Chapter 6
Cuatro Ciénegas: An Aquifer at Risk of Overexploitation

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6.1 Introduction

Groundwater is essential for the country's socioeconomic development, as it represents 39% of the volume licensed for consumptive uses. Over two million irrigated hectares depend on ground sources, which comprise one third of the irrigation surface area at the national level. In addition, aquifers satisfy most industrial water demands and are the primary source of supply for the rural population (CONAGUA 2018).

As we could read in Chap. 5 of this book, Mexico's 1917 Constitution establishes that water is the property of the nation, but groundwater can be withdrawn without any allocation deed, which means that anyone can extract groundwater without a permit or concession. Such a situation has already caused an overexploitation of aquifers. However, in this same statute, the Federal Executive branch of government is empowered to establish ordinances regulating groundwater extraction through regulations and closures or by the suspension of free extraction. This situation prevailed until the middle of the last century, when the Federal Executive established regulations on the extraction of water in 55% of the country's territory, leaving the rest with a free extraction status (CONAGUA 2020).

In the remaining 45% of the Mexican territory, water users opposed administrative and legal efforts to regulate the free extraction of groundwater, arguing that the development of economic activities would be limited. Farmers in northern Mexico took advantage of this situation and began to acquire large extensions of land, as

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V. Souza et al. (eds.), *Conflicts Between Biodiversity Conservation and Humans*, Cuatro Ciénegas Basin: An Endangered Hyperdiverse Oasis,
https://doi.org/10.1007/978-3-030-83270-4_6

well as increasing the extraction of groundwater, exceeding the natural recharge capacity of the aquifers (CONAGUA 2020). This caused an overexploitation of at least 15% of Mexico's aquifers, leading to the drying up of springs, the disappearance of wetlands, a decrease in the base flow of rivers, water pollution, and saline intrusion, in addition to large economic losses due to decreased well and land settlement yields (CONAGUA 2018).

On April 5, 2013, the Federal Executive signed eight agreements that provisionally suspended free extraction in the entire country. This aimed to regulate water use in the basins and aquifers affected by shortages and overexploitation and promote sustainability without limiting economic and human development (DOF 2013a).

The suspension of the free extraction of groundwater and the elaboration of the legal systems of groundwater (closed season, regulation, or reserve) required justification studies. These studies were based on technical, social, economic, and environmental considerations, including the sustainable use of renewable water resources by modifying water extraction by users, instead of the free and unlimited extraction at the expense of a finite reserve.

Given that, Article 18, Section III of the Law on National Waters stipulates that to establish a system for regulating groundwater use, a study must be conducted to justify it. In 2013, studies were conducted to justify the suspension of free extraction in 159 aquifers, most of which are located in the north of the country, due to natural water shortages and the urgent need to establish a system that regulates withdrawals (DOF 2013a).

Among the overexploited aquifers is the wetland of Cuatro Ciénegas. This valley is located in an arid region where mean annual rainfall is less than 200 mm, and evaporation reaches 2042 mm per year (Leal 2016). Although rain is scarce, water from aquifers feeds many water pools (>500) that originate from a great diversity of aquatic ecosystems composed of rivers, lagoons, floodplains, wetlands, and emergent wetlands (Wolaver 2008).

In this hyper-diverse oasis for millions of years, the stability of aquatic ecosystems has generated environmental conditions for extremely diverse biological communities, favoring isolation conditions for the evolution of endemism. This is more evident for the oldest inhabitants of the planet, microbes than conform microbial mats and stromatolites (Souza et al. 2018). However, in the twentieth century, agricultural channels were built, leading to alterations in soil humidity, changes in drainage patterns, and, in some cases, the loss of wetlands (Contreras-Balderas 1984). As you can read in Chap. 11 of this book, over 80% of the surface water is extracted through the Santa Tecla and Saca Salada canal systems. This water is mainly used for agricultural production, and only 10% of the volume is destined for the conservation of wetlands through a concession granted to Pronatura Noreste, A.C., for ecological use in 2014 (Leal 2016).

As a result of this series of malpractices, almost 90% of the original wetland in Cuatro Ciénegas has been lost (Souza et al. 2018, Chapter 11). A study conducted with satellite images over the last 25 years has estimated that the surface wetland area during this period decreased by over 10.5% mainly in areas close to the

Mezquites and Garabatal rivers (Leal et al. 2019). In the absence of guidelines on the use of the Cuatro Ciénegas aquifer, the extraction volume has exceeded the aquifer's recharge capacity, causing the collapse of the wetland.

In September 2013, the water authority established aquifer 0528 Cuatro Ciénegas as a regulated zone to protect the hydrological balance and improve, conserve, and restore the aquifer (DOF 2013b). However, CONAGUA (Comisión Nacional del Agua) did not issue any guidelines and provisions for the development, use, or exploitation of the waters nor any guidelines related to reviewing and updating the lists of users to guarantee the aquifer's water sustainability. This work aims to identify the status of the registry of users of the Cuatro Ciénegas aquifer to help generate the technical and legal strategies required to avoid the over-concession of the aquifer.

6.2 Materials and Methods

To fully model the aquifer 0528 Cuatro Ciénegas, we obtained the concessions contained in the databases of the Public Registry of Water Rights (REPDA) with a cutoff date of June 2018, which can be accessed from the CONAGUA portal (app.conagua.gob.mx/Repda.aspx). The records were obtained for the Cuatro Ciénegas aquifer and adjacent aquifers: Castaños, Cuatro Ciénegas–Ocampo, El Hundido, and Monclova (CONAGUA 2018).

The records were systematized in geographic databases using the ArcGis® program, where each concession was projected on a geographic plane following the coordinates registered. We integrated the shapes of the concessions and land use into a geographic information system, including the layers of aquifers, ejido nuclei of the National Agrarian Registry (Registro Agrario Nacional, RAN), and urban and rural localities, to compare the information and identify inconsistencies (Fig. 6.1).

The criteria for selecting the records for the analysis were geographical and administrative; we used the titles registered for the Cuatro Ciénegas aquifer and those contained within the aquifer limits in line with their geographic coordinates, even if the allocation deed belonged to another aquifer.

To assess inconsistencies in the information and trends in the granting of the concessions, we compared the volume of groundwater availability at the Cuatro Ciénegas aquifer published in the *Official Journal of the Federation* (DOF, Diario Oficial de la Federación) and the databases reported in the Public Registry of Water Rights.

The legal base was the decree for the establishment of a regulated zone in the area occupied by the Cuatro Ciénegas aquifer, published in the *Official Journal of the Federation* on September 2, 2013 (DOF 2013b). This recognized the presence of the Cuatro Ciénegas flora and fauna protection area within the aquifer, whose springs and gushing flows have fed the water bodies and wetlands where ecosystems of great importance and scientific interest have evolved. In the absence of water, some of the great diversity of ecosystems and endemic species was at risk of

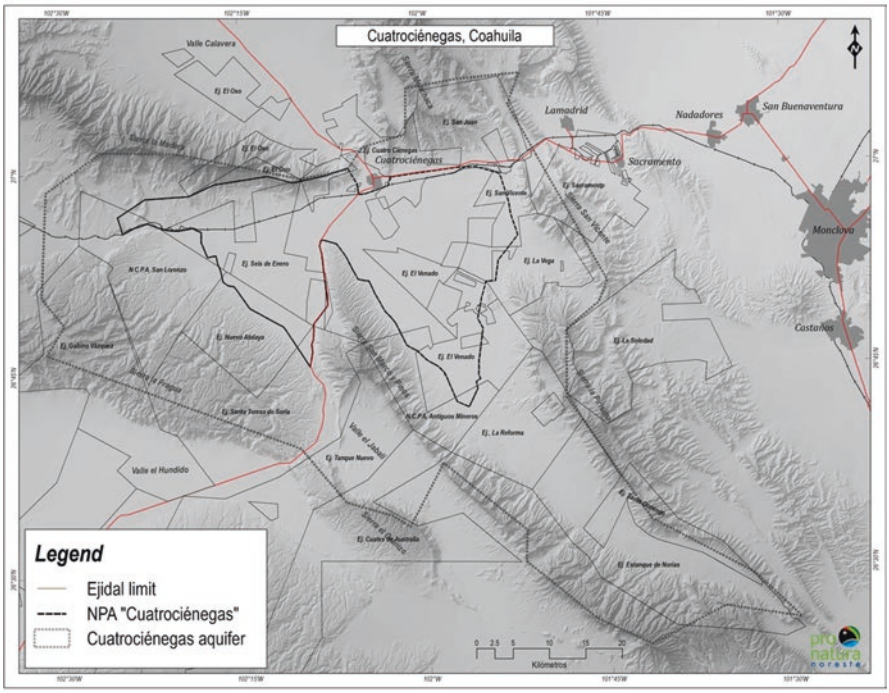

Fig. 6.1 Delimitation of the aquifer 0528 Cuatro Ciénegas, Coahuila, Mexico

becoming extinct. Consequently, it was considered necessary to regulate the extraction of national waters to prevent the disappearance of ecosystems and avoid risks to the population's water supply and to the development of the region, which depends largely on groundwater sources. From the most relevant aspects of the decree establishing the Cuatro Ciénegas aquifer as a regulated zone, the following are quoted verbatim:

CONSIDERING Sixteenth: *That by virtue of the existence of availability capable of being granted 11.084782 million cubic meters per year, and derived from the analysis of the technical studies indicated in the preceding paragraphs, it follows that the aquifer that is the subject of this instrument requires careful management that reconciles environmental protection with the development of human activities within a strategy of integrated management of natural resources, Therefore, although the technical studies recommended a ban on the Cuatrociénegas aquifer, code 0528, the* National Water Commission *decided to establish a regulated zone that would guarantee adequate control of extractions and hydrological sustainability in the area.*

ARTICLE ONE: *The reestablishment of the* hydrological balance *is declared of public utility, as well as the protection, improvement, conservation, and restoration of the Cuatrociénegas aquifer, code 0528, in the State of Coahuila, for which reason a regulated zone is established in the mentioned aquifer for the control of the extraction and the exploitation, use or development of the waters of the subsoil.*

ARTICLE FOUR: *The bases and provisions to be adopted by the* National Water Commission*, regarding the form and conditions under which the use, development, and*

exploitation of national underground waters, which are the subject of this Decree, shall be carried out, are as follows.

I. *National subsoil waters may only be used, exploited, or developed within the regulated area when there is a concession or assignment title previously issued by the Water Authority, in terms of the provisions of the Law on National Waters and its Regulations as follows*

   (a) *The concessions or assignments granted shall be recognized provided that the title is in force and no grounds for suspension, extinction, or revocation of the title have been incurred; and*
   (b) *A concession or allocation shall be granted to users who have registered volumes of water subject to this Decree or those who use, benefit from, or exploit the aforementioned waters, up to the volume they prove.*

II. *The natural or legal persons who are in the case of paragraph (b) of the previous section, may continue with the use of such waters, provided that within a period not exceeding 60 calendar days after the entry into force of this Decree, apply to the Water Authority for recognition of the volume they have used within the previous calendar year, upon accreditation of the same.*
III. *Users who fail to file the applications indicated in the previous paragraph shall be subject to the provisions of section IV of this Article.*
IV. *The new concessions and assignments shall be granted in terms of the Law on National Waters, in view of water availability and in accordance with the order of presentation, once the recognition and granting referred to in paragraphs (a) and (b) of section I of this Article has been made.*
V. *The recognition and granting referred to in this Article may not under any circumstances exceed the overall availability of water under this Decree.*
VI. *As from the commencement of the validity of this Decree, the works for the* extraction *of groundwater existing in the regulated area may not change the use for which they are intended, nor increase their extraction costs and volumes, nor may the construction characteristics or the capacity of the pumping equipment authorized or used before the establishment of the regulated area be modified without the prior authorization of the Water Authority.*

ARTICLE SIX: *Within the regulated area, the construction of works for the* extraction *of groundwater that affect existing waters or ecosystems shall not be permitted, and the activities developed shall be subject to the provisions of the Management Program for the Cuatrociénegas Flora and Fauna Protection Area.*

ARTICLE SEVEN: *The granting of water allocations in sites located within the Protected Natural Area shall be subject to the availability of water in the aquifer, compliance with the requirements established in the National Water Law, and the restrictions established in the Management Program for the Cuatrociénegas Flora and Fauna Protection Area.*

6.3 Results

According to the reports in the REPDA databases, the initial volume granted in aquifer 0528 Cuatro Ciénegas was set in 1997, with an allocated volume of 1,002,000 m^3 annually. Nowadays, the amount exceeds 6.1 million m^3 per year (Fig. 6.2).

The analysis included 156 groundwater records reported in the REPDA databases for the year 2018 according to the selection criteria (administrative and geographical). Only 72 records of the total number were correctly registered with the

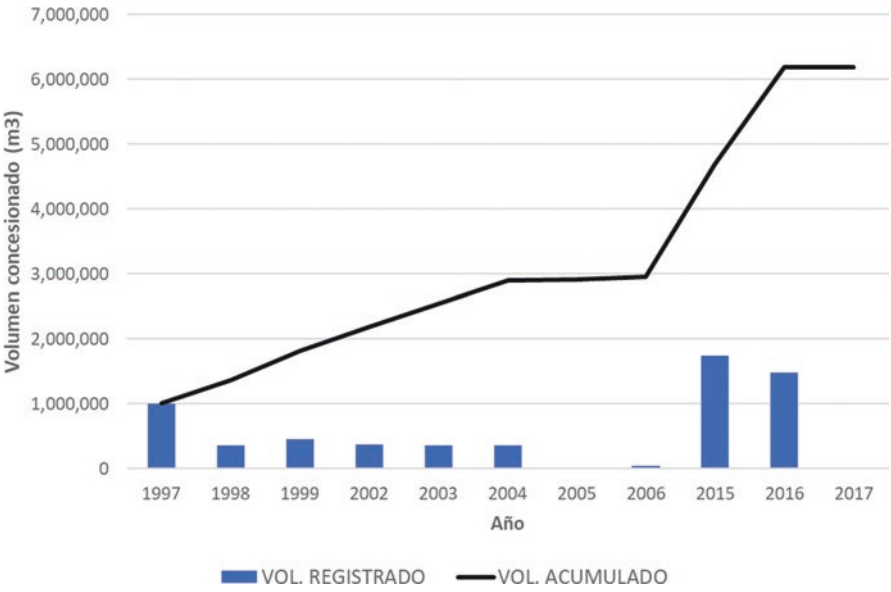

Fig. 6.2 The trend in allocated volume for aquifer 0528 Cuatro Ciénegas, Coahuila, Mexico

Cuatro Ciénegas aquifer (Fig. 6.3). The remaining 84 users were located at the Cuatro Ciénegas aquifer but were registered to a different aquifer. This analysis was conducted for the dates 2008, 2015, and 2018 to observe trends in the granting of concession titles (Table 6.1).

Our database analysis revealed that most of the records were erroneously assigned to the Cuatro Ciénegas–Ocampo aquifer (75 allocations), which is the neighboring valley to the north.

Of all the allocation deeds with discrepancies, 15 were registered in favor of the ejidos. To detect the source of the errors, we crossed the 15 allocation deeds of the ejidos with the shapefile of the ejido nuclei of the RAN and the name of the registered aquifer. In all 15 allocations, the deed holder (ejido) in the shapefile matched the RAN's layer of ejido nuclei, meaning the geographic location was correct; therefore, errors were imputed to the CONAGUA when registering the allocation deeds.

The analysis indicated that the differences in the volumes granted because of registration errors have increased as the CONAGUA issued new water concessions. Because of errors in allocation deeds, the water available from the Cuatro Ciénegas aquifer has lowered by 5,950,000 m^3 per year. Thus, the volume extracted from the aquifer is higher than that reported by CONAGUA (Table 6.2).

In the decree published in the DOF on September 2, 2013, which established the Cuatro Ciénegas aquifer as a regulated area, the water available was 11,084,000 m^3 per year (DOF 2013b). This document also established that the aquifer required careful management that reconciled environmental protection and human activities with the integrated management of natural resources. However, the DOF issued on

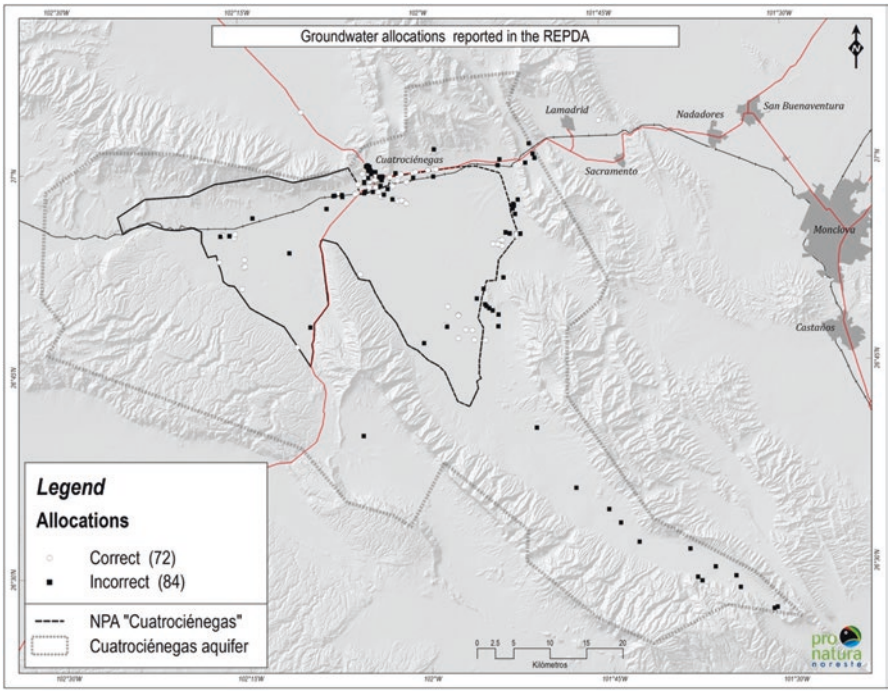

Fig. 6.3 Location and status of groundwater exploitation for aquifer 0528 Cuatro Ciénegas, Coahuila, Mexico

Table 6.1 Discrepancies identified in the granting of allocation deeds located in the Cuatro Ciénegas aquifer

Registered aquifer/year	2008	2015	2018
Castaños	4	4	4
Cuatro Ciénegas–Ocampo	73	76	75
Cuatro Ciénegas–Ocampo–San Miguel	2	0	2
El Hundido	1	1	1
Monclova	2	2	2
Misplaced records	82	83	84
Records correctly assigned to the Cuatro Ciénegas aquifer	21	25	72
Total records	103	108	156

January 4, 2018, reported a deficit in the water availability of −7,590,000 m^3 per year (DOF 2018).

Our results only considered the data reported by CONAGUA, without recognizing errors in the records, which can aggravate this situation because the deficit would increase to −13,540,000 m^3 when considering the difference of 5,950,000 m^3 (see Table 6.2). According to the total extraction volume (VCAS, Table 6.2),

Table 6.2 Differences found between REPDA official information, the *Official Journal of the Federation* (DOF), and the rectified data. The identifier is the acronym used in the official databases

Descriptor	Identifier	DOF	REPDA	Rectified data	Difference
2008					
Deeds			21	103	82
Well logs			25	113	88
Volume granted	VCAS	3.035	2.95	7.38	
Water availability	DMA	10.89	6.54	4.35	
2015					
Deeds			25	108	83
Well logs			29	117	88
Volume granted	VCAS	2.95	2.95	7.61	
Water availability	DMA	9.84		5.19	4.65
2018					
Deeds			72	156	84
Well logs			84	173	89
Volume granted	VCAS	4.7	6.18	10.65	
Extraction volume in free extraction suspended areas	SEE	11.509		11.509	
Volume of water to be titrated	VAPTYR	4.18		4.18	
Total extraction volume	SEE (VCAS + VEALA + VAPTYR)	20.39		26.34	
Water availability	DMA	−7.59		−13.54	5.95

Volumes expressed in million cubic meters per year

26,340,000 m^3 per year would be extracted from the aquifer, exceeding the capacity to maintain the wetlands' ecosystem functions (DOF 2018).

The 156 allocation deeds for groundwater withdrawal considered 173 well logs, including those with registration errors. Of these, 95% (10,150,000 m^3) were for agricultural purposes.

6.4 Allocations in the Natural Protected Area (NPA)

The natural protected area (NPA) of Cuatro Ciénegas includes 63 allocation deeds for obtaining underground water within its polygonal area. These allocations sum a total 5,600,000 million m^3 (including records with errors). After regulating the aquifer in 2013, the water authority registered 31 allocation deeds for agricultural use in the NPA comprising 2,690,000 m^3 per year. Therefore, the water authority granted the permits without any guidelines on issuing new allocations.

The results of our analysis indicate the urgent need to promote legal mechanisms to prevent the unregulated extraction of water in Cuatro Ciénegas and to avoid the overexploitation and depletion of the aquifer that sustains the population of Cuatro Ciénegas and the NPA wetland.

6.5 Discussion

The REPDA contains information on national surface and groundwater concessions that are the basis for determining the water available from river basins and aquifers. These data are the basis of national water management.

In the north of the country, where arid and desert environments predominate, the aquifers are a crucial source of water not only for human consumption but also for the development of activities such as agriculture, livestock, and industry. Therefore, it is essential to have reliable, up-to-date information on the uses and static levels of aquifers.

According to our analysis of the data on aquifer 0528 Cuatro Ciénegas, more than half of the allocation deeds circumscribed to this aquifer contain errors. This situation is attributable to the registration of the allocation deeds by CONAGUA. According to the data obtained, these errors underestimate the volume of extraction by 5,950,000 million m^3 per year, which implies a risk of overexploitation.

Because of the value of water resources for sustainability of ecosystems, the water authority issued sustainable management guidelines in the "ecological management of the Cuatro Ciénegas region" published in the Official Journal of the Federation on August 12, 1997 (DOF 1997). The document stated that it was necessary to limit water extraction to 16,000,000 m^3 per year to avoid a deficit in the aquifer affecting aquatic ecosystems. The volume estimated that year was the maximum extraction potential of the valley and its surrounding areas.

According to the DOF on January 4, 2018, the aquifer reached a deficit of −7,590,000 million m^3; however, if we consider the amounts of groundwater granted erroneously, then the volume was −13,540,000 m^3, which threatens aquatic ecosystems and their biodiversity (DOF 2018).

In light of these results and of Article 27, paragraph five of the Federal Constitution, which establishes the express and obligatory regulatory power of the Executive, stating that "… when the public interest demands it or other uses are affected; the Federal Executive may regulate its extraction and use and even establish prohibited zones, as it does for other waters of national property …", an indirect injunction (amparo indirecto) was filed against CONAGUA, to prevent the issuance of allocations for the use or extraction of national waters in the protected zone of the Cuatro Ciénegas Valley. The injunction considered that the right to a healthy

environment for development and well-being and the right to equitable and sustainable access to water resources had been violated.

In March 2019, the federal judge issued a ruling granting a definitive suspension due to the omission by the Federal Executive to establish guidelines on the development, use, or exploitation of national waters referred to in Article 4 of the decree establishing the Cuatro Ciénegas valley as a regulated zone. In this resolution, the General Director, the General Director of Water Administration, the Manager of Regulation and Water Banks, and the Manager of User Services, all of them from CONAGUA with its headquarters in Mexico City, as well as the general director and the director of Water Administration, both from the Commission's Rio Bravo Basin Organization, with headquarters in Monterrey, Nuevo León, were obligated not to issue new allocations and/or assignments for the development, use, or exploitation of national waters in the protected zone of the Cuatro Ciénegas valley.

Soon, the Supreme Court of Justice of the nation will determine whether, by not issuing the guidelines and provisions for the regulated zone of the Cuatro Ciénegas aquifer, the CONAGUA has incurred a normative omission of an obligatory exercise that is constitutionally mandated, because the public interest is affected. Therefore, the water authority is obliged to fully and effectively exercise its powers to reverse its overexploitation and reestablish the balance of the vital ecosystems linked to water in the Cuatro Ciénegas aquifer to ensure its environmental sustainability.

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