STRATEGIC ENVIRONMENTAL ASSESSMENT OF AN INTEGRATED DRINKING-WATER MANAGEMENT PLAN FOR RURAL COMMUNITIES AT THE ALTIPLANO POTOSINO

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Abstract

The purpose of this project was to develop a planning tool to help decision-makers to identify, manage and assess water sustainability for rural communities at the Altiplano Potosino, Central Mexico. This region of the State of San Luis Potosi has 15 municipalities. An Strategic Environmental Assessment (SEA) approach was chosen as the method to achieve project's objective and was supported by an intense fieldwork, interview with inhabitants in the municipalities and reports review. As a result, an Integrated Drinking-Water Management Plan for Rural Communities at the Altiplano Potosino was proposed to the state authorities with guidelines to improve water management in the region.

Introduction

The Altiplano Potosino is a semi-arid region in the state of San Luis Potosi, Mexico. It is composed of 15 municipalities with levels of high marginalization according to the National Council for Social Development Policy's Assessment (CONEVAL, 2015). This semi-arid region has a low rainfall (<350mm annual precipitation), with extreme temperatures ranging from -10°C to over 40°, and long drought periods each year (SAGARPA, 2013). The region has 12.93% of San Luis Potosi's population (334,261 inhabitants) according to the National Institute of Statistics and Geography (INEGI, 2010).

This project was proposed in response to a call for projects of the State in the aspect of "definition of potential areas of exploitation and alternative proposals for water use in drinking-water supply at the region of the Altiplano Potosino". The project's aim was "to propose the best alternatives for quality drinking water supply in rural communities at the Altiplano Potosino, the strategies for its management, and assess its sustainability at the short, medium and long term". The project had the following specific objectives:

1. Identify potential safe drinking-water supply sources

2. Propose alternatives for drinking-water supply at the Altiplano

3. Design strategies for the short, medium and large term for operation, control and efficiency of drinking water supply sources

The main approach to achieve the project's aim and to develop the Integrated Drinking Water Management Plan was the application of an Strategic Environmental Assessment (SEA) model to the project, this is a worldwide-recognized tool to help decision-makers to make more informed and sustainability decisions by integrating environmental and development decisions (Thérivel, 2010).

SEA is not fully developed or systematically used in Mexico, apart from few examples (Opperman, 2012; González *et al.*, 2014; Montañez-Cartaxo, 2014). However, due to the complexity of the problem, this was the best tool to use in this proposal. To apply the SEA basic information is needed from official entities and users of water. In the process to obtain this information several critical issues were found during the project, for example, unreliable information, limited access to existing water databases or information, and little public and governmental authorities involvement in the consultation workshops proposed within the project.

Despite previous critical issues, the project reached its objectives and developed an Integrated Drinking Water Management Plan (IDWMP) for Rural Communities at the Altiplano Potosino, a planning instrument designed for the state, municipal and communities' decision-makers to improve the drinking water management system in the

Altiplano Potosino. In the form of a Report, this document was delivered to the state authorities to help them in the better management of water resources for drinking purposes.

Methodology

In order to achieve project's aim, an SEA methodology was proposed for the development of the IDWMP for Rural Communities at the Altiplano Potosino as showed in Figure 1.

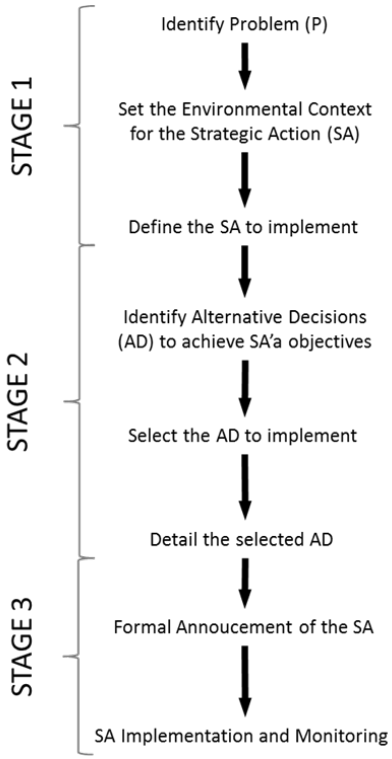

Figure 1. SEA process for using within Mexican decision-making and planning system (from Tejeda, 2017).

During the first year of the project (June 2013 – June 2014), stage 1 (identify problem, set the environmental context for the strategic action, and define the strategic action to implement) was developed. To identify IDWMP's problem we held several meetings between research group members and CEA's representatives, and we performed a thorough review of the legal aspects including international treaties signed by Mexico, the Mexican Constitution, and all federal laws related somehow to water management in the country. Also, state constitution and laws (from San Luis Potosi) were included.

Stage 1. The problem, according to Partidário (2012), is what the decision-making and planning are trying to solve. In this project, the problem was defined through interviews with the state authority (State Commission of Water, CEA) and the review of legal documents to identify all institutions and core legal principles related to water management in the state. We identified that 14 Federal, 10 State, and 15 municipal

institutions, plus a countless number of private and academic entities, and each of the rural communities, have legal obligation to participate in the water management in the Altiplano Potosino. The Constitutional principles in which any national, state, municipal or communal water management systems should be based is the "*pro hominem* principle and no discrimination". This is indicated in the Mexican Constitution in several articles: (a) Article 1 (right to health, healthy environment, and to water); (b) Article 4 (the Mexican State domain over the national development); (c) Article 25 (National Planning System and National Data System); (d) Article 26 (Mexican State ownership of land and water, its right to impose to private property any mode of public interest, the decision-making autonomy of 'ejido' communities); (e) Article 27 (municipalities' responsibility for drinking water services); (f) Article 115 (the obligation for State Governors to publish and enforce federal laws), and (g) Article 120. Finally, project's decision problem was resumed in the following question: *what is needed to have sustainable safe drinking water in rural communities at the Altiplano Potosino?*

Once the problem was defined, we constructed a Reference Framework (RF) for 'drinking water for rural communities at the Altiplano Potosino'. The RF was based on two fundamental features of the problem to solve - safe drinking water for rural communities: availability and quality. For each feature, we identified several environmental elements in a preliminary cabinet exercise, which help us to focus documentary and data research on setting the Environmental Context of the Altiplano Potosino. However, this Reference Framework was later improved after field work, as showed in Figure 2, where preliminary cabinet exercise elements are in italics, while improved elements from the field work are in boldface. During this part of the project, we visited several governmental institutions related to water management in the region studied and asked for data as number of water concessions in the region, number of water sources available in each rural community, state of water extraction and water distribution infrastructure, water plans, programs, or projects for the region, among others. At this stage of the project, we found a lack of reliable information even if authorities informed the existence of databases that were unavailable or of limited access. This was attended with the development of field work in order to fill those gaps.

Figure 2. Reference Framework for project's problem involving safe drinking water for rural communities in the Altiplano at the State of San Luis Potosi, Mexico (Tejeda, 2017).

To set the environmental context three methods were used: a Reference Framework template (Tejeda, 2017), a documentary review (including literature review and official documents collection), and field work as shown in Figure 3 (a 7 month's survey in nearly 77 rural communities in the Altiplano Potosino, including a drinking water sources' quality study). The last step was achieved through reviewing current policies, plans, and programs related to water management in the Altiplano Potosino during that period.

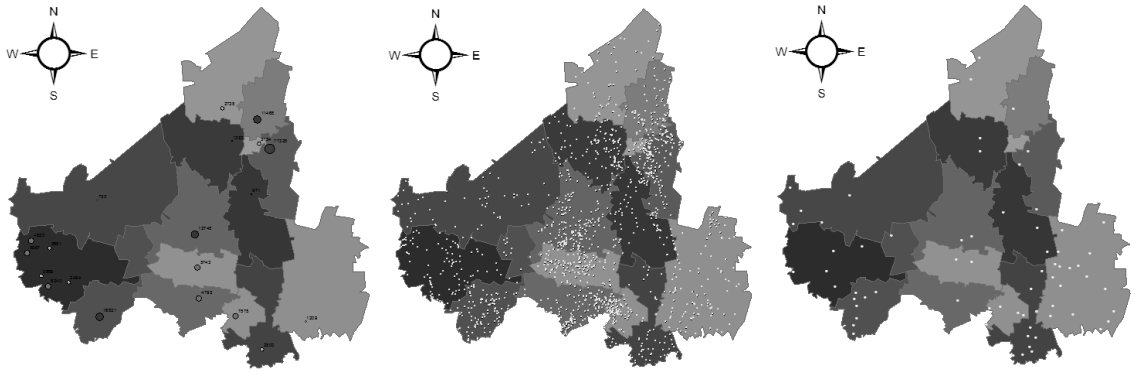

Figure 3. From left to right, urban cities, rural communities, and selected rural communities for this project in the Altiplano Region of the State of San Luis Potosí, Central Mexico.

In the second year of the project (June 2014-June 2015), the stages 2-3 of the SEA methodology proposed were developed. In this period, a technical study to propose a treatment method for removing main pollutants in water sources in the Altiplano was done by Dr. René Rangel Méndez from the IPICyT. The results obtained are not presented in this paper. The identification and selection of alternative decisions were performed through two workshops with stakeholders from communities, academy, the private sector, and municipal, state and federal government authorities. Also, three methods were used to performed data analysis: the use of a Driving Forces-Pressure-State-Impact-Response (DF-P-S-I-R) model, a network analysis, and a hierarchy analysis (Tejeda, 2017). The SEA process since the final step of stage 2 was not completed in the project as it will be further explained.

The *DF-P-S-I-R model* was used to classify each environmental element that was identified within the reference framework, in order to define what type of change (positive or negative) was causing to the strategic features of the problem. The *Network Analysis* and the *Hierarchy Analysis* were used to focus the efforts of identification about the alternative decisions to solve the problem drew from regional workshops. The network analysis focused in identifying the relationships between the driving forces from the reference framework in order to highlight the most significant. While the hierarchy analysis was used to categorize the alternative decisions for solving the problem through a doubly entry matrix, where the upper row contains the proposed alternative decisions for solving the problem of the strategic action, and in the left column are listed the main lines of actions from international and national policies, and national and state plans and programs related to the Problem (Tejeda, 2017).

Stage 2. For this stage, we organized two regional workshops carried out in Salinas and Matehuala, two cities of the Altiplano. For the workshops, we invited all water management related stakeholders in the Altiplano Potosino. The purpose of the workshops was to present the results of the Baseline Study to the participants and to identify the alternative decisions to improve the water management in rural communities for drinking purposes.

Unfortunately, public participation in both regional meetings was low although we were able to obtain significant results from the attending to both meetings (Images 1 and 2). Participants in the workshops were from academic institutions (Colegio de San Luis, UASLP) and the private sector (CUMMINS). Representatives from the government were from the federal level (Ministry of Social Development, SEDESOL), from the State (State Water Commission, CEA; State Commission for Protection of Sanitary Risks, COEPRIS; State Ministry of Agriculture Development and Water Resources, SEDARH) and representatives from the municipalities (Salinas, Villa de Ramos and Villa de Guadalupe). In addition, representatives from the municipal water authorities from Vanegas, Cedral,

and Matehuala and from few rural communities of the Altiplano participated in both workshops.

Image 1. Regional meeting in the city of Salinas, SLP.

Image 1. Regional meeting in the city of Matehuala, SLP.

As a result of the workshops, we were able to collect up to 100 proposals for solving drinking water problems described in the Baseline Study. These proposals made by the attendees were classified in seven general subjects: politics, education/training, research, planning, institutional, health, and laws. With the information thus classified, we performed a hierarchical analysis to identify the most significant proposals by crossing them with a list of strategies and lines of actions from international and national policies, plans and programs.

Results and Discussion

In this section, the main results will be briefly described to understand the integration of the IDWMP.

The most unexpected environmental elements identified in the reference framework were *security (robbery and damage of water wells equipment)* and *community decision-making*, both acknowledged after field work which included informal interviews with community members, as showed in Image 3. The first one was mainly related to the security of goods because electrical transformers for the water wells operation are sometimes stolen in rural communities to extract and sell copper metal; this leaves the rural communities without access to water for several days, even weeks and this is not really prevented by the authorities, and sometimes the community develop their own protection methods, as showed in Image 4. Regarding the second element, at the beginning of this project, we believed that the federal, state or municipal authorities would have great power within rural communities decision-making, but it was completely the opposite, being the rural communities through their self-organization in the form of a General Assembly, the highest decision-making authority in water-related issues.

Image 3. The community of 'Santa Lucía', Villa de Ramos, SLP.

Image 4. Protection infrastructure to prevent robbery, Villa Hidalgo, SLP.

The use of the DF-P-S-I-R method showed in Table 1 was helpful when analyzing the effects the environmental elements identified in the reference framework in the fundamental features of the problem.

Table 1. DF-P-S-I-R matrix filled (Tejeda, 2017).

DRIVING FORCES		PRESSURE	STATE	IMPACT	RESPONSE
SOCIAL	Demography	More population, more water demand	No effect	Reduce water availability	Population increase it is not a significant element.
	Energy [S]	Electricity production schemes and costs are a high pressure to the communities	-	Limits and negates access to water. Health risks.	Patterns of the human right to water violations.
	Community Structure	Community decision-making. Agreements are not reached. Low inter and intra community cooperation.	-	Limits access to water.	Most of the communities expect that anyone else fix their problems. There is not will to improve conditions.
		Decision-making in communities. Agreements are reached.	+	Stimulate access to water	There are a few successful examples of community water management.
	Social Gap	Poverty affects communities.	-	Negates access to water. Health risks.	High migration because low job opportunities and for development.
	Security	Theft of electrical transformators in wells.	-	Negates access to water.	Communities or municipalities are in charge of the expenses.
		Communities take care of their drinking-water infrastructure.	+	Stimulate access to water	The communities organize to protect their wells.
ECONOMIC	Economic Activities	Agriculture and industry (mining) compete for the resource.	-	Reduce water availability	Economic activities consuming more water are those whose give jobs to people.
	Residues [E]	Residues from economic activities	-	Limits access to water. Health risks.	There is not supervision for agricultural and mining residues, with a high risk

DRIVING FORCES		PRESSURE	STATE	IMPACT	RESPONSE
		contaminate water sources.			of water sources contamination.
	Energy [E]	Rates from electricity consumption of the wells.	-	Negates access to water.	Communities are left without water for weeks or months until they complete to pay for electricity fees.
	Infrastructure [E]	Costs of the type of infrastructure used.	-	Limits access to water. Health risks.	The type of infrastructure use is expensive and it has to be changed quickly.
CULTURAL	Residues [C]	Residues management within communities.	-	Limits access to water.	There is not community residues management.
	Uses	Drinking-water use competes with other uses within communities.	-	Limits access to water.	There is a lot of water consumption for inside houses agriculture.
		Water handling for consumption within communities.	-	Health risks.	People drink water without taking provisions for contamination.
	Infrastructure [C]	Type of infrastructure preferred by communities.	-	Limits access to water.	People prefer wells rather than other type of water supply infrastructure.
		Type of infrastructure used according to communities capacities.	+	Stimulate access to water	Communities that use alternative infrastructure have more water supply.
POLITICS	Concessions	High priority to agricultural use.	-	Limits access to water.	Water consumption in the region is dominated by agricultural use. There are communities without any kind of water source.
	Management	Water management is in response of personal motivation or by political parties´ interests	-	Limits access to water.	Communities have to reach agreements with current authorities or expect that their political party reach power to solve their problems.
	Energy [P]	It is priority expensive electricity production.	-	Negates access to water.	Communities have to pay high electricity bills that not always they can cover. They translate the problem to the municipalities.
	Financial supports	There is a big budget for hydraulic infrastructure	+	Increase water availability.	High infrastructure investments have no success.
		Electricity for wells used in agriculture is subsidized.	-	Reduce water availability	Water extraction for agriculture is huge, as well as their waste.
LAW-INSTITUTIONS	Laws	Currents laws are outdated.	-	Reduce water availability and access.	There is not rule of law for the accomplishment of the human right to water.

DRIVING FORCES		PRESSURE	STATE	IMPACT	RESPONSE
	Institutions	Institutions have low financial and human resources capacities.	-	Reduce water availability and access.	Water-related institutions concentrate their efforts into the big communities. There is a lack of supervision in the region.
		Low to none coordination between institutions related to water management.	-	Limits access to water. Health risks.	A lot of collaboration opportunities are wasted between authorities.
	Transparency	Little reliable information for informed decision-making.	-	Limits access to water. Health risks.	Decisions made are not the best because the lack of reliable information.
	Planning	There is not long-term planning.	-	Reduce water availability and access. Health risks.	Problems in communities are cyclic and unsustainable.
HEALTH	Infrastructure [H]	Low to none maintenance of infrastructure and it is no used the more appropriate material for the local biophysical conditions.	-	Reduce water availability and access. Health risks.	There are specific programmes that not always are successful.
BIOPHYSICAL	Water Cycle	Define what type of water sources are in the region.	-	Reduce water availability and access. Health risks.	Natural conditions of the region stimulate the underground water extraction.
	Ground relief	Makes difficult the construction of water related infrastructure.	-	Reduce water availability and access. Health risks.	Infrastructure suffers damages because bad design and ground relief conditions.
	Wheater	A region with extreme temperature and low raining rates.	-	Reduce water availability and access. Health risks.	Main water sources are underground and for the few surface sources, evaporation it is not considered.
		Climate change effects in the form of droughts.	-	Reduce water availability and access. Health risks.	Authorities do not have a strategy to fight long droughts in the region.
	Geology	Natural conditions of the underground contaminate aquifers (fluoride-arsenic).	-	Limits access to water. Health risks.	The water available in the region is naturally contaminated.

Meanwhile, the network analysis in Figure 4 was performed to identify the relationships between environmental elements in order to highlight leading and receivers driving forces' within the water management system in the reference framework.

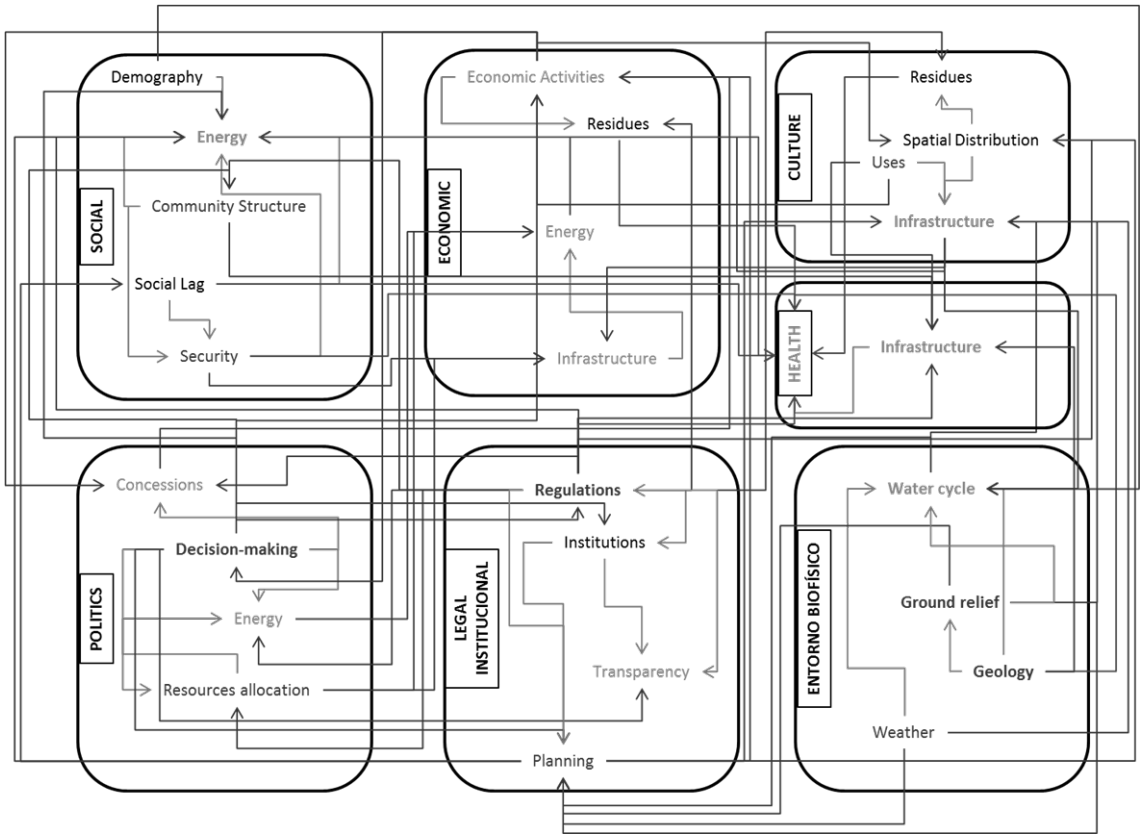

Figure 4. Network analysis for driving forces of the water management system in the Altiplano Potosino (Tejeda, 2017).

Finally, the main product of the first year of the project was a Baseline Study of the water management system in the Altiplano Potosino that was used for the development of the IDWMP.

After the hierarchical analysis in Figure 5, we identified that the group of alternatives related to the continuity of the long-term planning and projects between different public administrations was the most significant, with the 99% of strategies and lines of actions covered. This hierarchical analysis was helpful to identify the alternative decisions with the most likely impact on the water management system at the Altiplano Potosino.

	ALTERNATIVE DECISIONS																								LINES OF ACTION WITH MOST ATTENTION BY THE ALTERNATIVE DECISIONS	
	POLITICS				EDUCATION/TRAINING					RESEARCH				PLANNING		INSTITUTIONAL				HEALTH		REGULATIONS				
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Q'	R	S	T	U	V	W		
INTERNATIONAL POLICIES																										
Human Right to Water	1	1	1	1	1	1	1			1	1			1	1	1	1		1	1	1	1	1	1	19	79%
INTERNATIONAL PROGRAMMES																										
Water Security	1	1	1	1	1	1	1	1		1	1			1	1		1		1	1		1	1	1	18	75%
NATIONAL POLICIES																										
Human Right to Water	1	1	1	1	1	1	1			1	1			1	1	1	1		1	1	1	1	1	1	19	79%
Water belongs to the country			1				1			1	1		1		1		1		1	1		1			10	42%
Municipalities are in charge of drinking-water services	1			1		1	1		1	1	1		1		1		1	1	1	1	1	1		1	16	67%
Food Security	1										1			1	1				1	1		1			7	29%
Climate change	1		1		1						1	1		1	1				1	1		1			10	42%
ALTERNATIVE DECISIONS WITH BIGGER IMPACT IN THE LINES OF ACTION DESCRIBED IN UPPER COLUM	52	12	79	71	20	25	28	31	81	42	37	2	17	47	140	26	32	24	130	26	68	65	19	87		
	37%	8%	56%	50%	14%	18%	20%	22%	57%	30%	26%	1%	12%	33%	99%	18%	23%	17%	92%	18%	48%	46%	13%	61%		

Figure 5. Resumed matrix of the hierarchy analysis for the IDWMP (Tejeda, 2017).

At this point, the SEA process ended, failing in detailing selected alternative decisions and two steps from stage 3 (formal announcement of the plan, and the plan implementation and monitoring). The problematic here was internal changes in the CEA, the governmental authority at the head of the demand that this project attended. Thus, the results of the project were officially communicated to the authority in June 2015 through the IDWMP proposal. However, the IDWMP was personally presented and discussed with representatives from CEA in March 2016 (Image 5). We were expecting a follow-up of the results and eventually to be a reference through the IDWMP delivered to the CEA in the new State Development Plan for San Luis Potosi 2015-2021, nevertheless neither of our expectations were accomplished.

Image 5. Meeting with representatives of the State Commission of Water (CEA) in March 2016.

Integrated Drinking Water Management Plan for Rural Communities at the Altiplano Potosino (IDWMP). This planning document was developed following the proposed SEA methodology described in the previous section. Key features of the IDWMP are its strategic objectives and its lines of action to achieve such objectives. Table 2 shows the strategic objectives proposed and their main driving forces identified in the project for each one of the objectives.

Table 2. Description of IDWMP's Strategic Objectives

Strategic Objective	Goal	Key Element	Driving Forces
SUSTAINABLE ACCESS TO SAFE DRINKING WATER	Improve sustainable physical and economic accessibility to safe drinking water for people at the Altiplano Potosino	Physical accessibility	Weather; water cycle, geology, and land relief; regulations and institutions; decision-making process, water concessions, economic activities and economic support; infrastructure and energy.

		Economic accessibility	The water cycle, geology, land relief and spatial distribution of communities; regulations, institutions; decision-making process, concessions, economic activities and economic support; infrastructure, energy, and security.
QUALITY IN WATER SERVICES WITHIN AN IMPROVED WATER MANAGEMENT MODEL	Improve quality in drinking water services at the Altiplano Potosino	Quality of drinking water services	Regulations, institutions, transparency, and planning.
	Improve water resources management model for an effective citizen participation and economic sustainability	Improved water management model	Decision-making process, regulations, institutions, planning, economic activities, and transparency.
UPGRADED AND STRENGTHENED LEGAL FRAMEWORK	Propose adjustments to water management's legal framework to upgrade it with the recent legal provisions, and strengthen the institutions and stakeholder involved in water management	Adjustments to upgrade legal framework and strengthen institutions and stakeholders	Decision-making, regulations, institutions, planning

Based on the results obtained (see Table 2) and the proposals collected through the both workshops with key stakeholders, for the IDWMP we developed a set of seven programs. Much of the knowledge was obtained during the field work where 77 communities were visited, and inhabitants and authorities interviewed. Table 3 shows the programs with their main lines of action.

Table 3. IDWMP's Programs and Lines of Action.

Program	Lines of Action
RESEARCH	Alternative energy sources
	Potabilization alternatives
	Water reuse
	Materials and equipment improvement
HEALTH	Water quality monitoring
	Water sources protection
	Rain harvesting
PLANNING	Community development planning
	Long-term state and municipal planning
REGULATION'S UPGRADING	Right to water upgrading
	Municipal regulations upgrading
	Regulation's scope review
EDUCATION	Drinking safe water within rural communities
	Efficient water use
	Water services payment culture
	Training for municipal water authorities
	Community projects development
INSTITUTIONAL STRENGTHENING	Access to information

	Economic federal resources monitoring
	Interinstitutional cooperation
	Institutional competences upgrading
POLITICAL MANAGEMENT	Surveillance of economic support allocation
	Water concessions re-distribution
	Water use management
	Political support for cheaper water supply alternatives

Finally, the development of two scenarios for the water management in the Altiplano Potosino was developed. The first scenario considers that the water management system will maintain its current features, and the second scenario considers that the adjustments proposed by the IDWMP will be progressively implemented within the water management system. In the first case, we expect that the water management system will collapse due unsustainable current activities and decision-making procedures. In the second scenario, we expect a big negative economic impact in the short term due to the investment needed to implement the adjustments proposed by the IDWMP, but with positive results in the medium and long term in the seven proposed programs and the overall water management system. Also, we have considered uncertainty within our scenarios represented by three special driving forces: demographic factors, the water cycle, and the weather. Their impact on the drinking water supply goes beyond the scope of the work done.

Conclusions

This project shows that the methodology based on the SEA is very suitable to understand and propose actions to solve a complex problem such as the water supply for drinking purposes in marginalized regions of the State of San Luis Potosi, Mexico. No studies of this kind have been done previously in Mexico. The method based on SEA helped us to identify the disadvantages of the current water management system in the Altiplano Potosino, by identifying through a thoroughly documentary review and an extensive field work, plus the network analysis, its key elements that affected the decision-making within it, represented by the lack of access to information, a few participation of citizen and stakeholders in decision-making processes, the lack of community development planning, and the focus of decision-making on personal or political parties interests. Also, the methodology allows us to detect as well, the few good practices in the water management system within the rural communities in the region, such as that the best water management in communities were leading by women, and that there were some communities that had a medium to long term vision for their development, not just short term solutions. The project was developed under a low budget and had a significant positive impact by presenting to authorities sustainable and achievable alternatives for

the resolution of water supply in the region while attending an important regional problem that affects nearly 33% of the population of the Altiplano.

The analysis of the problematic and the solutions proposed in the IDWMP helped us to identify the problem and the solutions were drawn on concrete recommendations and lines of actions obtained from an intense field work and the opinion of the water management system stakeholders interviewed in the communities. It is important to highlight that a significant practical and research work is still required in our country to properly integrate environmental and development considerations within our planning instruments, we consider that this project contributed with some directions for a better water management to cover the actual demand of the populations.

The methodology developed during this project is in some way fundamental and can be replicable in any part of Mexico, thus, the cost-benefit investment in this kind of projects are highly profitable. We learned some lessons about certain aspects that can be improved in future similar projects, such the strategies used for data collection (the use of alternative channels for data collection instead of using official channels, and a more focused field work) and the tactics used to integrate citizen participation in decision-making processes (using formal interviews and communities meetings with local stakeholders instead of informal interviews and regional meetings, and integrate key governmental stakeholders in their higher ranks for the workshops organization instead of the University status only). Definitively, we need to insist on the use of the project's results by authorities in higher decision-making and planning instruments. As any learning process, the experience obtained with this project would help to improve future similar applications.

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