

Efficiency Actions in the 4 Water Utilities of Pátzcuaro Lake, Michoacán, México

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Abstract: Pátzcuaro Lake, found in the state of Michoacán, is one of México's most emblematic bodies of water, however, urbanization in this area during past decades has left it polluted and in serious need of rehabilitation. The present work describes a two-phase recovery process that was carried out within the framework of the Environmental Recovery Program for the Pátzcuaro Lake Basin (stage IV 2014-2017). It was undertaken with support from the Mexican Water Technology Institute (IMTA) and with funding from the Gonzalo Arronte River Foundation (GARF). The scope of the first phase of this work was to determine in conjunction with four coastal water utilities, the specific actions required to improve their water and drainage services so that contamination may be reduced in Pátzcuaro Lake. In the second phase, leakage reduction was implemented on the distribution/storage tanks, the IMTA arranged a collaborative agreement with the three levels of government (Federal, State and Municipal) in order to join resources and efforts for the Environmental Recovery Program of the Pátzcuaro Lake Basin. The IMTA provided the water utilities with diagnostics in the commercial area, and a plan of actions along with executive projects for potable water and drainage that include works creation, budget, implementation specifications, a works calendar, along with blueprints so that they could be integrated into the Annual Works Program (AWP) of the State Water and Basin Management Commission for the state of Michoacán (SWBC). Finally, as part of the agreement to improve commercial and physical efficiency, the IMTA provided the four water utilities with minor equipment, tools, control devices and domestic meters.

Key words: Pátzcuaro Lake, efficiency actions, water utility, rehabilitation

1. Introduction

In México, water utility operators are the entities entrusted with providing potable water, treatment and drainage services to municipalities, nonetheless, it is a challenging task on account of the constant demographic growth and service demand, which is why water utilities are being outpaced in terms of infrastructure and operative capacity. Moreover, in some cases the revenue that is collected for the provision of service is barely enough for the upkeep of existing infrastructure, thus it is not enough for its

expansion and preventative maintenance. Another priority is raising citizen awareness to prevent the contamination of the bodies of water that include streams which are currently being used for wastewater collection. As a specific case study, this is an account of the restorative efforts that are taking place in Pátzcuaro Lake in Michoacán, México. The municipalities that surround Pátzcuaro Lake are, Quiroga, Erongarícuaro, Pátzcuaro and Tzintzuntzan, and they are directly responsible for the care of the Lake.

The Pátzcuaro Lake basin is found in the state of Michoacán, México, see Fig. 1. It is a closed Basin with a surface area of 929 km², it has an elevation between 2,035 and 3,300 m.a.s.l., that averages 2,369 m.a.s.l.

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Fig. 1 Location of the basin and its municipal composition.

The average precipitation is 775 mm, the evaporation is 1,393 mm. It has an interior lake called Pátzcuaro lake that is 126.4 km², with an average depth of 4.9 m and holds 619.4 Mm³.

Eight municipalities make up the basin, its population is approximately 200,000 inhabitants and their economy depend fundamentally on tourism, forest exploitation, fishing, crafts and recently money sent by migrants from the U.S.A. It is considered one of the most emblematic regions in México on account of its particular beauty and historical importance which dates back to pre-Hispanic times.

The Gonzalo Río Arronte Foundation (GARF) with the Mexican Water Technology Institute (IMTA) began the fourth stage of the Environmental Recovery Program for Pátzcuaro Lake, Michoacán, México in 2014; the nine projects are found in a portfolio of projects called “*Efficiency actions for water utility operators of Pátzcuaro Lake*” and have the following four points as goals, among others:

Table 1 Coastal municipalities Pátzcuaro Lake¹.

Municipality	Inhabitants	Percentage
Pátzcuaro	91,377	62.01%
Quiroga	26,633	18.07%
Erongarícuaro	15,140	10.27%
Tzintzuntzan	14,212	9.64%
	147,362	100.00%

¹ Proyección de la población. INEGI; Censo de Población y Vivienda 1990, 1995, 2000, 2005 y 2010.

- To achieve 87% coverage in sewerage services.
- To eliminate flood zones in urban areas thus avoiding the arrival of trash and waste to the lake and its urban zone.
- To reach potable water coverage beyond 95%
- To increase billing coverage with the objective of helping water utilities arrive at sustainable operations.

These are specific actions aimed at contributing to the improvement of potable water drainage and treatment services so as to reduce contamination in the emblematic Pátzcuaro Lake.

2. Methodology

2.1 Project Scope

In the year 2014, the fourth stage of the Environmental Recovery Program for Pátzcuaro Lake kicked off and will conclude in the year 2018; in this period, several projects will be carried out, among them “*Efficiency Actions for Water Utility Operators for Pátzcuaro Lake*” in which the following results are specifically intended:

- Reduction of residual water discharge to Pátzcuaro Lake.
- Community protection against flood damage through the reduction in waste volume in the Lake.
- Reduction of trash to the lake.
- Potable water service access for the urban population.
- Consolidation of water utilities.

2.2 Specific Problems to Be Resolved

- There is an issue with the pipelines that currently pass through private lots and even under home constructions, putting the general population as well as the water-utility personnel at risk, which is why it is necessary for the pipeline be relocated along public lines.
- Loss of water volume from leaks in the storage/distribution tanks, which, aside from

physical losses represent the investment of electricity, infrastructure wear-and-tear, pumping equipment, pipelines, chlorine and man-hours. Moreover, leaks create a poor institutional image for the water utility and the municipality.

- There's an issue of infrastructure at latent risk because it is located in vulnerable points.
- There is an issue with the lack of infrastructure in the potable water and drainage network that would otherwise prevent contamination from different sources.
- The five deep coastal wells for Pátzcuaro Lake require rehabilitation so as to make the system more efficient and to allow for a rational use of the supply source.
- The rehabilitation of potable-water distribution and drainage lines is needed on account of continuous leaks and the contamination problems they create since they are both along the same trench and are divided only by a layer of dirt.
- Low payment-collection rates for the services provided by the water utility which impede preventive maintenance to the infrastructure as well as its potential expansion. Regarding this issue, measures are being taken to reduce the number of late-paying clients.

2.3 Results from the 2014-2017 Period

Table 2 shows a summary as well as the status of 70 actions from 2014 up to December, 2017 that were identified in the first phase and agreed upon *pari passu* in the second phase by the three levels of government; Federal (CONAGUA, IMTA, CONAFOR, COMPESEA, SUMA); State (CEAC), and Municipal (Pátzcuaro, Quiroga, Erongarícuaro, Tzintzuntzan 4 water utilities) as well as Non-Governmental Agencies.

2.4 Evidence of Actions Taken

Rehabilitation of potable water distribution and

storage tanks (metallic and masonry): Storage tanks are the principal junction of any hydraulic network, nonetheless, the lack of a maintenance program as well as economic resources has given rise to several coastal tanks of Pátzcuaro Lake currently having considerable fissures that generate the leak of potable water, a natural resource which has had electrical energy invested in it for its extraction and piping along with man-hours and chlorination. On top of this, there is a negative impact on the image of the water utilities as a result of the leaks and waste that result from absent rehabilitation. In the first phase, tanks that had immediate potential to be rehabilitated without major work or adaptations were repaired. Fig. 3 and 4 show the works carried out on the elevated metallic tanks and a superficial masonry tank as well as a scanned guarantee of the works expedited by the company that provided the repair services (Fig. 2).

Provision of limiting valves (multi closing anti-fraud): The main function of the limiting-flow valve is to partially or completely limit the flow of water to a specific point at a domestic intake, in the national market, the valves are found in diverse commercial names so as to make them more attractive



Fig. 2 5-year guarantee expedited by the IMTA service providers.

Table 2 Project: Efficiency actions for costal water utilities of the HC-1425.4 project (PRACLP).

STATUS (DECEMBER 2017) OF THE PROJECTS CURRENTLY UNDERWAY BY THE 4 WATER UTILITIES OF THE PÁTZCUARO LAKE BASIN STAGE IV 2014-2017			
No.	Year	Project name	Status
Pátzcuaro			
1	2014	Rehabilitation of FOVISSTE elevated metallic tank of approximately 60m ³	ACTION COMPLETED (GARF/IMTA)
2	2014	Rehabilitation of INFONAVIT elevated metallic tank of approximately 60m ³	ACTION COMPLETED (GARF/IMTA)
3	2015	Rehabilitation of hydraulic network for the Eréndira St. and Vasco de Quiroga neighborhood area	CONCLUDED IN CEAC AS OF THE 21ST OF JULY 2017
4	2015	Benigno Serrato street hydraulic network expansion	CONCLUDED IN CEAC AS OF THE 21ST OF JULY 2017
5	2015	Change in the placement of the hydraulic piping for the Itzi-huriata pumping site 8" in diameter	CONCLUDED IN CEAC AS OF THE 21ST OF JULY 2017
6	2015	Rehabilitation of berths to reinforce the pumping line for the Huecorio well	PROJECT WAS CHANGED IN 2017
7	2015	12" diameter sewage collector in the San Jose neighborhood	BEING UNDERTAKEN BY THE TOWN OF PATZCUARO
8	2015	Compliment stretch of 6" diameter, hydraulic tubing corresponding to the "San José" line on up to "Los Reyes" tank	CONCLUDED IN CEAC AS OF THE 21ST OF JULY 2017
9	2015	Change of pipe stroke 6" in diameter of Jacarandas street in the colony of Cadelinas	
10	2016	Provision of 2,000 antifraud valves (for non-paying users)	ACTION COMPLETED (GARF/IMTA) PMSAP INSTITUTIONS
11	2016	Diagnostic of PMSAP commercial area	ACTION COMPLETED (GARF/IMTA)
12	2016	Weed cleanup and trash collection along 3 stretches of the Guan river as well as its flanks	ACTION COMPLETED (GARF/IMTA)
13	2017	Changing the conduction pipe that runs from the "Huecorio" well to "Redondo" tank	UNDER PMSAP REVISION
14	2017	Provision of 1,200 domestic micro-meters	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
15	2017	Rehabilitation of "Los Reyes" storage tank approx. 1600m ³	CONAGUA/CEAC/MUNICIPALITY PMSAP EXECUTIVE REC. PROP
16	2017	Rehabilitation of "El Calvario grande" storage tank approx. 150m ³	CONAGUA/CEAC/MUNICIPALITY
17	2017	Rehabilitation of "Los Nogales" storage tank approx. 50m ³	CONAGUA/CEAC/MUNICIPALITY
18	2017	Rehabilitation of "Linda Vista" storage tank approx. 60m ³	CONAGUA/CEAC/MUNICIPALITY
19	2017	Rehabilitation of "La Loma" storage tank approx. 130m ³	CONAGUA/CEAC/MUNICIPALITY
20	2017	Rehabilitation of "Plaza Vasco de Quiroga" drainage	CURRENTLY UNDERWAY BY THE PATZCUARO MUNICIPALITY
21 y 22	2017	Executive potable water project for Janitzio/project execution	CEAC COMMITMENT
23 y 24	2017	Integral sewerage project for the eastern zone (eastern Pátzcuaro, Manzanilla, Tzurumutaro and las Trojes/ project execution	CEAC COMMITMENT
Quiroga			
25	2014	Provision of 1,600 anti-fraud valves (for non-paying clients)	ACTION COMPLETED (GARF/IMTA) OOAPASQ
26	2015	8" PVC conduction pipe for the "Las Palmas" springs	ACTION COMPLETED OOAPASQ/PENDING CEAC VALIDATION
27	2015	Rehabilitation of well no. 1	VALIDATED BY CEAC
28	2015	Rehabilitation of well no. 2	VALIDATED BY CEAC
29	2015	Rehabilitation of well no. 3	VALIDATED BY CEAC
30	2016	Provision of 1,600 anti-fraud valves (for non-paying clients)	ACTION COMPLETED (GARF/IMTA) OOAPASQ
31	2016	Commercial area diagnostic for OOAPASQ	ACTION COMPLETED (GARF/IMTA)
32	2017	Rehabilitation of well no. 4 (IMTA/MUNICIPALITY)	CONCLUDED GARF/IMTA DIAGNOSTIC
33	2017	Provision of video-inspection camera for drainage pipes	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
34	2017	Provision of pipe and cable locator	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
35	2017	Provision of concrete/pavement cutter	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
36	2017	Provision of jackhammer	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
37	2017	Rehabilitation of "ICATMI" storage tank approx. 330m ³	CONAGUA/CEAC/MUNICIPALITY
38	2017	Rehabilitation of "Calvario viejo" storage tank approx. 320m ³	CONAGUA/CEAC/MUNICIPALITY
39	2017	Rehabilitation of "Antenas" storage tank approx. 290m ³	CONAGUA/CEAC/MUNICIPALITY
40	2017	Rehabilitation of "Calvario nuevo" storage tank approx. 280m ³	CONAGUA/CEAC/MUNICIPALITY
41	2017	Rehabilitation of "Unidad Deportiva" storage tank approx. 250m ³	CONAGUA/CEAC/MUNICIPALITY
42	2017	Carry out executive projects (S). Conduction pipe for well no. 4 to two different delivery sites	SEE NO. 32 "LOS RESTANTES" CANCELLED BY OOAPASQ (minute 7 Dec. 2016)
Tzintzuntzan			
43	2014	Provision of 1,000 antifraud valves (for non-paying clients)	ACTION COMPLETED (GARF/IMTA) OOAPAS
44	2015	Rehabilitation of the deep well "del Mezquite"	VALIDATED BY CEAC
45	2015	Rehabilitation of the potable water distribution pipe for Lázaro Cárdenas Av.	CANCELLED BY MUNICIPALITY
46	2015	Expansion of drainage line for Aristeo Mercado street	CANCELLED BY MUNICIPALITY
47	2015	Expansion of potable water line for Hospital street	CANCELLED BY MUNICIPALITY
48	2015	Rehabilitation of the potable water distribution pipe for Mezquite street.	CANCELLED BY MUNICIPALITY
49	2015	Rehabilitation of the potable water distribution pipe for Zaragoza street.	CANCELLED BY MUNICIPALITY
50	2015	Expansion of potable water distribution and drainage line for del Miedo street.	CANCELLED BY MUNICIPALITY, WILL BE RESUMED IN 2017 BY THE IMTA
51	2016	Provision of 200 antifraud valves (non-paying clients)	ACTION COMPLETED (GARF/IMTA) OOAPAS
52	2016	Diagnostic of commercial area OOAPAS	ACTION COMPLETED (GARF/IMTA)
53	2017	Provision of concrete/pavement cutter	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
54	2017	Provision of jackhammer	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
55	2017	Provision of a jumping jack compactor	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
56	2017	Rehabilitation of the storage/distribution masonry tank (VITROACERO).	CONAGUA/CEAC/MUNICIPALITY OOAPAS
57	2017	Creation of integral sewerage project for the towns of del Tigre, Puerto del Tigre, Sanambo, Tzintzuntzan and Quiroga, respectively	CONAGUA/CEAC/MUNICIPALITY (NO DATA)
Erongaricuaró			
58	2014	Rehabilitation of superficial masonry tank of approx. 280m ³	ACTION COMPLETED (GARF/IMTA)
59	2015	Rehabilitation of the deep well "el Toril"	VALIDATED BY CEAC
60	2015	Rehabilitation of km 1 drainage for km 1 along the Erongaricuaró-Pátzcuaro highway	COMPLETED BY CEAC AND MUNICIPALITY
61	2015	Rehabilitation for the drainage of the "San Antonio" and Ma. Luisa Martínez" neighborhoods	COMPLETED BY CEAC AND MUNICIPALITY
62	2016	Provision of 300 antifraud valves (for non-paying clients)	ACTION COMPLETED (GARF/IMTA) CAPAME
63	2016	Diagnostic of commercial area OOAPAS	ACTION COMPLETED (GARF/IMTA)
64	2016	Desilting of drainage with a Vactor truck in several points of the municipal capital	ACTION COMPLETED (GARF/IMTA)
65	2017	Rehabilitation of the well "El Llano" (IMTA/MUNICIPALITY)	ACTION COMPLETED (GARF/IMTA) DIAGNOSTIC MUNICIPALITY EQUIPING (PENDING)
66	2017	Provision of a concrete/pavement cutter	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
67	2017	Provision of a jackhammer	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
68	2017	Provision of a portable, electric pipe threader	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
69	2017	Provision of a compressor 2.5 hp	CURRENTLY IN THE IMTA WAREHOUSE PENDING DELIVERY
70	2017	Rehabilitation of storage/distribution masonry tank (VITROACERO)	CONAGUA/CEAC/MUNICIPALITY

to clients, these valves were provided to the water utility in order to obligate past-due clients to proceed to the utility offices to make their timely payment. This

measure is intended to fortify the collections mechanism of the water utility. The anti-fraud valve that is shown here has the advantage that it cannot be

manipulated by the user, hence its commercial name. The installation was carried out by the water utility as shown in the images of Fig. 5.

It is worth noting that the 21 rehabilitation and expansion projects budgeted in the year 2014 and updated in 2015 that are mentioned in the list of Table 3, resolve a previously-mentioned problem related

either to contamination, health risks, latent dangers for the physical safety of persons or improving the efficiency of electro-mechanical equipment. To make the most judicious use of the limited space allotted for this article, however, only five well rehabilitation works will be described in detail (numbers 27, 28, 29, 44 and 59 Table 2).



Fig. 3 Rehabilitation of metallic tanks with VITROACERO® (Concluded work).



Tank with multiple fissures responsible for potable water waste



Rehabilitation Works to prevent the leak of water in The Superficial tank in Erongarícuaro, Michoacán, México.

Fig. 4 Rehabilitation of masonry tanks with VITROACERO® (concluded work).



Anti-fraud valve provided to water utility of cute town to obligate late paying customers to pay.

Installation of anti-fraud valves by water utility personnel for late-paying customers.

Fig. 5 Provision of multi-closing, anti-fraud valves, installed by water utilities (concluded work).

Table 3 Carrying out of 21 rehabilitative and expansion projects for potable water and drainage.

COASTAL PROJECTS FOR THE PÁTZCUARO LAKE BASIN FOR DECEMBER 2014		
	PÁTZCUARO	BUDGET 2016
1	Rehabilitation of hydraulic network for the Eréndira St. and Vasco de Quiroga neighborhood area	\$690,046.31
2	Benigno Serrato street hydraulic network expansion	\$712,018.97
3	Change in the placement of the hydraulic piping for the Itzi-huriata pumping site 8" in diameter	\$799,558.89
4	Rehabilitation of berths to reinforce the pumping line for the Huecorio well	\$333,960.99
5	12" diameter sewage collector in the San José neighborhood	\$2,533,742.69
6	Compliment stretch of 6" diameter, hydraulic tubing corresponding to the "San José" line on up to "Los Reyes" tank	\$343,188.28
7	Change of placement of a 6" pipe for Jacarandas street in the Camelinas neighborhood	\$147,201.45
	SUBTOTAL	\$5,559,717.58
	QUIROGA	
1	8" PVC conduction pipe for the "Las Palmas" springs	\$2,243,731.98
2	Rehabilitation of well no. 1	\$635,196.62
3	Rehabilitation of well no. 2	\$761,433.66
4	Rehabilitation of well no. 3	\$900,408.41
	SUBTOTAL	\$4,540,770.67
	TZINTZUNTZAN	
1	Rehabilitation of the deep well "del Mezquite"	\$491,757.25
2	Rehabilitation of the potable water distribution pipe for Lázaro Cárdenas Av.	\$118,484.94
3	Expansion of drainage line for Aristeo Mercado street	\$285,667.44
4	Expansion of potable water line for Hospital street	\$102,372.59
5	Rehabilitation of the potable water distribution pipe for Mezquite street.	\$284,808.17
6	Rehabilitation of the potable water distribution pipe for Zaragoza street.	\$347,430.20
7	Expansion of potable water distribution and drainage line for del Miedo street.	\$225,817.89
	SUBTOTAL	\$1,856,338.48
	ERONGARÍCUARO	
1	Rehabilitation of the deep well "el Toril"	\$504,432.46
2	Rehabilitation of km 1 drainage for km 1 along the Erongarícuaro-Pátzcuaro highway	\$251,668.63
3	Rehabilitation for the drainage of the "San Antonio" and Ma. Luisa Martínez" neighborhoods	\$196,580.67
	SUBTOTAL	\$952,681.76
	TOTAL	\$12 909 508 40

Evaluation of the electromechanical infrastructure and video inspection of five deepwells. Result: rehabilitative actions budgeted: The scope of these works was to determine the actions needed to rehabilitate five deep wells found on the coast of Pátzcuaro Lake through the evaluation and diagnostic of the electromechanical infrastructure as well as the video inspection of the well. Finally, as deliverables, the IMTA provided a report with the rehabilitative actions that each one of the five wells need, including the specification for their execution and budgeting so that they receive consideration in the Annual Works Program for the year 2016 by the State Water and Basin Management Commission (CEAC) for the State of Michoacán. Fig. 6 shows some images of the works performed on the deep wells, including, measurement of the electrical and hydraulic parameters, video inspection of the inside of the well, evaluation of electrical system, identification of rehabilitative actions and budgeting.

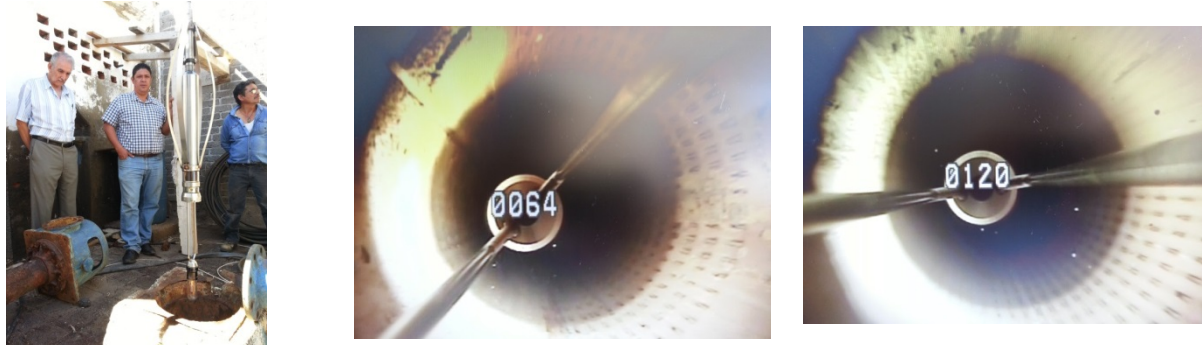
Drainage rehabilitation in the residential area of San Antonio and María Luisa Martínez as well as in KM 1

of the Erongarícuaro-Pátzcuaro Highway: In June of 2016 the CEAC validated the projects performed by the IMTA, the municipality of Erongarícuaro and the CEAC and convened to have these drainage works done in the town of Erongarícuaro. At the end of the month of June, the CEAC began drainage works that correspond to the rehabilitation of the drainage of the San Antonio and Ma. Luisa Martínez residential areas as well as Km 1 on Erongarícuaro-Pátzcuaro Highway all of which are in Erongarícuaro and concluded at the end of the month of September. Fig. 7 shows images of the works done.

Cleanup and weed removal of three parts of the Guan River as well as it's sides 2.1 km: One particularly relevant action for the town of Pátzcuaro to prevent flooding from the overflow of the Guan River (its current flows through the municipal capital, see Fig. 8) was the weed clean-up service and the trash collection on along three strategic parts that make up a 2.18 km stretch of riverbed. It was performed by the IMTA from mid-November on up to the end of December of 2016. The different stretches



Extraction of pumping equipment in well number one in Quiroga to introduce video-inspection camera.



Interior well inspection to determine conditions and propose rehabilitative actions.

Fig. 6 Diagnostic video inspection of five coastal wells of Pátzcuaro Lake.



Fig. 7 Beginning of rehabilitative drainage works and their construction process.



Fig. 8 Rio Guan trajectory (blue line) and the mentioned parts (in red) were dredged.

that were cleaned are as follows and are shown in Fig. 9.

- 1) Situnero neighborhood to “Michoacán” residential area (approximately 460 m.l.).
- 2) Pueblita St-Ahumada bridge (approximately 721 m.l.).
- 3) Héroes de Nacozari St.-Huecorio-Pátzcuaro highway (approximately 1 km).



Stretch 2: Pueblita St. - Ahumada bridge



Stretch 3: Héroes de Nacozari St. - Huecorio-Pátzcuaro highway

Fig. 9 Cleanup and weed removal of three stretches of the Guan River as well as its slopes (2.1 km).

Diagnostic of the commercial area of the four coastal water utilities: In the first semester of 2016

under petition from CONAGUA and CEAC, the IMTA performed a diagnostic of the commercial area for the

four coastal water utilities. Different actions have been identified and budgeted the improvement each water utility, there are projections for different scenarios with different phases (alternatives in the implementation of actions). The following is a draft of the diagnostic for the water utility of Pátzcuaro (PMSAP). The client log, made up of 18,146 intakes, 54% of which have preferential “union” tariffs and 34% have the domestic “popular” tariff, together they represent 88% of the users on average which is shown in Fig. 10. The labor

index is 5.6 on average and the best year for this index was in 2014 with 5.03%. Collections efficiency is 58% on average and there is an average revenue of \$655 pesos per intake. Additionally, there is an estimated backlog of payments worth 40 million pesos, see Fig. 11. Finally, actions were identified that improve all five areas of operations, each of them was proposed, budgeted and programmed in the works calendar and are as follows:

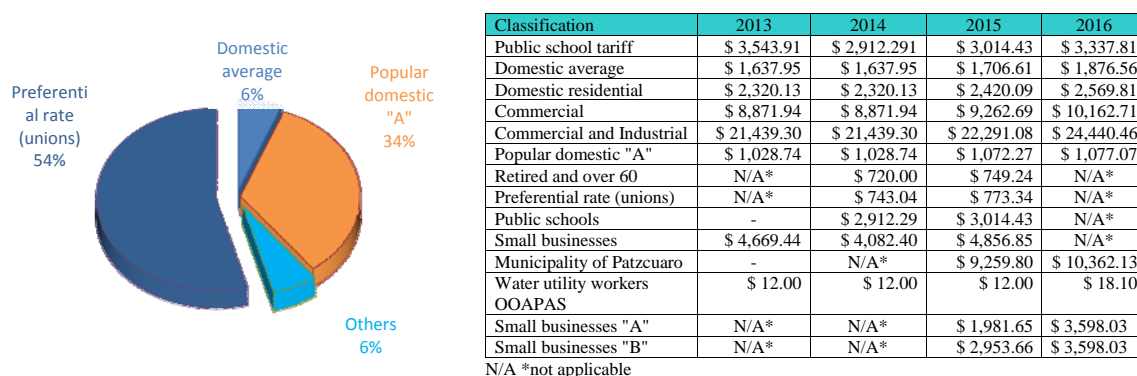


Fig. 10 Customer log and its corresponding annual tariffs (2013-2016).

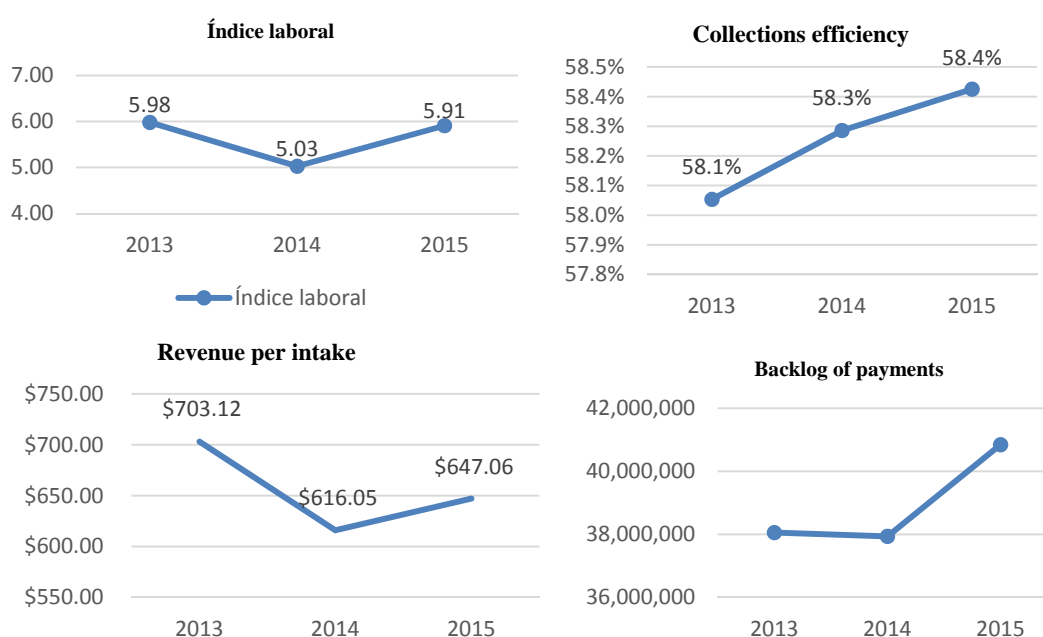


Fig. 11 Indicators coming from the Pátzcuaro water utility (PMSAP) that were analyzed.

- 1) Commercial system planning (macro and micro measurement tariff plan, updating of client log, leak detection, efficiency improvement, update of sectorization and land plotting).

- 2) Functioning and organization of the system (organizational structure, measurement register, billing, payment through banks, commercial efficiency, backlogged payments, past due payments, pro-pay campaign, communication and installation campaign for limiting valves).
- 3) Training (training courses for achieving quality service, complaints handling, existing commercial system management and customer service, as well as certification of personnel and the creation of a system for complaints and suggestions).
- 4) Equipment and furniture (desktop computers, laptop computers, printers and furniture).
- 5) System maintenance (programmed supervision and rehabilitation of the hydraulic infrastructure).

2.5 Social, Economic and Technological Impact

The social impact is of great relevance given that health problems are being attended to that arise on account of the absence of hydraulic infrastructure, in the short-term, from 2014-2017, executive projects (rehabilitative and or expansive) have been carried out that maintain and broaden the infrastructure with which potable water and drainage services are provided for by the four coastal water utilities that contribute to the care, conservation and good use of the water resource.

The economic impact is reflected in the development of projects which benefit the four coastal water utilities primarily in the form of reducing great volumes of hidden physical losses by performing rehabilitative actions on the hydraulic infrastructure. Improving physical and commercial deficiency allows for an increase in the collection of revenue in the water utilities and lastly, it is worth mentioning that there is a savings on behalf of the water utility in the creation and financing of executive projects by the IMTA and the GARF.

Scientific and technological impact; part of the mission and vision of the IMTA involves the

dissemination of knowledge for the broadening and better use of technology on behalf of the water utilities as well as contributing to the transfer of technology that is developed and becomes the principal pillar for fortifying the water utilities with the security and trust that the IMTA can afford as an institution committed to research excellence and technological development in water for the country.

3. Conclusions

Teamwork sub divides the tasks and multiplies their successes in the midterm (2018) while completing public works projects and taking the four water utilities to sustainability in the long-term (2021) allowing for the recovery of the emblematic Pátzcuaro Lake, reestablishing an equilibrium between environment and society. The divulgation of the experience as a successful case study is pending its conclusion and will go on to be shared internationally up finalizing.

Acknowledgements

The current acknowledgement is for the Gonzalo Río Arronte Foundation and the Mexican Water Technology Institute who collectively financed and carried out the Environmental Basin Recovery Program for Pátzcuaro Lake stage IV (2014 2017) in benefit of the four coastal water utilities of Pátzcuaro Lake.

Special recognition also goes to the collaborating water utilities of Pátzcuaro, Quiroga, Erongarícuaro, and Tzintzuntzan for their interest in the actions and collective projects herein mentioned that benefit the population and care of the emblematic Pátzcuaro Lake in Michoacán, México. Finally, an additional recognition goes out to the National Local Water Commission and the State Water and Basin Management Commission for their collaboration in the review, validation and carrying out of executive projects for potable water and drainage.

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