trends assessing the practical application of the 2000 Water Framework Directive and its "offspring" are emerging. The European Commission wants to encourage the involvement in river basin management plans of elements regarding the status, quantitative via balances between resources and demand, how it is progressing and how new tools are being implemented that help to quantify benefits and costs in the most adequate way.

Recovery of costs

Different schools of economic sciences do not dispute water as a free common good in nature. They largely differ on the role of the market and planning in managing the economic supply and demand of water; in other words, that which is established in situations of scarcity over time and space.

A differentiation must be made between water as a human right, which under no circumstance can be subject to economic patterns and constitutes a compulsory public service, and water as a factor of production, in which the need to lean towards cost recovery is manifested.

Some water management principles, which directly influence economic sustainability, are generally accepted. They can be summarised as transparency and efficiency in governance. Transparency involves indentifying beneficiaries, distributing the costs among them, and not incorporating the costs that do not correspond to the water sector. Efficiency in governance seeks to reduce the costs to recover.

Regarding recoverable costs, it is evident that there is no obligation to recover 100% of costs, neither in European legal framework, nor in Spanish legal framework. Spain already has a cost recovery procedure, although it falls short of 100% recovery. In any case, it must be taken into account that water is free; recoverable costs refer to those necessarily incurred in order to provide a service and make water available to users. The recovery of costs requires a guarantee and a level of adequate service; only in that way is it possible to generate a positive upward spiral that assures the financing of the sector.

Estimates provided, regarding the revenue received by the Administration that is directly associated to water management (regulation tax, rate of water usage) and the average expenditure on water of a Spanish household (supply), suggest that there may be margin to increase the degree of cost recovery, albeit it must adjust according to its impact on different sectors.

The neo-liberal school justifies the adoption of market mechanisms and the role of prices to balance supply and demand in the context of overall equilibrium, which ensures the best citizen well-being. In the case of water, the different alternative schools, evolutionists and institutionalists, see situations that favour greater regulation by the State on water production, transport and distribution mechanisms.

In this regard, the different elasticities regarding the price of water and the consequence of the integrated recovery of costs on social and environmental aspects must be taken into consideration. It is evident that those elasticities will depend on the technical possibilities that exist to reduce consumption and loss, as well as the substitution possibilities.

To use the price of water as a management instrument, it is essential to adjust the estimation models of demand elasticities, which take into account the possibilities of substitution and economy in specific consumption. It is appropriate to have models, when planning public spending on new water infrastructures, which explain the relationship between water and economic growth.

Water consumption for physiological functioning is obviously very rigid, as it is dictated by natural laws. The remaining water uses by the population are rather more flexible in terms of price. In this case, the price can be used as an instrument for reducing consumption.

The water economy must support the proper operating and selection of activities, looking to the desirable scenario of "water financing water", which leans towards cost recovery, and apply the principle of "he who contaminates, pays". As a result, water demand will be contained, and environmental costs and the resource of those who enjoy private water usage to obtain an economic benefit will be internalised. However, these considerations must not be applied when they could restrict actions used to obtain the resources for water as a human right, or the consumption needs to reach a minimum level of social development in disadvantaged places.

5. SOCIAL ASPECTS

The social impact of reservoirs

The construction of a dam, the corresponding reservoir, the land changes it entails, and the subsequent and significant modification of the environment, all have considerable impacts on society. It is necessary to be aware of both the negative and positive impacts to adequately manage them.

Impacts include those on the population, its health and well-being, its social structure, its productive activity and the natural resources associated with it, its access to infrastructures and social services, as well as impacts on cultural and traditional resources, including relationships with the environment (landscape).

Among the positive impacts, we find the very development of the reservoir, the meeting of energy needs - if applicable-, the supply of water, irrigating agricultural production, flood control and the emergence of leisure and recreational activities, etc.

However, there are negative impacts that include the displacement of populations, which are often particularly vulnerable, limited resources or specific cultural features (indigenous). Historically, around 40-80 million people have been displaced by dam constructions.

The flooding of fundamental resources for production activity and the destruction of cultural resources, infrastructures and social services can also occur. Due to the geographical distribution of those affected, resources contribute to inequality in terms of the benefits of people who are better off, more widespread and further away, and those who are at a disadvantage, closer and local.

The transformation of the landscape itself is an impact that we must consider, although it is not always negative, as the emergence of sheet water in certain environments can significantly improve the environment. Adequate consideration, with care and without obstruction, of the different repercussions of change will need to be undertaken. The same applies to the discontinuance of a river, which generally affects species in a negative way, but it may also have repercussions on the flow of materials, changing positively or negatively sediment dynamics.

Finally, the alteration of the water system and quality of the resource (repercussion on current uses), and the consequential alteration of the relationship that a population always has with a river and the land must also be considered.

All of that leads to the possibility of social disputes based on perception, whether real or not, of the imbalance between the benefits of a project and the costs on society and nature. Disputes may also include mistrust amid promises of compensation, mitigation of environmental impacts, uneven geographical distribution of positive and negative impacts, and disputes between those benefited and those affected.

For that reason, it is increasingly important to act before disputes arise, or at least before they become serious and widespread. Disclosure, participation and agreement from the beginning of a project, along with the social and environmental cost-benefit analysis and the search for balance between development and global social well-being, as well as effective compensation to directly or indirectly affected local communities, are fundamental elements.

Solidarity and fairness

Water is a vital resource. However, its availability is limited by scarcity and its rather uneven distribution. One of the most important UN Millennium Development Goals is ensuring the supply of quality water to every person on the planet.

In Spain, the rainfall distribution among the different regions, which is very irregular, and its seasonality must be taken into account. Furthermore, the period with the greatest water demand also happens to be that with the least rainfall; and the regions with the greatest water requirements are also those with the biggest shortfall. A clear example of this can be seen in the summer tourism of Andalucía or the fruit and vegetable production in the Levante area, where such development can be limited by the shortage of water. If we add to all of that the expected temperature increase and rainfall decrease due to climate change, which will greater affect the most vulnerable territories, water will increasingly become more limited.

The foregoing emphasises the need to carry out an integrated and sustainable planning of water resources, which bears in mind the needs of all regions and the uses of water, while also establishing water solidarity and fairness throughout the territory as one of its goals. Specifically, the drawing up of Article 45.2 of the Spanish Constitution supports indispensable joint solidarity to achieve the rational use of all natural resources with the aim of protecting and improving quality of life, as well as protecting and restoring the environment.

The interpretation of fairness, as a general principle in water planning, may depend on its territorial acceptance or on the principles of users. The first entails the planning of water infrastructures in such a way that the allocation of flows among different regions contributes to reducing the differences in the income and quality of life in fragile rural areas, developed rural areas and urban areas. The second implies that the balance between different user groups must be maintained so that the benefits of some do not negatively affect others or distort the markets.

Specifically, dams and reservoirs play an extremely important role in the regulation of water availability, guarantying the supply in summer seasons and in times of drought, when need is higher. The future water needs that regional socioeconomic development may bring and the differential distribution of social impacts, ensuring that negative impacts, or positive impacts arising from infrastructure construction, are not always felt by the same people, must be considered in dam planning processes. Furthermore, the principle of fairness is fulfilled if, for example, dams improve the quality of life of the most disadvantaged members of society or if those relocated have and wish for better financial and social conditions in their new location.

It is increasingly clear that the current situation and feeling point to the need to principally address social rather than technical issues: it is extremely necessary to communicate the situation, problems, possible solutions to water issues (with international scope, not just in Spain) to society with clarity and transparency. There is no doubt that well informed participative planning is an adequate, globally recognised method of fostering those processes. Education and communication is required.

Public participation

Water management in Spain was established by the creation of the Hydrographic Confederations (first third of the 20th century). From then on, it was recognised that water management must be participative. After the enactment of the Water Law of 1985, public participation began to become institutionalised through the planning and management bodies of the Hydrographic Confederations: Operation Boards, Reservoir Withdrawal Commissions, Assemblies of Users, etc. In 1991, the National Water Council was founded, a participative institution representing the General State Administration, Autonomous Regions and the Basin Organisation, as well as national-based professional, economic and ecological organisations and local authorities. The Water Councils in each river basin are other public participation bodies.

On an international scope, the current conception of public participation in environmental matters arose and became widespread with the 1992 Rio Declaration and, subsequently, the 1998 Aarhus Convention was developed.

In Europe, the Water Framework Directive (WFD) has brought significant progress as regards public participation, ensuring that it forms part of water planning through public information and public consultations, fostering the active participation of all interested parties.

In Spain, Law 27/2006 of 18 July governing rights of access to information, public participation and access to justice regarding environmental matters, as well as the Law of Water, approved by Royal Decree Law 1/2001 of 20 July with the Water Planning Regulations, fully provide for the requirements of the WFD in their articles and establish the public participation committees and bodies of the river basin districts. The field of public participation covering all interested parties and not just users has been broadened.

The aim pursued is that all groups of interest, from governmental institutions and user groups (agricultural, industrial, etc.) to civil society (citizens and their non-governmental organisations) are involved in the process to jointly reach the best possible solution in considering all points of view on the matter. Members of the community are the ones who best know the local environment and their socio-economic conditions. As such, consideration of their opinions and ideas is a good resource in improving the efficiency and quality of final decisions.

Public participation in the planning process under the Water Framework Directive must ensure three levels of public involvement, namely: a) public information, b) public consultation, and c) active participation, which entails not only the most traditionally interested parties, but also a wider and more diverse representation of the interests of society in decisions regarding water planning. The Water Framework Directive requires that the first two levels are guaranteed and the third fostered.

Public information comprises the supply of information to citizens through different means, such as Websites, paper documents in offices, Public Information sessions, informative publications, leaflets, etc.

Public consultations include a 6-month consultation process and the integration of input regarding each of the following documents: the, • Programme, schedule and consultation forms; • General study on the river basin district; • Public Participation Project; • Provisional outline of important Topics; • River Basin Management Plan (including the adaptation of the Special Drought Management Plan [*Plan Especial de gestión de Sequías*]); • Flood Risk Management Project Plan [*Proyecto del Plan de Gestión del Riesgo de Inundación*] (in this case, the consultation lasts 3 months), and •

the Strategic Environmental Study [*Estudio Ambiental Estratégico*] and the Flood Risk Management Plan [*Plan de Gestión del Riesgo de Inundación*].

Finally, active participation entails the active involvement of interested parties by means of bilateral meetings, sector-based committees, sessions, etc., during the whole planning process.

In this sense, and so public participation is fruitful, there are three core elements that drive the process: will, ability and knowledge. Regarding "will", the involvement of the administration and people who truly want to open those participation processes and participate in them is required. "Ability", so those well-established channels are formed and provided with real means and opportunities. "Knowledge", clear and transparent information has to be given, as they are complicated subjects, generating knowledge of the debated topics.

Reaching agreements requires will. In the process, it is necessary to differentiate purposes and means. In other words, certain means will be needed (actions), and these actions could also have alternative ones, depending on the purposes to achieve. Ultimately, given that there are many aspects to assess, advising and professional scientific and technical knowledge are needed for these processes to be fruitful. These services must be made available to the general public so adequate decisions can be made in the participation processes.

State legislation compels water plans to be subject to a Strategic Environmental Assessment to justify that the alternatives chosen are the best of those available. Furthermore, before undertaking the construction of dams and other facilities destined for permanent water retention or storage when the dams exceed a certain storage threshold, the state legislation requires that projects be subjected to an Environmental Impact Assessment. There is a public information phase in both procedures, in which interested individuals or groups can find the environmental information relating to the plan or project and submit arguments or suggestions.

Dam and reservoir projects have a big impact on society (people who are forced to move, loss of cultivation areas, effects on the landscape, etc.) and, in many cases, they are not warmly welcomed by residents in the area. A good way of reducing possible disputes that may arise in the initial project phases is to ensure that the different interested groups, which may be affected by a construction project, see that their interests are being represented throughout the planning process.

The main premises aimed at accomplishing satisfactory public communication and participation in accordance with dam and reservoir project sustainability, are: using local knowledge in decision-making; identifying the diversity of communities and involving diverse public groups from the outset; being prepared to negotiate with local communities; paying attention to local social structures; using local language in communications; ensuring sufficient available time and resources for the participation process; providing local communities with multiple opportunities to express their concerns and participate in the design and execution of the project; and, being as transparent as possible and keeping promises on agreements reached.

Public participation is fundamental to ensure the success of projects and to reduce complaints and claims that may arise throughout the different phases of the life cycle of dams. In fact, far from hindering dam construction, such participation strengthens and legitimises it when it is fair and well planned and designed.

Transparency

The principles of public participation are: 1.- Transparency of information and establishment of communication channels, 2.- Improvement of knowledge regarding needs, points of view, interested and affected party perceptions, 3.- Fostering of governance and joint responsibility in defining water policies, 4.- Reaching satisfactory agreements and solutions, overcoming possible disputes, and 5.- Educating and informing citizens regarding topics related to water management.

The principle of transparency involves making information openly available, as well as it being comprehensive, clear and traceable. The transparent planning and management of water resources entails that users have easy access to the information they require, which may contribute to increasing the trust and credibility of the responsible bodies among citizens.

Dams and reservoirs have a decisive impact on the local population and its lifestyles, influencing the economic, demographic, institutional, political and the socio-cultural processes of communities. It seems clear, regarding the influence of projects and criticisms from those opposed to the undertaking of waterworks, that clarity and transparency in decision-making processes, along with a continuous demand from interest groups, are fundamental.

As such, it is essential to clearly and reasonably represent the whole process so everyone can understand the reasoning and method behind all the decisions that have been or will be taken.

Furthermore, taking the water debate to dams and using social media to reach out to the large part of society are also required. In fact, it is surprising that even though Spain has a broad regulative framework and that so much effort is occasionally put into public participation, that water infrastructure, dam and reservoir debates often fail to finally make it into society.

On the other hand, it is also true that there is no good protocol on how to carry out positive subsequent actions when social impacts occur. These guidelines, lines of action to be followed, should be clear and made known to the public to guarantee honesty, transparency, fairness and distributive justice in the process. They open up channels to models of rural development, attending to the part of the population that we do not always consider, and provide for a strategic environmental assessment and compensation measures that are participated in and agreed to by those affected.

Furthermore, the Territorial Restitution Plan [*Plan de Restitución Territorial*] that every reservoir has, must not become outdated over time. It must suitably reflect the main dam or reservoir work so that those affected are timely compensated (and not when production activity has ended and or when there is no ability to remain in the territory). If time is allowed to lapse and actions are not effectively carried out, there is a risk that those who made the agreements will no longer be present and that such agreements will be reversed. This could lead to what was good news at the time, ending in failure, because disputes arise at the moment of truth.

It would be regrettable if the sustainability of dams and reservoirs were to be based on depopulation; if no-one were to be affected; if, in the end, there were no-one in the territory to oppose them.

Consolidating the credibility of national and international guaranties is necessary in order for them to become dialogue tools, meeting the costs of their application. Only transparency (and clarity) can lead to the credibility required for a satisfactory outcome of the social process.

6. ENVIRONMENTAL ASPECTS

Maintenance of ecosystems

Dams and reservoirs create and put numerous pressures on the natural environment. Consequently, their viability must be clearly justified through in-depth studies of alternatives that internalise all the costs they generate, providing evidence of their social and economic interest.

Our current regulations recognise, as priority general interests, the subjects listed in Chapter III of Title I of the Constitution, which expressly includes the protection and restoration of the environment (Article 45). As a result, Public Administrations have a mission to defend the aforementioned general interests with objectivity. They must safeguard environmental preservation and restoration, limiting the construction of new infrastructures to cases in which their need and viability is proven, as well as assessing the possibility of decommissioning dams that are no longer required, particularly those that have been abandoned.

In several construction projects of large dams, serious problems during the Environmental Impact Assessment stage have been recorded. These were due to the lack of real alternative studies and could have been overcome by carrying out a Strategic Environmental Assessment on the water plans.

Ecological flows

Flow regimes play a vital role in the structure and functioning of aquatic ecosystems.

To meet the needs of a future with efficient resources, to maintain human and economic development, as well as the essential ecosystem functions and services relating to water, an approach integrated in water resource management is required.

The Law of the National Hydrological Plan [*Ley del Plan Hidrológico Nacional*] and the Water Law establish that ecological flow regimes are prior restraints imposed on operating systems used for socioeconomic purposes. That means that those regimes are a part the natural flow that must not be extracted from or abated, and cannot be considered, therefore, as part of the regulating. The ecological flow in regulated rivers should always be respected, provided it is technically possible due to the availability of reservoir water and at least, in any case, when the reservoir receives a water intake that is equal to or over the volume of fixed ecological flow.

It is advisable to make clear that ecological flows are understood as a regime of ecological flows and that they do not refer to a minimum unchangeable flow, but are formed by different elements. These include, at least, minimum flows, the flood flow regimes and seasonal variability, given that aquatic ecosystems are diverse and dynamic, changing the composition of species and the population density. Ecological flows must reflect these changes relating to the intrinsic dynamics of ecosystems. The disturbance regime (wet and dry cycles) and the interannual variability are crucial for the long-term preservation of wetlands. The adaptation ability of ecosystems depends on a dynamic system between species, including the relationships among them, and their environment, as well as physical and chemical interactions in the environment. From this perspective, the protection of such interactions and processes constitutes a key element in the long-term preservation of biological diversity, which is much more than the mere protection of species. The preservation of the water system is fundamental to maintain such processes.

The Water Framework Directive establishes that Member States must implement measures to ensure that the hydromorphological conditions of bodies of water are consistent with the achievement of the required ecological status or good ecological potential for bodies of water designated as artificial or heavily modified. However, the EU neither has a definition of "ecological flows", nor an agreement on how they should be calculated, even though both are necessary requirements for coherent application.

In this context, the European Guide on Ecological Flows has emerged. Although it is not binding, it does provide clarification and recommended "Good Practices". It also defines ecological flows as a flow regime consistent with the achievement of the environmental objectives of the WFD, that is, the good ecological status or potential of surface water bodies (rivers, lakes or transitional water) and connected water bodies, as well as the good quantitative status of groundwater (when groundwater levels depend on the discharge of surface water bodies) and preservation of related protected areas, including the habitats and species in the Birds and Habitats Directives.

Cases have been detected in which the spillway elements of dams do not allow, with the due safety precautions and guarantees, the established ecological flows to be released. In these situations, the spillway mechanisms should be adjusted as necessary.

The implementation and maintenance of ecological flow regimes entail two economic costs. On the one hand, there is an effect on the use of water prior to their implementation. On the other hand, other costs arising from infrastructure management and adaptation to facilitate their release can be identified.

Climate change

It is essential to also consider the role of dams and reservoirs on a global scale and in the context of climate change, regarding both the mitigation of and adaption to it. If we lose that global concept, including on a planetary scale, of what is happening to us regarding natural resources and our reality, such loss of perspective could lead us to make the wrong decisions.

In view of the damage and loss that climate change may cause, reservoirs can play an important role regarding adaptation (water reserve, security amid floods, etc.) and mitigation (reduction of GHG emissions).

Climate change could entail a significant fall in water resources, especially in the most vulnerable territories. Dams and reservoirs can play an important part in adapting to said scenario, as it is evident that the systems with the greatest regulation ability better resist the effects of climate change, providing a greater response and resiliency ability.

Furthermore, amid the extreme weather phenomena that are likely to become more frequent due to the effects of climate change, dams and reservoirs reduce the impacts caused by floods and droughts.

As regards mitigation duties, land flooded by reservoirs releases a significant amount of methane gas (CH_4), one of the main greenhouse gases (due to the fact it has 25 times more impact on global warming than carbon dioxide), produced by three main sources: vegetation prior to flooding, native organic matter and non-native organic matter (sediment carried into the reservoir), although variable depending on many factors, such as the latitude and age of the reservoir, and biological factors, etc.

Additionally, the electricity generated thanks to the existence of reservoirs is of zero direct emissions. Due to the operating of electricity generating systems in Spain, hydroelectric power production is replacing other technologies that have higher rates of emission (usually an ordinary thermal system) and that contribute more to global warming.

When comparing both factors, the CO_2 emissions released by reservoirs is a small part of the total atmospheric emissions that Ordinary Thermal Systems would generate to produce the same amount of electricity as hydroelectric plants. Furthermore, reservoirs usually fully compensate regarding direct emissions and also avoid releasing a significant amount of CO_2 into the atmosphere.

In fact, Hydroelectric Plants can be seen as Clean Development Mechanisms (CDM), considering the density of the energy capacity (the capacity of installed electrical power divided by flooded surfaces W/m2) and without taking into account the net balance of carbon. Under these conditions, assessing the carbon retained in sediment, as organic or inorganic matter processed by reservoirs and predominantly brought by tributary rivers, the CH_4 emissions produced by the breaking down of organic matter and the balance of land ecosystem carbon substituted by flooding produced by reservoir constructions are necessary.

In this type of operations, it is essential to never overlook the considerations of non-fulfilment that have been given, on occasions, with regard to respecting human rights in certain countries, and the devastating environmental and social impacts, including the destruction that has occasionally taken place of carbon sinks (in the Amazon, for example). This undoes the final positive outcome the project could have had in just considering reservoirs themselves. This is the loss of the sustainability perspective, considered the necessary equilibrium among all the elements, and the perspective of not focussing on one of them.

However, the great potential that dams and reservoirs have, in view of climate change, regarding the mitigation of and adaptation to the new scenario which seems, to a greater or lesser extent, to be inevitable.

Continuity of the river resource

Practices carried out on rivers throughout the twentieth century have led to a very significant morphological deterioration in flows. So much so that in Spain it is difficult to identify rivers that are not seriously affected by problems of continuity, both transversal and longitudinal.

The breaking of river continuity is one of the most evident effects of dams and reservoirs. Thus, only a smart part of the many current transversal barriers in Spanish river basins are unpassable, whether under or over, for fish. That adds to the change in the lotic system of the very river by the lentic ecosystem of the reservoir, causing water to rise above the dam, which benefits the establishment of different fauna and flora, occasionally exotic and even invasive, in the section of river.

The transport of sediment material via suspension, saltation or rolling is an integral part of the natural flow of rivers, and vital for its morphological evolution and development. As a result, dams should facilitate the movement of this sediment. When that is not technically possible, the water Administration, responsible for protecting public water, may foster its artificial transporting by occasionally depositing retained sediment in the water downstream from the dam, favouring the liquid flows needed to adequately move it. The inclusion of costs from this activity in the infrastructure operating costs should be studied.

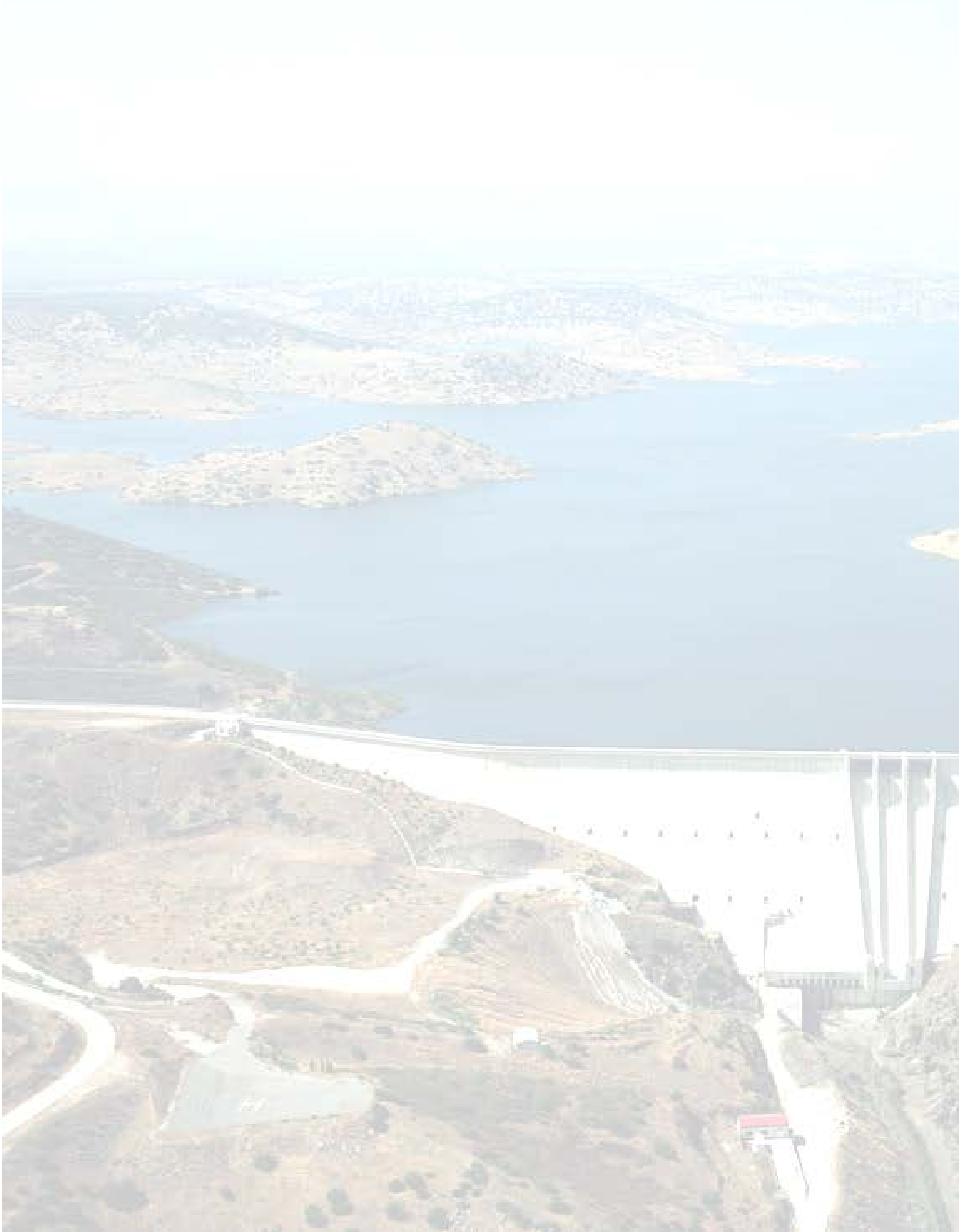
Reservoirs are barriers, often total barriers, to the continuity of rivers. The authorising of compensatory measures for this purpose on flows, sediment and biota should be considered.

Reservoirs and dams have a purpose while they provide a service. Nevertheless, when they stop providing this service, in such case, there should be no fear in considering their removal. However, it must be stressed that decommissioning them is a complicated matter in which detailed assessments must be conducted considering the pros and cons. This is because it is not a matter, in many cases, that is sufficiently developed and because the situation in each case may be different.

For those reasons, it is worth distinguishing between small diversion works and large dams. In the first case, check dams, which stop river continuity, are perhaps the most common and easiest to remove when they stop providing their service. As for large dams and reservoirs, in which the operation is more complicated, given they normally - except on rare occasions - continue in service for longer periods of time, their decommissioning requires a more detailed and complex study. After the study, whether to remove them or not must be addressed because - even though it is true that they can improve the balance regarding heat, dissolved oxygen, availability of light and nutrients, ability of longitudinal displacement of migrating fish, moving and transporting of sediment downstream, river morphology, and the physical and biological relationship between rivers and banks - they can also have negative effects, including: contaminating water downriver from dams, reduction in the availability of physical fish habitats, elimination of wetlands, loss of species of recreational interest (fish), and the expansion of exotic fish and the reduction in aquifer recharge.

Furthermore, according to nature and the use of dams considered, we could see numerous risks when contaminated sediment, large deposits of sediment or other factors that move toxic substances exist.

As such, the decommissioning and even the eventual demolition of some of them must be carefully considered, along with the numerous less drastic alternatives, following assessment, which are available to us today.



Technical Committee "Engineering activity in planning"