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National Water Reserves Program in Mexico.

Experiences with Environmental Flows and the Allocation of Water for the Environment.

Water and Sanitation Division

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Abstract

Mexico faces overexploitation of water resources in the country's major economic productivity areas. This situation is causing a loss of biodiversity, limiting economic development and making society vulnerable to the uncertainty of climate change. The allocation and recovery of water for the environment is proposed as a means for climate change adaptation and the attainment of water security for Mexico. This process is based on the enforcement of the Mexican Norm of Environmental Flows *(NMX-AA- 159-SCFI-2012)* in 189 basins with potential water reserves for the environment and the establishment of an equal number of water reserves that would preserve 97 natural protected areas and 55 wetlands of international importance (Ramsar). This document records the experiences and results of the program's conceptualization phase and the start of the process with its implementation in six pilot areas. Given its relevance, this initiative has taken shape as the National Water Reserves Program, coordinated by the National Water Commission's General Office for Technical Affairs, with the collaboration of the World Wildlife Fund-Gonzalo Río Arronte Foundation Alliance, and the participation of the National Natural Protected Areas Commission and support of the Inter-American Development Bank.

Acronyms

CBD	Convention on Biological Diversity
CFE	Federal Electricity Commission
CONABIO	National Commission for Knowledge and Use of Biodiversity
CONAGUA	National Water Commission
CONANP	Natural Protected Areas Commission
DECE	Assessment of Environmental Flows Document
EIM	Environmental Impact Manifests
FCS	Carlos Slim Foundation
FGRA	Gonzalo Río Arronte Foundation I.A.P.
GAS	Subterranean Water Office
GASIR	Surface Water and River Engineering Office
GCA	Water Quality Office
GIABA	Water Engineering and Bi-National Affairs Office
GIS	Geographic Information System
IDB	Inter-American Development Bank
IMTA	Mexican Institute of Water Technology
INECC	National Institute of Ecology and Climate Change
IWRM	Integrated Water Resources Management
MAR	Mean Annual Runoff
NGO	Non-Government Organization
NMX	Mexican Norm of Environmental Flows
NPA	Natural Protected Area
PNRA	National Water Reserves Program
PWR	Potential Water Reserve
SEMARNAT	Secretariat of Environment and Natural Resources
TJS	Technical Justification Study
UNAM	National University of Mexico
WGIS	Water Geographic Information System
WMO	World Meteorological Organization
WWF	World Wildlife Fund Inc.

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Introduccion

The foundation for water policies in Mexico is Article 27 of the 1917 Political Constitution of the United Mexican States, which establishes that water is the property of the nation and heritage of its people. The National Water Act (LAN, acronym in Spanish) is the primary set of laws related to continental waters under the Constitution and international treaties; it regulates water use, distribution and control. Its main principles establish the decentralization of its management into thirteen administrative hydrological regions, an integrated management of water resources, the participation of the private sector and the involvement of social stakeholders. The legal framework pertaining to water is comprised of laws, regulations and complementary norms, such as the Ecological Balance and Environmental Protection Act, the Health Act, the Federal Rights Act, which establishes payments and tariffs for the use of the nation's assets, and the Federal Metrology and Normalization Act, which establishes the policies for all technical norms regulating water and the environmental sector.

The great transformation in water management in Mexico began in 1989 with the creation of CONAGUA, the enactment in 1992 of LAN, its regulations in 1994 and its amendments in 2004. CONAGUA is the top federal authority for water management; originally, it was a decentralized entity of the Secretariat of Agriculture and Water Resources, but in 1994 it became an independent entity from the recently created Secretariat of Environment, Natural Resources and Fisheries (Barrios, 2013).

Water management in Mexico follows a water basins model based on 13 hydrological-administrative regions, 37 hydrological regions, 732 management units or basins and 653 aquifers. Within this context, the IWRM was developed encompassing water, land, related resources and the environment. However, ownership of water usage rights in Mexico is not linked to land ownership, and in the scope of an integrated management its influence has been very limited. Today, there is no instrument linking both resources. On the contrary, a lack of coordination among authorities overseeing land usage changes, which falls under municipal authorities, and subterranean water extraction, under federal authority, represent an important cause for the advancement of the agricultural border and overexploitation of aquifers (*Idem*, 2013).

Regarding the environment, as an IWRM component, there are a number of reasons why a specific policy to protect water required for biodiversity conservation and its environmental services has never been implemented. During the 1990's, water management in Mexico accepted the challenge of building a system to administrate water concessions by determining water balances at each basin or management unit, regularizing existing water concessions and issuing new concession titles based on available volumes. This process did not contemplate the protection of a volume of water for the environment mainly because of the lack of information and of scientifically appropriate and economically accessible methodologies to determine this volume.

Since 1995 to date, water concession titles were regularized and issued to practically all of the country's users, placing 100% of the annual mean runoff as the limit, whether measured or estimated. To assume 100% of annual mean runoff as distribution criteria for water availability at a basin represents a scenario of elevated water risk, as the natural availability will not be enough to supply the volume of water rights issued in years when precipitation is lower than average. This implies that its management will have to accommodate this deficit among all users, with its consequent social, economic and environmental impacts. It is important to mention that it is recognized internationally that a basin or hydrological system is subjected to high water pressure if water extraction is above 40% of the basin's natural annual mean runoff (EEA, 2003).

The adoption of these criteria for the distribution of water shapes a management of scarcity, high risk for users and vulnerability before the growing climate uncertainty. Without doubt, this situation has been one of the causes for the overexploitation present in the country's leading economic areas and represents strong pressure for biodiversity conservation. Presently, it is recognized that eight of these thirteen regions, where 75% of the Gross Domestic Product is produced, are found under conditions of high water pressure (CONAGUA, 2014). The other side of this overexploitation is recorded in the loss of biodiversity: freshwater fish are the biological group with the highest extinction rate in Mexico; of 500 registered species representing 60% of North America's species, 127 have been extinguished, 75 of these endemic species, and 139 are in danger of extinction (Sarukhán, J, et al., 2009). High pressure on the water resource and biodiversity loss are both sides of the same coin: an unsustainable development that doesn't contribute to build a future of water safety and resilience before climate change.

Within this context, Mexico's government, with the participation of society, has begun a process to reserve water required by the environment in the form of environmental flows. Due to its relevance in water management and biodiversity conservation, this initiative has taken the form of the National Water Reserves Program, coordinated by the CONAGUA General Office for Technical Affairs, with the support of the WWF-FGRA Alliance, and with the participation of CONANP. This program's initiation was financed by IDB via the Non-Reimbursable Technical Cooperation No. ATN/OC-12827-ME-1, National Potential Water Reserves Program in Mexico as Management Measure, and supported by the Technical Cooperation Agreement between CONAGUA and WMO through the Premia Project.

The present Technical Paper describes the idea and start of this program, its first results, lessons learned and expectations of development for the following years. To complement this description, testimonies of some of the program's participants have been inserted throughout the text, mainly of expert researchers in some of the areas of knowledge required to determine environmental flows and of experts in related topics who are familiarized with the program. These testimonies reflect their opinions, expectations and stories.

1. Environmental Flows

The concept of environmental flow, or ecological and environmental expense, which are considered synonymous for the purpose of this document, originates in the United States of America in the 1940's, but it isn't until the 1970's, with the construction of large dams, when the first systematic attempts are reported to determine the minimal volume required to maintain a river's ecological conditions (Stalnaker, 1982). Tennant (1976), with the also called Montana Method, made the first contribution of impact for the prescription of flows for fish, wildlife, recreational activities and related natural resources. The method consists of identifying base flows –as percentages of the annual mean runoff– seasonally, both for the low water level and rainy seasons, with the purpose of maintaining the system at different conservation levels. This proposal prevailed during many years, surely due to its simplicity and the convenience of adopting a minimal volume as an environmental flow.

It wasn't until the early 1990's when there was greater clarity regarding the direct dependency of aquatic ecosystems on the variability of a hydrologic regime and not on a minimal constant expense as had been previously proposed. Richter et al. (1996 y 1997) worked on a new approximation to determine the ecosystems' hydrological requirements based on the analysis of the regimen's variability in terms of magnitude, length, frequency, momentum and change rate of its different components or seasonal events. This approximation was called the range of natural variability of a hydrologic regime. Following this train of thought, Poff et al (1997) explained the importance of the hydrologic regime in water quality, energy availability, physical habitat configuration and biotic interactions, aspects considered as primary regulators of the ecosystem's integrity, and consequently, of its ecological integrity. These contributions allowed understanding that the ecological functionality of an aquatic ecosystem depends on the variability of the hydrologic regime, and that therefore, allocating a constant minimal expense was inadequate to maintain the ecological conditions of these ecosystems. This contribution of science represents a challenge for water management as it makes clear that what must be guaranteed in any allocation of water for the environment is the variability of the hydrologic regime to ensure that the resource is being used properly. This challenge implies understanding the ecological functionality in light of the IWRM, and the limits, restrictions, but also the synergies and benefits, of a regime of environmental flows.

1.1 Determination challenge

In the last century, river flows throughout the world have been modified by the extraction of water and the presence of hydraulic infrastructure, which has caused important alternations in the variability and seasonality of the hydrologic regime. It has been estimated that over 60% of the world's rivers have been fragmented by these hydrologic alterations, which has given way to a generalized degradation of aquatic ecosystems (Dyson et al., 2003; Postel and Richter, 2003; Ravenga et al., 2000; and Millennium Ecosystem Assessment, 2005, quoted in Global Environmental Flows Network, 2006).

A regime of environmental flows implies determining the ecological significance and importance of the different components of the hydrologic regime, this is, how seasonal expenses contribute to maintain different ecological processes and environmental services provided by the ecosystem (Forslund et al., 2009). In this sense, environmental flows have been gaining ground as a management instrument which helps reach agreements on the integrated and sustainable management of water resources, understood as a process that promotes the development and coordinated management of water, land and related resources in a basin, with the intention of maximizing economic and social wellbeing in an egalitarian way and without compromising the sustainability of vital ecosystems (GWP, 2000).

The scope and amount of methodologies to estimate environmental flows has increased considerably in the last years. Tharme (2003) described the use of over 200 calculation methodologies in 44 countries, which were grouped based on their approach in hydrologic, hydraulic, hydro-biologic or habitat simulation, and holistic methods. In Mexico, the first experiences to determine environmental flows were done in the 1990's by the Mexican Institute of Water Technology (IMTA, acronym in Spanish) in the Santiago River in Nayarit, Tonto River in the Papaloapan basin in Veracruz, and Tijuana River in Baja California. These experiences were done in stretches affected by dams and were presented in a guide recommending the application of the Tennant method; however, it recognized that the conservation of water quality, sustainable exploitation of the water resource, maintenance of biodiversity and minimization of human impact is only possible by applying the eco-systemic management of resources (García Rodríguez et al., 1999).

In 2004, the WWF-FGRA Alliance began a project called "Development of New Models of Water Management in Mexico" directed to integrated water management, with special emphasis on resource conservation, cross-sector cooperation in basin management and the protection and restoration of aquatic ecosystems. The Alliance's approach was to propose environmental flows as a means to guarantee wise water usage, to which end a methodology had to be defined to determine this flow, reach an agreement with users and legally adopt it. The project was developed in the Conchos River in the Chihuahua Desert ecoregion, Copalita-Zimatán-Huatulco in Oaxaca's Coastal Sierra, and the San Pedro-Mezquital River in Nayarit, Durango and Zacatecas; three very important basins given their biodiversity and the fact that they are representative of the different conditions facing water management in the country (Figure 1).

Figure 1 WWF-FGRA Alliance model basins.

Source: WWF (2005)

The determination of environmental flows was based on the holistic method known as Building Block Methodology (King, 2000) and took several years of work with the participation of approximately 100 experts and water users from over 37 organizations. This process provided a detailed understanding of the implications of determining environmental flows and their adoption in Mexico. It was especially relevant as it showed that in many cases environmental flows were happening and what was required was their conservation. The results showed that of a total of 33 analyzed sites in the three basins, in 73% of cases (24 sites) environmental flows occurred under conditions of water transference from higher to lower areas; in 21% (7 sites) environmental flows occurred in expense but required adaptation of the extraction conditions and infrastructure operations; and in only two sites, both in the Conchos River, water volumes had to be recuperated. The results of this experience led to conclude that:

- It is feasible to determine an environmental flow with the available knowledge and information.

- The existence of different methodologies is not an obstacle for their determination as results are comparable if they adhere to valid scientific principles.
- A hydrologic analysis is the fundamental component in determining environmental flows.
- Real impact on water availability within a regime of environmental flows must be evaluated considering commitments of water delivery downstream, in other words, within the water management sphere.

Systematization of work in these three basins set the basis for the methodologies and practices to develop the Mexican norm that had been discussed since 2007 and was finally issued in 2012 as: *NMX-AA-159-SCFI-2012 which establishes the procedure to determine environmental flows in hydrologic basins* (Secretaría de Economía, 2012).

Without doubt, this norm was a great achievement and surely it will be recognized as a milestone in water management in Mexico. Among the most relevant aspects of this achievement was the leadership of a non-government organization that built and systematized an experience that allowed the integration of actors, previous experiences and developed solutions; CONAGUA's openness and support, and the active participation and information contributed by other entities in the environmental sector such as CONABIO, CONANP, IMTA and the present day INECC, and from academia, mainly the UNAM. These aspects created an environment of collaboration which helped reach agreements in definitions, principles, scopes and methodologies, always aware of the need to initiate, once and for all, the development of environmental flows in Mexico.

When a regulatory document is generated on ecological bases –such as the Mexican norm– all the technical and scientific language related to the valuation and measurement of ecological and environmental processes is facilitated; the instrument establishes a common-use language for everyone, both for the discussion and assessment of environmental flows. Through PNRA's studies, protocols have been developed and tried in each discipline for procedures on the field. At the completion of the assessments we have been able to demonstrate that the norm works and that it does so very well.
When we were shown and used hydraulic models, we quantitatively and explicatively saw the impact that flows have on other variables such as speed, depth and area to provide habitat, and on the river's dynamic, for example; this was very useful during assessment. I had been thinking for a long time on how to generate a graphic model that represented ecological processes this way. Personally, I saw the dreams I had cherished materialize.

Ricardo Miguel Pérez Munguía, PhD. Researcher from the University of Michoacán of San Nicolás de Hidalgo

The NMX has resulted in an innovative instrument due to the following aspects:

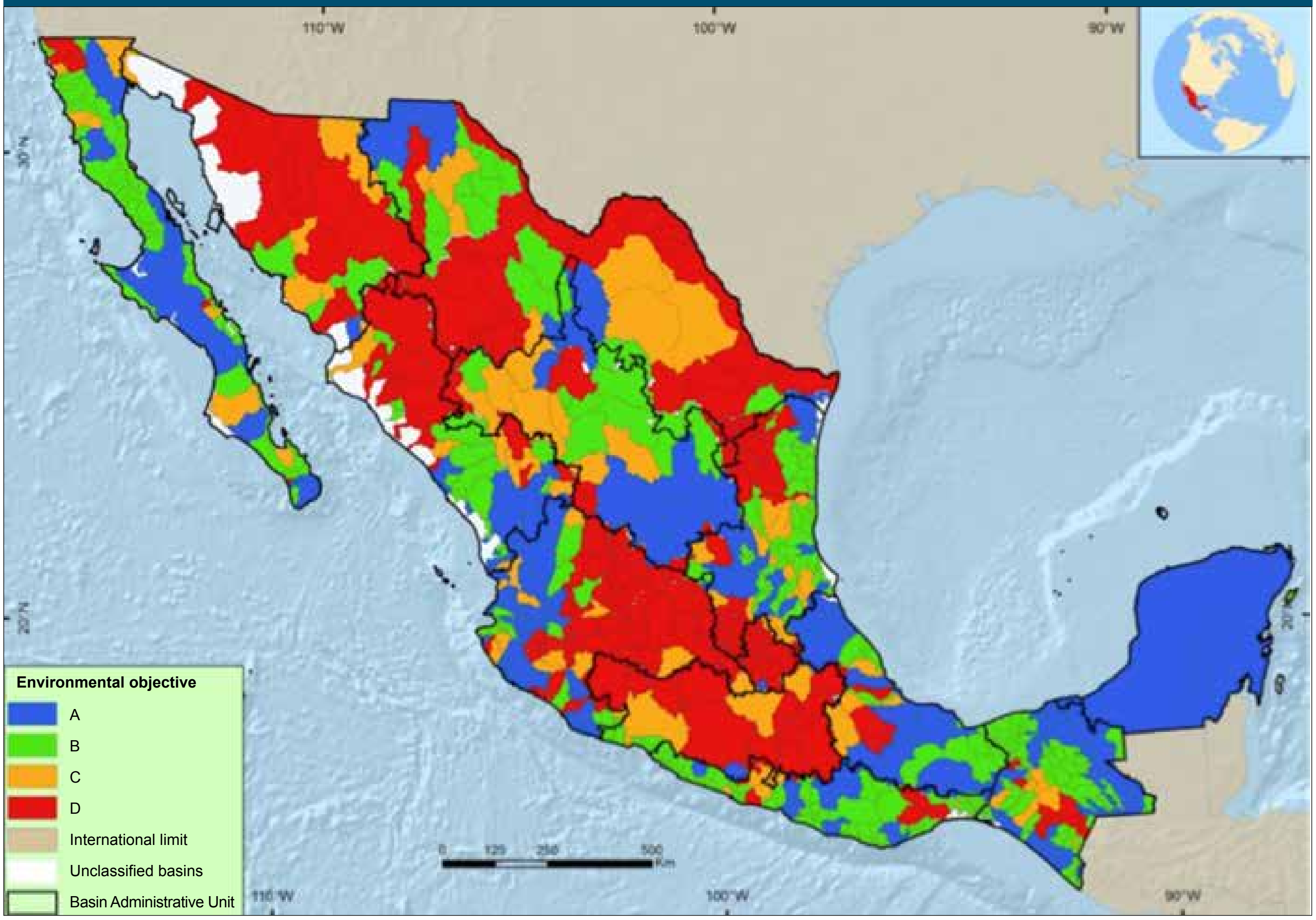
- Discussions on methodologies were set aside to address main scientific principles, but addressed from the IWRM instruments, possibilities and requirements.
- It's based on two scientific concepts that must rule any proposal for environmental flows independently of methodology: the natural regime (Poff et al., 1997) and the biological condition gradient (Davies y Jackson, 2006). This implies recognizing that a proposal for an environmental flow must understand the variability of the hydrologic regime and not focus on a minimum permanent flow.

- It integrates the social valuation of water in the environment to ensure its availability for the consumption and wellbeing of rural communities (fewer than 2,500 inhabitants).
- It recognizes, as principle, creating a balance between water extraction pressure and the conservation of ecological functions and environmental services that benefit society. This translates into establishing different levels of water extraction or biodiversity conservation associated with environmental objectives, which are defined based on the ecological importance of a basin and the water pressure to which it is subjected. An environmental objective “A” corresponds to a basin with low water pressure and very high ecological importance; on the contrary, a basin with a “D” environmental objective corresponds to basins with high water pressure, generally overexploited, and low ecological importance, generally due to its deteriorated conditions (Figure 2). That is, a basin with a potential water reserve will tend to have an “A” environmental objective, but with a perspective of increased demand could become a “B”, “C”, or “D” objective, if and when the ecological conditions associated with each environmental objective are maintained.
- It establishes a hierarchical condition for the application of methodologies based on the pressure from water usage and management needs. More complex and expensive methodologies would be required for cases with higher water demands and simpler methodologies for basins with lower pressures.
- It integrates the territory’s ecological valuation and establishes its application to assess infrastructure projects, particularly hydroelectric projects.

In summary, the NMX integrates the ecological, social and economic significance of the hydrologic regime in water management, and establishes a framework based on hydrologic and eco-regional criteria to address estimates of environmental flows in Mexico under a precautionary principle and within the sphere of the IWRM.

A summary of the norm’s structure and its components are included as Annex 1.

Figure 2 Environmental objectives in determining environmental flows in Mexico's hydrologic basins.



Source: Secretariat of Economy (2012) and CONAGUA (2011)

1.2 The Challenge of Implementing Environmental Flows

Implementation of an environmental flows regime continues to be a great challenge for water management, not only in Mexico but throughout the world. According to the report on the IWRM's application state in the world (UNEP, 2012), over 75% of the countries surveyed considers that water for ecosystems is a priority in their respective countries, while only 5% of the countries consider that it does not pose a problem; 45% of countries implement programs in some degree to allocate water resources which include environmental considerations, but only 12% have undertaken a complete implementation.

Different authors and institutions have analyzed the challenge in implementing a policy for environmental flows (Moore, 2004, Rafik and Davis, 2009). Some aspects identified as obstacles are: lack of understanding of the economic and social benefits, lack of political will, non-existent or inadequate legal and institutional framework, scarce or no involvement by users, lack of financial resources, limited scientific and technical capabilities, non-existing scenarios of development and planning for the resource, and lack of hydrological information.

An environmental flow is an excellent alternative to maintain the functioning and integrity of our riparian ecosystems, as it connects high, middle and low portions of a basin, which ensures freshwater supply in coastal areas. This effort cannot wait any longer; it requires the coordinated leadership of government, academia and organized civil society to conduct studies based on the implementation of the environmental flows norm. People from the communities know and provide very valuable information. They know when and where the river moves, how silted it is, what environmental changes have occurred and how these have affected their uses and customs. We must listen to and consider their knowledge and integrate it to the knowledge provided by specialists to assess the environmental flow addressing those lost ecological functions and therefore be able to recover them. During the work in the Papaloapan area, in San Juan Evangelista, we found a fragment of well-conserved relict flood rain-forest within the large transformation of the country's natural vegetation cover, with enormous Ceiba trees which we thought no longer existed in the State of Veracruz and a group of totally isolated howler monkeys (a species in danger of extinction in Mexico) that struggle each day to remain in a place surrounded by large transformations. With this project and its field campaigns, we discovered this area whose conservation is an effort that cannot wait any longer.

Dulce María Infante Mata, PhD. Researcher from El Colegio de la Frontera Sur

In Mexico's case, CONAGUA's political will and the proactive presence of the WWF-FGRA Alliance provided enough elements to compensate for deficiencies and overcome these obstacles. The joint work was especially relevant to identify opportunities outside basins where there is a strong competition for the resource and where the aforementioned obstacles are often times insurmountable.

Regarding legal implementation, it was based on a water reserve mechanism established by LAN, which explicitly acknowledges the objective of ecological protection in two articles:

- Article 41 … the Executive Branch can decree the total or partial reserve of national waters with the purpose of "guaranteeing minimal flows for ecological protection, including the conservation or restoration of vital ecosystems."
- Article 86 BIS 1 states the Commission's power to "…promote national water reserves or ecological reserves, according to the relevant law, for the preservation of wetlands."

A water reserve consists of a total water volume susceptible to concession in a basin, which is designated for an exclusive function, in this case for ecological protection. The law also stipulates the possibility of establishing water reserves for urban public use and power generation for public consumption. A water reserve is the most powerful instrument for the protection of a water volume and is established by Executive decree.

Based on these principles, the implementation of environmental flows was considered feasible and led to the identification of what is now known as potential water reserves for the environment (CONAGUA, 2011).

2. Identification of Potential Water Reserves for the Environment

The concept of potential water reserves emerges as result of the feasibility assessment made to establish environmental flows in Mexico. This assessment was developed taking as its main criterion the identification of scenarios of minimal conflict associated with water demand. The main variable was water availability in the hydrologic basins that CONAGUA has defined for their administration in Mexico and, in second term, the recognized value of each basin based on its biodiversity.

To identify potential water reserves for the environment, 732 hydrologic basins were analyzed, with their respective balance of water availability; information relative to its ecological importance, whether based on the presence of natural protected areas, wetlands of international importance recognized by the Ramsar Convention or of other sites of importance identified by CONABIO; information relative to potential scenarios of pressure on the resource (projections of population growth, presence of dams, overexploited aquifers or irrigation districts); and the presence of bans as an administrative condition of water in the basin. This last condition was identified as an important factor in the analysis, as by then 433 basins in the country were in this condition, many since the first half of the 20th century, and had water availability; therefore there is a social pressure to lift this restriction. This situation offered an opportunity to establish a regime of environmental flows lifting the ban partially, which would free volumes for concession while ensuring water to create a water reserve for the environment.

A multi-criteria analysis was done with the integrated information using three decision alternatives called linear assessment, decision tree and weighted assessment. By comparing results and adjusting criteria derived from a sensitivity study of these three methodologies, 189 basins were identified as having favorable features in determining environmental flows and establishing water reserves, which were called Potential Water Reserves (PWR). These were classified into three feasibility levels: 19 basins with “Very High” priority, 54 with “High” priority and 116 with a “Medium” priority (Figure 3).

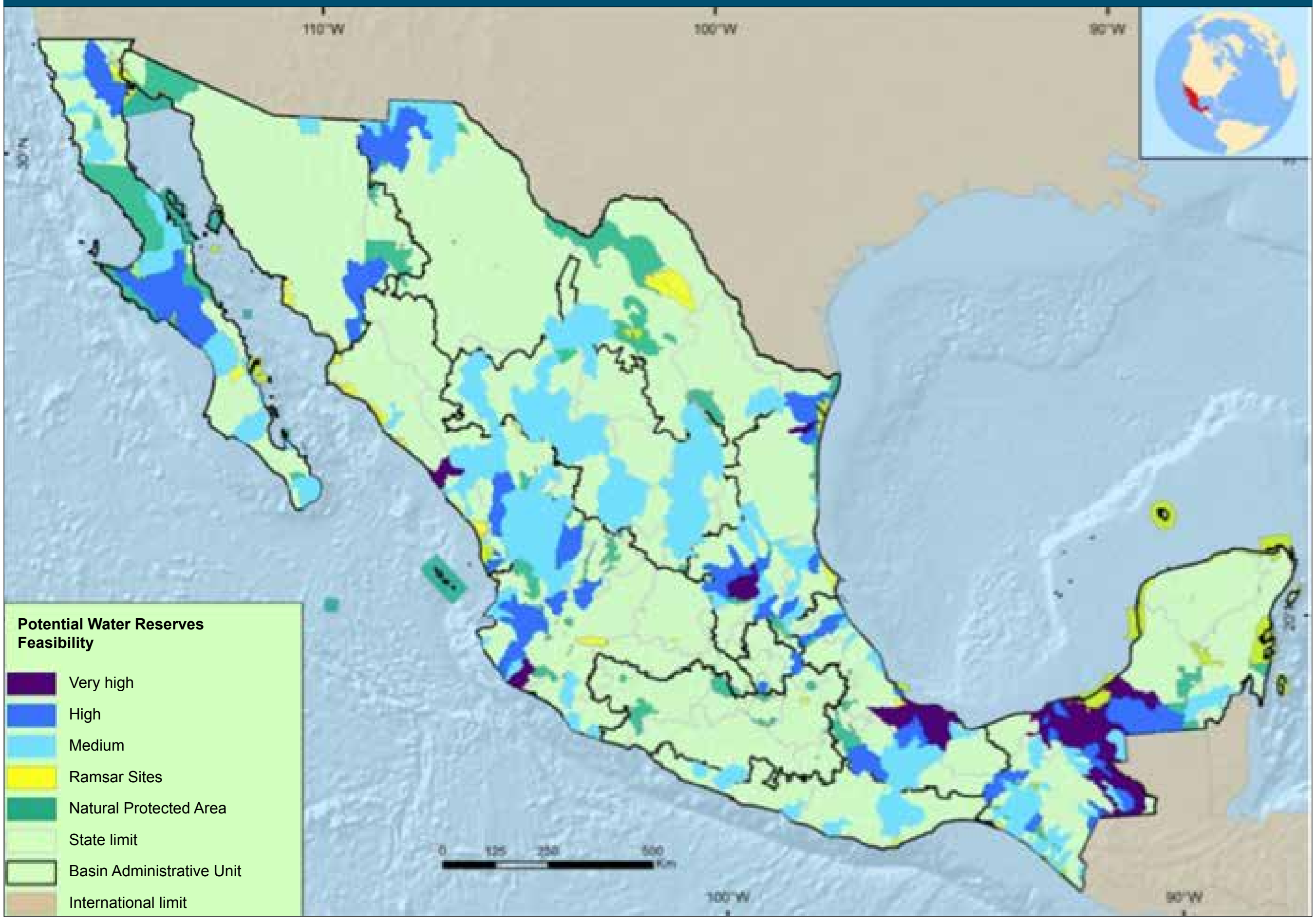
In terms of water availability, the 189 basins identified as PWRs represent a volume of 256 km^3 of the 379 km^3 of mean natural runoff of the country’s total surface; therefore they represent most water not given in concession in 2009. Of this volume, it is estimated that water reserves could reach approximately 192 km^3, leaving approximately 64 km^3 as the available volume for concessions, which would mean increasing to more than double the volume given in concession from surface sources and which ascended to 50 km3 (CONAGUA, 2009). If we also consider that the country presents global efficiencies in water usage near 50% and that the main challenge to having balanced basins is to maintain the present water offer and work towards a more efficient demand, there would be no reason to think of reserves as a restriction to development but as a condition to reach a sustainable condition (CONAGUA, 2011).

To date, the volume given in concession from surface sources has notoriously increased up to 82 km3 (CONAGUA, 2014), which represents a 64% increase to the value reported in 2009. This situation shows the urgent need to advance in the creation of reserves as this growth implies that some basins are reaching conditions of high water pressure, low water safety and elevated vulnerability when confronting climate change.

An aspect of great importance in the identification of PWRs was corroborating their condition of low confliction due to water demand, which represented a great opportunity to develop local and institutional capacities when enforcing the NMX and to clearly define the procedure for water reserve decrees, without possible objections from the water users. This way, PWRs offered authorities enough certainty and safety to begin a national environmental flow implementation process.

A first analysis of the territorial implications of these 189 PWRs showed that they encompass 23% of the country's surface, they are present in all N1 Level Ecoregions (INEGI, et al., 2008), and in 59% of Epicontinental Aquatic Ecosystems of Freshwater Ecoregions of the World (www.feow.org) present in Mexico; and coincide with 97 NPAs and 55 Ramsar sites. This territorial coverage made clear the strategic value of implementing an IWRM action –the water reserves– for the protection of biodiversity in the country.

Figure 3 Potential water reserves for the environment in Mexico.



Source: CONAGUA (2011)

A GIS was developed from this exercise and became the instrument for the analysis and planning of land and water to support PNRA's strategy. To validate its content and analysis, a work group was established at CONAGUA's General Office for Technical Affairs with the participation of all its offices (GIABA, GAS, GCA, GASIR) and a WGIS was conducted. Based on this GIS, other complementary studies have been carried out to reinforce the water reserves' justification.

2.1 Potential Subterranean Water Reserves

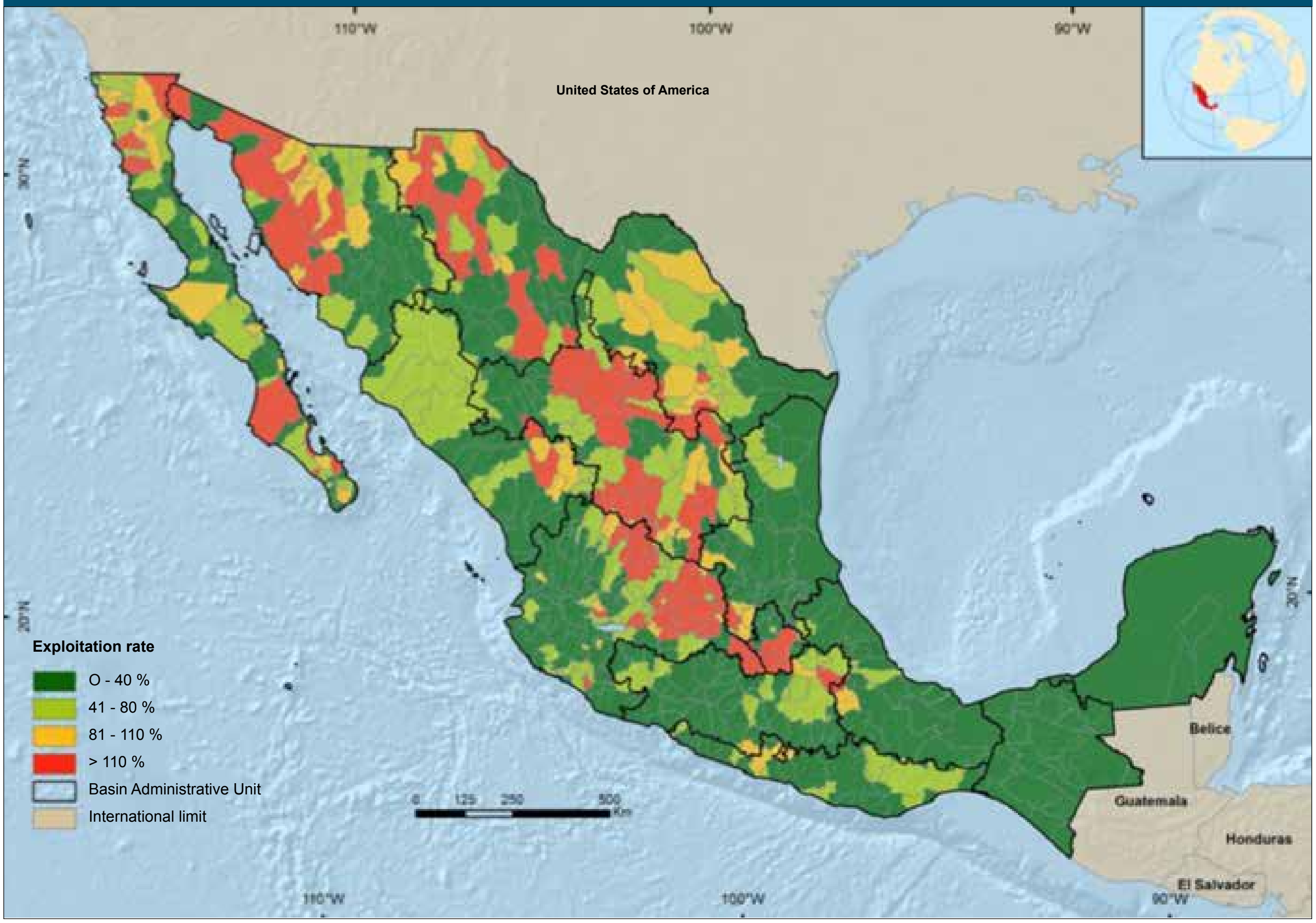
The objective of this analysis was to identify the contribution of subterranean water to the conservation of PWRs. From an environmental standpoint, it is important to consider the impact of water extractions on an aquifer's natural discharge which is reflected in the reduction of the rivers' base flows, reduction of subterranean inflows into wetlands, saline intrusion in lagoon systems, and flow reduction or loss of water discharge at springs. All these impacts alter the hydrologic regime, particularly in the low water season. There are also other impacts on water management, such as the progressive reduction of subterranean water levels, increase in extraction costs, differential settlements, cave-ins, infrastructure damage and deterioration of water quality. All of these are indicators of aquifer overexploitation that affect conservation of the water reserve volumes.

To assess the contribution of subterranean water in PWR conservation, an indicator was established to identify reserves in risk of being affected by an excessive use of subterranean waters. Criteria for subterranean water management in countries such as Australia, Denmark, Spain, the United States, Holland, New Zealand, South Africa and Switzerland, indicate that in general terms the extraction- recharge ratio must be between 0.4 and 0.6 (SNIFFER, 2005). Within this context, 0.4 was established as the extraction-recharge ratio threshold value to determine the exploitation rate (ER) for the aquifer, with the following considerations:

- Exploitation Rate < 40% = Low pressure. **Low risk for Potential Water Reserves to be affected.** There is no significant pressure from subterranean waters on the hydro-ecological dynamic of the surface body of water. If any environmental problems caused by water extraction exist, these problems would correspond to surface sources and would be easily identifiable.
- Exploitation Rate > 40% = High pressure. **High risk for Potential Water Reserves to be affected.** There is great pressure on subterranean waters with significant potential impacts on the ecosystems depending on these waters.

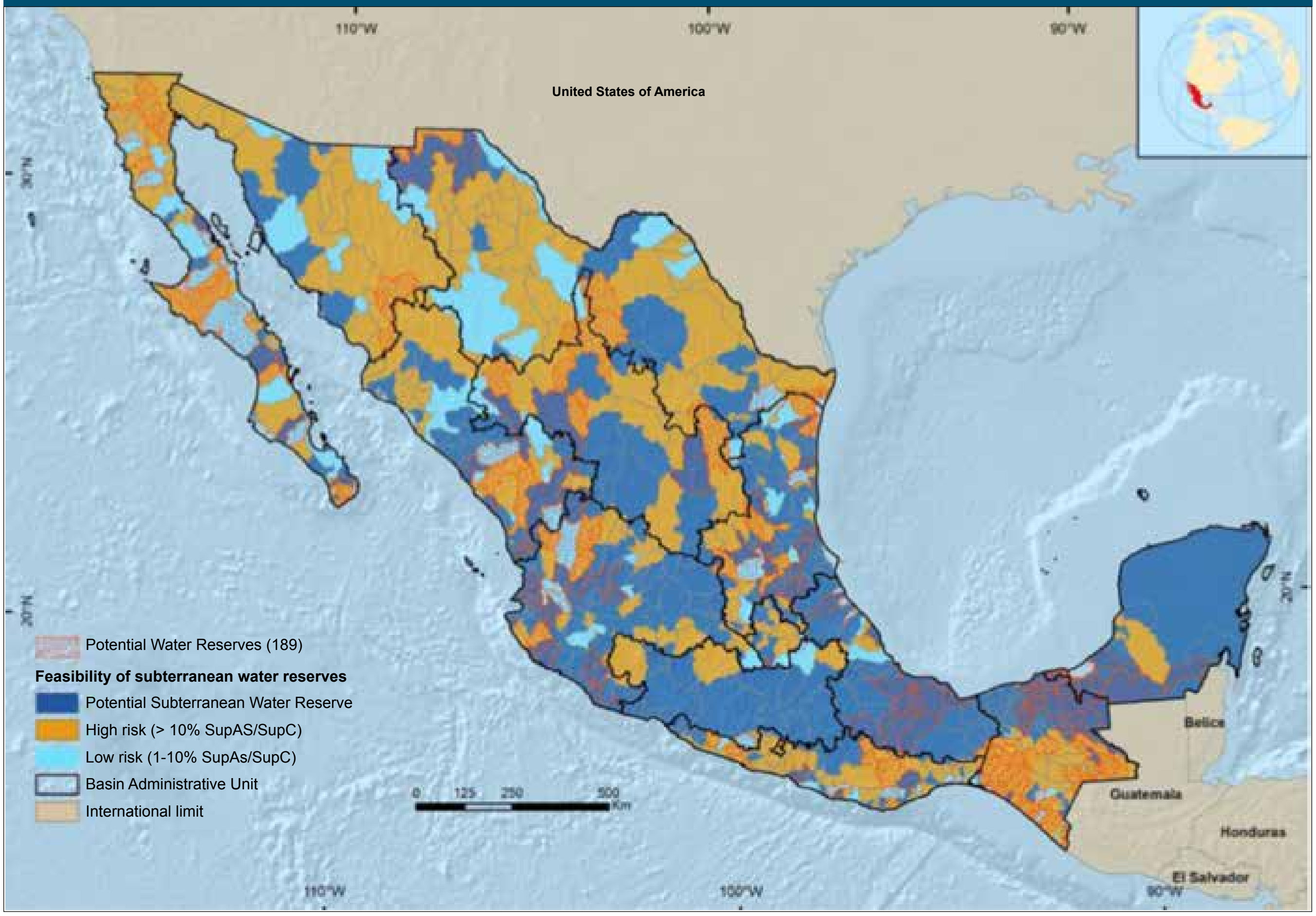
At present, the extraction-recharge ratio is used by GAS to determine the degree of exploitation of the country's aquifers. GAS considers that an aquifer is overexploited if it presents an extraction- recharge ratio of 110% during several consecutive years. The threshold value of 40% indicates the degree of pressure on the aquifers and establishes a preventive situation in accordance to the principle of potential water reserves, in this case, subterranean. Figure 4 shows the classification of aquifers in the country based on ER; those with 40% or lower are considered as subterranean PWRs.

Figure 4 Classification of the country's aquifers based on exploitation rate.



When establishing water reserves it is indispensable to integrate surface and subterranean balances at each basin. As a first step, with the purpose of complementing the assessment of surface PWRs and have a general vision of this interaction, a PWR's risk of being affected was defined according to the surface each aquifer (SupA) occupies in relation to the total basin surface (SupC). That is, an aquifer that is completely contained within a basin's territory or vice versa is at risk of overexploitation affecting the reserve, whether hydrologically by decreasing the natural discharge or administratively by increasing the demand for concessions from surface sources. A PWR's high risk of being affected was considered if SupA resulted higher than 10% of the basin's surface. Figure 5 shows subterranean and surface PWRs, and their classification based on the risk of being affected. The results of this analysis indicate that of the 189 PWRs, 77 are located in high-risk aquifers, 23 in low-risk aquifers, and 89 basins correspond to subterranean and surface PWRs. This analysis is the first step to integrate balances in surface and subterranean water when determining water reserves and advancing toward an integrated management of the two sources.

Figure 5 Potential reserves of surface and subterranean waters, and risk of being affected.



2.2 Eco-hydrological Function of PWRs: Natural River Systems and Potential for Hydroelectric Power Generation

Another complementary analysis assessed PWRs based on three major ecological functions and their location within the hydrologic system, which resulted in their classification as: 1) water capture and inflow reserves; 2) water connecting, conducting and flow regulating reserves; and 3) reserves receiving the total inflow in a regime of natural water, sediments and nutrients.

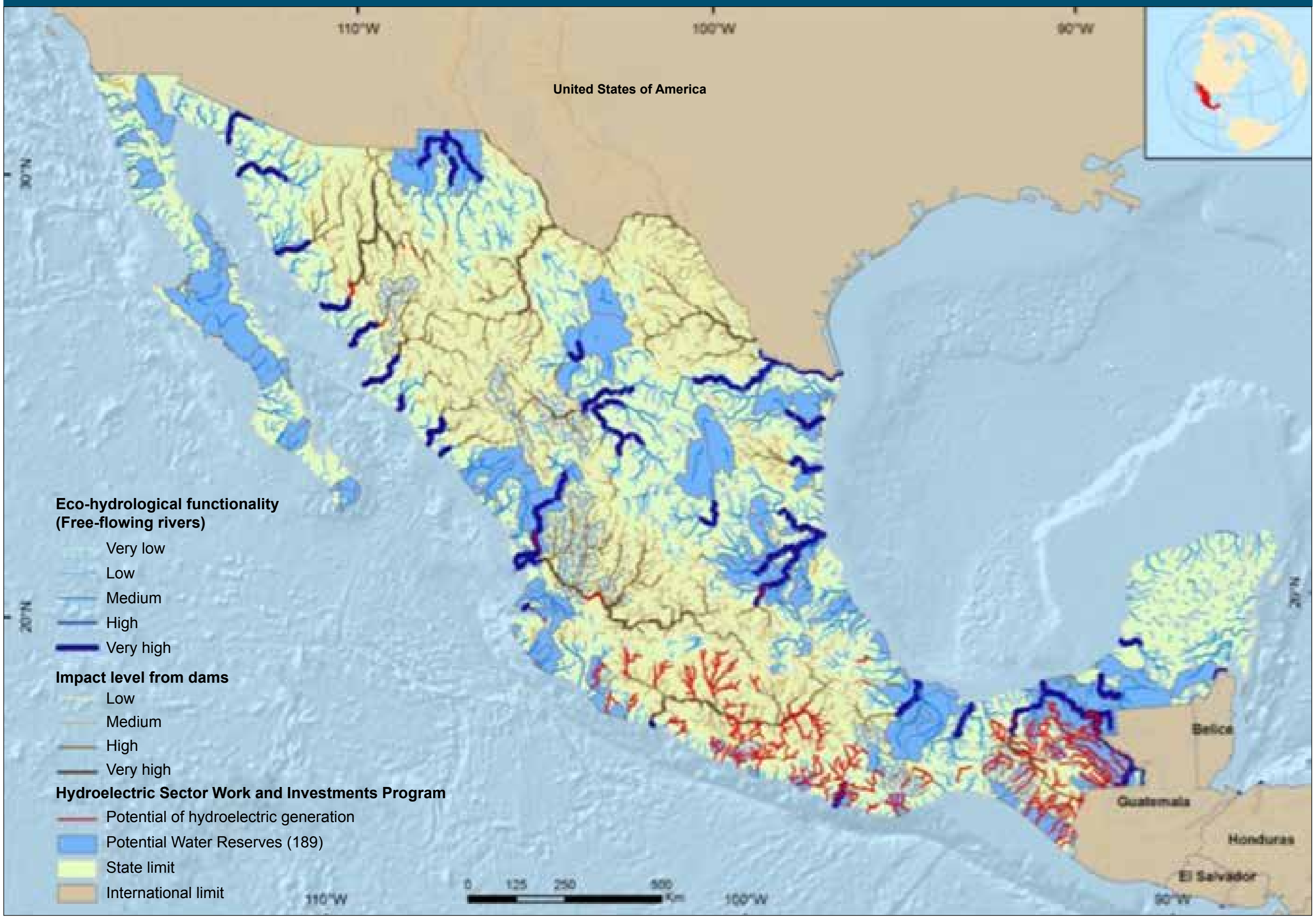
In terms of their connectivity, identification was made of the PWRs that maintain infrastructure-free courses in at least a 100 km length of their main course and a drainage area network superior to 90% in relation to their basin and that have not been affected by dams higher than 15 m. These were jointly identified as natural river systems.

At present, the country has four large natural river systems that maintain their associated eco-hydrologic connectivity and functionality, which are: Usumacinta, Pánuco, San Pedro Mezquital and Verde-Atoyac, and which encompass 49 PWRs (Figure 6). According to specialized literature (Ortíz Pérez, 2010), these four cases represent allochthonous basins or rivers, that is, they have a diversity of arrangements in their spatial composition, they maintain their connectivity and include among their main features the following:

- Far off or distant sources, with flows being shaped by crossing several natural regions, with different climates, as well as diverse geological terrains and different relief areas.
- Along their journey, they drain from large arid, temperate, and dry tropical and sub-humid areas. At each climate, there are vegetation associations that better define the diversity of ecosystems existing in the basin.
- There is a constant flow from a base runoff which translates into a wide range flow that ensures high connectivity to capture, store, concentrate, assimilate, transform and transfer energy and matter through open channels of coastal, estuarine, lateral, riverine and lowland flood wetland exchanges, and between bodies of water and shores or with aquifers.

As that the main threat in these river systems is the construction of hydroelectric dams, an analysis was done considering stretches with potential of hydroelectric generation identified by the CFE and the projects already identified by the Works and Investments Program from the Hydroelectric Sector (POISE 2012- 2026). Based on the above, 79 PWRs were identified in which their connecting function would be affected by the potential construction of this infrastructure (Figure 6).

Figure 6 Potential water reserves, functional river systems and stretches with hydroelectric generation potential (POISE 2012-2026) in Mexico.



Source: CONAGUA-WWF (2013) and CFE (2012)

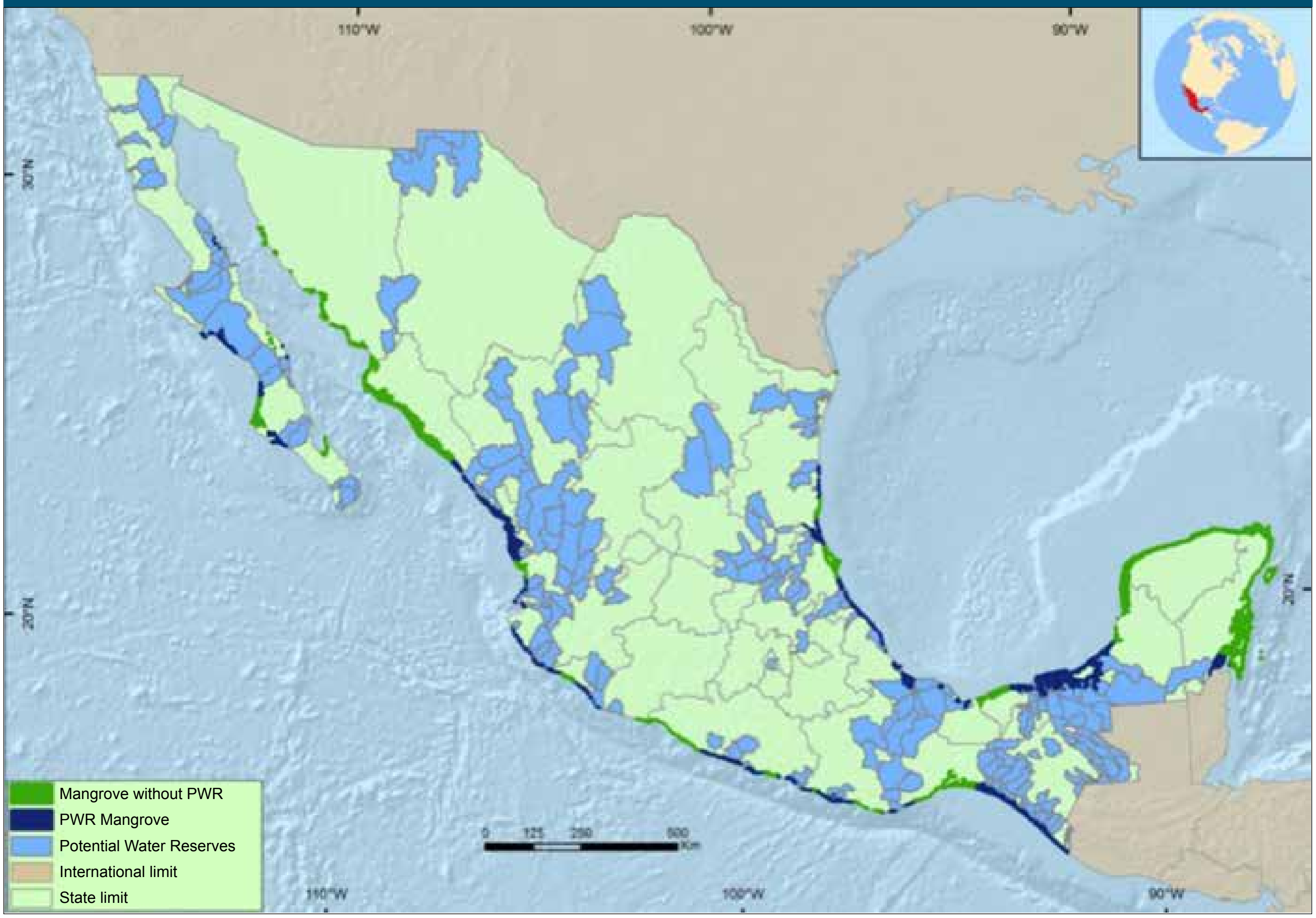
3. The Potential for Biodiversity Conservation and Climate Change Adaptation of Environmental Water Reserves

The identification of PWRs for the environment offered the opportunity to analyze its implications, mainly territorial, with other programs and public policies, and evidence the high influence potential from managing this water for biodiversity conservation. An example of this influence can be seen in the relation between water reserves and the conservation of mangrove ecosystems. Water reserves would protect the basins' hydrologic regime for 43% of the mangrove's surface in Mexico (Figure 7). Within this context, it is important to highlight that approximately half of potential reserves are found in coastal areas; therefore, their creation ensures transportation of sediments and nutrients for the geomorphological subsistence of deltas, estuarine systems and coastal shorelines. This environmental service was documented in an analysis conducted at Marismas Nacionales which showed that sediments in the area of influence of San Pedro Mezquital come from the middle and high basin, with sedimentation rates of 1-4 cm/year registered in a 40 year period (CONAGUA-BID-Alianza WWF-FGRA, 2014).

It is evident that PWRs strengthen biodiversity conservation policies and programs simply because they make water management for conservation purposes consistent with the management of the protected land. However, to guarantee this consistency and ensure its benefits, the integration of current regulatory instruments, initially the water reserve decree, with the NPA's management programs at a federal level has been suggested.

Among the synergies identified, there are on one side those that strengthen the protection framework of the NPA by reducing pressure from activities associated to water uses not considered or limited by the reserve. This is the case of restricting water usage for productive activities, such as agriculture or aquaculture. This represents a pressure reduction in the different NPA protection areas, and consequently in changes in land usage, which is one of the main threats facing NPA management in the country. Water reserves would also provide extraterritorial conditions by ensuring that runoff from the basin, which is part of the water reserve's volumes, would reach the NPA downstream. This is especially relevant for coastal and marine NPAs, as it implies usage limitations upstream, it ensures the transportation functions for sediments, genetic material and, in general, it ensures the system's eco-hydrologic connectivity, essential for the conservation of coastal ecosystems.

Figure 7 Potential water reserves and their influence on mangrove distribution in Mexico.



Source: CONABIO (2013) and CONAGUA-WWF Mexico (2013)

On the other hand, there are land management actions that the very NPA must adopt to guarantee that the reserve meets its ecological functions within its territorial context, such as those related to the adequate management of extreme events, be they floods or droughts, by avoiding water retention berms, blockage, invasion of riverbeds, etc. This requires carrying out physical actions and working with resident communities and local governments.

It is very important to consider that these actions complement the implementation of the water reserve, which is enforced by issuing the decree, and must be considered within the NPA's management programs.

Another important contribution to conservation refers to the designation of new NPAs. PWRs occupy a surface of 78,568 km2 additional to NPAs and Ramsar sites and to date they are under no land protection mechanism, but due to the presence of hydrologic regimes with low or non-existing alteration, they would suppose good conditions for biodiversity conservation. These areas have already been considered by CONANP under their criteria for NPA expansions in order to achieve the 17% goal of protected land –a commitment made by the Mexican government to the CBD.

The PNRA has offered the opportunity of improving existing knowledge on ichthyofauna in the State of Jalisco. We found very rare fish communities, in ichthyologic terms, whose distribution at a national level and along the lengths of the rivers was surprising. We found two species listed in NOM-059-SEMAR-NAT-2010: the Mountain Clingfish (*Gobiesox fluviatilis*; threatened) and Pacific Molly (*Poecilia butleri*; under special protection). We also collected the Riverine Stargazer (*Dactyloscopus amnis*) that was not previously reported in the state. Finally, there were a couple of surprises I wasn't expecting to collect during the dry season upstream from the coast, lakes or in more immediate areas to the ocean in brackish water: the Bigmouth Sanddab (*Citharichthys gilberti*) and still unidentified specimens at a species level of *Caranx sp.*

Norman Mercado Silva, PhD. Researcher from the University of Arizona (USA), currently researcher at the University of Morelos

Within the context of climate change, the latest report from the Intergovernmental Panel on Climate Change recognizes that a large part of land and freshwater species face a growing risk of extinction due to projected climate conditions, which at the same time interact with other stress factors such as habitat modification, overexploitation, pollution and invasive species (IPCC, 2014). This same report indicates that under these projections, surface and subterranean water availability would be substantially reduced in subtropical dry regions, which would result in an intensifying competition for water and therefore increased pressure on the ecosystems. Not having to this date the water protection required by the ecosystems, as has been indicated throughout this document, represents a high vulnerability situation for many species and ultimately for biodiversity conservation.

Considering that adaptation is defined as the adjustments and measures in human and natural systems that are necessary to reduce negative impacts of climate change and optimize its positive aspects (INECC, 2012), potential water reserves were recognized as a climate change adaptation action in water management and biodiversity conservation policies by the 2014-2018 Climate Change Special Program of the Federal Government. Within the scope of water management, reserves create a hydrological capacity (buffer) to cushion the impact of extreme events that would affect the hydrological cycle and therefore favor a resilient and less vulnerable management. Within the conservation scope, a water reserves system or network, by guaranteeing the hydrological cycle functionality, promotes the connectivity conservation in at least 90 basins in the country and of its riparian corridors, thereby creating favorable conditions for the movement of species and their adaptation to new climate conditions. All these aspects are being analyzed in detail as part of the process of establishing water reserves as an adaptation measure to climate change.

Within the infrastructure development scope, PWRs evince the value of the eco-hydrological connectivity and therefore the need to incorporate this attribute in land planning. By travelling along a flow, PWRs avoid invasions of federal lands and maintain the riverbed free from materials, garbage and vegetation, which conserves the evacuation capacity for extreme events, that is, PWRs maintain a green or natural infrastructure that reduces people's vulnerability to floods.

The NMX states Environmental Impact Manifests (EIM) as a field of application. This implies that the authorities can request, for any project that potentially alters the hydrologic regime in a PWR, an assessment of environmental flows in order to conserve the regime with all its benefits. This way, PWRs and the enforcement of the NMX are instruments with the potential to facilitate EIM development and assessments. At present, the modification of the EIM regulatory framework is a current issue in the country's environmental agenda and where PWRs have much to contribute as a strategic environmental planning instrument for the territory.

As a planning instrument, potential water reserves have already influenced several national policies, such as the National Policy on Wetlands, the National Policy on Oceans and Coasts, and are explicitly part of the 2014-2018 Special Climate Change Program and the 2014-2018 National Water Program.

> One of the PNRA's wisest decisions has been to leave its execution to the organized civil society, in this case, WWF Mexico. This ONG's added value is its strategic position in building trust relations, promoting collaboration with the academic sector and connecting the public and private sectors, and the communities, with government institutions; this helps build a well-founded public policy. The PNRA is one of the first of its type in the world, designed and implemented with a bottom-up vision, and that turns policy and water management into a reality. It can therefore take the lead and its experience to other countries with different realities and contexts.
>
> One of the great threats to water safety in Mexico is overexploitation of surface resources –in rivers and lakes–, but also of subterranean resources. The program's importance resides in being completely developed using adaptation methods against climate change impacts, with an initial objective centered on all sites with high conservation interest and low water pressure.
>
> *Bart Wickel, PhD., Senior Scientist, Stockholm Environment Institute*

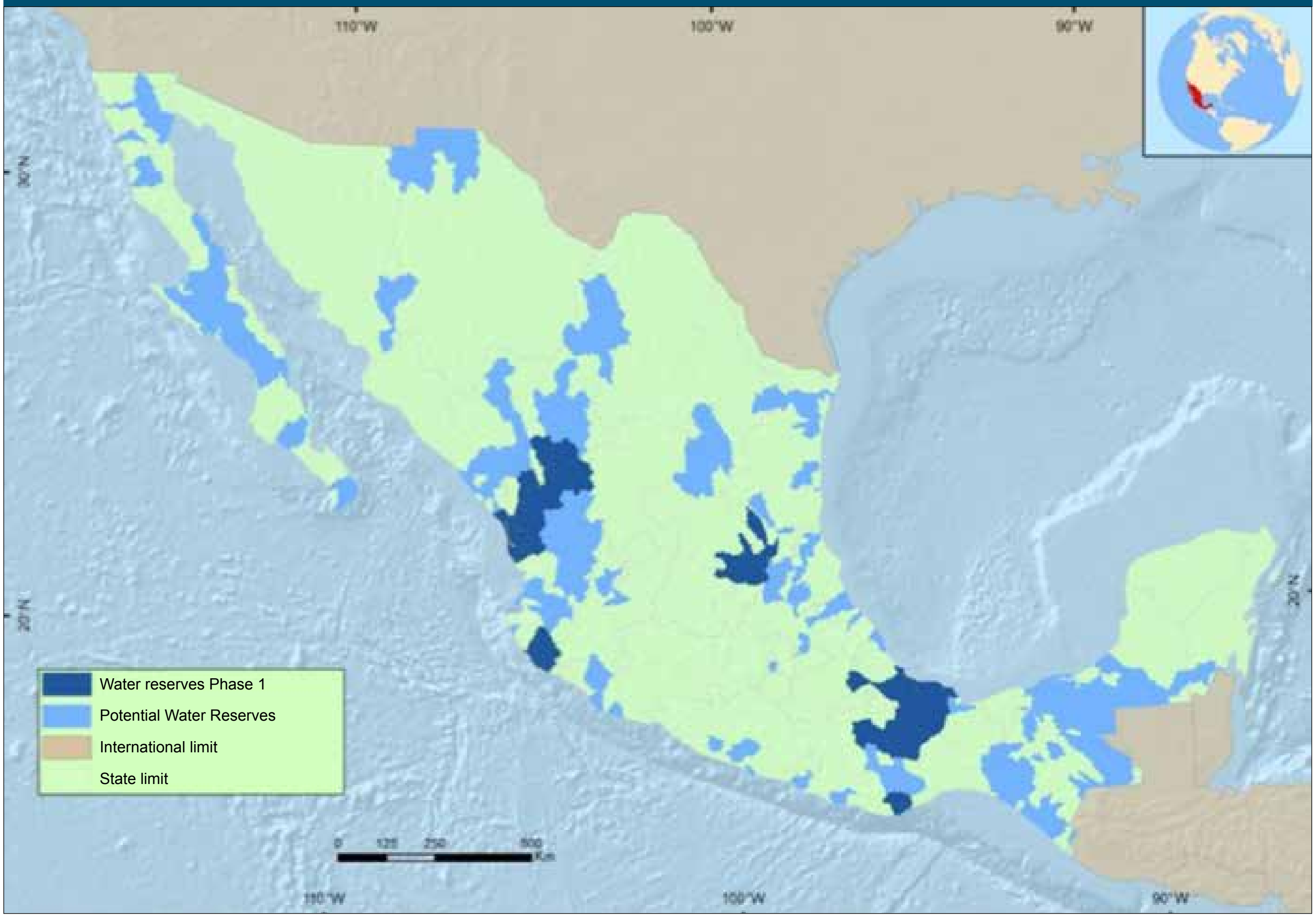
4. Implementation of pilot PWRs

After the NMX was issued and the PWRs were identified, CONAGUA, with the collaboration of the WWF-FGRA Alliance, the support of IDB and of WMO consultants, initiated the current National Water Reserves Program. CONANP also joined due to implications for NPAs and particularly for Ramsar wetlands in the country. During its first phase the program established as its objectives:

- Create the 189 water reserves by 2018, and especially protect the hydrologic regime in 55 Ramsar sites and 97 NPAs.
- Prove the benefits of water reserves as an instrument to guarantee the functionality of the hydrological cycle and its environmental services.
- Build the country's capacities for the determination, instrumentation and surveillance of environmental flows in the water reserves and subsequently in the rest of the country.

Six pilot areas (Figure 8) were selected for the startup among the basins classified with "Very High" feasibility in the PWR identification analysis and which had presence of academic groups or organizations of Civil Society with knowledge of the area. The areas selected were Copalita-Zimatán-Coyula and San Pedro Mezquital, which already had an environmental flow proposal from previous WWF-FGRA Alliance work, and areas in Sierra Gorda, Papaloapan, Chamela and Acaponeta. The institutions responsible for implementing the projects in the field were the University of Querétaro in Sierra Gorda, Institute of Ecology A.C. in Papaloapan, the University of Guadalajara in Chamela and Pronatura Noroeste A.C. in Acaponeta.

Figure 8 PNRA's pilot areas.



Source: CONAGUA-WWF Mexico (2013)

The project's development during this pilot phase was defined by a technical coordination area overseen by the WWF-FGRA Alliance. Its roles were:

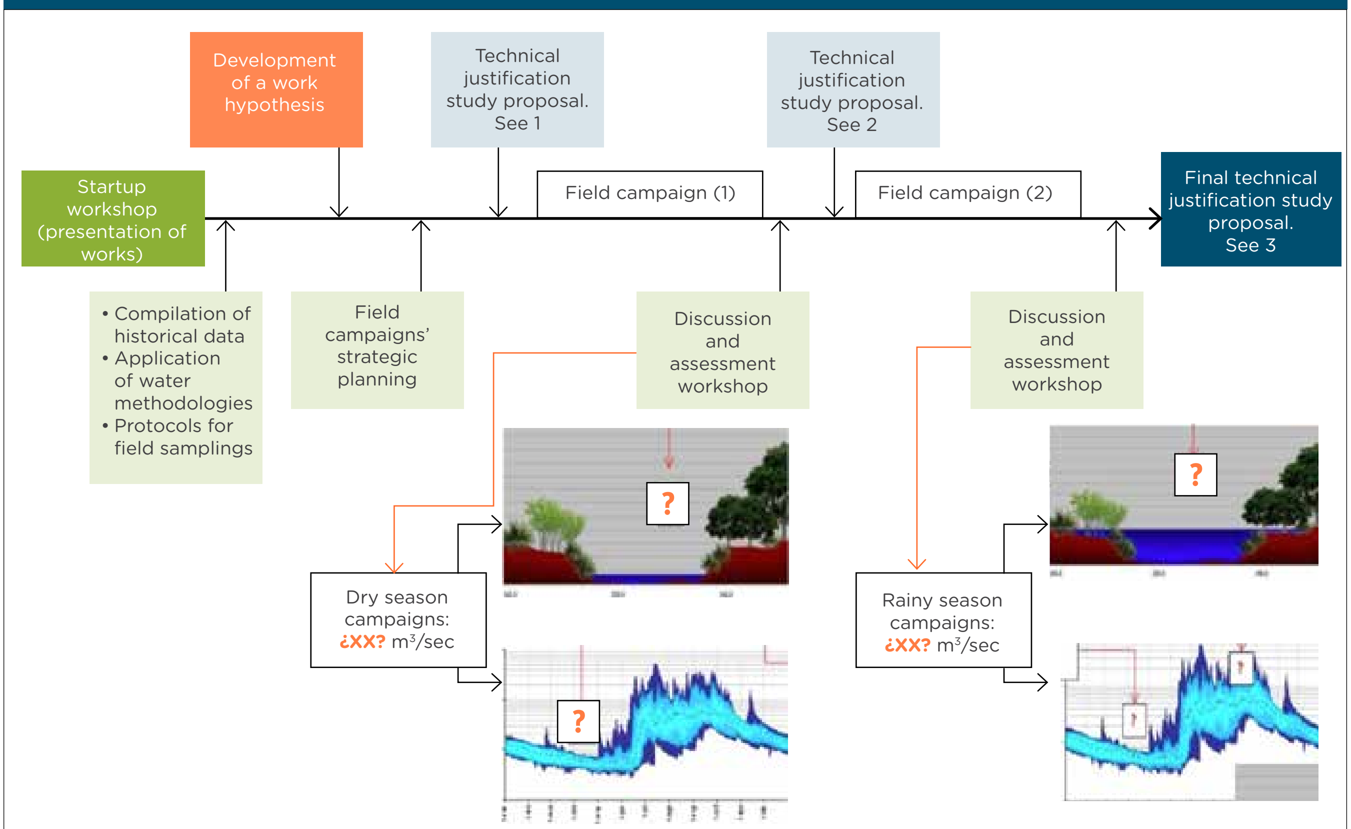
- Identify work groups for each pilot area and integrate participants from CONAGUA and CONANP.
- Train the participants and guide the application process for the environmental flow norm.
- Guide the discussions for the integrated proposal of the environmental flows regime for each area.
- Develop a file for CONAGUA to process the water reserve decree.
- Function as a link between CONAGUA's General Office for Technical Affairs and CONANP.
- Systematize the experiences in the development of work protocols to strengthen the NMX.

Once the work groups for each zone were established, the process began by applying the NMX through an iterative process, with continuous feedback, which included startup workshops, hydrology workshops, planning sessions for the field campaigns (low water and rains) and environmental flow discussion workshops. This process' sequence is shown in Figure 9.

Environmental flow discussion workshops are the main analysis exercise. This is a multidisciplinary process to develop the flows' proposal based on each participant's knowledge, data gathered by the field campaigns and information from other sources. All this is integrated into a work hypothesis on the current ecological state and possible management scenarios associated to the four environmental objectives specified in the norm. This process, which also includes representatives from CONAGUA and CONANP, is highly relevant for a common understanding of the basin, its functioning and the value of the environmental flows for an IWRM. A diagram of the analysis dynamic followed in these workshops is shown in Figure 10.

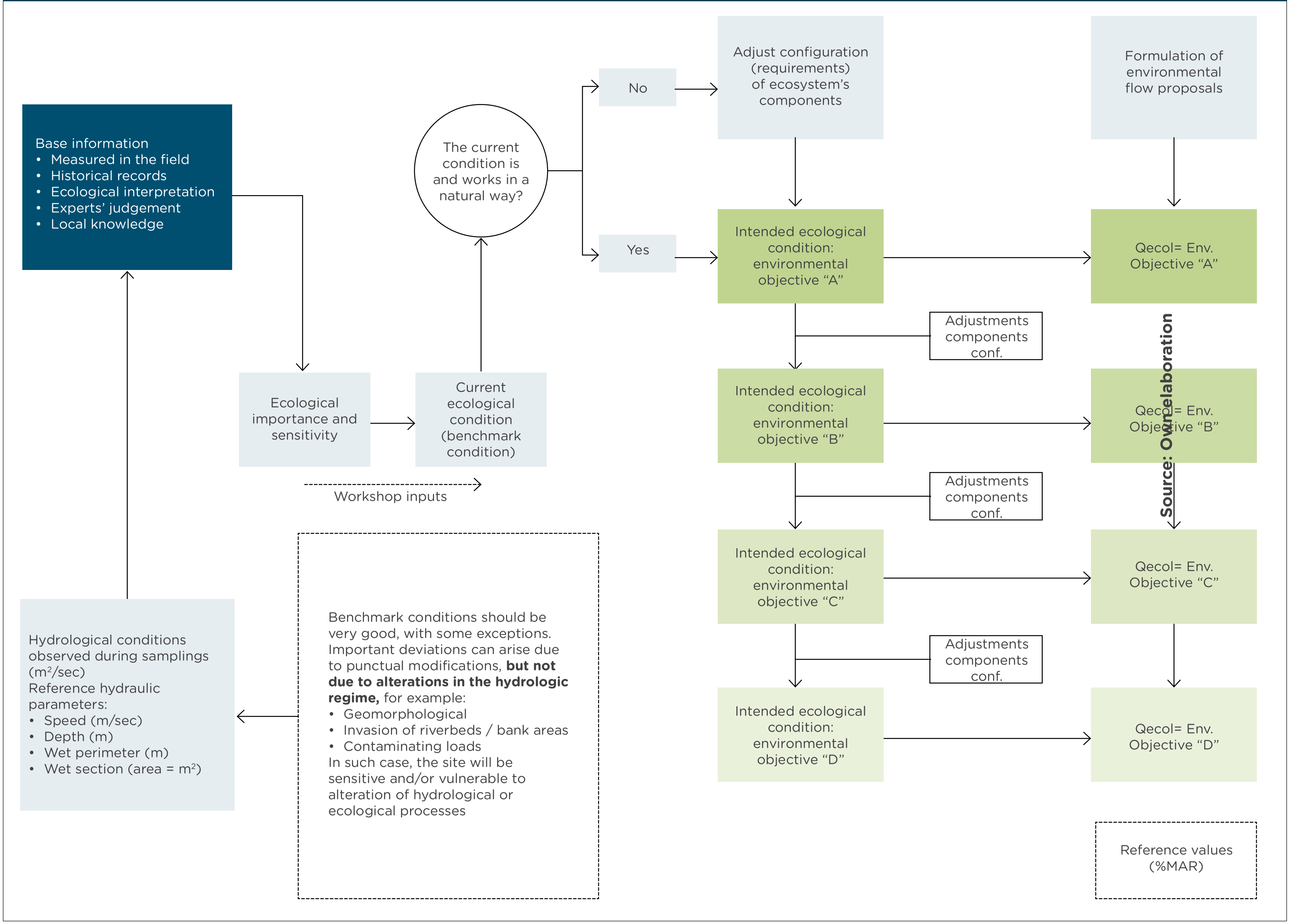
The basins selected during this first phase have differentiated climate –and consequently hydrologic– features, and therefore the application of the norm represented an especially relevant enriching experience to make it stronger. This was the case in the determination of environmental flows in hydrologic basins without hydrometric information, of intermittent flows with high tropical influence such as San Nicolás B, which discharges into the Chamela-Cuixmala Biosphere Reserve and Ramsar Site, or of perennial flows with a high contribution of base flows such as the Papaloapan plains, where the Alvarado Lagoon System Ramsar site is located. This work was systematized in field protocols for geomorphology, water quality, vegetation, macro-invertebrates and fish.

Figure 9 Work dynamic for environmental flows studies



Source: Own elaboration

Figure 10 Environmental flows discussion and assessment workshops dynamic.



Source: Own elaboration

5. Results

Results from the environmental flows proposals in these pilot areas have helped assess the geographical, biological and social scope of the evaluations. Water reserves in these areas involve:

- 43 hydrologic basins with an extension of 91,676 km^2 (4.5% of the country's territory), where a longitudinal, vertical and lateral connectivity will be maintained for 4,552 km of main riverbeds, 31 aquifers, 17 NPAs and 13 Ramsar sites.
- A reserve volume that in average represents 53% of the basins' annual mean runoff and jointly is 48,646 annual Hm^3, representing approximately 11% of the country's annual mean runoff.
- Regarding their biological context, these water reserves will guarantee water needs for 546 species under some protection category, 99 of these directly considered within the analysis to determine environmental flows.
- Capacities were strengthened in 58 institutions including government agencies, academic institutions and civil society organizations, and a total of 138 experts participated in the development of the studies and environmental flows proposals.

On September 15, 2014, the first executive order for a water reserve was issued, comprising 11 basins from the San Pedro river hydrological sub-region, which feeds the Marismas Nacionales Biosphere Reserve and Ramsar Site. This decree establishes the environmental reserves, domestic and public urban usage, and electric power generation for public consumption for the next 50 years, as well as the conditions to authorize these uses and guarantee they act in a complementary and synergic manner. The results of the environmental flows studies for each area are presented in the technical files in Annex 2.

5.1 Environmental Services from Water Reserves

The establishment of environmental flows, as with any water allocation, implies limitations for other uses, as well as benefits and costs for society and individuals. As was mentioned above, the NMX establishes a principle of balance between different levels of conservation or environmental objectives that involve different water volumes. Higher states of conservation require higher water volumes in the environment and minimal alteration of the hydrologic regime, and higher water uses mean less water in the environment and greater regime alteration that implies a lower conservation state or environmental objective. This balance between water uses and conservation is the principle for the assessment of environmental water reserves, which seeks to guarantee the maximum benefits for society.

For many years, water allocation for the environment was only considered as a restriction to its use and therefore a limitation to the development of productive activities; hence the common rejection to its adoption or establishment as minimal volumes. This project has offered the possibility of beginning to understand the benefits of maintaining water in the environment and therefore, the conditions that involve achieving a balance between water allocation for a productive activity in hands of an individual, and maintain water that guarantees services for all, in particular for marginalized communities whose sustenance depends on good measure on these services. This idea is beginning to change the perception illustrated with the old saying *"… a drop that reaches the sea is a wasted drop"*, to an understanding that, expressed with the same saying, would be *"…a drop that reaches the sea is more productive for society"*, the true principle of an integrated water resources management.

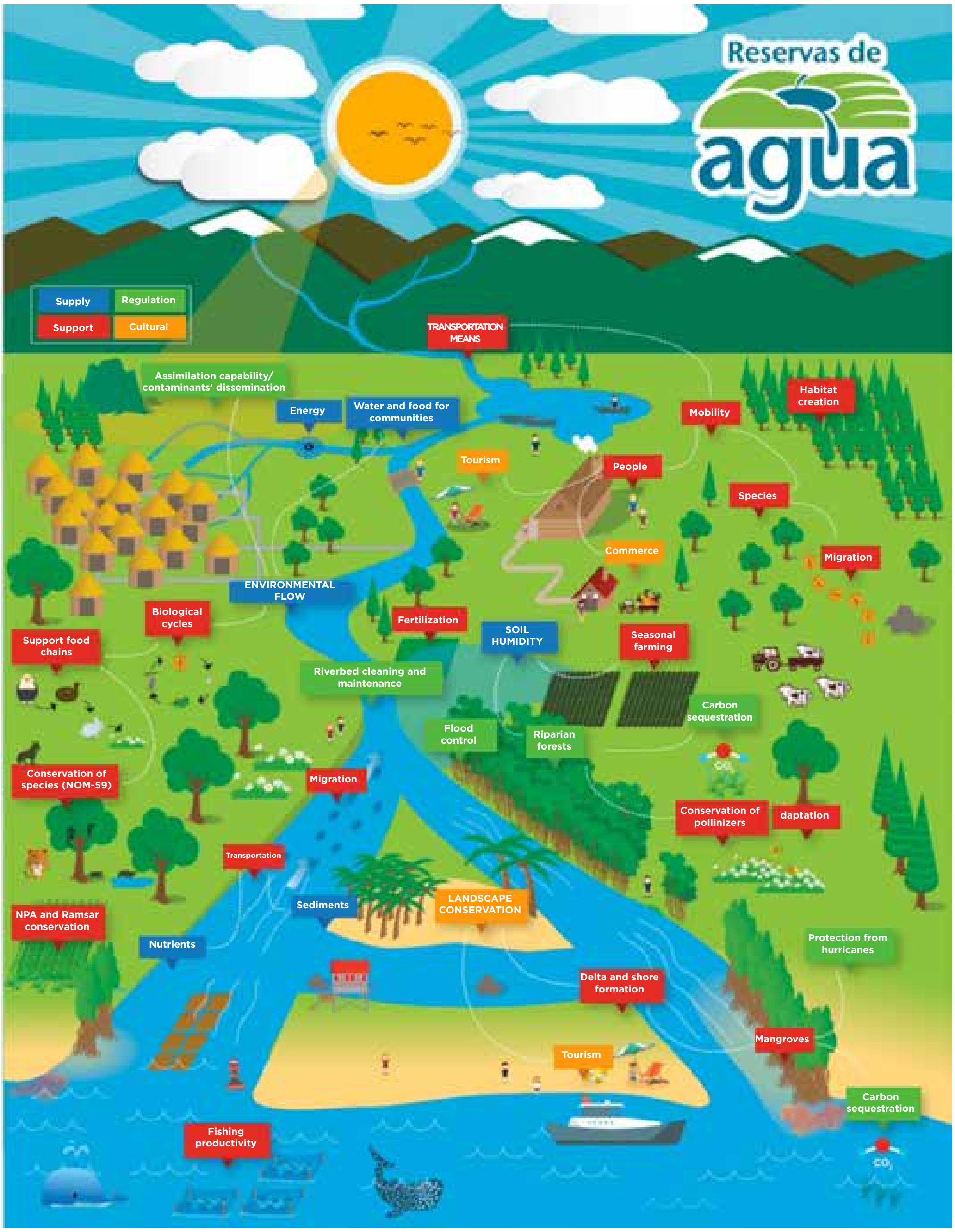
Eco-systemic or environmental services are generally classified as support, supply, regulation and cultural services. Water reserves sustain different types of services. The possibility of receiving a certain water amount year after year is considered a supply service, which can be from the river itself or from the basin's aquifers. Other supply services are sediments being washed and the transportation of nutrients thereby ensuring the fishing productivity in coastal areas. This same process shapes riverbeds, meanders and shores, services considered as support or sustenance for biodiversity conservation and tourism development.

The hydrological cycle regulation services assimilate and dilute pollutants, which improves water quality. The capacity to buffer extreme events –whether storms or droughts that are present in a healthy basin with a natural and functional hydrological cycle– is also a regulation service.

Environmental services classified as cultural allow the conservation of livelihoods for indigenous people, world heritage sites and regions or landscapes with some interest or cultural significance.

Figure 11 shows the environmental services associated with the conservation or establishment of a water reserve.

Figure 11 Water Reserves and eco-systemic or environmental services.



Source: Own elaboration

5.2 Water Reserve Decree

The assessment process for an environmental flow proposal ends with the development of an Assessment of Environmental Flows Document (DECE, acronym in Spanish), which represents the technical memory of the process and includes all collected and generated information, the considerations and work hypothesis, and the results of multi-disciplinary discussions to reach the proposal of environmental flows for an agreed environmental objective for each of the hydrologic basins in the study region. It should be pointed out that as part of the environmental flow proposal and in accordance to the NMX, a hydrologic regime or environmental flow is determined for an environmental objective that must be conserved or recovered, which works as reference to allocate available volumes.

In the case of water reserves, as these represent areas in good conservation condition, the environmental objectives were generally the highest (“A” or “B”) and require a higher amount of water; however, volumes for environmental objectives “C” and “D” which require lower water quantities were also determined. This has provided two advantages; on one hand, the flexibility to accommodate the proposed hydrologic regime within a volume interval considered for the proposed environmental objective, according to the reality at each basin; and on the other hand, it provides management criteria to increase water extraction with ecological criteria, passing to lower level environmental objectives.

From the environmental flow proposal supported by DECE, several different discussion stages occur of the implications of the environmental expenses proposed for the region’s water planning and their respective development plans. As part of these stages, formal participation means opened for water users and society in general. Figure 12 provides a simplified illustration of this process, which involves the development and publication of a Technical Justification Study (TJS) –the official document through which CONAGUA recommends to the Executive Branch the establishment of a water reserve– and ends with an Executive Decree to create a water reserve, the ultimate legal protection of a water volume in Mexico.

Figure 12 Process to issue a water reserve decree

5.3 Discussion and Agreement on Final Volumes for Water Reserves

Even though the development of environmental flow studies have the participation of government authorities, the process of volume adjustments begins only when the DECE has been developed. It is required to reconcile the water management's own requirements for each basin with the ecological requirements according to the proposed environmental objective.

The adjustment and negotiation process has great transcendence as it is here when the ecosystems' water requirements are integrated into water planning for the basins or management units, specifically, in determining the balance of official availability. This is the fundamental management instrument; its establishment and revision is established by the National Waters Act and the procedure is regulated by the Mexican Official Norm 011-CONAGUA-2015 Conservation of the water resource – That establishes the specifications and method to determine the annual mean availability of domestic waters.

The importance of a balance in availability resides in establishing the volumes that can be given in concession or allocated for different uses and the volumes that must be respected for a specific use; such is the case of water reserves for ecological protection, urban public supply and power generation for public consumption.

Because the ultimate end of water allocation for the environment is to maintain a certain hydrologic regime flowing through a course in a basin, then any expense independently of its use downstream, contributes to the hydrologic regime sought to be ensured. This way, the volume required to ensure this regime in a hydrologic basin is made up of volumes that must flow because they have already been allocated or reserved for the lower basin and by those related to water reserves for urban public supply and energy within the same basin. This situation favors the allocation of water to the environment, as generally exclusive volumes will be covered or even exceeded by these synergies with water being conducted throughout the course, provided that this flow does not alter the conditions of the environmental flows' hydrologic regime. That is, the environmental flows regime rides on the regime of commitments for the delivery of water downstream. Figure 13 shows a diagram of this situation for water reserves in the San Pedro Mezquital River. In the basin's highest area, the hydrologic regime present corresponds to 86% of MAR and functions as an environmental flow; it is formed by supply commitments for the 055 Irrigation District (34%), a water reserve for urban public use for the city of Durango (30%) and the environmental flow volume allocated to the reserve for environmental or ecological conservation (22%). The area of higher water use is located lower down the basin; it is here where the city of Durango, the 055 Irrigation District and the industrial area are located. In this part of the basin, the ecological functionality is integrated by a water reserve volume for the environment and a volume committed downstream, which jointly represent 25% of MAR. In the following basin, a reserve was established for power generation that represents 76% of MAR, and if it respects the hydrologic regime, it will create a very important synergy with the water reserve for the environment and achieve an environmental flow regime of 90% of MAR (92% if the water reserve is not destined for urban public use); that would guarantee the hydrologic regime required in the basin's discharge for the Marismas Nacionales lagoon system, Biosphere Reserve, and Ramsar wetland of international importance. This diagram also illustrates the connectivity that can be established with water reserves for the environment present throughout the basin.

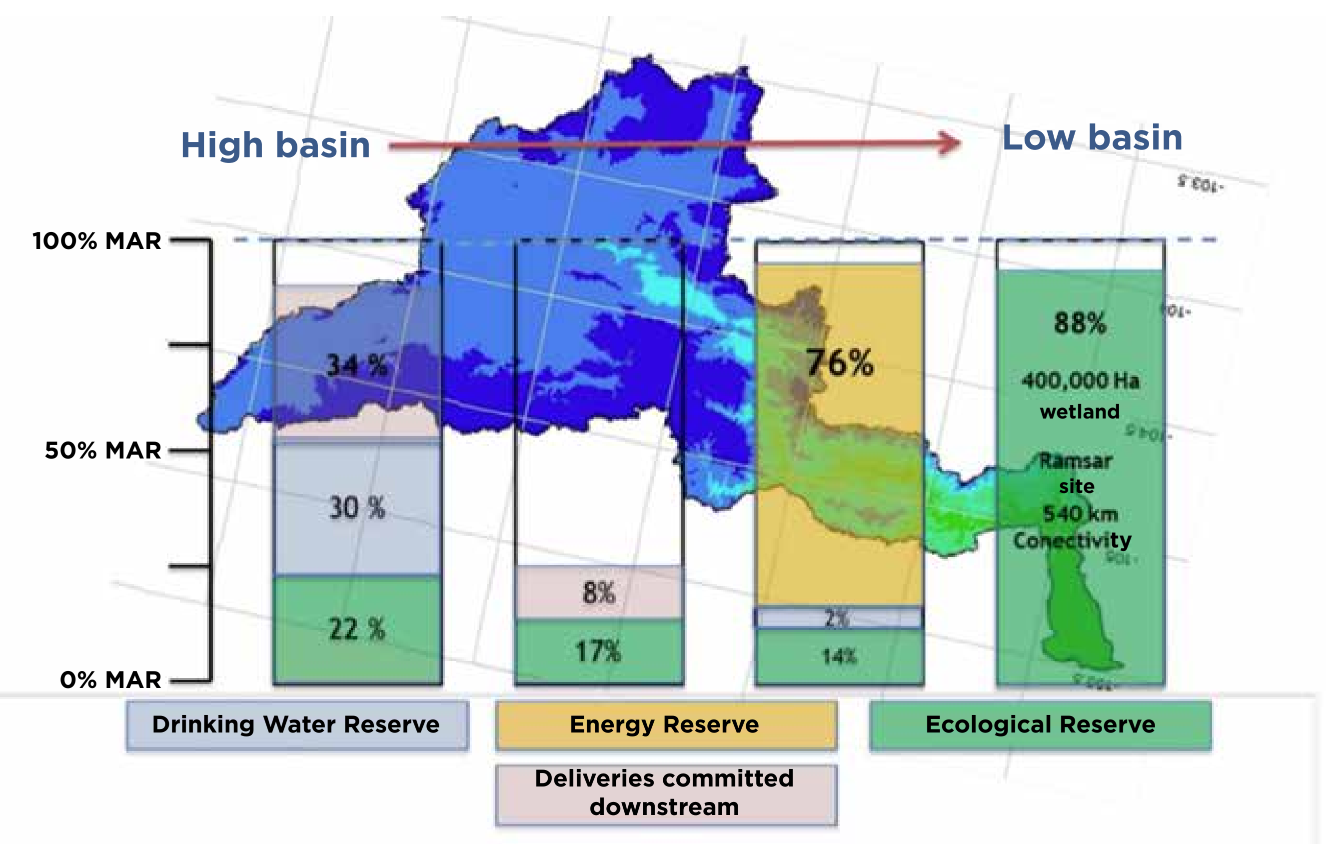
The identification of synergies among the different types of reserves has been of great relevance, as it reduces the impact on availability from adopting an environmental flows regime. It is important to note that these synergies will be valid provided they contribute to the regime's conservation and not its alteration. The synergy of these reserves is a great example of an integrated management of water resources.

The concept of actual cost of environmental flows in water management emerges from the complementarity of these volumes; understanding "cost" as the water volume that is excluded from the allocation process and that consequently reduces the availability of each basin's official balance for other uses.

Expressed in terms of balance, the actual cost of an environmental flow in a water reserve's volume for the environment (Vol_{RAA}) is given by the following equation:

$$Vol_{RAA} = Vol_{\text{Proposed Environmental Flow}} - Vol_{\text{Committed Downstream}} - Vol_{\text{Reserved Urban Public Use}} - Vol_{\text{Reserved Energy}}$$

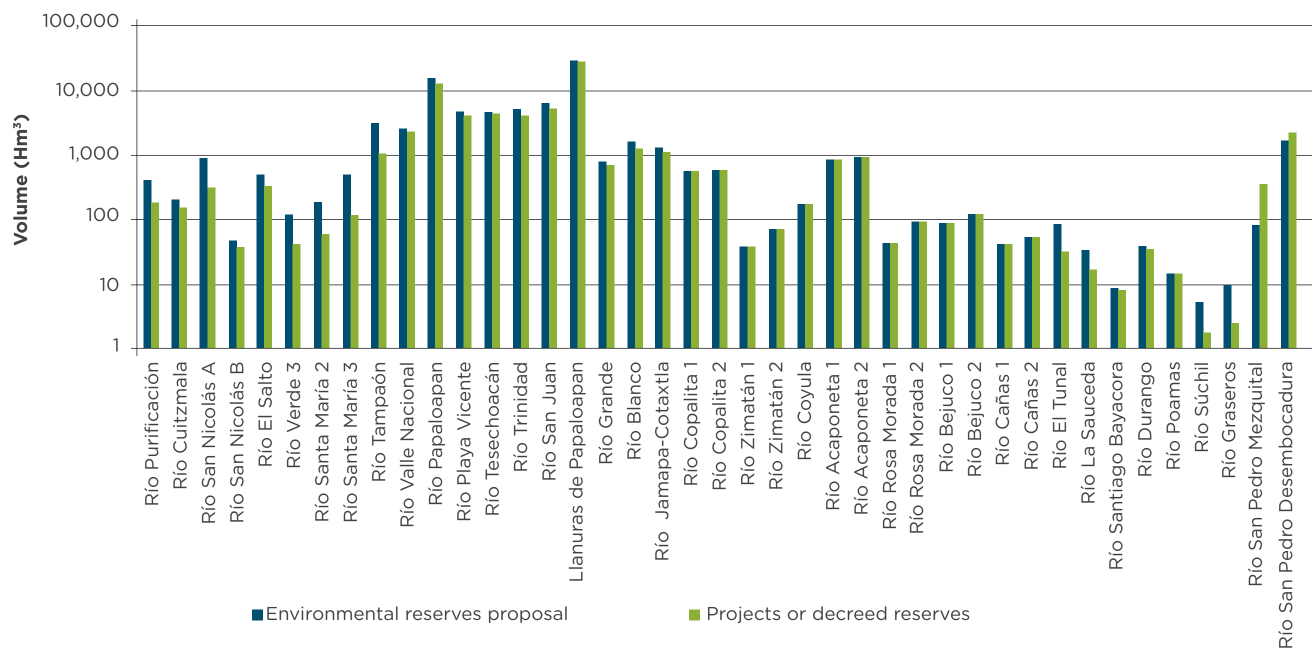
Figure 13 Synergy among water reserves and deliveries committed downstream in the San Pedro Mezquital River basin.



Source: Own elaboration

The result of this balance integration process in the whole basin and identification of synergies for the 43 basins in the six pilot areas shows that it was possible to allocate the volume proposed by the environmental flow studies in 24 basins. In the remaining basins, proposed volumes were reduced in 12 basins by approximately 30%, which was considered acceptable within the proposed environmental objective. A criterion of relevance to make this adjustment was to avoid as much as possible modifying the availability zone established by the Federal Rights Act, which would result in a higher water tariff due to the reduction in relative availability. This would increase the reserve's costs and impact users in the basin. In the 7 remaining basins, the reduction was over 30% due to conditions outside the scope of this process: in three cases (La Sauceda, Súchil and Graseros rivers) volumes were assigned before the NMX was issued and in another four (Purificación, San Nicolás A, Santa María 2 and Tampaón 1) there were differences with official hydrometric information. Figure 14 shows the differences between proposed volumes as environmental flows and those assigned or proposed as water reserves for the environment. However, the most interesting result of this environmental flows and water management integration was that in 40 of the 43 basins, important volumes were maintained for consumptive concessions, which shows that adopting environmental flows is compatible with such uses.

Figure 14 Comparison of annual volumes proposed for environmental flows and proposed for the water reserves decree.



Source: Own elaboration.

5.4 International Impact

The initiative of creating water reserves has attracted the attention of the international community, mainly because it is a decisive response to meet the allocation of water for the environment mandated by Law, and recommended by international agreements; at the same time, it has been valued as a highly relevant climate change adaptation action through a water policy action.

The initiative has been presented at international forums and has been recognized as a practice to be followed by the WWF network and it's starting to be replicated in countries such as Guatemala, Colombia, Bolivia and Peru. However, the highest impact at an international level to date has been Resolution XII-12 "Call To Action To Ensure And Protect The Requirements Of Wetlands For The Present And The Future", adopted by a consensus of the 168 contracting parties of the Convention on Wetlands, called the Ramsar Convention, in the recent Conference of the Parties held in Uruguay from 1 to 9 June, 2015. The Ramsar Convention is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

The resolution recognizes the PNRA's experience and invites the countries to consider Mexico's experience in the identification of opportunities to reserve water in a preventive way and adapt it according to national and regional requirements.

> Water Reserves are an example from Mexico to the world, as they demonstrate an effective climate change adaptation action and sustainable water management. In times of climate uncertainty and increase in competition for water resources, WWF-Mexico and CONAGUA have demonstrated how to build a national reference framework to implement water usage as a common, dynamic and changing resource for ecosystems, communities and the development of infrastructure and the economy. I believe that many countries could learn of this vision and of their practical and operative lessons.
>
> *John Matthews, Coordinator, Secretariat for the Alliance for Global Water Adaptation (AGWA)*

6.3 Closing Comments

Mexico's experience in creating and consolidating its own water management, and in particular the decision to address the challenge of determining environmental flows and their implementation in low-conflict basins, has made it possible:

- To understand the validity of different methodologies and develop its own framework to apply at a national level.
- To establish a gradual process to build capacities at each of the country's regions.
- To act immediately in those basins where the hydrologic regime is still conserved in its natural state or with low alteration, and where establishing an environmental flow is facilitated.
- To understand that the real impact of environmental flows in water availability for other uses is minimized by water commitments with users lower down the basins, by adjustments in infrastructure operation, or by the synergy with reserves for domestic use and power generation.

- To establish a framework for the objective discussion of projects that alter the hydrologic regime, in particular hydroelectric projects.
- To take preventive actions to avoid future conflicts among potential users against water allocated for the environment. Many of these sites coincide with regions of high ecological importance, due to their biodiversity and the environmental services they represent.

It is more evident each day that water availability in the environment guarantees the provision of useful services for management, such as the recharge of aquifers, the fertility of flood plains and farmlands, the conservation of the hydraulic capacity of courses and the improvement in water quality, to name a few. The IWRM has the great potential of becoming a conservation force for biodiversity if these services are internalized.

Additionally, water reserves have resulted in an adaptation measure to climate variability. The annual mean runoff percentage represented by the reserve acts as an impact buffer, it allows to manage risks from climate uncertainty, and creates resilience conditions.

The PNRA has helped understand that the implementation of environmental flows isn't a matter of capacities, but of water safety and protection of the nation's patrimony.

In the development of this initiative, building a relationship of trust among government, civil society and academia has been critical. Civil society organizations are an ally for the IWRM by recognizing the needs of designating water for the environment, and therefore, in strengthening its management.

From this pilot experience, the reserves program has increasingly become established as a public policy of great vision. The development of this policy has been an innovative experience for the water sector, as it is based on the creation of a working relationship with civil society and the openness to an active participation in water management by other entities in the environmental sector. It is desirable to maintain this work structure which without doubt will enhance water governance in the country.

These experiences have set the foundations to continue with a work program that establishes, in a first phase, the 189 water reserves for the environment, which will allow building capacities and complementary instruments to address the adoption of environmental flows in the rest of the country.

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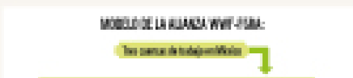
Annex 1

1. Antecedentes

Desde el año 2004, la Alianza WWF-Fundación Gonzalo Río Arronte, I.A.P. (FGRA), en colaboración con la Comisión Nacional del Agua (CONAGUA) y otras dependencias, instituciones académicas, organizaciones, usuarios del agua y comunidades rurales, ha realizado propuestas de **caudal ecológico (CE)** en tres cuencas con contextos de conservación, presión y gestión muy distintos: i) Conchos en Chihuahua; ii) Copalita-Zimatán-Huatulco en Oaxaca; y iii) San Pedro Mezquital en Durango y Nayarit. De 33 sitios analizados a detalle en las tres cuencas, en el 73% de los casos el caudal ecológico ocurre bajo las condiciones actuales; en un 21% el manejo de agua requiere de regulación en las condiciones de extracción y operación de la infraestructura; y sólo en un 6% es necesario realizar adecuaciones en la asignación de agua a los usuarios. Estos resultados fueron sistematizados para la propuesta de la Norma Mexicana de Caudal Ecológico (NMx) (Figura 1).



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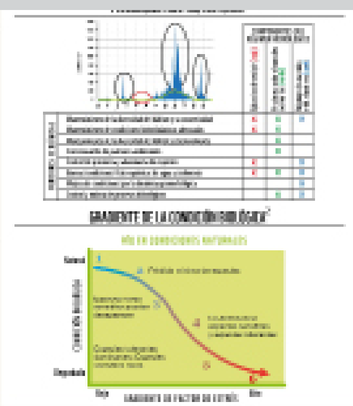


Figura 2. Fundamentos científicos de la NMx

Cualquier metodología para determinar el régimen de CE será válida si lleva a la práctica los fundamentos científicos clave, es decir:

- Deberá comprender el significado ecológico de cada componente del régimen hidrológico natural y generar propuestas, desde un punto de vista funcional, para su conservación o restablecimiento.
- Las propuestas tendrán que considerar el rango natural de variabilidad hidrológica, tanto en condiciones ordinarias como en su régimen de avenidas.
- Reconoce que un ecosistema acuático modifica sus atributos como respuesta al aumento de los niveles de estrés, por lo tanto permite ajustar las propuestas de CE a los objetivos ambientales o conservación del río.

3. Objetivo

Establecer el procedimiento y especificaciones técnicas para determinar el régimen de caudal ecológico en corrientes o cuerpos de agua nacionales en una cuenca hidrológica.

4. Campo de aplicación

Asignaciones, infraestructura, obras que impliquen trasvases entre cuencas y similares que requieran de una Evaluación de Impacto Ambiental. Todas las corrientes o cuerpos de agua cuyos acuerdos de disponibilidad publicados en el Diario Oficial de la Federación (DOF) no consideren un caudal para la conservación de ecosistemas acuáticos.

5. Referencias normativas de especial interés para la NMx

NOM-011-CNA-2000, Conservación del recurso del agua – Que establece que las especificaciones y el método para determinar la disponibilidad media anual de las aguas nacionales.

tivo ambiental asociado, de acuerdo a la importancia ecológica y presión de uso de la cuenca conforme al Anexo Técnico 1 de la NMx, ya sea en corrientes superficiales, en cuerpos receptores de diversa índole, o como parte de la descarga natural del acuífero asociado, para conservar y proteger las condiciones ambientales fomentando el equilibrio ecológico.

Los objetivos ambientales representan al estdo ecológico que se pretende alcanzar o conservar en la cuenca, estableciendo la relación entre su valor de conservación (importancia ecológica) y su implicación en los usos productivos del agua (presión de uso) (Figura 3).

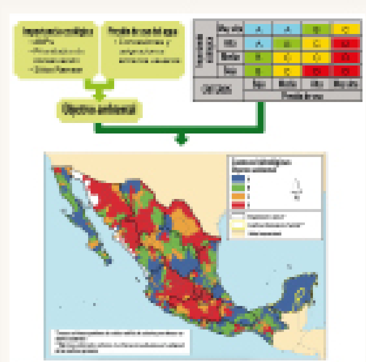


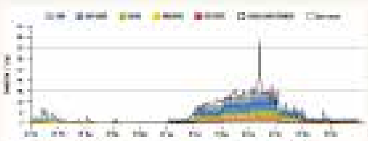
Figura 3. Modelo conceptual: matriz de criterios y mapa de objetivos ambientales

NORMA MEXICANA (NMX) QUE ESTABLECE EL PROCEDIMIENTO PARA LA DETERMINACIÓN DE CAUDAL ECOLÓGICO DE CUENCAS HIDROLÓGICAS

6.2. Metodologías

i. Hidrológicas (Anexos Técnicos 2, 3 y 4)

- Sin conflictividad por el uso del agua y sin régimen hidrológico alterado (Figura 4).
  - Con base en valores de referencia a manera de intervalos en el porcentaje del escurrimiento medio anual y llevado a escala mensual



- Presencia de infraestructuras hidráulicas o hidroeléctricas con alteración sobre el régimen hidrológico (Figura 5):

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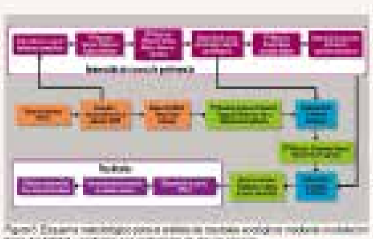
ii. Hidrobiológicas (Anexo Técnico 5)

- Modelos de simulación de hábitat para proyectar el ambiente físico y sus cambios en función del caudal, con el propósito de cuantificar las preferencias de hábitat de la especie que se tome como objetivo (Figura 6). Utilizan variables hidráulicas para auxiliar la determinación de la conectividad de los ríos, sus inundaciones y capacidades de los cauces. Entre los modelos más utilizados destacan:
  - Metodología incremental (*Instream Flow Incremental Methodology* – **IFIM**)
  - Sistema de simulación del hábitat físico (*Physical Habitat Simulation System* – **PHABSIM**)



iii. Holísticas (Anexo Técnico 6)

- Recomendables para casos donde se requiere detallar la propuesta de CE debido a la complejidad, dificultad o conflictividad social. Atienden particularidades de las zonas de estudio y, en específico, identifican el significado ecológico de los componentes del régimen hidrológico y su relación con la importancia ecológica y el impacto de los usos del agua (Figura 7). Metodologías de este tipo son:
  - La de Construcción por Bloques (*Building Block Methodology* – **BBM**)
  - Respuesta a la Modificación del Flujo Aguas Abajo (*Downstream Response to Impose Flow Transformation* – **DRIFT**)
  - Condiciones de Referencia (*Benchmarking*)
  - Límites Ecológicos de Alteración Hidrológica (*Ecological Limits Of Hydrologic Alteration* – **ELOHA**)

las estaciones hidrométricas en parte alta, media y baja de la cuenca y a la salida de las subcuencas, presentando el reporte con la siguiente estructura:

i. Descripción de la cuenca hidrológica
ii. Selección y características de la subcuenca
iii. Caudales ecológicos por cuenca
   a) Descripción de la metodología utilizada, justificación y determinación preliminar de caudales ecológicos
   b) Sitios de referencia y propuesta de régimen de caudal ecológico
iv. Anexos. Fichas técnicas de cada sitio de referencia analizado

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Instituciones participantes en el proyecto de Norma Mexicana

Comisión Federal de Electricidad, Comisión Nacional del Agua, Comisión Nacional de Áreas Naturales Protegidas, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Institutos de Biología e Ingeniería de la Universidad Nacional Autónoma de México, Instituto Mexicano de Tecnología del Agua, Instituto Nacional de Ecología, Secretaría de Medio Ambiente y Recursos Naturales, The Nature Conservancy y World Wildlife Fund, Programa México.

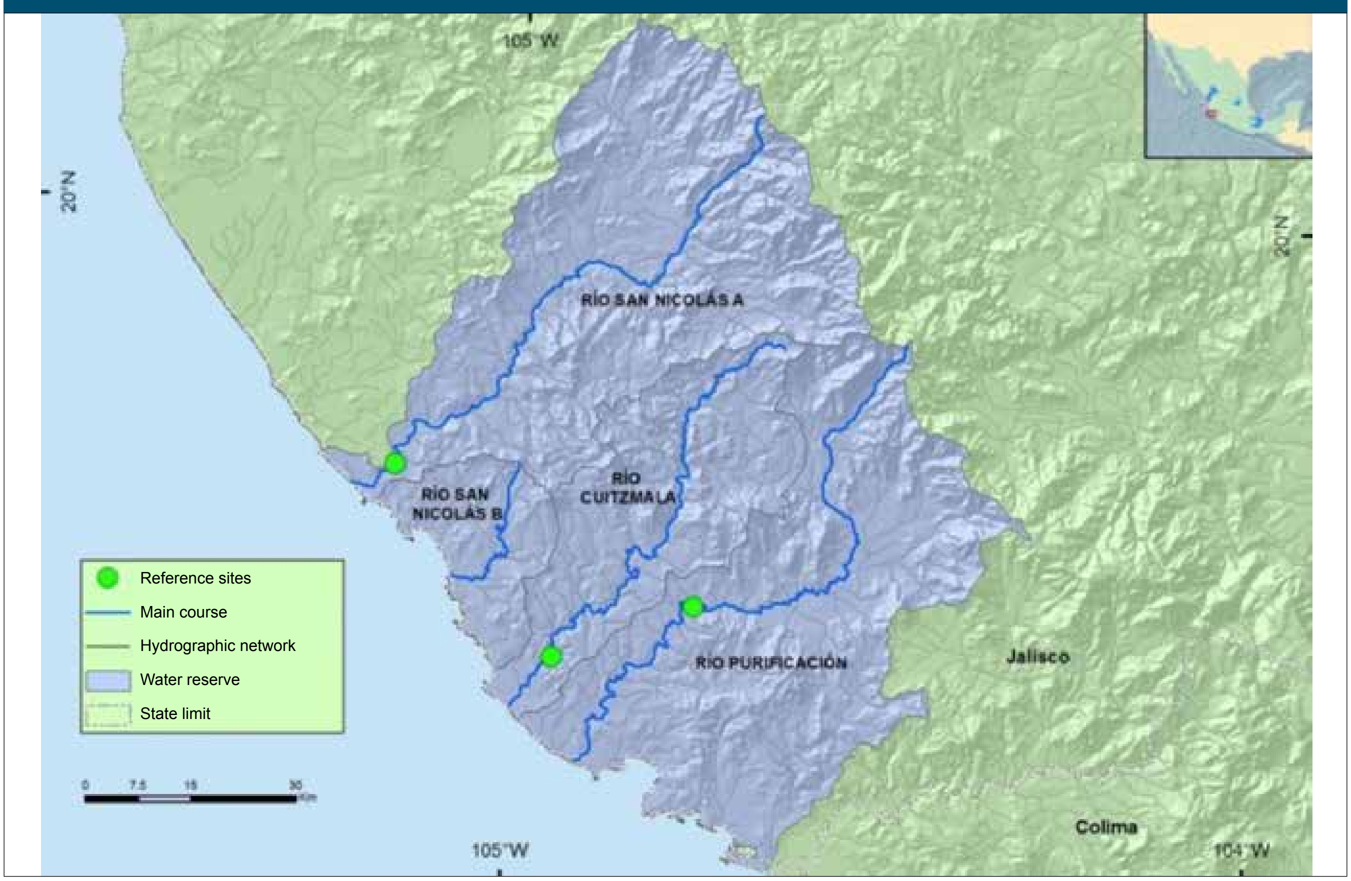
Annex 2

Environmental Flow Studies' Technical Files per Work Area

1. Chamela Area

The "Chamela" work area is located in the State of Jalisco under the jurisdiction of CONAGUA's Lerma-Santiago-Pacific Basin Administrative Unit (Figure A2-1 "Chamela" pilot area). The environmental flow's assessment was conducted by the Costa Sur University Center from the University of Guadalajara, with collaboration of specialists from the Institute of Geology, the Institute of Biology and the Research Center on Ecosystems, all from the UNAM, as well as the University of Arizona.

Figure A2-1 "Chamela" pilot area.



Source: CONAGUA-WWF Mexico (2013)

Application of the norm was conducted in reference sites in four hydrologic basins that belong to the Jalisco Coast hydrological region and discharge into the Pacific Coast. Results are presented in Table A2-1.

Table A2-1 Assessed hydrologic basins and proposal for water reserves in the "Chamela" pilot area. Source: Own elaboration

Hydrologic Basin	Reference Sites	Intended Conservation State	Environmental Objective	Environmental Flow Proposal	
				Volume (Hm^3)	MAR's percentage
Purificación River	Los Baños PP4	Very good	"A"	186.8	40
Cuitzmala River	Cuitzmala CP4	Very good	"A"	153.0	67
San Nicolás A River	San Nicolás SNP1	Very good	"A"	316.7	66
San Nicolás B River	-	Very good	"A"	39.1	79

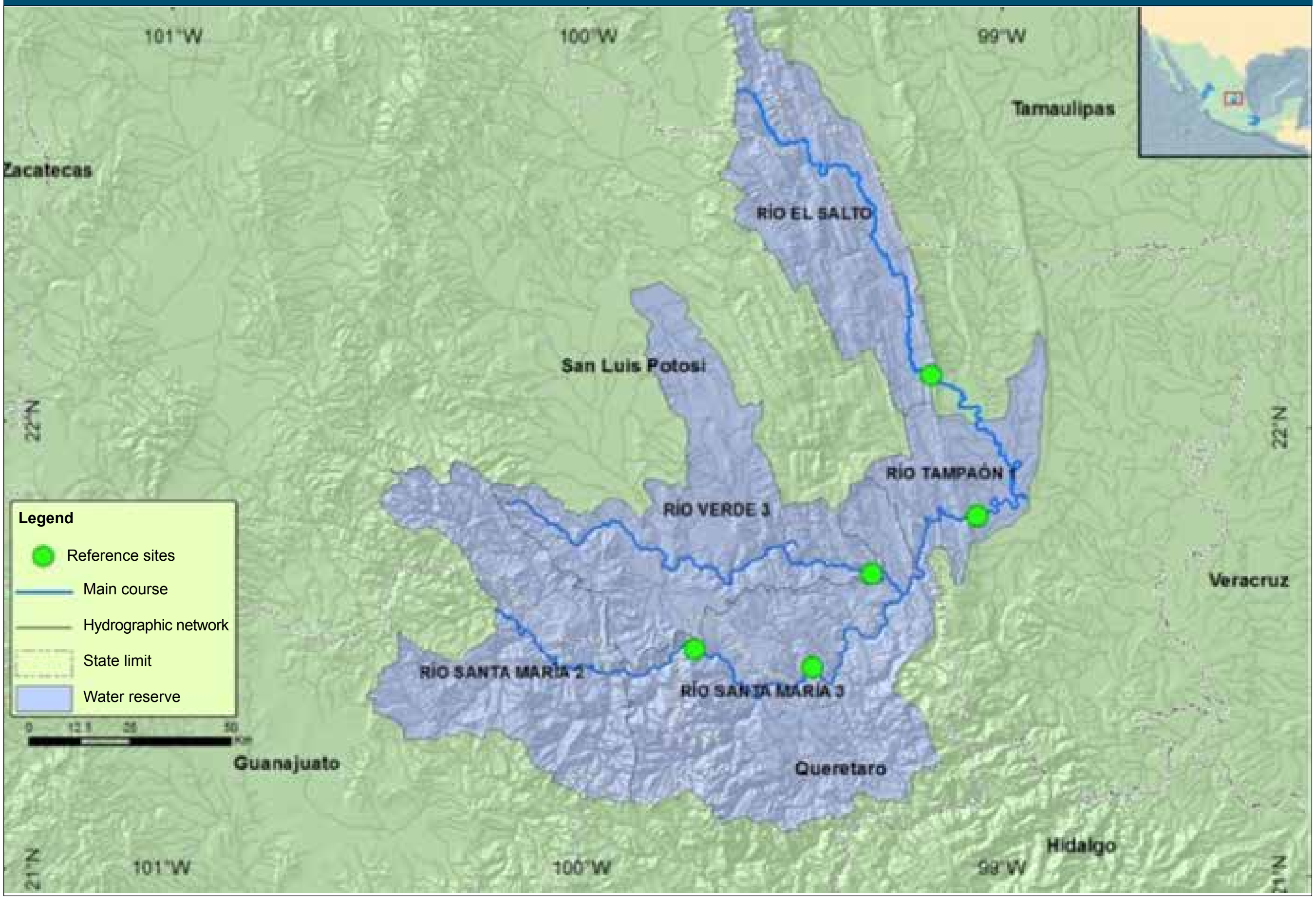
...When discussing the suitability of the reference sites for the environmental flow studies, we became aware that the most favorable habitat for invertebrates was the richest for fish. This showed us that one sole environmental indicator isn't enough and that we must define which are the most adequate. Hence the great value of conducting environmental flow studies in the context of holistic methodologies. Water reserves for the environment are an innovative approach because they represent a national scope strategy, based on a Mexican norm which provides a solid water management foundation, conservation of natural resources, biodiversity, and is compatible with economic development. It considers the natural infrastructure's value as basis for development. For us, as members of the academia participating in the work group, it offered a good experience because, even though a norm already existed, this was a new norm and there were doubts on how to apply it.

Luis Manuel Martínez, PhD. Researcher from the Costa Sur University Center, Coordinator for the Chamela area studies

2. Sierra Gorda Area

The "Sierra Gorda" work area is located in the states of Guanajuato, Querétaro and San Luis Potosí; the water's administrative management is responsibility of CONAGUA's Northern-Gulf Basin Administrative Unit (Figure A2-2). The environmental flow's assessment was conducted by the University of Querétaro, with the participation of specialists from the University of Guerrero, the University of Michoacán of San Nicolás de Hidalgo and the Institute of Biology from the UNAM.

Figure A2-2 "Sierra Gorda" pilot area.



Source: CONAGUA-WWF Mexico (2013)

The norm was applied in reference sites of five hydrologic basins that belong to the Hydrological Sub-region of the Panuco River in the Gulf of Mexico watershed. Results are presented in Table A2-2.

Table A2-2 Assessed hydrologic basins and proposal of water reserves in the "Sierra Gorda" pilot area. Source: Own elaboration

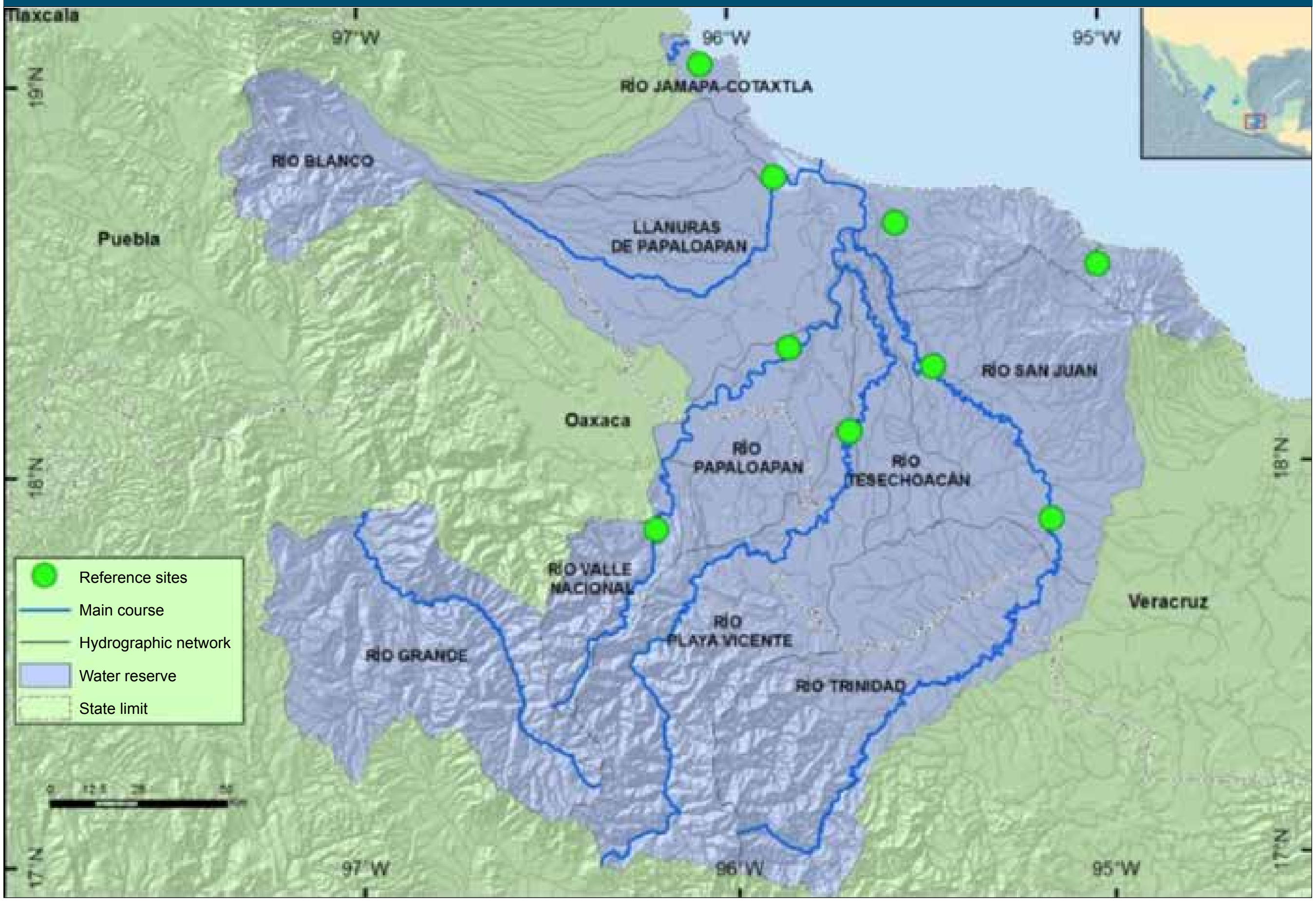
Hydrologic Basin	Reference Sites	Intended Conservation State	Environmental Objective	Environmental Flow Proposal	
				Volume (Hm^3)	MAR's percentage
El Salto River	Micos	Very good	"A"	499	63
Verde 3 River	Tanlacut	Good	"B"	119	37
Santa María 2 River	Vegas Cuatas	Very good	"A"	188	54
Santa María 3 River	San Pedro Mezquital	Very good	"A"	571	54
Tampaón 1 River	Puente de Dios	Very good	"A"	3,225	60

> The freshwater issue in the world is so urgent that it doesn't matter where you begin: with the environmental flow norm, with work groups for its implementation or with operating organizations. In any case we must take into consideration: 1) development styles and models based on the amount of available water, 2) amount of water required to maintain the rivers' eco-systemic services required for development, and 3) know what will be done with what has already been dirtied or degraded. There is no use in guaranteeing domestic water if we don't have mechanisms to guarantee water for the environment, the basis for the future. We can pay for all the water we want in the cities but that doesn't ensure that we will have enough for the ecosystems. Advisors cannot view water as liters per second, they must see it under a basins' approach. The work in Sierra Gorda was a great experience. Those of us who had already worked in the area were curious to know where organisms went when the main flow decreased. As we worked on the water reserves for the environment we noticed the existence and importance of cavities that form beneath riparian trees, such as the Ahuehuete trees; during critical periods of low waters and rains, the richness is there, on the banks of the main course. Through lab analysis, not only did we find diversity but also high abundance. In the Micos River we also found an epifauna that is highly dependent on the substrate (habitat) supplied by the natural stream. Without these flows we suffer a high loss of an important mollusk biodiversity segment in Mexico.
>
> *Luis Raúl Pineda, PhD. Researcher from the University of Querétaro, Coordinator for the Sierra Gorda area studies*

3. Papaloapan Area

This work area is located in the states of Oaxaca, Puebla and Veracruz; its administrative management belongs to CONAGUA'S Central-Gulf Basin Administrative Unit (Figure A2-3). The environmental flow assessment was responsibility of the Institute of Ecology A.C., with the participation of specialists from El Colegio de la Frontera Sur, the University of Veracruz and the Institutes of Biology and of Geology from the UNAM.

Figure A2-3 Location of the "Papaloapan" pilot area.



Source: CONAGUA-WWF Mexico (2013)

The reference sites are located in rivers of 10 hydrologic basins that belong to the Papaloapan and Papaloapan A Hydrological Sub-regions in the Gulf of Mexico watershed. Results are presented in Table A2-3.

TablE A2-3 Assessed hydrologic basins and water reserves in the "Papaloapan" pilot area.
Source: Own elaboration

Hydrologic Basin	Reference Sites	Intended Conservation State	Environmental Objective	Environmental Flow Proposal	
				Volume (Hm³)	MAR's percentage
Valle Nacional River	Valle Nacional	Very good	"A"	2,549	65
Papaloapan River	Papaloapan	Good	"B"	15,358	72
Playa Vicente River	Playa Vicente	Very good	"A"	4,878	79
Tesechoacán River	-	Very good	"A"	4,545	68
Trinidad River	Río Trinidad	Very good	"A"	5,272	89
San Juan River	Río San Juan	Very good	"A"	6,584	84
Papaloapan plains	La Popotera y Tuxtlas	Very good	"A"	29,874	71
Grande River	-	Very good	"A"	807	67
Blanco River	Río Blanco	Very good	"A"	1,602	67
Jamapa-Cotaxtla River	Mandinga	Good	"B"	1,312	73

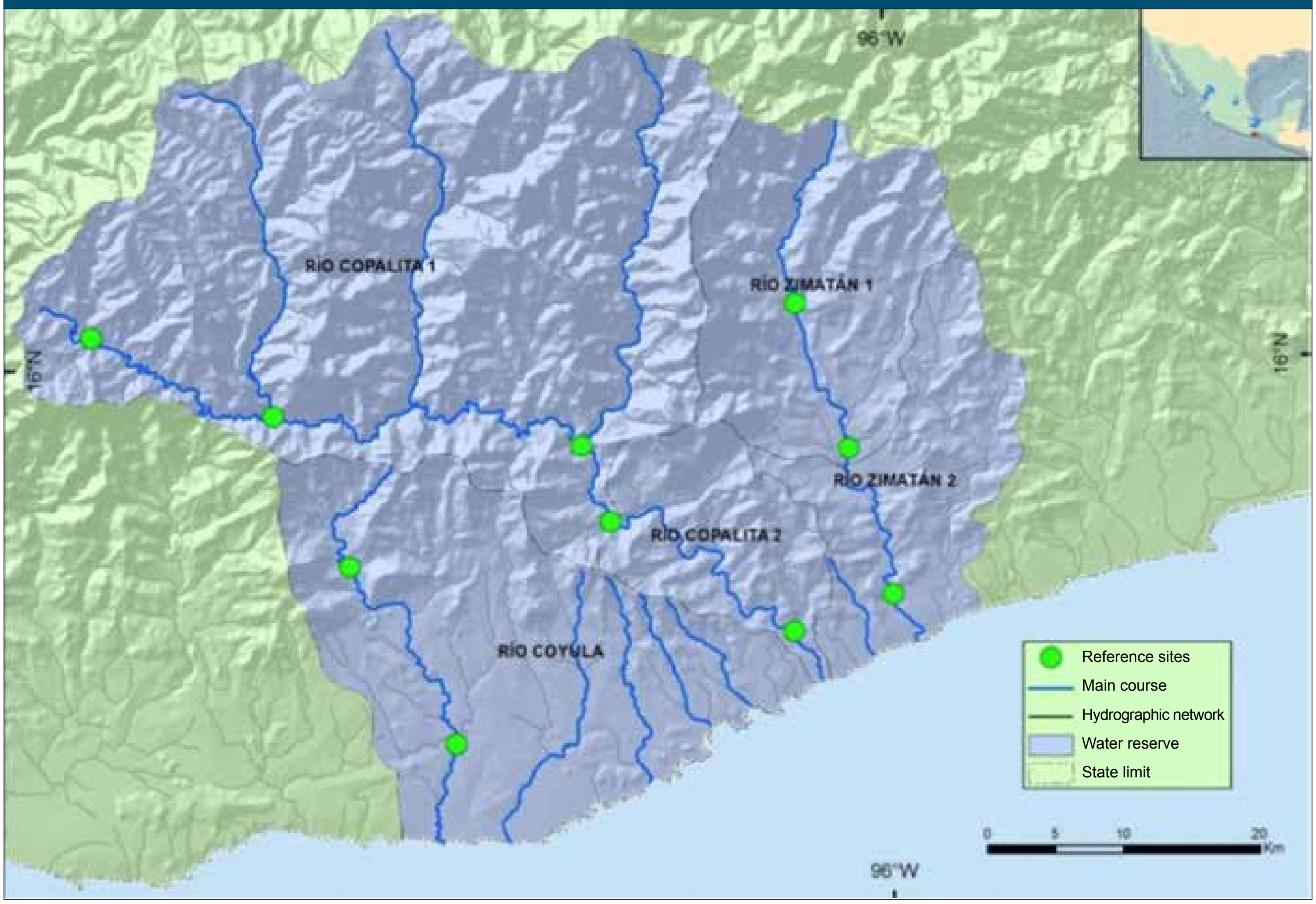
Besides using a territorial approach to protect ecosystems, we must integrate a basin vision into our natural environments' management programs, assess where water is coming from –many times it is subterranean–, and include follow-up and assessment criteria on these inflows; on the contrary, we won't be truly conserving the main source for a complete integrity. An environmental flow maintains the resource's origin, it conserves and guarantees the water's quantity and periodicity required by rivers and wetlands and, even though the systems may be degraded or polluted, it can be restored or recovered. We must influence and demonstrate that the hydrologic regime is an integral part of an ecosystem's health and that as a whole it is important for society due to the environmental services it supplies and the critical resources it provides, such as freshwater. Egyptians, Babylonians, Aztecs and Olmec, among other civilizations, settled near water bodies on which their subsistence depended. The modern world has chosen engineering and this resource's control for its convenience, creating large environmental imbalances and loss of ecosystems due to an unsustainable management. In contrast and following the customs' of ancient people, in San Juan Evangelista in Veracruz, crops and cattle are picked up before the floods because rivers' periodically overflow. The people's productive activities are synchronized with the hydrologic regime, and they recognize that natural rises are needed to fertilize and maintain the fields; this allows the conservation of large tropical forest patches of dense vegetation.

Patricia Moreno Casasola, PhD., Researcher from the Institute of Ecology A.C.,
Coordinator of the Papaloapan river studies

4. Copalita-Zimatán-Coyula Area

This work area consists on a complex of hydrologic basins located in the State of Oaxaca. Its administrative management depends on CONAGUA's Southern Pacific Basin Administrative Unit (Figure A2-4). The environmental flow assessment was developed by the WWF-FGRA Alliance, with the collaboration of specialists from the Institutes of Biology and of Geology from the UNAM, and the National Union of Agricultural Workers of Oaxaca.

Figure A2-4 Location of the "Copalita-Zimatán-Coyula" pilot area.



Source: CONAGUA-WWF Mexico (2013)

The reference sites are located in five hydrologic basins that belong to the Coast of Oaxaca hydrological region and discharge into the Pacific Ocean. Results are presented in Table A2-4.

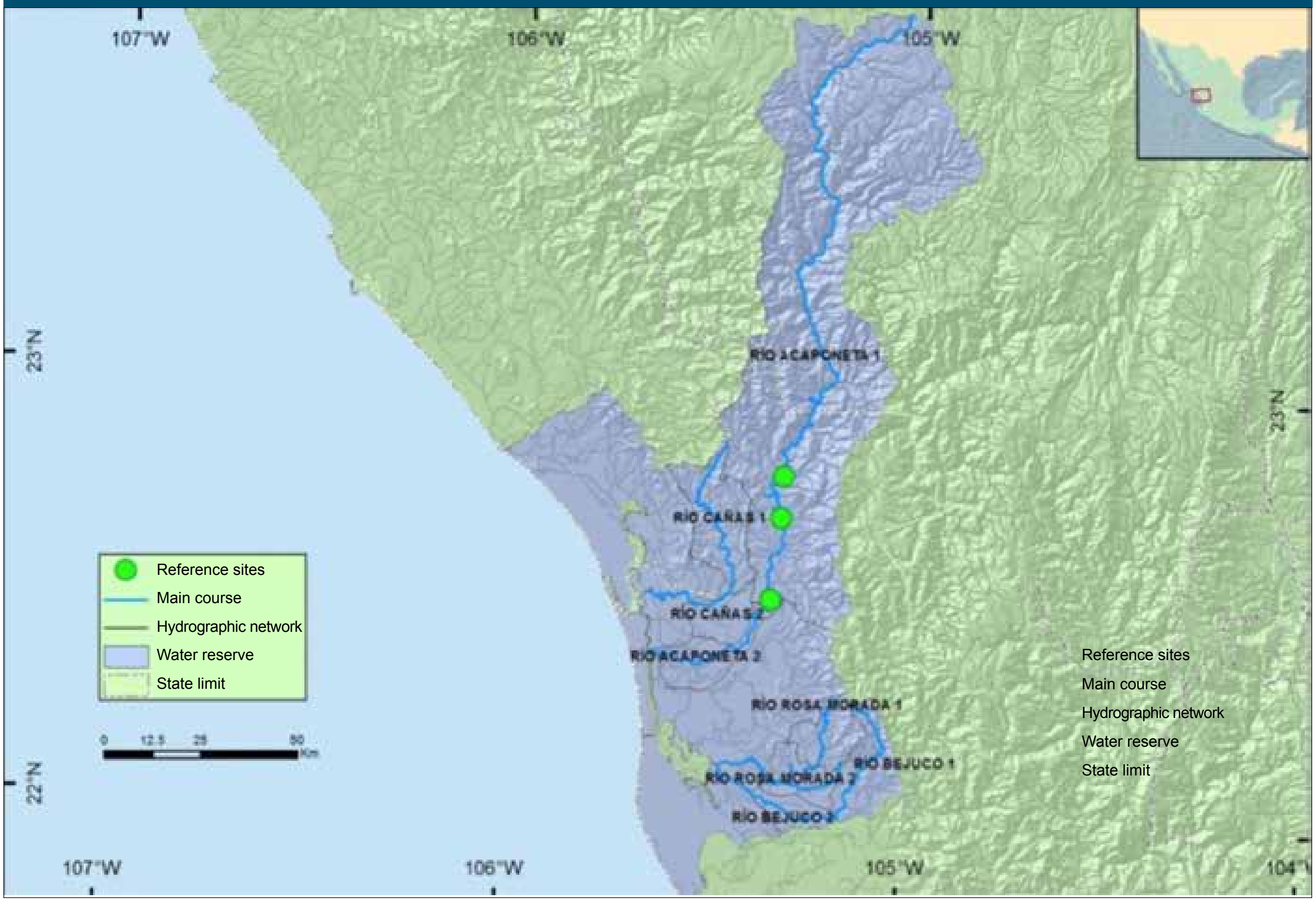
Table A2-4 Assessed hydrologic basins and water reserves in the “Copalita-Zimatán-Coyula” pilot area. Source: Own elaboration

Hydrologic Basin	Reference Sites	Intended Conservation State	Environmental Objective	Environmental Flow Proposal	
				Volume (Hm^3)	MAR’s percentage
Copalita 1 River	Copalita La Hamaca	Very good	“A”	566	99
Copalita 2 River	Puente Copalita	Very good	“A”	587	92
Zimatán 1 River	Puente Petatengo	Good	“B”	39	98
Zimatán 2 River	Puente Zimatán	Very good	“A”	71	98
Coyula River	Puente Coyula	Good	“B”	176	34

5. Acaponeta Area

The complex of hydrologic basins for this study is located in the states of Durango and Nayarit, and under the jurisdiction of CONAGUA’s Northern Pacific Basin Administrative Unit (Figure A2-5). Assessment of the environmental flow was conducted by Pronatura Noroeste A.C., with the contribution of specialists from the University of Sinaloa, the University of Nayarit, the Culiacán Botanical Garden, and the Research Center on Food and Development A.C. This work was financed by the WWF-Carlos Slim Foundation Alliance.

Figure A2-5 Location of the “Acaponeta” pilot area.



Source: CONAGUA-WWF Mexico (2013

The reference sites are located in the Acaponeta River basin, as it’s the largest basin; however, the study included the assessment of other hydrologic basins in the Presidio-San Pedro hydrological region that discharge into Marismas Nacionales. Results are presented in Table A2-5.

Table A2-5 Assessed hydrologic basins and water reserves in the "Acaponeta" pilot area. Source: Own elaboration.

Hydrologic Basin	Reference Sites	Intended Conservation State	Environmental Objective	Environmental Flow Proposal	
				Volume (Hm^3)	MAR's percentage
Acaponeta 1 River	Mineral de Cucharas, Tepehuajes	Very good	"A"	860	63
Acaponeta 2 River	El Recodo	Very good	"A"	937	66
Rosa Morada 1 River	-	Good	"B"	44	55
Rosa Morada 2 River	-	Very good	"A"	91	57
Bejuco 1 River	-	Good	"B"	90	61
Bejuco 2 River	-	Good	"B"	122	61
Cañas 1 River	-	Good	"B"	41	33
Cañas 2 River	-	Good	"B"	54	34

The National Water Reserves Program is an initiative adopted and leaded by authorities, which is uncommon and unusual. It's important that this initiative comes from a sector that traditionally supports development through infrastructure works. This legal conservation instrument for hydrologic regimes is coordinated by civil society and CONANP, directed to the integral protection of water resources, natural environments and the environmental services they provide. This type of program can be used as model for other government programs and initiatives, and is replicable in others countries.

Miguel Ángel Vargas Téllez, Co-Director, PRONATURA. Work Coordinator in the Acaponeta area.

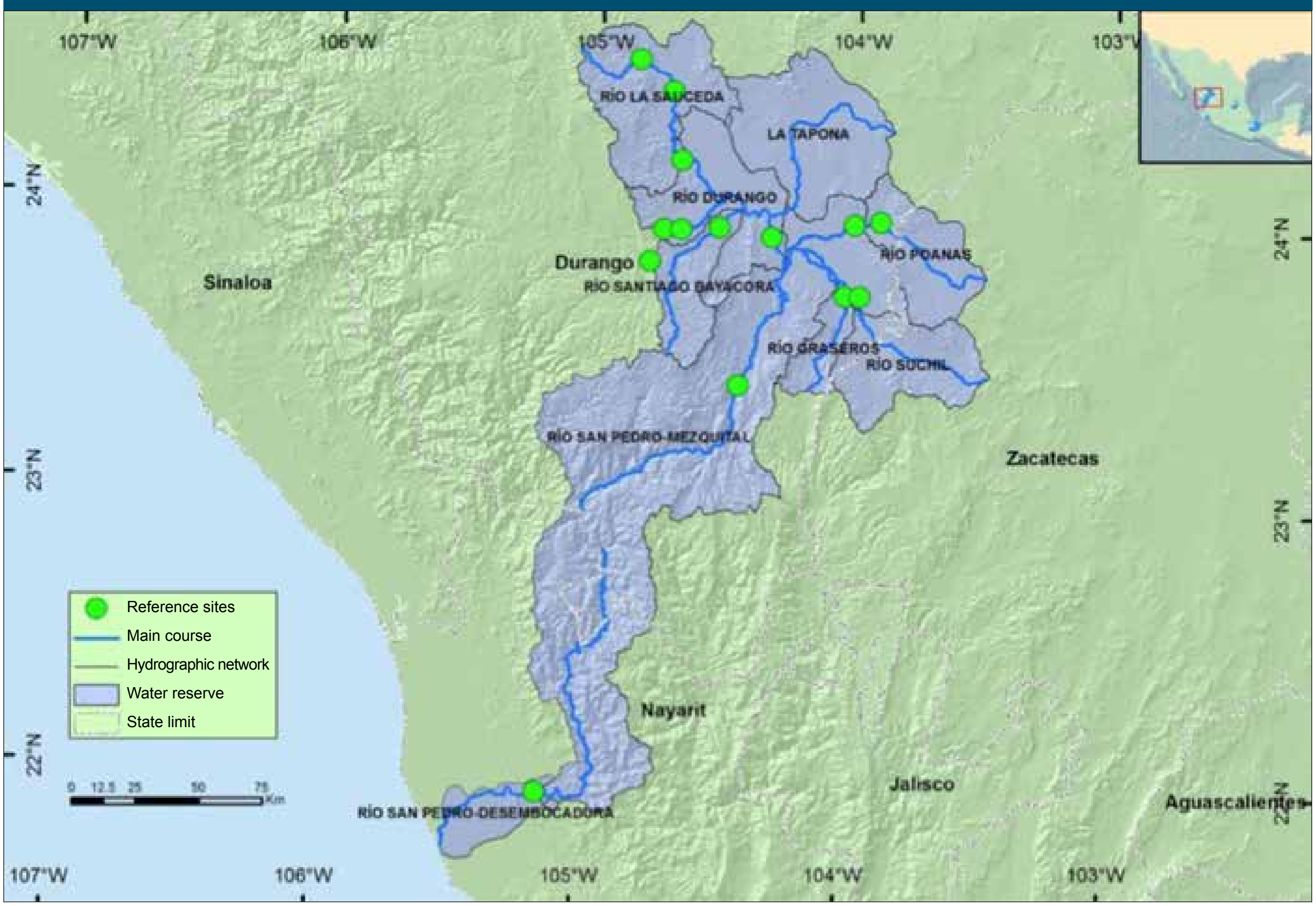
The opportunity to determine an environmental flow for its adoption as a water reserve has been very motivating. The great commitment shown by the work group greatly exceeded expectations and must be highlighted. During the field campaigns, members from different specializations were always willing to wait for the rest of the team. We never heard someone say "I'm tired". On the days when the sun beat down, they covered their heads with a turban and continued on working.

Mauricio Cortés Hernández, Director of priority species, PRONATURA Noroeste A.C.

6. San Pedro Mezquital Area

This study was concentrated in hydrologic basins in the states of Zacatecas, Durango and Nayarit, with an administrative management from CONAGUA'S Northern Pacific Basin Administrative Unit (Figure A2-6). Assessment of the environmental flow was conducted by the WWF-FGRA Alliance, with the collaboration of specialists from the Institutes of Biology and of Geography of the UNAM, the Institute of Ecology A.C., the Juarez University of the State of Durango, and the Interdisciplinary Research Center for Integral Regional Development of the National Polytechnic Institute (Durango Unit).

Figure A2-6 Location of the "San Pedro Mezquital" pilot area.



Source: CONAGUA-WWF Mexico (2013)

This project began since 2009 by the WWF-FGRA Alliance. The work conducted in this basin was used to systematize the experience in determining environmental flows and a first draft for a norm of environmental flows was proposed. The reference sites were located in different points along the hydrologic basins to cover the whole interconnected system of the San Pedro River hydrological sub-region, with exception of the middle basin which has no access. Results are presented in Table A2-6.

Table A2-6 Assessed hydrologic basins and water reserves in the "San Pedro Mezquital" pilot area. Source: Own elaboration.

Hydrologic Basin	Reference Sites	Intended Conservation State	Environmental Objective	Environmental Flow Proposal	
				Volume (Hm^3)	MAR's percentage
El Tunal River	El Tunal T1	Very good	"A"	85.2	61
La Sauceda River	La Sauceda S1 y S2	Moderate	"C"	33.3	25
Santiago Bayacora River	SB1	Moderate	"C"	8.7	10
Durango River	Durango AS1, T2, T3 y SP1	Moderate	"C"	38.0	11
Poanas River	Poanas P1	Very good	"A"	14.5	23
Súchil River	Súchil AS2	Moderate	"C"	5.4	15
Graseros River	Graceros AG1	Very good	"A"	9.5	35
San Pedro Mezquital River	San Pedro Mezquital SP2	Moderate	"C"	82.0	3
San Pedro Desembocadura River	San Pedro Desembocadura SP3	Very good	"A"	1,678.0	59

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