TRANSBOUNDARY IMPACT ASSESSMENT OF WASTEWATER INFRASTRUCTURE PROJECTS IN AMBOS NOGALES

AGREEMENT NO. CONTA18-005

FINAL REPORT

October 2019

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This study is also available in Spanish.

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CONTENTS

ACRONYMS

NADB:	North American Development Bank
BEIF:	Border Environment Infrastructure Fund
CILA:	Comisión Internacional de Límites y Aguas
CONAGUA:	Comisión Nacional del Agua (Mexico´s National Water Commission)
COAPAES:	Comisión de Agua Potable y Alcantarillado del Estado de Sonora (Sonora State Water Utility)
EPA:	Environmental Protection Agency
IBWC:	International Boundary and Water Commission
INEGI:	Instituto Nacional de Estadísticas y Geografía (National Institute of Statistics and Geography)
IOI:	International Outfall Interceptor
NIWTP:	Nogales International Wastewater Treatment Plant
WWTP:	Wastewater Treatment Plant
OOMAPAS:	Organismo Operador Municipal de Agua Potable, Alcantarillado y Saneamiento de Nogales (Municipal Water Utility)

Unit Conversions

1 liter per second = 86.4 cubic meters per day
1 kilometer = 0.62 miles
1 meter = 3.28 feet

EXECUTIVE SUMMARY

The purpose of the Transboundary Impact Assessment of Wastewater Infrastructure Projects in Ambos Nogales is to identify changes in the quality of life in Nogales, Arizona and Nogales, Sonora, resulting from the implementation of those projects. This report presents the results and recommendations of the study funded by the North American Development Bank (NADB) to evaluate the applicable infrastructure projects. The study was conducted by *El Colegio de la Frontera Norte*, the University of Arizona and *El Colegio de Chihuahua*.

To establish context, it is important to describe the two infrastructure projects involved, which include the Rehabilitation and Expansion of the Nogales International Wastewater Treatment Plant (NIWTP) in Nogales, Arizona, and the Rehabilitation of the Wastewater Collection System in Nogales, Sonora. These two communities are sister cities separated only by the international boundary line between Mexico and the United States and have become known locally as "Ambos Nogales."

Projects Evaluated

Wastewater Collection Project in Nogales, SON	
Certified:	*2004*
Cost:	US$ 11.4 million
Objective:	Rehabilitation of 30 linear kilometers (18.6 linear miles) of wastewater collection lines
Direct impact:	Rebuilt the municipal wastewater collection system; 27,300 households with improved wastewater connections; eliminating 5.6 million gallons (mgd) of wastewater.

Wastewater Treatment Plant in Nogales, AZ	
Certified	2000
Cost:	US$ 64.8 million
Objective:	Expand the capacity of the plant to 14.74 mgd to treat 9.90 mgd of raw wastewater from Nogales, SON, which was not being treated and was generally flowing into its neighboring city, along with 4.84 mgd from Nogales, AZ.
Direct impact:	Preventing sewage from both cities, and particularly from Sonora, from overflowing into Nogales, AZ, thus reducing health risks in both communities.

The proposed objective of the study was addressed using both quantitative and qualitative methods. From a quantitative standpoint, official data of various urban development indicators were reviewed for both cities to establish baselines for conditions in the different sectors *before* and *after* project implementation. The qualitative approach refers to the perception or opinion of local residents regarding the quality of life in their cities after implementation of both projects.

Evidence-based Approach

The impact assessment is not intended to establish a quantitative cause-effect correlation, but rather to identify evidence of the impact, whether positive or not, of the projects under review.

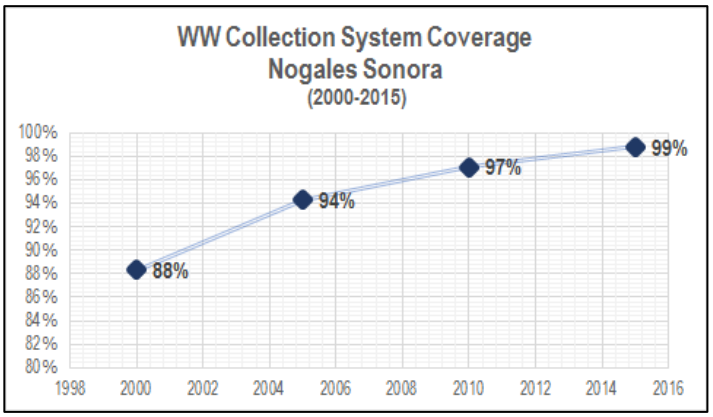
Orographic Context of the Region

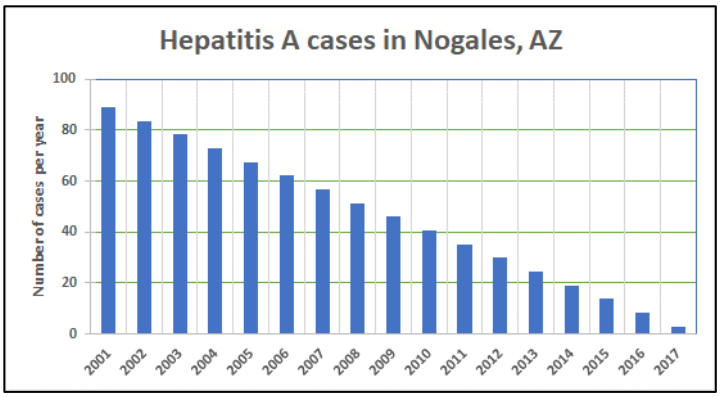
Runoff in the Ambos Nogales region flows naturally from south to north. Consequently, installing a sewer system in Nogales, SON, was not enough; uncontrolled wastewater flows from Mexico to the U.S. had to be treated in a location that was geographically feasible for a treatment plant.

Project Outcomes

Wastewater Collection Project in Nogales, Sonora

This large-scale wastewater collection project solved a critical local issue by providing viability to the current urban development of the city and largely helps explain its growth to 243,000 residents in 2017—a population 12 times larger than that of Nogales, AZ. The municipal wastewater collection system prevents wastewater from the Mexican side from spilling into the neighboring city of Nogales, AZ. The NADB project increased wastewater collection system coverage from 88% to 97% in 2010 and enabled the system to reach 99% coverage in 2015.





NIWTP in Nogales, Arizona

The plant treats wastewater from Nogales, AZ (20,000 residents in 2017), as well as from Nogales, SON, where flows frequently spilled across the border to the U.S. Contact with raw wastewater increased health risks for residents, including diarrheal diseases, skin conditions and Hepatitis A. Today, the NIWTP, located north of the city near the community of Rio Rico, AZ, produces a continuous flow of good quality water, which has led to the greening of the area and very successful suburban development that has reactivated the economy of the area.

It is fair to say that the projects in Ambos Nogales, along with other contributing measures, positively impacted public health in Nogales, AZ, as cases of Hepatitis A dropped from 89 in 2001 to just three in 2017.

Perception of Quality of Life by Residents

Another important aspect of the study was to understand the public perception in both cities regarding any change in the quality of life as a result the projects carried out by NADB. Public perception was measured through 750 household surveys: 650 in Nogales, SON and 100 in Nogales, AZ.

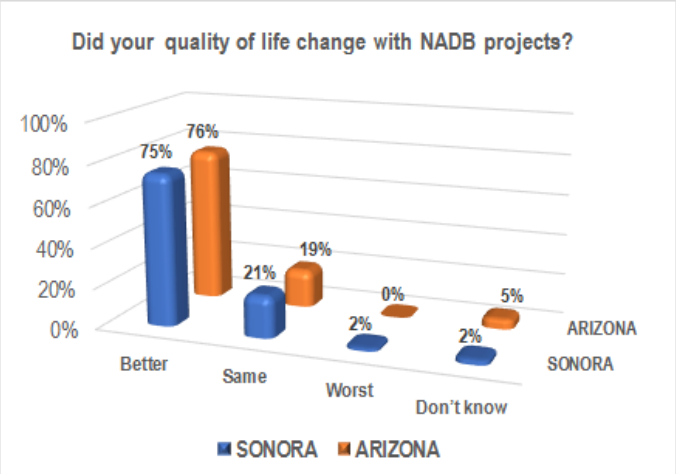
Results of Household Surveys

What did people think about the sewer project in Nogales, SON?

- 75% of those surveyed indicates that it improved their quality of life
- 71% thought there was a positive impact on the local economy

What did people think about the WWTP Project in Nogales, AZ?

- 76% said it improved their quality of life
- 76% thought there was a positive impact on the local economy.



Conclusions

The study confirmed the positive binational transboundary impact that the NADB projects have had on both cities. In Nogales, Sonora, the projects largely solved the city's wastewater collection service problems by collecting and conveying 5.6 mgd of wastewater to the NIWTP in Arizona, for treatment. Today, the NIWTP prevents flows of raw wastewater from the neighboring Mexican city from impacting the urban health and safety of residents in Nogales, AZ. Both cities largely agree (76%) that the quality of life in their sister cities has been improved. The binational cooperation strategy used in carrying out these projects proved to be successful.

INTRODUCTION

The purpose of the *Transboundary Impact Assessment of Wastewater Infrastructure Projects in Ambos Nogales,*[1] is to identify changes in the quality of life in Nogales, Sonora and Nogales, Arizona, based on the implementation of two projects financed by the NADB: 1) Wastewater Collection System Rehabilitation in Nogales, Sonora; and 2) Replacement of the International Outfall Interceptor, Upgrade and Expansion of the International Wastewater Treatment Plant, and Partial Replacement of the Wastewater Collection System in Nogales, Arizona. This study responds to the need to identify the impacts resulting from environmental infrastructure projects that have been financed in the U.S.-Mexico transboundary region.

The following table shows the final costs of the projects:

Table 1: Final Project Costs

Project	Cost (US$ Million)		
	BEIF Funds	Other sources	Total
Nogales, Arizona: ID 292 (Year 2000): Rehabilitation of the Outfall and Expansion of the International WWTP.[2]	59.1	5.7	**64.8**
Nogales, Sonora: ID 206 (Year 2004): Extensive Rehabilitation of the Municipal Wastewater Collection System.[3]	5.5	5.9	**11.4**
Total	**64.6**	**11.6**	**76.2**

Source: Self-reported

As of 2014, NADB started carrying out Impact Assessment Studies, which began a process of generating cumulative knowledge that has improved environmental infrastructure project assessment practices and actions. Prior to the beginning of this study, the NADB had carried out the following impact assessment efforts: 1) Juarez Valley Impact Assessment; 2) Baja California Impact Assessment; and, 3) El Paso, Texas Lower Valley Impact Assessment.

[1] Ambos Nogales is the name commonly given to the pair of border cities of Nogales, Sonora and Nogales, Arizona.
[2] Source: April 22, 2019 Memorandum from Tom Konner, EPA R9, to G. Calza, NADB.
[3] Source: Project Close-Out Report ID (206), NADB, November 2018.

The development of this study, however, presented additional conceptual and methodological challenges, compared to previous studies, due to the following characteristics.

1. The Transboundary Impact Assessment of Wastewater Infrastructure Projects in Ambos Nogales is the first study of its kind that has an eminently cross-border nature, since it was conducted both in Nogales, Sonora, and in Nogales, Arizona, a pair of cities known locally as Ambos Nogales.

2. Wastewater management in Ambos Nogales forms an intrinsically interconnected transboundary system, due to the topography of the study area –the ground generally slopes downward in a south-to-north direction. Most of the wastewater from Nogales, Sonora flows by gravity to Nogales, Arizona so, historically, it has been more feasible in economic terms, to treat wastewater on the U.S. side, since there is no adequate space for this type of facilities on the Mexican side. This binational wastewater collection and treatment arrangement has compelled the authorities and stakeholders of both countries to work in close collaboration in order to properly manage the wastewater discharged by Ambos Nogales.

3. This transboundary study of sister cities is the first one carried out by the NADB in which, in addition to objective indicators that measure the evolution of different dimensions of economic and social development associated to wastewater treatment, indicators are used to measure the perception of residents of Ambos Nogales regarding their quality of life.

Officials and researchers of El Colegio de la Frontera Norte (COLEF), the institution responsible for this study, immediately recognized the relevance of a project of this nature –as both a research topic and as a public policy issue– to support the economic, social and environmental development of the study area. Thus, a decision was made to establish a binational interagency research team to address the challenges presented by a distinctly transboundary issue, such as the assessment of the wastewater collection system in Ambos Nogales. This team was made up of a total of 10 members, four from COLEF, five from the University of Arizona´s Udall Center, and one from El Colegio de Chihuahua.

To achieve the general objective of this research, the study was centered on a conceptual and reference framework formed by three main pillars. First, the framework of the sister cities; second, the concept of Transboundary Water Security; and third, the concept of Quality of Life envisioned as a coordinated approach that considers objective (quantitative) and subjective (qualitative) elements based on the public perception.

The methodological operation of these three components was aimed at identifying the evolution of a series of dimensions, measured through indicators developed specifically to achieve this objective, within a period that covers the “before and after” of the construction and entry into operation of the Ambos Nogales Wastewater Collection and Treatment System.

On the issue of the sister cities framework, it should be noted that few academic papers have adopted this approach (Jayne et al., 2012). Most of the existing literature has addressed cultural issues around the communication ties that exist in these types of cities, including food, holidays, and music (Cremer et al., 2001; Papagarufali, 2005; Ewen and Hebbert, 2007); or the political and economic determinants of their current situations (Clarke, 2009).

Key studies of the region's hydrology at the basin level have resulted in innovative and holistic solutions (Norman et al. 2006, 2010). However, a major aspect addressed in these studies is that the sister cities approach involves a deeper economic, political and social complexity due to the fact that the cities are located in different countries; and achieving equitable development requires building a genuine reciprocity of efforts and benefits in both cities, so that no community benefits at the expense of the other (Zelinski, 1991).

The previous point is directly related to the second pillar of the conceptual framework of this study, which is transboundary water security as it relates to the wastewater collection and treatment system, since one of the issues that is inherent to sister cities, regardless of the political and cooperation dynamics that may exist between them, is the comprehensive management of water resources, and especially water security, as it directly affects the quality of life of local residents and all economic activities. This inevitably entails cooperation among agencies and stakeholders in cross-border sister cities.

Scott et al. (2013) defines water security as “the availability of an acceptable quantity and quality of water for social needs and environmental resilience, in the context of present and future climate change.” Accordingly, water security leads, in the specific case of this research project, to the discussion of transboundary governance and the management of wastewater for its handling, treatment and disposal with the purpose of achieving economic, social and environmental sustainability.

Finally, the third pillar of the conceptual framework corresponds to the relationship between wastewater treatment –in the framework of water security– and the quality of life of the population living in border sister cities.

With regard to this social dimension, a fundamental aspect of the concept of water security, which has been used in most of the definitions, is the access to an acceptable volume and quality of water. That is, the well-being and quality of life of residents is directly linked to access; however, this well-being must be understood as part of the relationship between the community and the environment, in the sense that the wastewater discharged by a given community (in this case, Ambos Nogales) is a waste that must return to ecosystems in a sustainable manner. This research project recognizes the relationship between access, well-being/quality of life, and sustainability.

The study of the impact produced by wastewater collection and treatment infrastructure projects in two cities that have severe economic, social, and political asymmetries was addressed on the basis of this conceptual framework. On the one hand, the process of urbanization of Nogales, Sonora has been accelerated as a result of economic relations with the United States, especially following the Border Industrialization Program (BIP) implemented by the Mexican Government in the second half of the 1960s.

From then on, Nogales experienced a remarkable population growth due, among other things, to increased employment opportunities in the maquiladora export industry. The economic and demographic dynamics of Nogales, Sonora were further enhanced by the signing of the North American Free Trade Agreement in 1994.

This source of employment has attracted many people from the interior of Mexico who settle in border cities like Nogales. The population of this city increased from 24,568 in 1950 to 242,764 in 2017 (INEGI, 2018; Garza, 2003), which represents an increase of almost 900% in 67 years. On the other hand, Nogales, Arizona has not experienced the same growth rate as its twin city, as its population grew only 226% in the same period, from 6,153 in 1950 to 20,076 in 2017. Its economy has historically depended on the trade and services sector, as well as the agribusiness sector.

In addition to asymmetric growth processes that lead to a greater need for infrastructure on one side of the border, there are clear economic asymmetries between the two countries. This means that the United States has greater economic power to provide public services to its population, while Mexico does not have the funds to do so.

Another asymmetry relevant to this study is water management. The United States is a country that manages water in a decentralized manner, that is, each state is free to manage its water resources as it deems convenient and has the legal ability to formulate its own legislation. In Mexico, by contrast, water is managed centrally at the federal level by the National Water Commission (*Comisión Nacional del Agua,* CONAGUA).

All these asymmetries constitute a scenario that makes wastewater management even more complex in Ambos Nogales.

Having discussed the objective and the conceptual framework of this research project, the structure of the study is explained below. First, a background section is presented, in which the historical context of the research problem is described, as well as the main characteristics of the two projects financed by the NADB to address and solve the existing issues.

Next, the methodological framework is presented, and a general explanation is given of the strategy used to obtain the necessary information to achieve the research objective, as well as the strategy for the statistical and geographical analysis of said information.

Subsequently, an analysis of the evolution of the four components of the study´s baseline is presented, as well as the main results obtained in the public opinion survey, both in Nogales, Sonora and Nogales, Arizona. Next, a discussion of the binational impact (in Ambos Nogales) of the results obtained is presented. Finally, the paper presents the conclusions of the study and a reflection on future steps for a potential follow-up investigation.

Figure 1. May 24, 2018 Meeting

BACKGROUND

Historical Context

The hydrography of Ambos Nogales is complex partly because of the elevation of Nogales, which is 1,200 meters above sea level, and because the city sits on a mountainous region. There are two rainy seasons during the year. According to Mexico´s National Institute for Federalism and Municipal Development (*Instituto Nacional para el Federalismo y el Desarrollo Municipal*, INAFED), the Ambos Nogales region comprises two streams: one that originates in the south at Los Alisos Canyon, on the headwaters of the Magdalena River, which receives flows from tributaries Bambuto, Santa Barbara and Planchas de Plata. The Magdalena River is part of the Asuncion river basin, which crosses the Altar Desert region and the Nogales Wash to join the Santa Cruz River, whose waters enter the United States territory and become part of the Gila River watershed. The Nogales Wash is formed without any contributions from natural springs and flows violently during periods of heavy rainfall but runs dry during the rest of the year. Nogales obtains its drinking water supply from groundwater sources in the Nogales Wash, a small feeding basin. As the population increased, the need arose to use water from the Santa Cruz River, which originates in the United States, flows into Mexican territory and joins the Terrenate and Cuitaca Creeks, crossing the border near Nogales. The river then returns to the territory of Arizona, where it joins the San Pedro River, a tributary to the Gila River (inafed.gob.mx).

The city of Nogales, Arizona operates the following public utilities, all under the Department of Public Works: the agency responsible for drinking water is the Nogales Water Department: wastewater collection is the responsibility of the Nogales Department of Environmental Services, and the agency in charge of wastewater treatment is the Department of Wastewater Management.

The Ambos Nogales Binational Wastewater Collection and Treatment project is not a recent project. It began in the 1940s following the signing of the 1944 Water Treaty between the United States and Mexico. In the 1950s, the city of Nogales Arizona was responsible for wastewater treatment operations with the assistance of the International Boundary and Water Commission (IBWC), a counterpart of Mexico´s *Comisión Internacional de Límites y Aguas* (CILA), which financed the construction of the Nogales International Wastewater Treatment Plant (NIWTP) to treat wastewater from Mexico and its residents. On December 30, 1943, the Principal Engineers of CILA and IBWC in Ambos Nogales signed an agreement recommending that their governments approve the start of the binational management and operation of an international wastewater treatment system for Nogales, Sonora and Nogales, Arizona.

This system was built in 1951 and consisted of an international outfall that had subcollectors connected to a main sewer on the Mexican side for the city of Nogales, Sonora (2,200 meters long and 0.46 meters in diameter) and a main sewer on the side of Nogales, Arizona (2,483 meters in length and a diameter ranging from 0.53 to 0.84 meters). These mains connected to the binational wastewater treatment plant located in Nogales, Arizona. This plant was able to treat 6,050 cubic meters of water per day (70 lps) and operated using a primary sedimentation system. The secondary treatment consisted of a digester, two percolating filters with box meters and sludge drying beds.

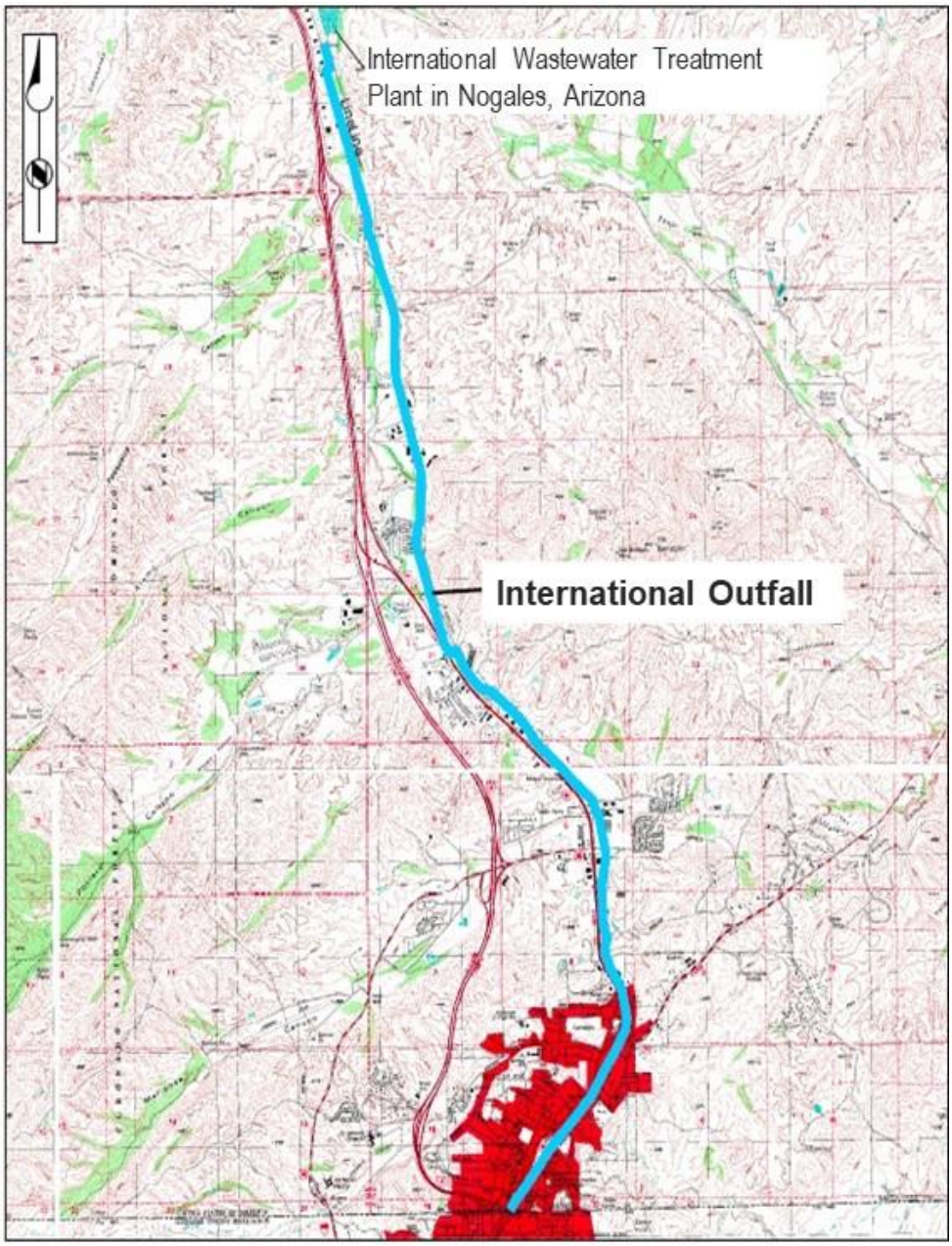
From the beginning, it was established that the treatment system would be managed by local authorities on both sides of the border under the supervision of IBWC and CILA. A proposal called for Mexico to pay based on the proportion of wastewater that it contributed annually to the wastewater treatment plant. The cost of the chlorine used for wastewater treatment and the cost of preparing the sludge for sale were assumed by the United States.

CILA recommended that Mexico reimburse the United States for the cost of the operation and maintenance of the treatment system used by both countries since the construction of the system in 1951. On September 5, 1967, both countries agreed to expand the international wastewater treatment facilities to address the needs projected up to the year 1980. CILA agreed that the capacity of the WWTP was “extremely low” to meet the wastewater treatment needs of Ambos Nogales (CILA, 1967: 1), a scenario that, since then, posed “a serious danger to the health and well-being of the residents of the two cities.” (Ibid). CILA then proposed that the existing facilities be expanded to meet the existing wastewater treatment needs.

As a result, in 1972, the NIWTP was relocated to Rio Rico, a community situated 13.7 km (8.5 miles) north of Nogales, AZ, precisely where the Nogales Wash converges with the Santa Cruz River (Map 1). There is a 762 m (2,500 ft) difference in elevation between the facility and the Mexican side, which causes water to flow by gravity from Mexico to Rio Rico. The treatment process was improved, converting it from a primary treatment with sedimentation lagoons and coarse and fine filters, to a secondary treatment that included two lagoons with surface aerators, followed by more polishing lagoons with aerators and a final chlorine contact chamber whose effluent is discharged to the Santa Cruz River. Part of the sludge is dried, sold, and applied to soils for crops not intended for human consumption (IBWC 2009).

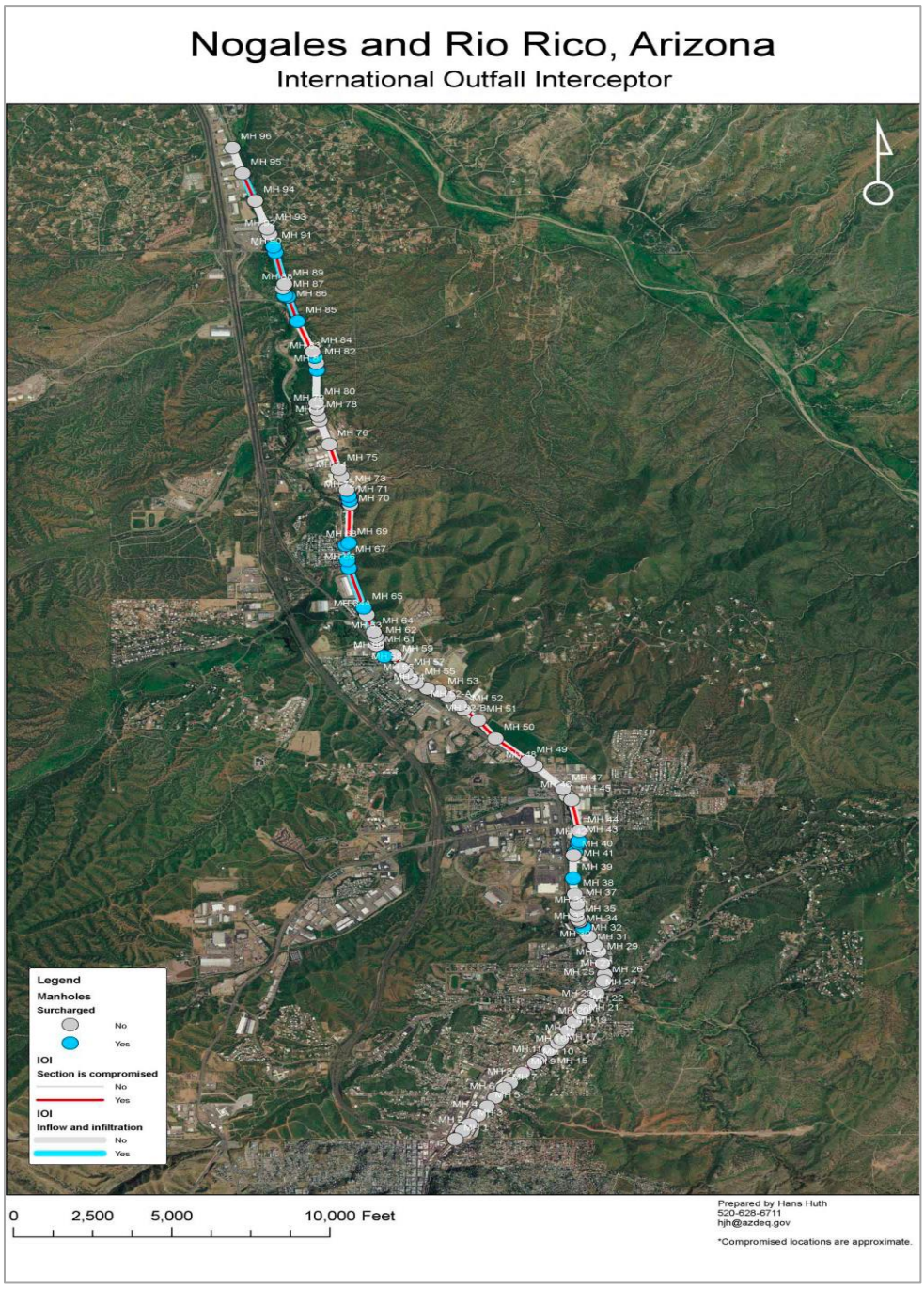
In order to transport the wastewater from both cities to this new treatment plant in Rio Rico, a pipe or tunnel was built, which is called the International Outfall Interceptor (IOI). On the Mexican side, a system of wastewater collection lines was constructed using PVC pipes that meet imperviousness requirements. The system is equipped with gates that have mechanisms designed to prevent it from opening during storms.

Map 1. Location of the Original Wastewater Treatment Plant (in red) and the New Nogales International Wastewater Treatment Plant (NIWTP) connected by the IOI



Source: Self-reported

Map 2. International Outfall Interceptor (IOI) Layout



Source: Hans Huth (2016)

These improvements were intended to reduce the prevalence of diseases associated with the infiltration of wastewater into aquifers, which negatively impacts both sides of the border (Map 2).

Figure 2. NIWTP Discharges to the Santa Cruz River

Wastewater Treated at the NIWTP Discharging into the Santa Cruz River	
Mexican wastewater treated by the NIWTP belongs to Mexico; however, it is financially and logistically very difficult to transport the treated wastewater upstream into Mexico, since it would entail a high financial cost associated with the energy required. Treated wastewater from Mexico is released to the Santa Cruz River. This situation has resulted in benefits to ecosystems in the riparian areas of Arizona, primarily in the communities of Tumacacori and Tubac.	

On July 26, 1988, engineers and officials from Mexico and the United States presented a report to CILA about the conveyance, treatment and disposal of wastewater from Nogales, Sonora and Nogales, Arizona. This report proposed addressing the issue of excess wastewater conveyed to the NIWTP (in relation to allocated volumes). This condition made it necessary to increase the volume of treated wastewater to 217 liters per second for Mexico and 114 lps for the United States. For this service, Mexico had to pay the United States US $1 million in 10 annual payments of US $100,000 each.

In 1992, the technology in the NIWTP was improved to comply with applicable federal rules governing water quality in the United States (Clean Water Act). With these upgrades, the plant was able to not only treat a higher volume of wastewater, but to also reduce higher levels of pollutants such as nitrogen. The significant economic, demographic and urban growth of Nogales, Sonora during the 1990s, as well as the excess water resulting from heavy rains during the summer season, rendered the NIWTP insufficient to treat the required water volumes.

Two points of great importance were addressed at the IBWC/CILA meetings of 1967 and 1988. The first has to do with acknowledging that addressing the issue of the treatment of wastewater discharged by Ambos Nogales is consistent with Article 3 of the 1944 Water Treaty, which states that the Governments of Mexico and the United States “agree to give preferential attention to the solution of all border sanitation problems” (Water Treaty, 1944: 5).

The second is that Mexico's authority to partially or totally dispose of wastewater generated in its territory was also recognized. In other words, it is clear that the conveyance, treatment and disposal of wastewater discharged by Ambos Nogales is a complex phenomenon that needs to be addressed under a systemic vision. This is consistent with NADB's vision of jointly analyzing two projects financed in Ambos Nogales.

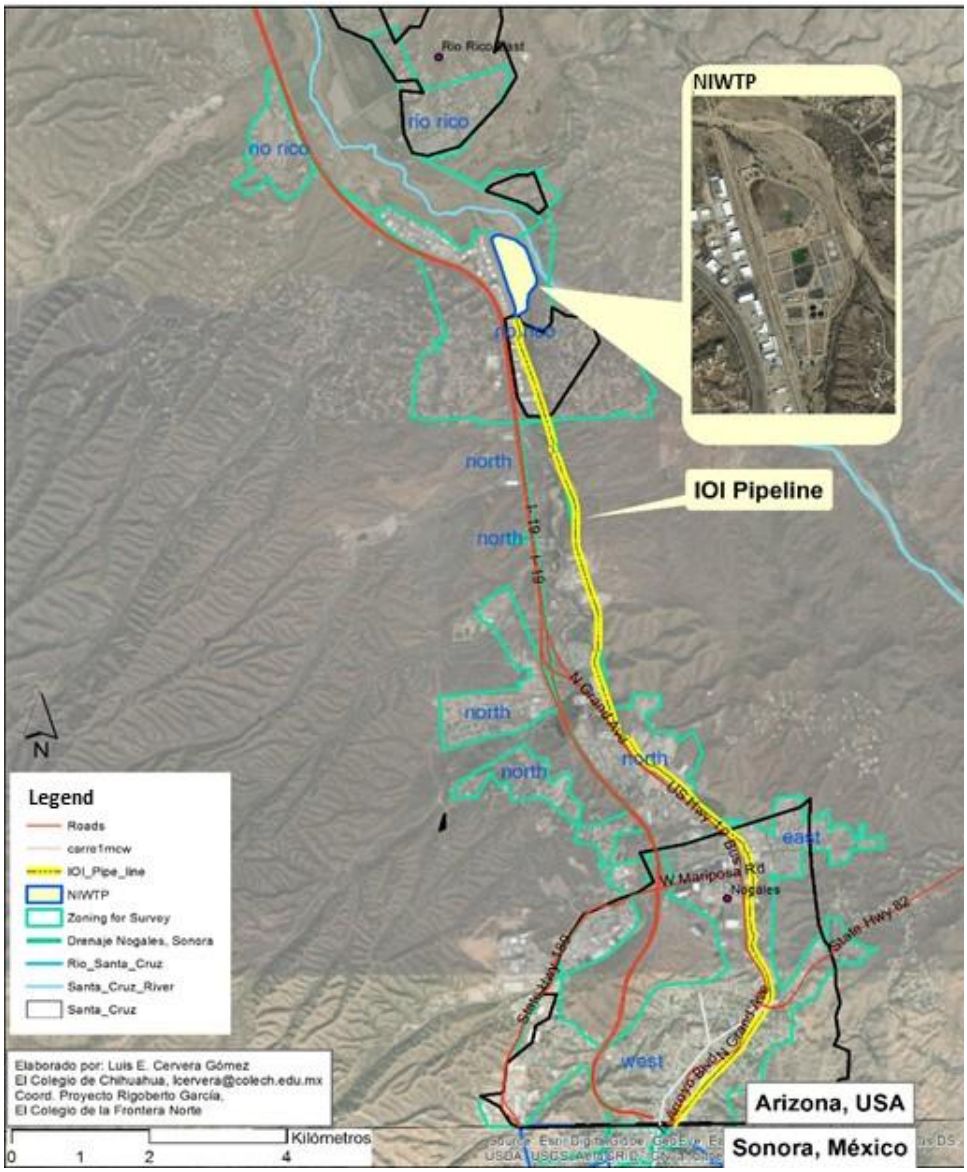
In general terms, a history of respect for the 1944 Water Treaty is observed among the main political and institutional stakeholders of the Ambos Nogales community. It has been understood that an infrastructure issue of this nature must be addressed jointly, since what is done on the Mexican side impacts the United States side financially, socially and environmentally, and vice versa.

Project Descriptions

Nogales, Arizona

It was within this context that the need arose to upgrade, under a comprehensive and systemic vision, the Ambos Nogales wastewater treatment system. In 2000, NADB financed the project for the expansion and improvement of the NIWTP and parts of the Nogales, Arizona wastewater collection system.

Map 3. Nogales International Wastewater Treatment Plan and International Outfall



Source: Self-reported

The purpose of this project was to expand the wastewater treatment capacity to a total of 14.74 mgd to accommodate wastewater flows from Nogales, Sonora that exceeded its allocation, and increase the allocation to 9.90 mgd, a volume that the plant could receive during storm events, system failures or in case of increased deliveries associated to urban growth. In the case of Nogales, Arizona, the allocation was 4.84 mgd (Map 3).

This project introduced a series of modifications aimed at eliminating the nitrogen found in wastewater, with the objective of achieving compliance with current regulations.

The process implemented was the Ludzack-Ettinger system. In the case of the international outfall interceptor, the objective was to eliminate the bottlenecks that occurred during extreme rainfall events, and to provide additional capacity to deal with the demographic growth projected for Nogales, Sonora. This 14.4 km interceptor has the capacity to transport an average flow of 180 liters per second (4.1 mgd) for Nogales, Arizona, and 434 liters per second (9.9 mgd) for Nogales, Sonora. This interceptor transports incoming wastewater that crosses the international boundary between the United States and Mexico and flows to the NIWTP located in Rio Rico, Arizona. The estimated cost at the time the project was proposed was US $46.1 million, with an annual maintenance cost of US $2.3 million.

Nogales, Sonora

Subsequently, in 2004, the NADB financed the project for the Rehabilitation of the Wastewater Collection System in Nogales, Sonora. This project consisted of the rehabilitation of approximately 30,000 linear meters of wastewater collection lines, which required virtually rebuilding the city´s entire wastewater collection system. The project was developed within the Nogales Wash basin, which begins in Arizona and then crosses to Sonora and returns to Arizona.

Figure 3. Santa Cruz River Watershed

Santa Cruz River Watershed

The river flows south towards Mexico, crossing towards Santa Cruz in Sonora.

Then it turns west, south of the Sierra de San Antonio.

At this point it changes direction towards the northeast and enters the United States, east of Nogales and southwest of Kino Springs.

It continues north towards the international border crossing through the Tumacacori National Historic Park, Tubac, Green Valley, Sahuarita, San Xavier del Bac and Tucson.

This project consisted of 19 tasks for the rehabilitation of wastewater collection sewers and mains. Of these, two tasks were intended to improve the city's collectors, while the other 17 focused on subcollectors (Table 2). All the tasks were carried out in areas where drinking water, wastewater collection and wastewater treatment were already available. The wastewater collection project was developed using a binational approach with the goal of addressing the issue in both Nogales, Arizona and Nogales, Sonora. For this purpose, a Binational Technical Committee was created that included representation from U.S. and Mexican local, state and federal agencies.

The project sought to improve public health and environmental conditions in Ambos Nogales through the rehabilitation of wastewater collection lines, in accordance with the corresponding regulations; this would help reduce the potential infiltration of rainwater to the wastewater collection network and avoid exceeding the water volumes received by the NIWTP during the rainy season.

The approximate cost of the project initially considered was $ 124,618,086 pesos, equivalent to US $ 10,836,355 at the current exchange rate (NADB, 2004). Due to the lack of borrowing capacity by COAPAES, the project was financed partly by EPA grant funding and partly by the Mexican government.

Table 2. Rehabilitated Sewer Lines and Mains in Nogales, Sonora

No.	Collector or subcollector	Length meters	Diameter inches
1	Álvaro Obregón	3747	18, 24, 28
2	Astolfo R. Cardenas	890	12
3	Buenos Aires	668	16
4	Ensueño	2011	12, 16
5	Ruiz Cortines	9139	24, 28
6	Tecnológico	2200	14, 16, 18, 20
7	5 de febrero	1080	12, 16
8	Virreyes	1120	18
9	Reforma	1830	12
10	Hermosillo	1242	12, 16
11	De los Maestros	720	12
12	Kennedy	400	12
13	Olimpia	823	12
14	Penitenciaria	1072	12
15	Niños Héroes	510	12
16	Celeya	511	12
17	Orizaba	723	12
18	Jesús García	860	12, 16
19	Las Aguilas	370	12

Source: NADB (2004)

Figure 4. Survey Team Training Workshop

METHODOLOGY

The purpose of this project is to identify the impact that the construction of wastewater treatment infrastructure has had on the quality of life and the environment of Ambos Nogales. To achieve this objective, a methodological strategy was implemented to identify the situation before and after the operation of the wastewater treatment system. It should be noted that the original proposal was to cover the 2000-2017 period, but the availability of information contained in statistical databases varies greatly in both Nogales, Sonora and Nogales, Arizona, so it was not possible to establish a homogeneous time frame.

This methodological strategy consists of three main prongs. The first prong addresses the construction of a baseline based on indicators that measure impacts on different dimensions of development, which is called hard data. The second prong consists of identifying the perception of the residents of Ambos Nogales regarding the impacts produced by the wastewater infrastructure, in order to compare the hard and objective data with subjective information.

The third prong aims to identify the opinion of the main stakeholders regarding the subject under study. Next, each of these prongs will be explained in greater detail.

Baseline

The construction of the baseline was based on the following components and indicators:

a. Project Indicators
    i. Water coverage
    ii. Wastewater collection coverage
    iii. Existing wastewater treatment plants and capacities
    iv. Percentage of wastewater treatment coverage
    v. Number of households with latrines or similar systems

b. Socioeconomic Indicators
    i. Population size
    ii. Employment levels
    iii. Household income levels
    iv. Cost and/or reduction of household spending on drinking water
    v. Land and property values (assessed value, evolution of property or commercial taxes), presence or addition of new housing developments
    vi. Increase in the number of economic units in the different productive sectors

c. Urban Infrastructure Indicators
    i. Utility fees
    ii. Number of paved streets or paved surface area
    iii. Street lighting (number of street lamps)
    iv. Schools
    v. Public parks
    vi. New subdivisions

d. Public Health Indicators
    i. Existence of hospitals or health care units
    ii. Presence and/or reduction of diseases related to water management (water-borne or diarrheal diseases)

Perception Survey

The second prong corresponds to a perception survey and geo-referenced information. The purpose of this survey was to analyze the public perception of the changes implemented in the water and wastewater systems of Nogales, Sonora and the improvements to the NIWTP in Nogales, Arizona, in order to assess the impact on the quality of life and local environment.

The administration of the surveys was carried out as follows:

Table 3: Number of Surveys Administered

City	Number of Surveys
Nogales, Sonora	650
Nogales, Arizona	100

Source: Self-reported

The survey consisted of 24 questions that covered the socioeconomic dimensions of:

1. Quality of life,
2. System operation during the rainy season,
3. Urban development,
4. Environmental and binational cooperation.

See Appendix 1, Public Perception Survey, at the end of the document.

The survey was designed with two levels of representation in mind, one based on the size of the universe and the other based on spatial representation, which means that the results are spatially related to socioeconomic and demographic variables. These results are presented spatially, i.e., answers are physically related to homes located in the surveyed blocks.

The general criteria for the implementation of this geo-referenced survey were:

1) In the case of Nogales, Sonora, the population residing in blocks located 200 meters from a main collector or sub-collector of the wastewater collection line.

2) In the case of Nogales, AZ, the population residing in the vicinity of the International Outfall, as well as the population residing north of the Rio Rico International WWTP.

These criteria were used to form the Ambos Nogales space.

Methodology for the Selection of Samples in Nogales, Sonora

A project was developed in ArcGIS® using information about the water and wastewater collection systems and socio-spatial indicators. The following vector information was established:

- Blocks (INEGI)
- Blocks that had occupied private homes were selected.
- Block centroids (development of centroid layer)
- Wastewater collection lines

ArcGIS® processing was conducted as follows:

- A cartographic procedure was carried out using the ArcGIS application, based on spatial location to find the blocks situated 200 meters from a wastewater collection line.
- Geoprocessing was used to cut the centroids located within 200 meters of the wastewater collection lines (see map 4).
- The total number of occupied private homes within the selected blocks was extracted.
- A random geostatistical *sample* was calculated (using the subset module), with statistical representation of the approximately 250,000 residents, as well as spatial representation (see final result in Map 5).

Figure 5. Survey Implementation

Survey Implementation Methodology

Two meetings were held with the interviewers to provide training on the study subject.

Two pilot surveys were applied, one in Sonora and one in Arizona.

The interviewers had the ability to communicate clearly with the respondents and knew how to accurately record the answers.

It was verified that the interviewers understood the purpose of each question and how to express it without suggesting or biasing the answers.

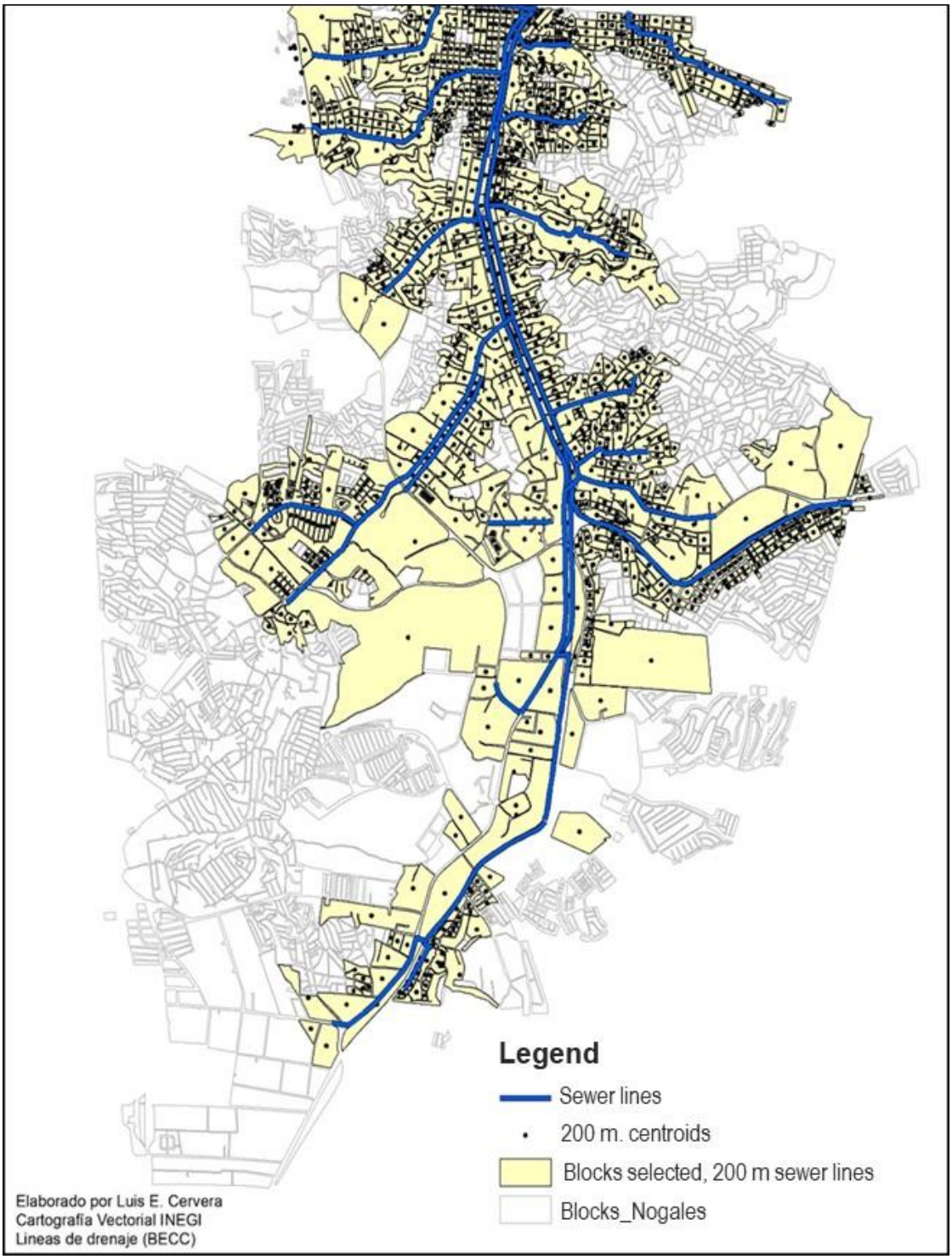
The same procedure was followed when administering the survey in all cases and in both cities, minimizing the bias of individual practices.

The survey administration was based on a geo-referenced and sector-based structure.

Interviewers had to follow the same procedures when administering the survey, so that the results would not be biased by individual practices.

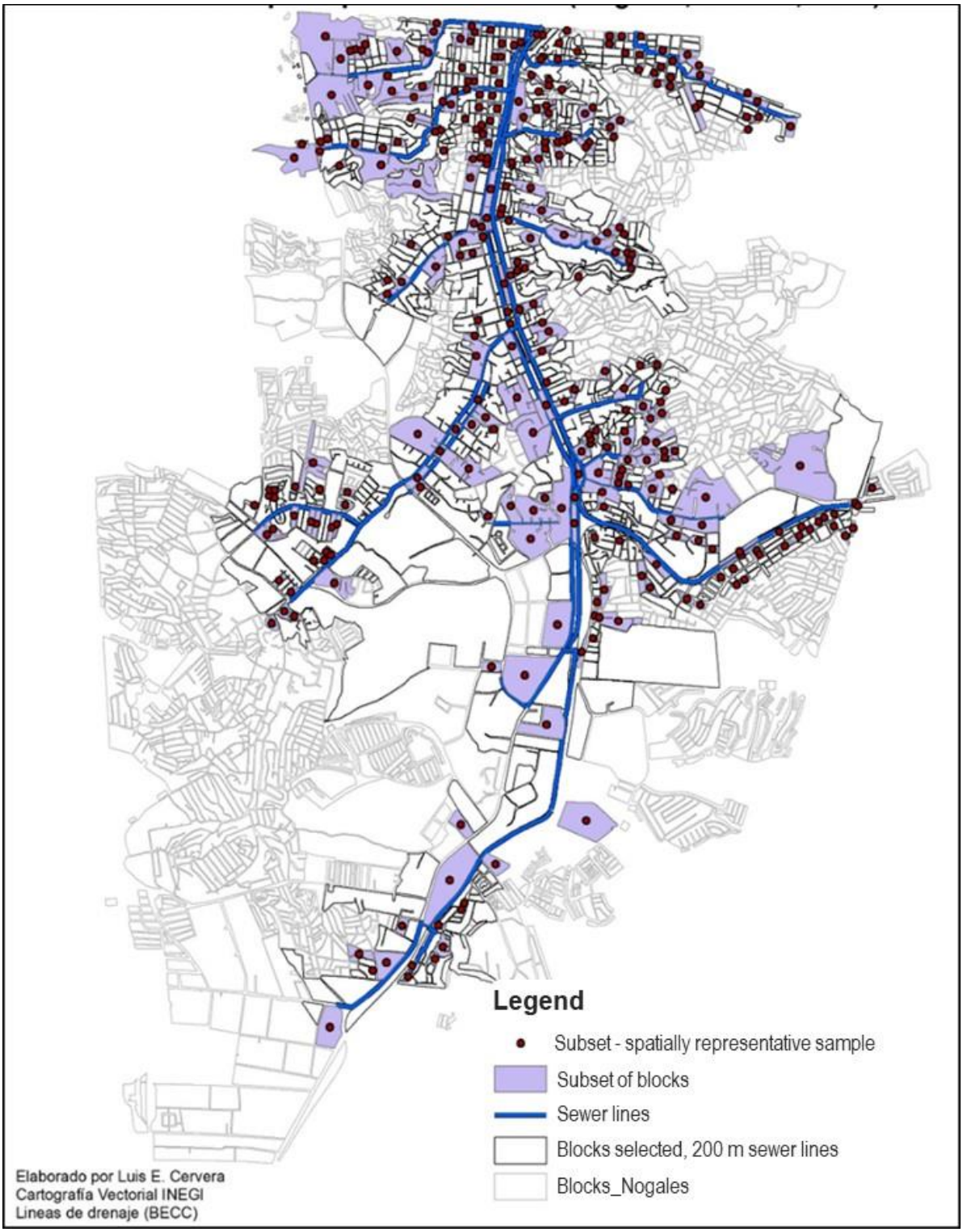
Additionally, when comparing the spatial results obtained in both sister cities (see chapter titled *Comparison*), more extensive zoning was established for Nogales, Sonora, so that the results could be analyzed in four areas: Northeast, Northwest, Southeast and Southwest (Map 6).

Map 4. Selection of Survey Blocks in Nogales, Sonora



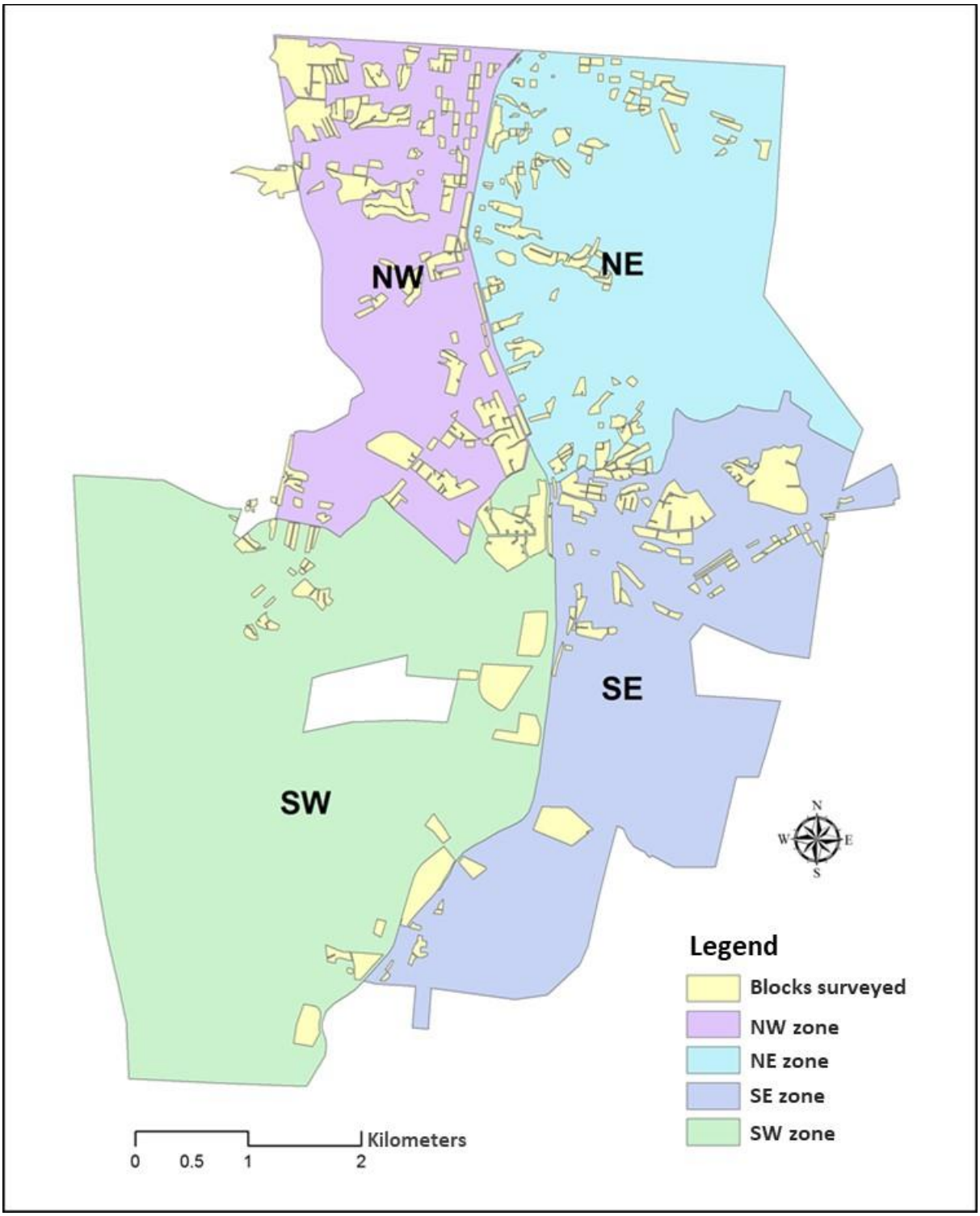
Source: Self-reported

Map 5. Subset or Geo-statistically Random Selection of Final Blocks



Source: Self-reported

Map 6. Nogales, Sonora Zoning for Comparative Analysis



Source: Self-reported

Calculation of Sample Size

The total population located in the area of influence was approximately 80,000 in 2015. This population resides in approximately 28,000 homes located in 1,107 blocks adjacent to the area of impact of the wastewater collection lines in Nogales. Based on water and wastewater user registry records provided by the water utility, the final sample size was determined considering a 99% confidence level and an estimated 5% maximum error, resulting in a total of 650 surveys distributed. Additionally, two households per block were considered, obtaining a total of 325 blocks to be surveyed, which were selected based on spatial representation, using the geostatistical subset module available in Arc GIS (Map 5).

Methodology for Survey Implementation in Nogales, Arizona

In the case of Nogales, Arizona, the target population to be surveyed was the population residing in the vicinity or to the left and right sides of the International Outfall line that collects water flows from Ambos Nogales. The selection of this area was strategic because this is the area where the population that experiences the operation of the wastewater collection and treatment systems resides, which is a key element to identify their opinion about the quality of life.

The sample size was calculated using exactly the same methodology used for Nogales, Sonora. In this case, a 95% confidence level with a population universe of 20,000 residents and a 10% confidence interval (+- 5% error) was considered, resulting in a total of 96 surveys, although in actuality, a total of 100 surveys were administered following these steps:

1. U.S. Census Bureau cartography was selected for the Nogales, Arizona area.
2. Centroids of the polygons representing census units were calculated.
3. 1,000-meter buffer area was established to the left and right sides of the International Outfall Interceptor (IOI pipe line), from the international boundary to the blocks immediately downstream of the Nogales International Wastewater Treatment Plant (NIWTP).
4. A random selection of blocks was made geostatistics module subset.
5. A spatial representation was determined based on four zones: Rio Rico, North, East, and West (Map 7).

Key Stakeholders

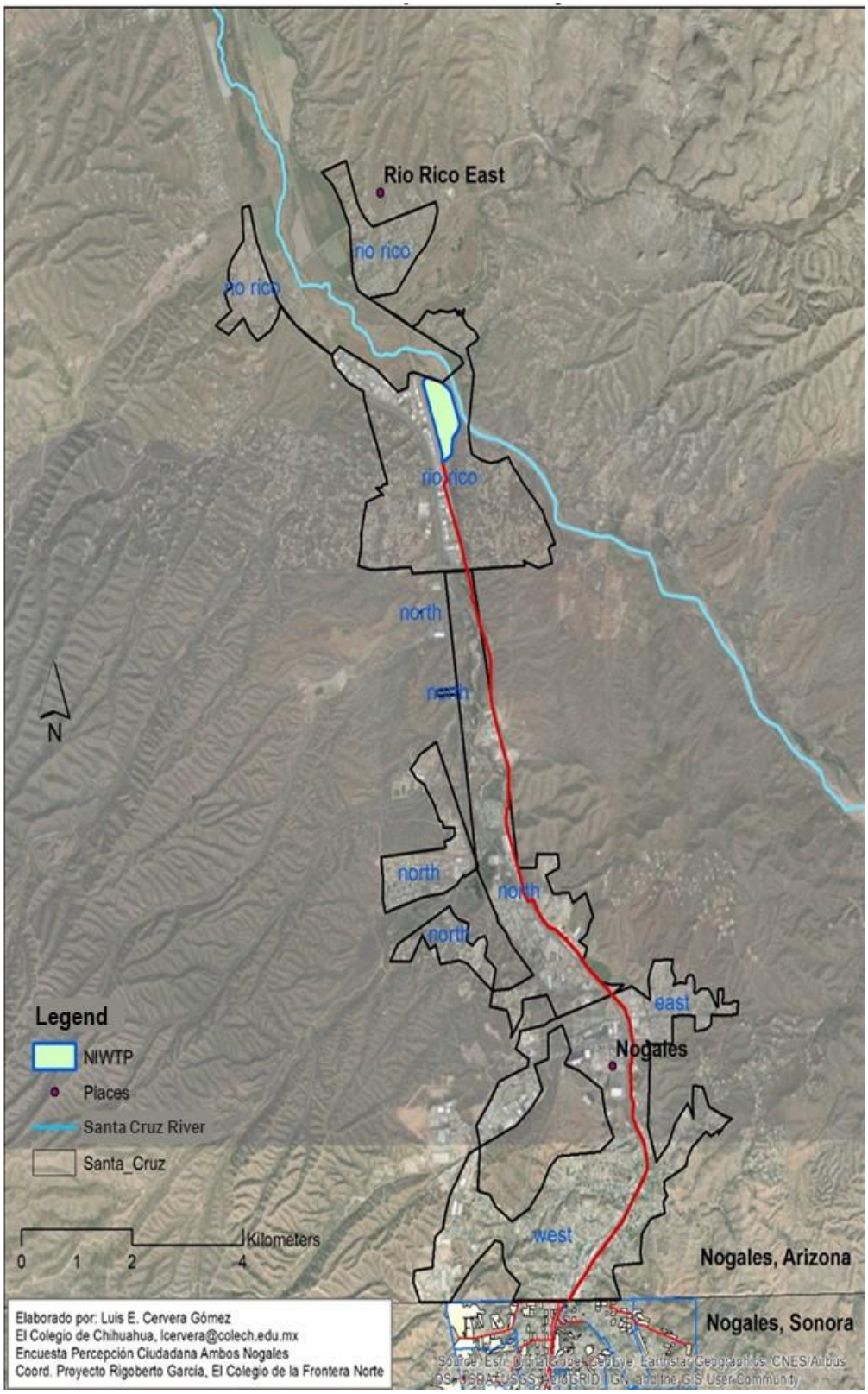
The third part of the methodological strategy of this study consists of identifying the opinion of key stakeholders in Ambos Nogales. This strategy, as a method, is essentially qualitative, and intends to compare the results obtained in the objective indicators developed using secondary sources and in the perception survey. For this purpose, key stakeholders were sought in Ambos Nogales who were familiar with the study area before and after the construction and commissioning of the wastewater project, so that information could be collected to complete the analysis of the evolution of the different dimensions considered in this study.

To collect this information, a semi-structured interview was administered to seven key stakeholders who were familiar with the changes occurred before and after the implementation of the wastewater projects in Ambos Nogales, addressing the following topics: 1) wastewater project impacts; 2) binational cooperation; 3) opportunities for improvement; 4) potential water reuse; 5) general opinion. Subsequently, the most important issues addressed by the stakeholders were recognized, and a comparative analysis was carried out with the purpose of identifying, using a binational and transboundary approach, the main impacts resulting from the wastewater projects—from the perspective of the key stakeholders—as well as the emerging issues that must be addressed so that this project contributes to the sustainable development of Ambos Nogales.

Figure 6. Project Team Visit to the Public Works Administration Center

Source: Self-reported

Map 7. Selected Survey Blocks in Nogales, Arizona



Source: Self-reported

IMPACT ASSESSMENT OF THE WASTEWATER COLLECTION PROJECT IN NOGALES, SONORA

Introduction

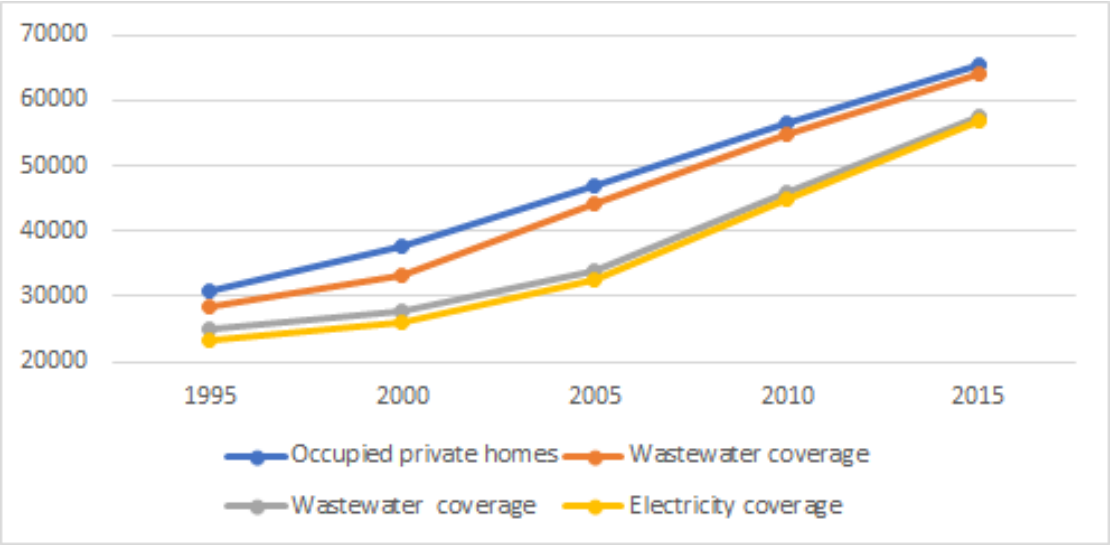
The purpose of this section is to present indicators from three sources: 1) objective indicators using statistical data, 2) perception data based on a survey of city residents, and 3) geo-referenced data through geographic information systems. The combination of indicators makes it possible to triangulate the information and thus reach more solid and valid conclusions that help to make a diagnostic assessment of the impact of wastewater projects in Nogales, Sonora that received financial assistance from NADB. Specifically, the assessment focuses on the Nogales, Sonora wastewater collection project.

The impact assessment, as explained in the Methodology section, focuses on four components that are considered the best indicators to capture the potential effects/benefits of wastewater projects in the community. The first component focuses on wastewater infrastructure coverage indicators. The second component takes into account socio-economic indicators, not only in relation to people, but also to the habitat. The third component includes urban infrastructure and equipment indicators. Finally, health indicators are presented.

Component 1: Basic Infrastructure Coverage Indicators

Chart 1 presents an approximation of the infrastructure trend in Nogales, Sonora. It shows the housing growth trend and the basic infrastructure associated with housing, which allows people to have a better quality of life. The trend shows that in 1995, there was a gap in service coverage vs. the number of homes with public services. A turning point is identified beginning in 2000, as coverage was improved –mainly in the areas of electricity and wastewater collection–, a trend that did not include water coverage. In this respect, by 2015, electricity and wastewater collection services practically met the totality of the demand, but a deficit in water coverage still existed. In summary, wastewater collection did show the expected positive growth behavior to meet demand. It would be necessary to investigate what happened to water coverage.

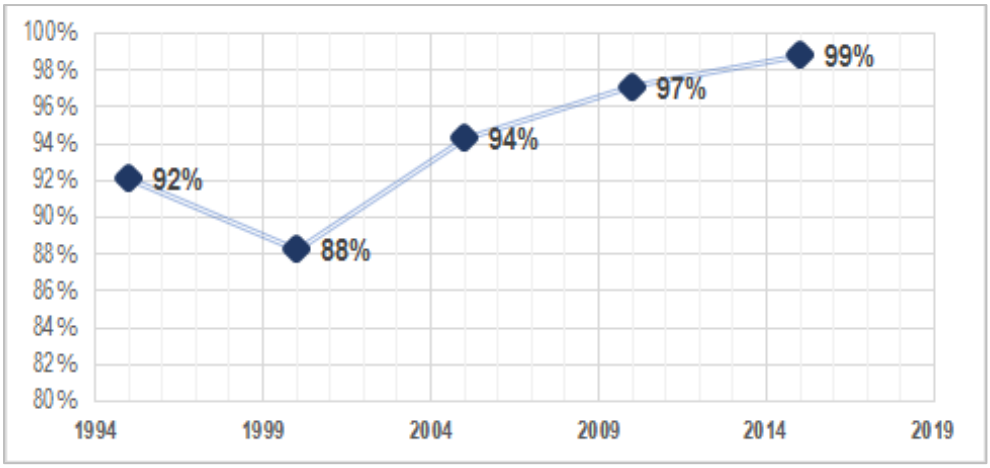
Chart 1. Evolution of Basic Infrastructure in Nogales, Sonora



Source: Prepared by the authors based on INEGI data (1996, 2001, 2006, 2011, y 2016)

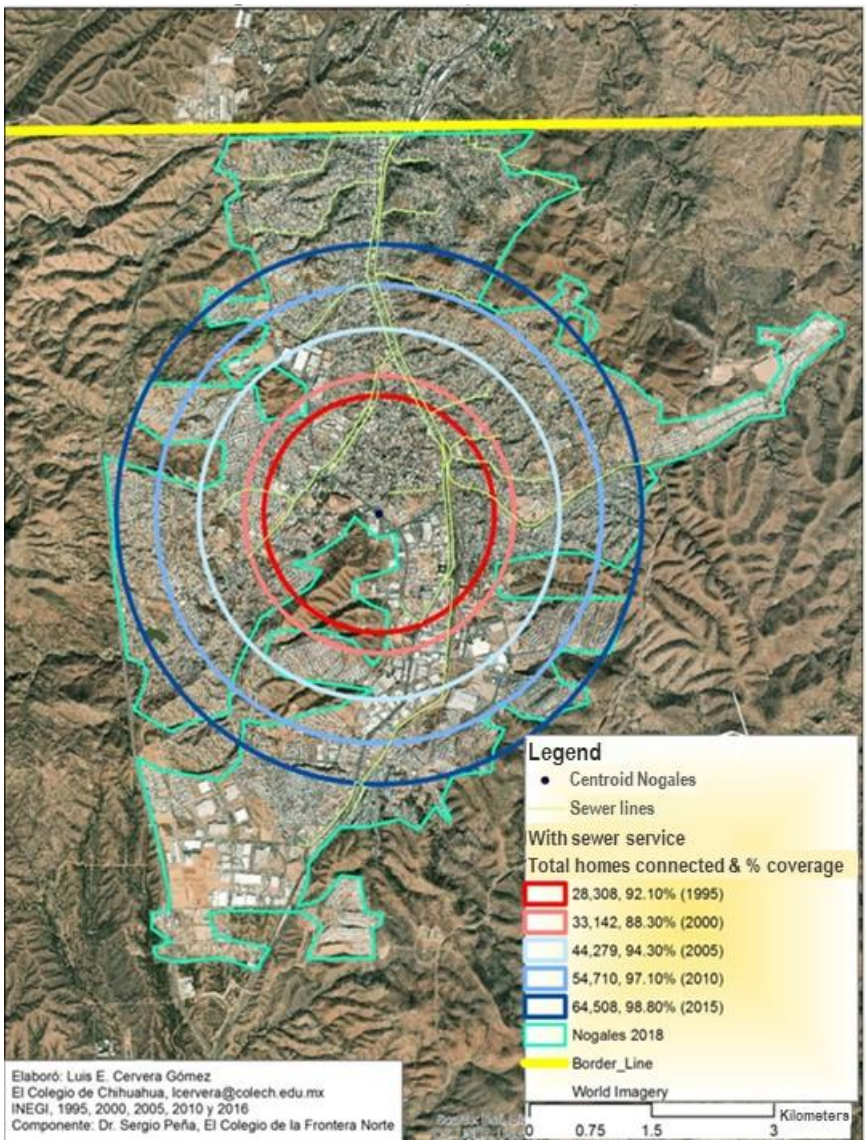
As for the number of households with wastewater collection, a total increase of 35,662 homes was observed during the 1995-2015 period. This represents 126% more households with wastewater collection. What is important to highlight for the purpose of evaluating the impacts of the NADB investment is the change in the percentage of households that now have this service. Available data shows that between 1995 and 2000, wastewater collection coverage decreased from 92% to 88%, due to population growth. However, it is worth noting that the NADB wastewater collection project implemented in 2004 was a factor that helped to increase coverage from 88% to 94% in 2005. By 2010, the coverage reached 97%, and by 2015, it reached 99%; that is, total coverage was practically achieved.

Chart 2. Evolution of Wastewater Collection Infrastructure in Nogales, Sonora 1994-2015



Source: Prepared by the authors based on INEGI data (1996, 2001, 2006, 2011, y 2016)

Map 8. Concentric Representation of the Evolution of Wastewater Collection Coverage in Nogales, Sonora (1995-2015)

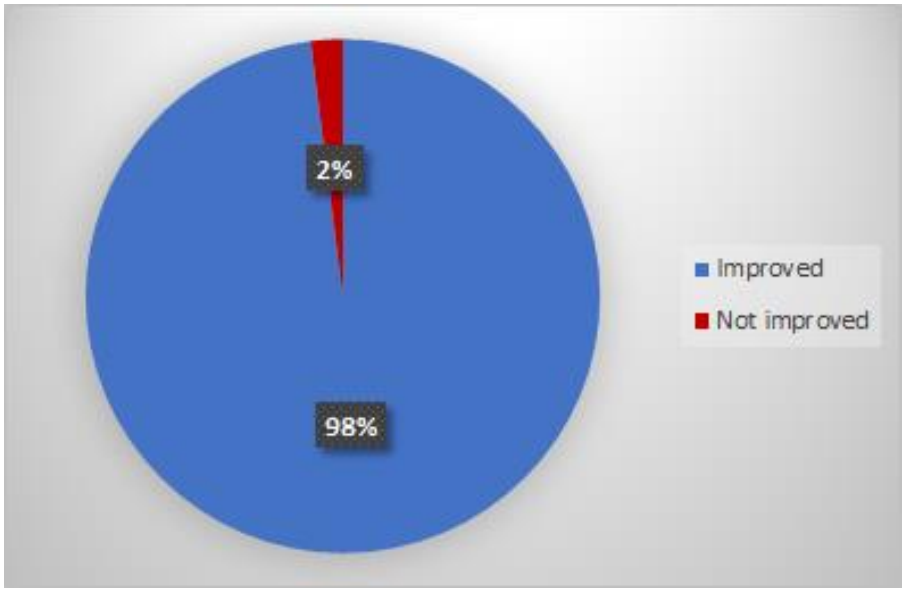


Source: Self-reported

Map 8 spatially illustrates the comparison between the wastewater collection coverage growth observed and a homogeneous (hypothetical) growth of a central point in the city between 1995 and 2015. The key point here is that the blue circle (2015) covers an area twice as big as what existed in 1995; this indicates that, although the relative change was only seven percentage points (92% to 99% during the period analyzed), the absolute change was significant.

Based on data obtained from the survey administered, Chart 3 shows that the residents´ perception of how their quality of life improved with this environmental infrastructure project is compatible with official data, which indicates a high degree of validity of the survey.

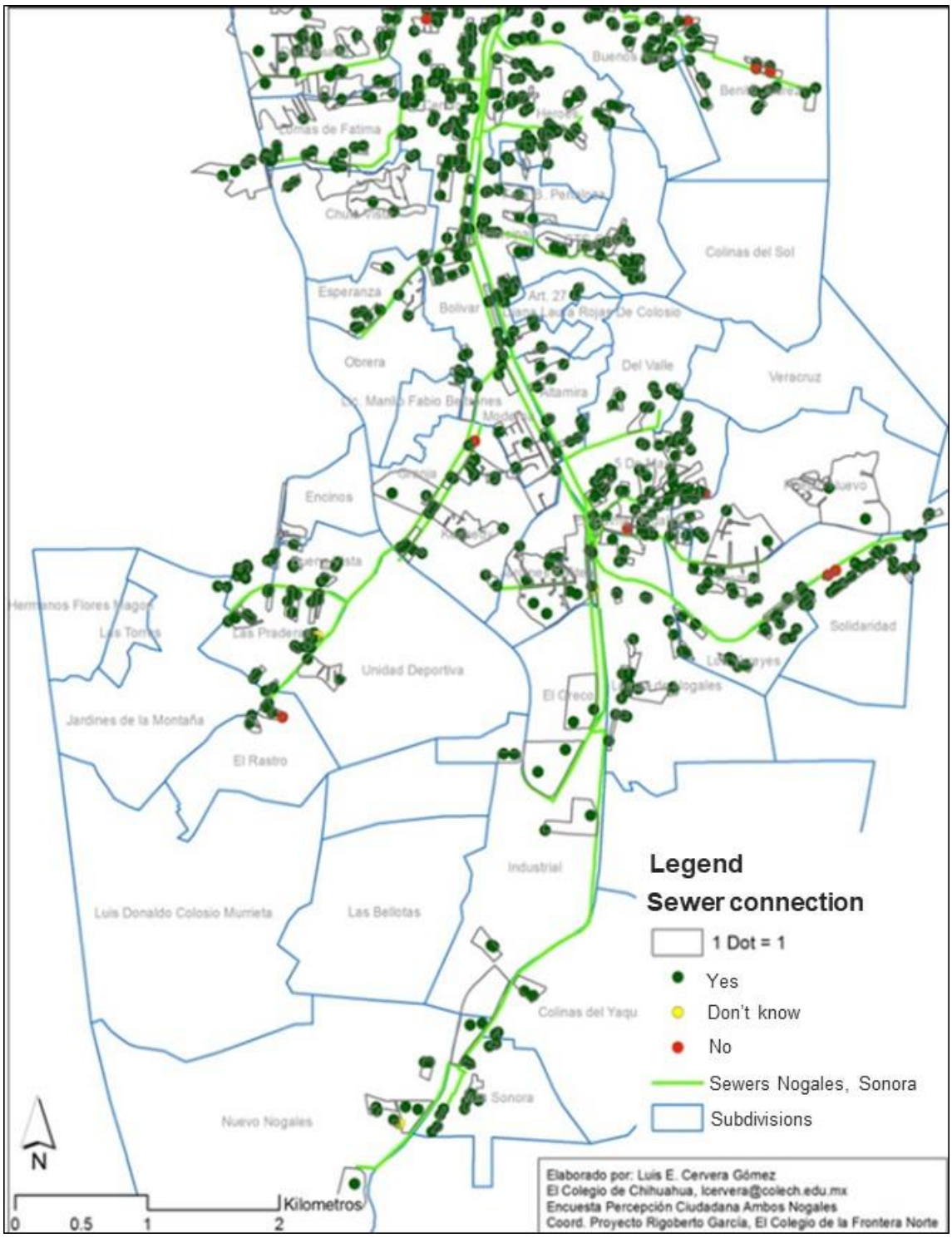
Chart 3. Perception of Quality of Life Improvement as Related to Wastewater Collection Coverage



Source: Nogales Survey

As for the spatial distribution of the responses obtained, based on whether respondents are connected to the wastewater collection system, Map 9 shows that there were only a few cases where respondents reported that they were not connected or did not know if they were connected to the system. That is, the significance of wastewater collection coverage in Nogales, Sonora was established spatially.

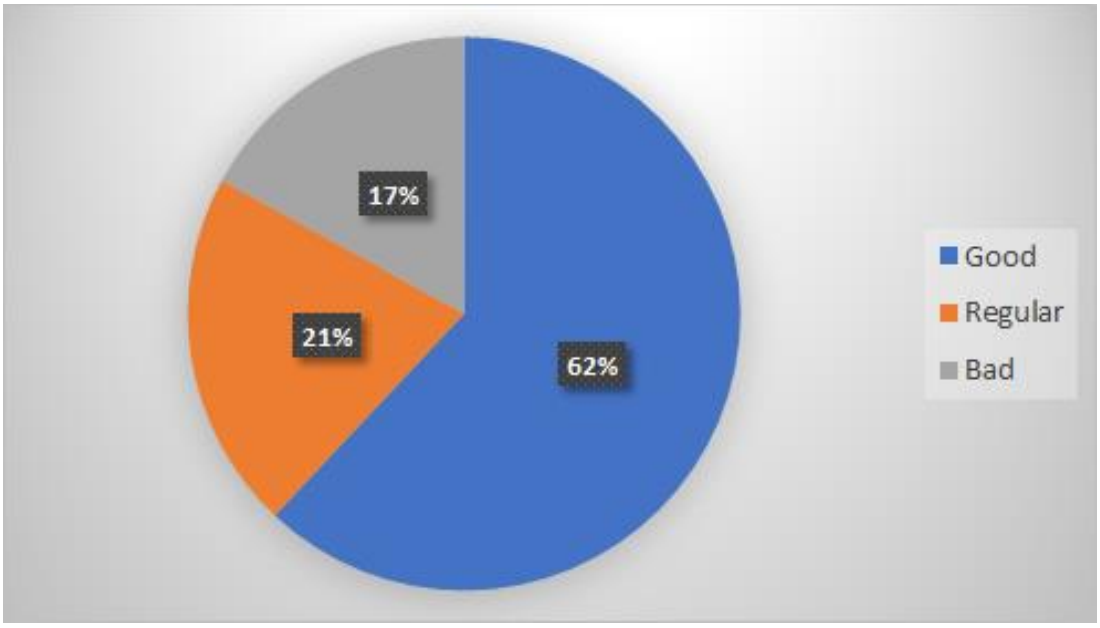
Map 9. Spatial Distribution, Question 8:
Is Your House Connected to the Municipal Wastewater Collection System?



Source: Self-reported

Residents of Nogales, Sonora evaluated the operation of the wastewater infrastructure through the following question: How would you rate the operation of the wastewater system (Sonora) or the wastewater treatment system (Arizona) in your neighborhood during the rainy season? The results show that the majority of the population rated the operation as good (62%); although 21% think it is fair and 17% rate it as bad (Chart 4).

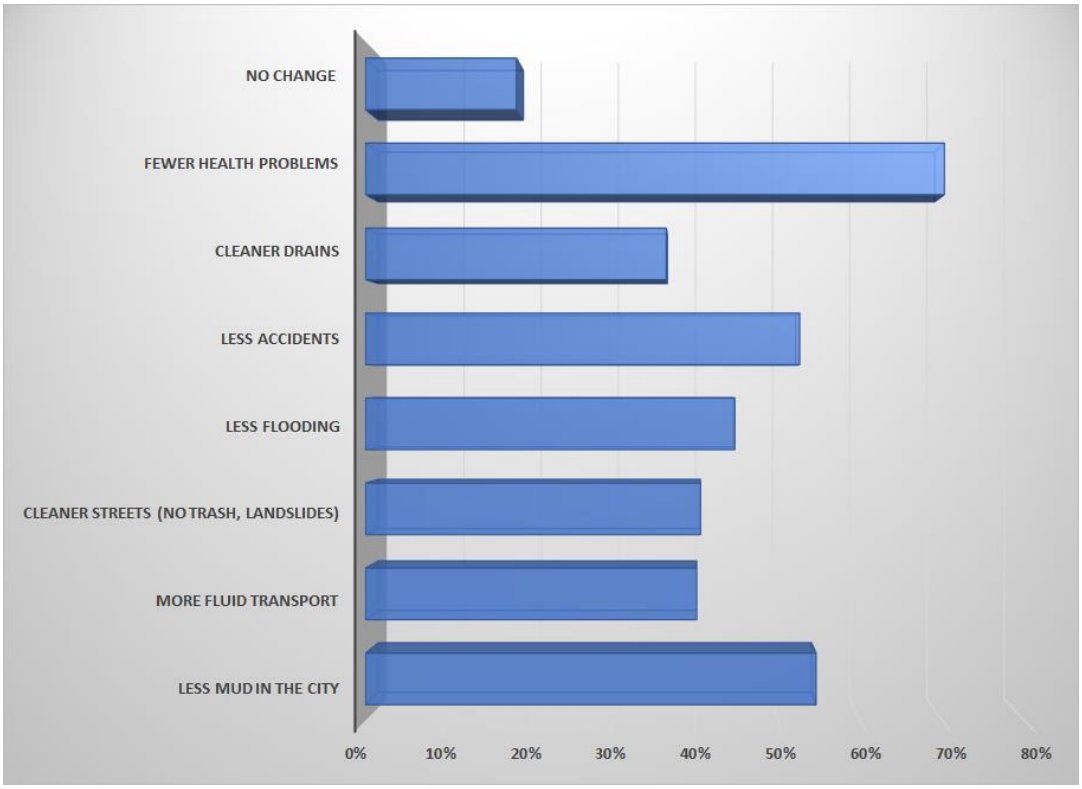
Chart 4. Wastewater System Rating in Nogales, Sonora



Source: Self-reported

With regards to the impacts identified by residents in their subdivisions, positive impacts –those related to health, mud, accidents and flooding– were highlighted first, and to a lesser extent, the cleanliness of the canals and streets, floods, and transportation (Chart 5). Positive effects stood out in the answers, with the exception of dirty streets, flooding and disruptions in traffic flow; these are elements that remain in the collective memory (flooding) or issues (transportation and traffic) that impact the daily lives of residents.

Chart 5. Wastewater System Impacts in Nogales, Sonora Neighborhoods



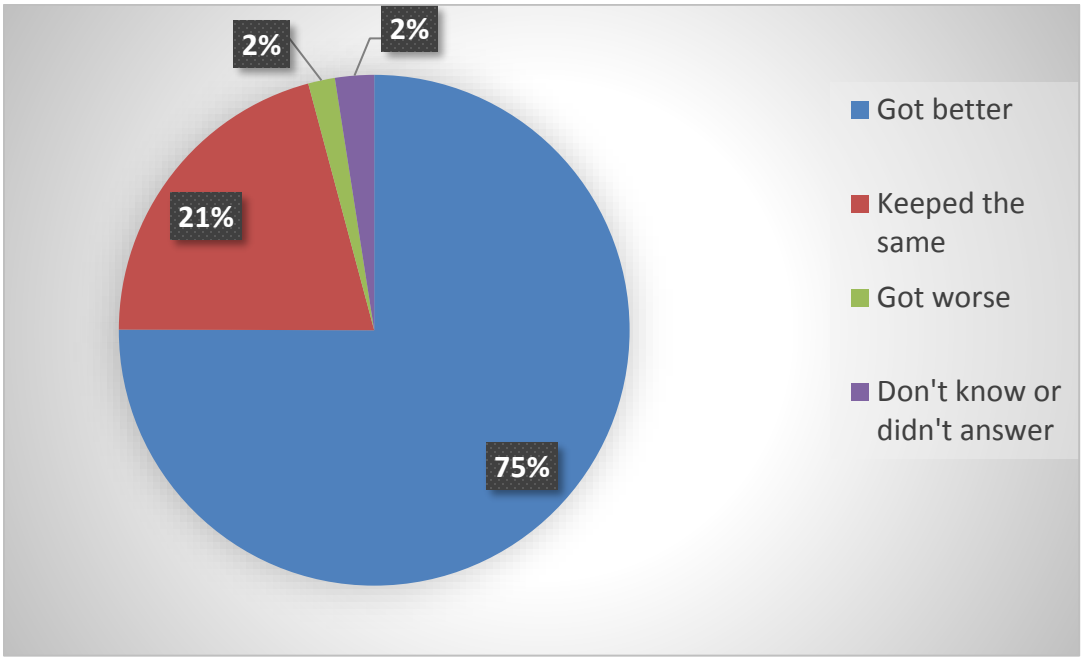
Source: Self-reported

Continuing at the subdivision level of neighborhood, Chart 6 shows how residents perceive the way in which their quality of life has improved in connection to the wastewater system. In general terms, residents of Nogales, Sonora perceive a substantial improvement in their quality of life. The specific question was: How much do you think the quality of life in your neighborhood has improved with the wastewater treatment plant and the wastewater collection system?

While most of the wastewater treated by the Rio Rico facility in Arizona, comes from Nogales, Sonora, it is relevant to identify the residents´ perception of wastewater collection and treatment efforts both in the Mexican city and in the neighboring Nogales, AZ.

The results show that more than three fourths of the respondents said that their quality of life improved. On the other hand, it was also found that 21% of people think that their quality of life remains the same, while only a minimal proportion (2%) thinks that it has worsened.

Chart 6. Public Perception of the Impact of Wastewater Infrastructure on the Quality of Life in Nogales, Sonora



Source: Self-reported

This subject inevitably came up during interviews with stakeholders and decision makers in Ambos Nogales (see chapter titled *Comparison*). In the social imaginary of Nogales residents, there is a perceived idea that Nogales, Sonora is entitled to obtain a benefit from the wastewater that flows by gravity towards the Rio Rico NIWTP, since Mexico´s National Water Commission (CONAGUA) must pay the cost of treatment.[4] On the U.S. side, conversely, the perception is that the issues of flooding and wastewater spills resulting from extreme rains or storms are due to the lack of adequate infrastructure on the Mexican side. Additionally, it was underscored that, since 2012, Mexico has failed to make the payments for wastewater treatment provided in Arizona as agreed.

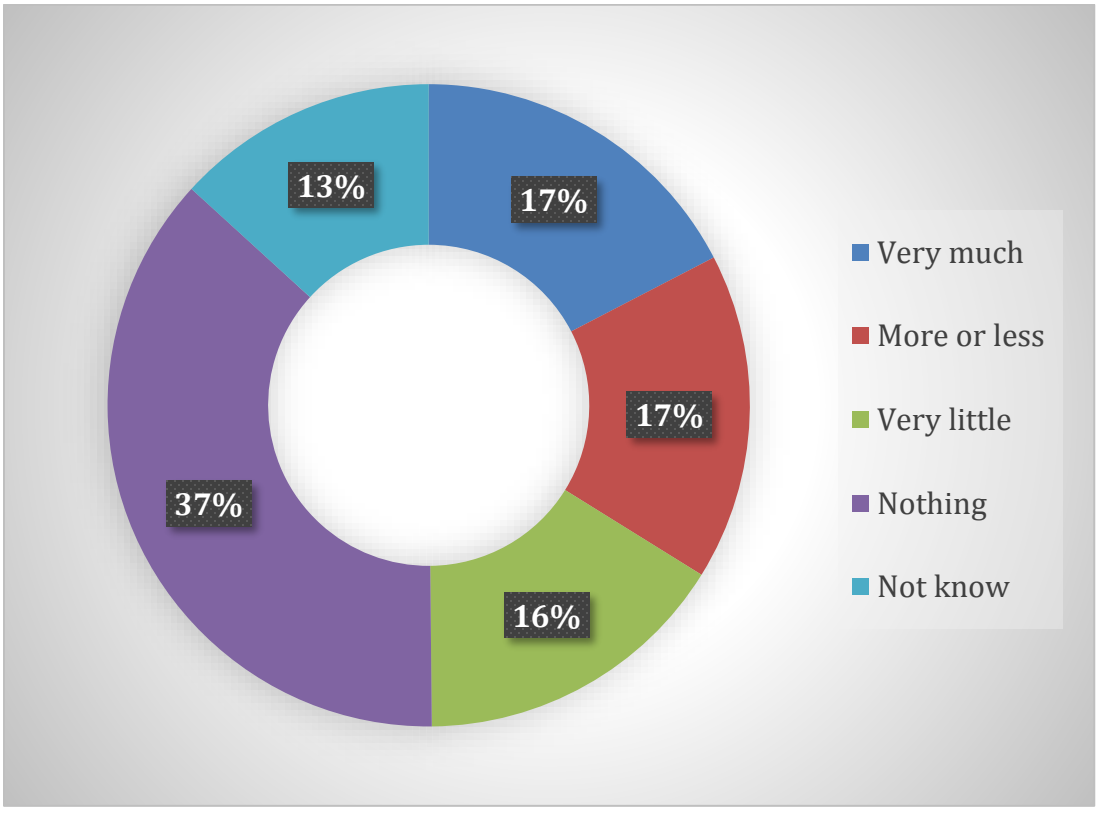
The scenario described above illustrates the implicit complexity of a binational wastewater treatment system, as is the case of Ambos Nogales. It should be noted that the public perception about what is done on either side of the border regarding this issue, reveals in general terms a deep ignorance of the reality. This means that, despite having implemented an eminently transboundary project of great relevance for the social and environmental well-being of the

[4] In fact, Nogales, Sonora, is the only Mexican city where CONAGUA pays for wastewater treatment. This situation stems from the transboundary nature of the wastewater system in Ambos Nogales, as explained in the historical background section.

community, most of the population of Nogales, Sonora (37%) thinks that what is done on the Mexican side has little or no impact—or an unknown impact—on the American side. Only 17% of the population perceives an important level of transboundary involvement and, another 17%, think that this level of involvement is moderate (Chart 7). In fact, only 24% of the population is aware that wastewater is treated in both countries, and 45% is completely unaware that wastewater treatment is being provided.

In summary, the analysis of the basic infrastructure coverage component shows a positive relationship with the wastewater infrastructure project financed by the NADB. In total, five objective indicators of this component were constructed, whose evolution over the period of time analyzed is summarized in Table 4, and a positive trend is clearly observed in both absolute and relative terms.

Chart 7. Answer to the Question: How Much Do You Think That What Happens to Wastewater in Nogales, Sonora, Impacts Nogales, Arizona and Vice Versa?



Source: Self-reported

Table 4. Basic Infrastructure Coverage Indicators in Nogales, Sonora

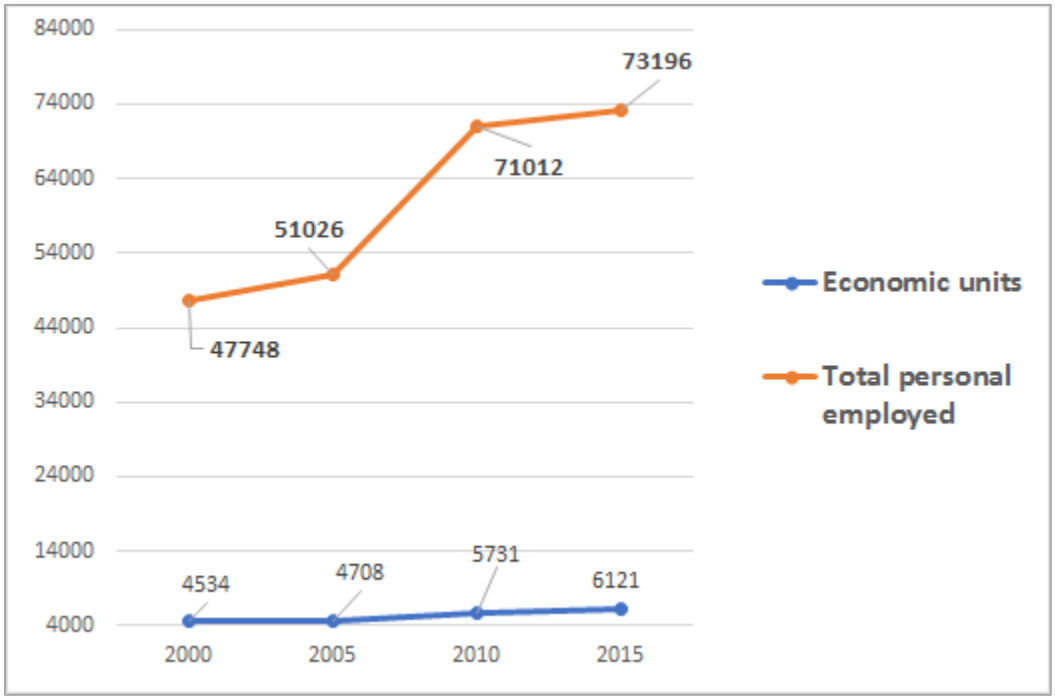
INDICATOR	Year	
	2000	2015
Private homes occupied	37,545	65,256
Wastewater collection coverage	88 %	98 %
Water coverage	84 %	90 %
Electricity coverage	94 %	99 %
Wastewater treatment facilities	0	1 (Los Alisos)

Source: Self-reported

Component 2: Socioeconomic Indicators

According to information provided by Mexico´s National Institute of Statistics and Geography (INEGI), the total gross production resulting from economic activities in Nogales increased from 10.658 billion pesos in 2003 to 18.240 billion pesos in 2013, which represents a 71% increase if 2003 is taken as the baseline year. The analysis of data from economic units between 2000 and 2015 shows that they went from 4,534 to 6,121 units, which represents a 35% increase during the period under review. In turn, the number of employed persons increased by 53%; which means that, on average, economic units increased their employment numbers. Growth rates for both cities are different (Chart 8).

Chart 8. Evolution of Economic Units and Employment in Nogales, Sonora (2000-2015)



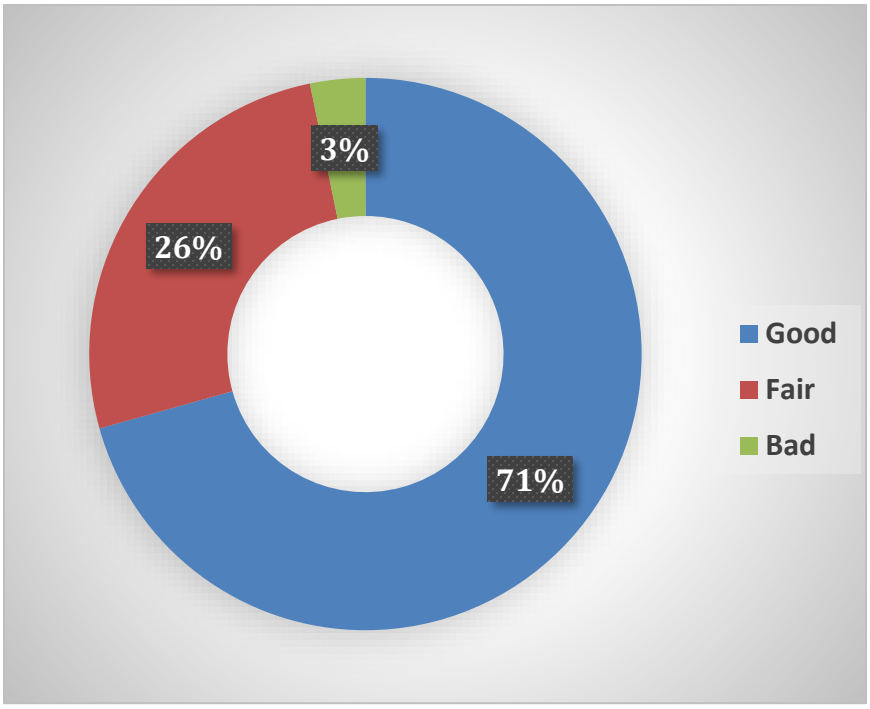
Source: Prepared by the authors based on INEGI data (1999, 2004, 2009 y 2014)

The size of these companies remained practically constant, with an average of 11 people per economic unit in 2003 and 12 people in 2013. The average annual salary per worker went from $85,000 to $111,000 pesos; while the gross production of each economic unit went from $2,264,000 to $2,980,000 pesos in the same period.

Major economic sectors in terms of job creation (excluding the primary and extraction sectors) include retail –the largest one, employing just over 40% of the labor force–, the manufacturing or maquiladora industry, lodging, health services, and social welfare. Though the same structure has been maintained, it is important to note that in relative terms, sectors associated with business support, waste management, and financial and insurance services, have begun to rebound.

In general terms, the opinion survey shows that residents of Nogales, Sonora assessed as satisfactory the impact on economic development resulting from the implementation of the wastewater collection system in their neighborhood (Sonora). Almost three-fourths of them (71%) rated it as good, 26% as fair, and only 3% as bad (Chart 9).

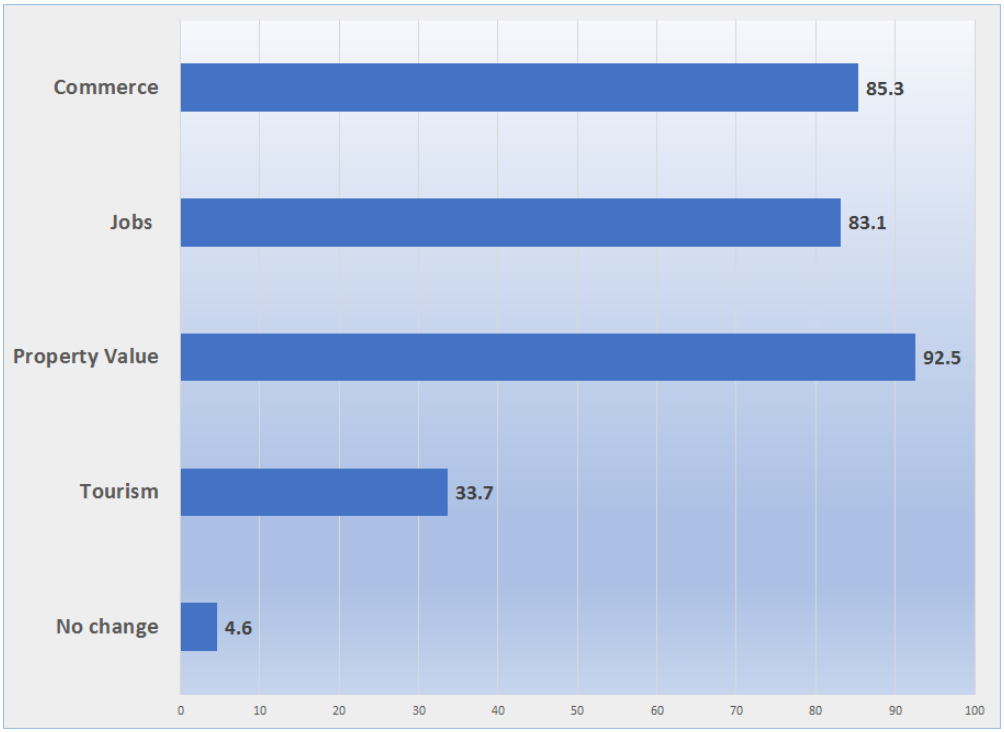
Chart 9. Perception of Impacts on Economic Development in Nogales, Sonora



Source: Self-reported

Among the positive impacts on economic development, it is worth noting that there has been an increase in property values (92.5%), trade and number of stores (85.3%), as well as increased employment (83.1%), while tourism showed a relatively low value (33.7%). A notable fact is that only 4.6% of the population thinks that there has been no change (Chart 10).

Chart 10. Perception of Different Positive Impacts on Economic Development



Source: Nogales, Sonora Survey

The public perception regarding the economic impacts resulting from wastewater collection in Nogales, Sonora, is consistent with the information provided by the indicators mentioned above and is also consistent with the results obtained from a number of indicators in the commercial and service sectors, as well as assessed property values in different city areas. The analysis of these indicators is relevant because, as shown before, the positive impacts perceived as more important by the population are related precisely to property values, the increased number of stores and retail activity, and the number of jobs.

Table 5 summarizes the results of some of the main economic performance indicators of the trade sector (retail and wholesale) in Nogales, Sonora. These results show that both the number of economic units, persons employed, total gross production, persons employed per economic unit (with the exception of the wholesale sector), and total gross production per economic unit, showed a significant increase in the period analyzed.

Table 5. Main Economic Indicators in the Trade Sector of Nogales, Sonora

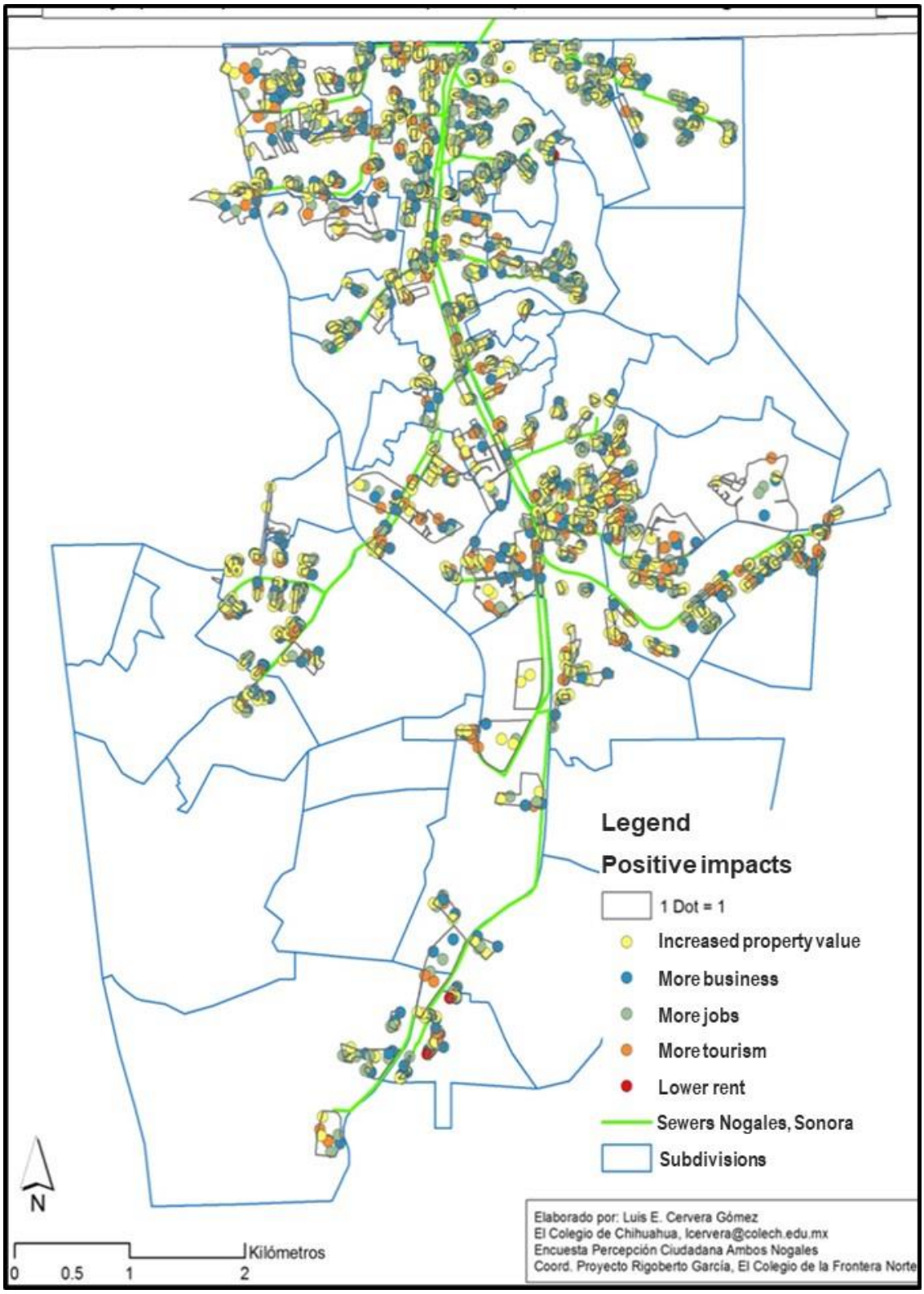
Variable	Wholesale Trade		Variation	Retail Trade		Variation
	2003	2014	%	2003	2014	%
Economic units	76	196	157.9	2,269	2,668	17.6
Persons employed	1,012	1,196	17.8	7,319	9,561	30.6
Total gross production (thousands of pesos)	264,444	1,197,400	352.8	1,055,457	1,710,425	62.1
Persons employed by economic unit	13	6	-53.8	3	4	33.3
Total gross production by economic unit (thousands of pesos)	3,480	6,109	75.7	465	641	37.8

Source: Prepared by the authors based on INEGI data (2004 y 2005)

Map 10 shows the responses related to impacts on economic development. The positive impacts are distributed evenly throughout the city; that is, aggregates of responses in the different areas show the same pattern. There is a greater concentration of the response associated with the increase in tourism in the northern part of the city adjacent to the international boundary –which is logical, given that this is an area where trade and services associated with tourism are concentrated.

In summary, there is a positive trend in the economic development of Nogales, Sonora. Table 6 shows the 13 objective indicators that were constructed for this component. It should be noted that, although it seems clear that the 13 economic performance indicators analyzed improved in the period of time between the pre- and post-construction phases of the infrastructure project financed by the NADB, it cannot be concluded that there is a causal relationship. However, it seems clear that there is a pattern proving a positive relationship between both dimensions. This can be seen more clearly in the case of wholesale and retail. On the other hand, the public perception of the economic impact generated by this project, which was measured through the public opinion survey, is clearly consistent with these results.

Map 10. Spatial Distribution of the Perception of Impacts on Economic Development



Source: Self-reported

Table 6. Socioeconomic Component Indicators

Economic Sector	No.	Indicator	Year One	Value	Final Year	Value	Variation (%)
Total Economic Activity	1	Total gross production (millions of pesos)	2003	10,658	2013	18,240	71.1
	2	Economic units	2003	4,534	2013	6,121	35
	3	Persons employed	2003	47,778	2013	73,196	53.3
Wholesale	4	Total gross production (millions of pesos)	2003	264,444	2013	1,197,400	352.8
	5	Economic units	2003	76	2013	196	157.9
	6	Persons employed	2003	1,012	2013	1,192	17.8
	7	Persons employed by economic unit	2003	13	2013	6	-53.8
	8	Total gross production per economic unit (thousands of pesos)	2003	3,480	2013	6,109	75.5
Retail	9	Total gross production (millions of pesos)	2003	1,055,457	2013	1,710,425	62.1
	10	Economic units	2003	2,269	2013	2,668	17.6
	11	Persons employed	2003	7,319	2013	9,561	30.6
	12	Persons employed by economic unit	2003	3	2013	4	33.3
	13	Total gross production per economic unit (thousands of pesos)	2003	465	2013	641	37.8

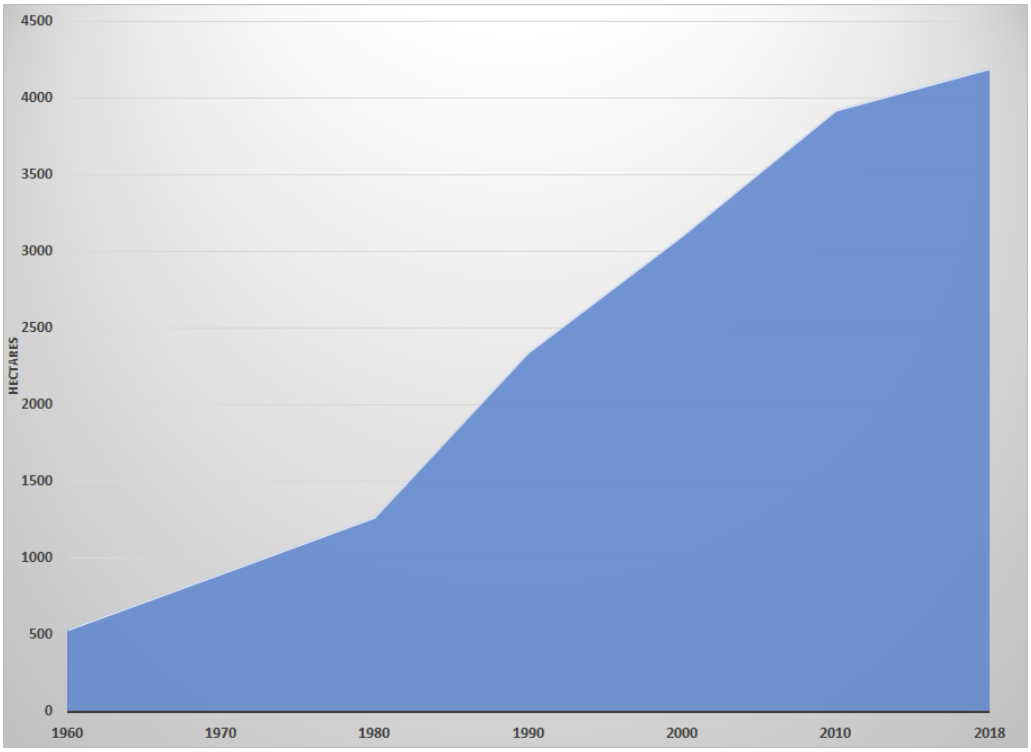
Source: Self-reported

Component 3: Urban Development Indicators

The urban area of Nogales, Sonora has grown significantly as a result of its economic development associated to the transformation industry sector. The urban area grew from 533.13 to 4,190 hectares during the 1960-2018 period, which represents an increase of 7.8 times (Chart 11). During the period covered by this investigation, in 2018, the urban area was 35% larger than in 2000, since it grew in absolute terms by 1,088 hectares.

Map 11 presents a spatial approach to the growth of Nogales, Sonora. The map shows that until 1991, urban growth basically followed a linear pattern along the main avenue –Plutarco Elías Calles– and up to the south margin. Subsequently, from 2000 on, most of the growth occurred mainly towards the city´s southwest area, which is where the greatest incremental changes (from red to blue) are noted on the map.

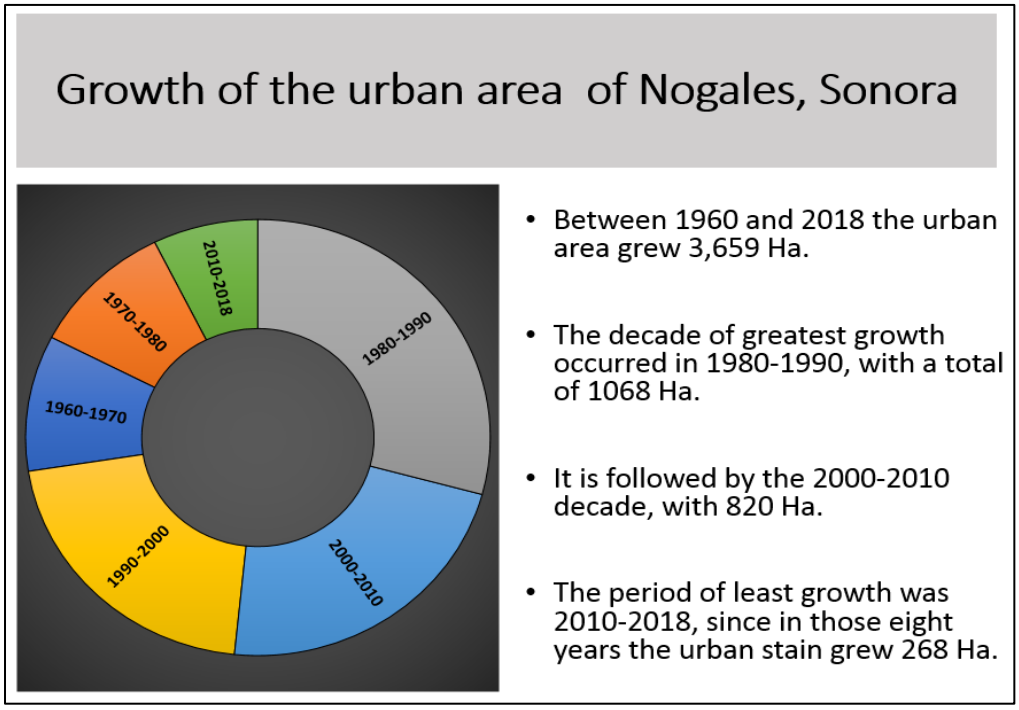
Chart 11. Urban Area Growth in Nogales, Sonora (1960-2018)



Source: COLEF (2009)

This growth of the urban area was due, among other factors, to the significant increase in the number of homes, which went from 37,249 in 2000 to 65,265 in 2015; this represents an increase of 1.8 times in the number of homes. This also led to the need for paving new streets. Available data shows that in 2010, 65% of the streets in Nogales, Sonora were paved, totaling 3,989,109 square meters of street paving.

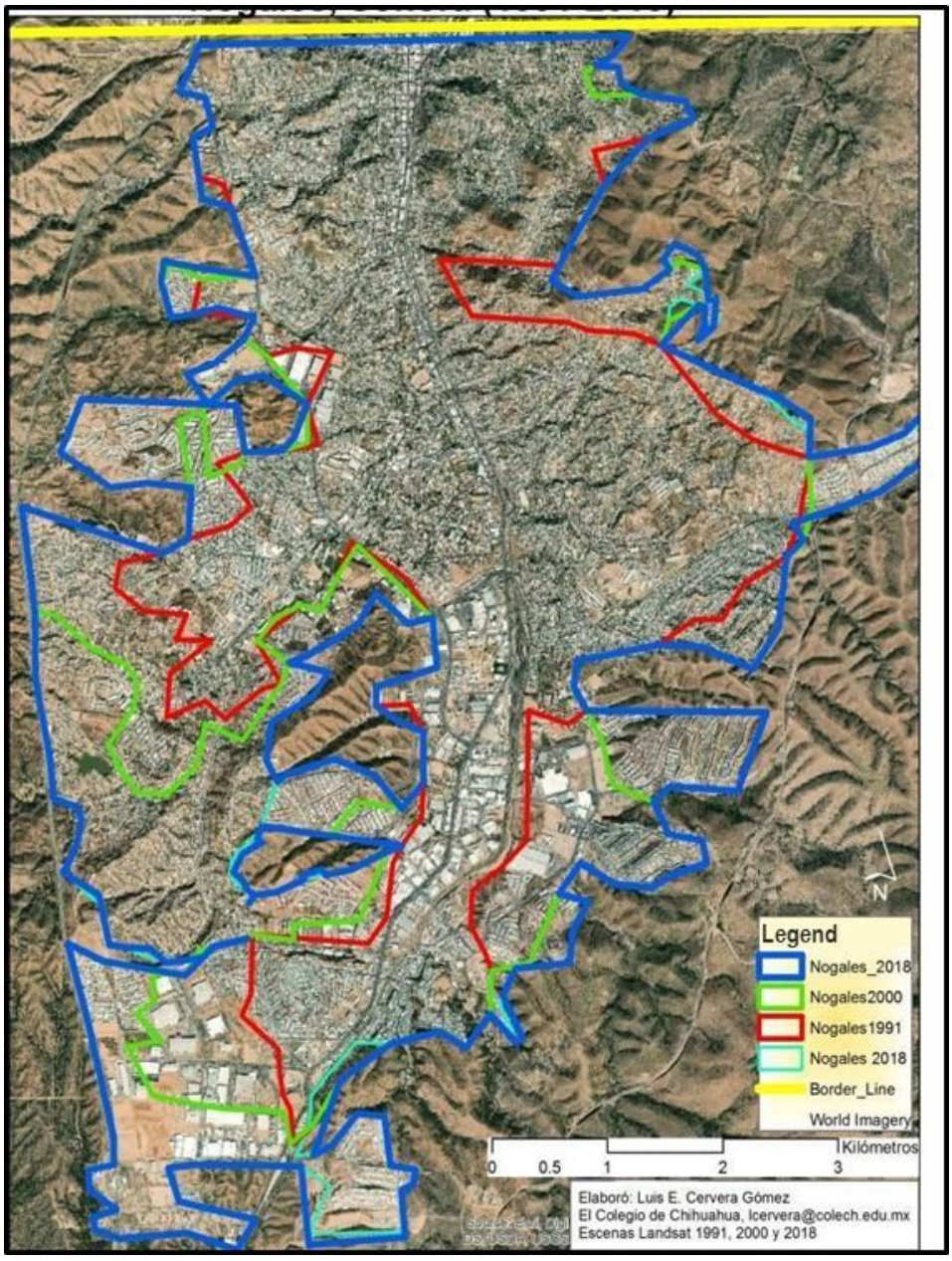
Figure 7. Urban Growth



Educational facilities in the municipality of Nogales consisted of 238 educational centers in the 2008-2009 school year, of which six were higher education institutions. For the 2018-2019 school year, the number of educational centers is 283, and there are now eight higher education institutions. Between the 2008-2009 and the 2017-2018 school years, school enrollment increased by 20%. The increase in the number of educational facilities was sufficient to meet the education demand, since the student-to-school ratio remained within a range of 261 to 274 students per school; the same can be said of the student-to-teacher ratio, which is 20 to 21 students per teacher.

In summary, the municipality of Nogales, Sonora has managed to maintain stable educational coverage. The issue in Mexico is no longer education coverage, but the quality of education, which has an effect on the possibilities of people to achieve their greatest human potential.

Map 11. Urban Area Growth in Nogales, Sonora (1991-2018)



Source: Self-reported

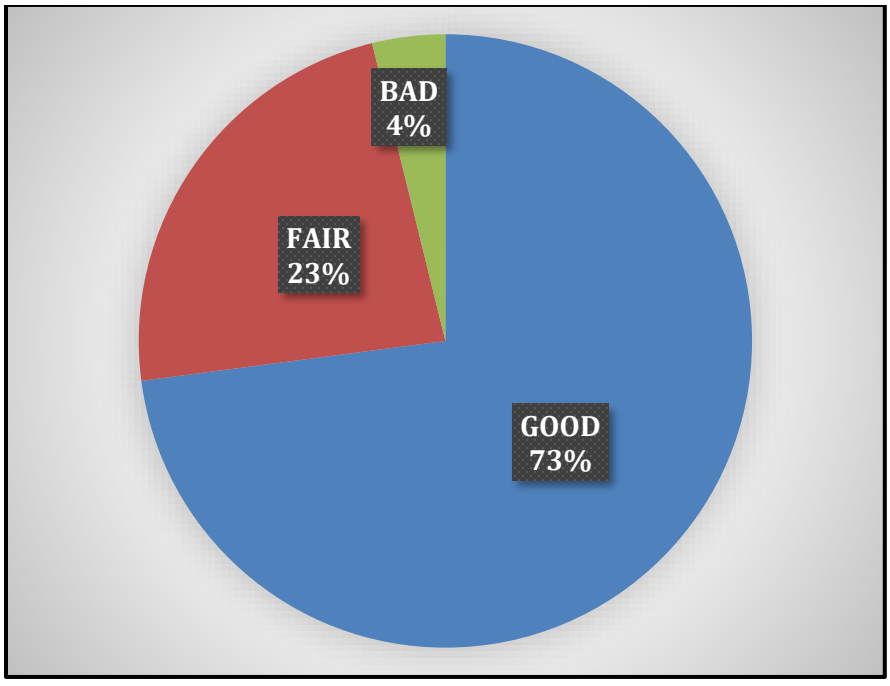
The trend in the growth of public areas in Nogales, Sonora is positive. According to IMIP (2011), in 2005 there were 0.9 square meters per resident; for 2009, it increased to 2.6 and finally, in 2011, public areas reached 3.1 square meters per resident. The total surface covered by green areas in the city in 2008 was 210,865 square meters, which results in less than one square meter of green areas per person (COLEF, 2008), an indicator well below the 9 to 10 m^2 standard

recommended by the World Health Organization (WHO) and the standard established by the Ministry of Urban Development and Ecology (SEDUE), which is 8.5 m2 per resident.

The public opinion survey captured this lack of public spaces and green areas in the city. Approximately 73% of the population of Nogales believes that the wastewater project had a positive impact on urban development; 23% thinks that this impact was moderate, and only 4% believes that the impact was negative (Chart 12). As for parks and green areas, although slightly more than 50% of the population believes that there was a positive impact, when compared with the rest of the indicators, it is clear that the respondents' level of satisfaction is much lower (Chart 13).

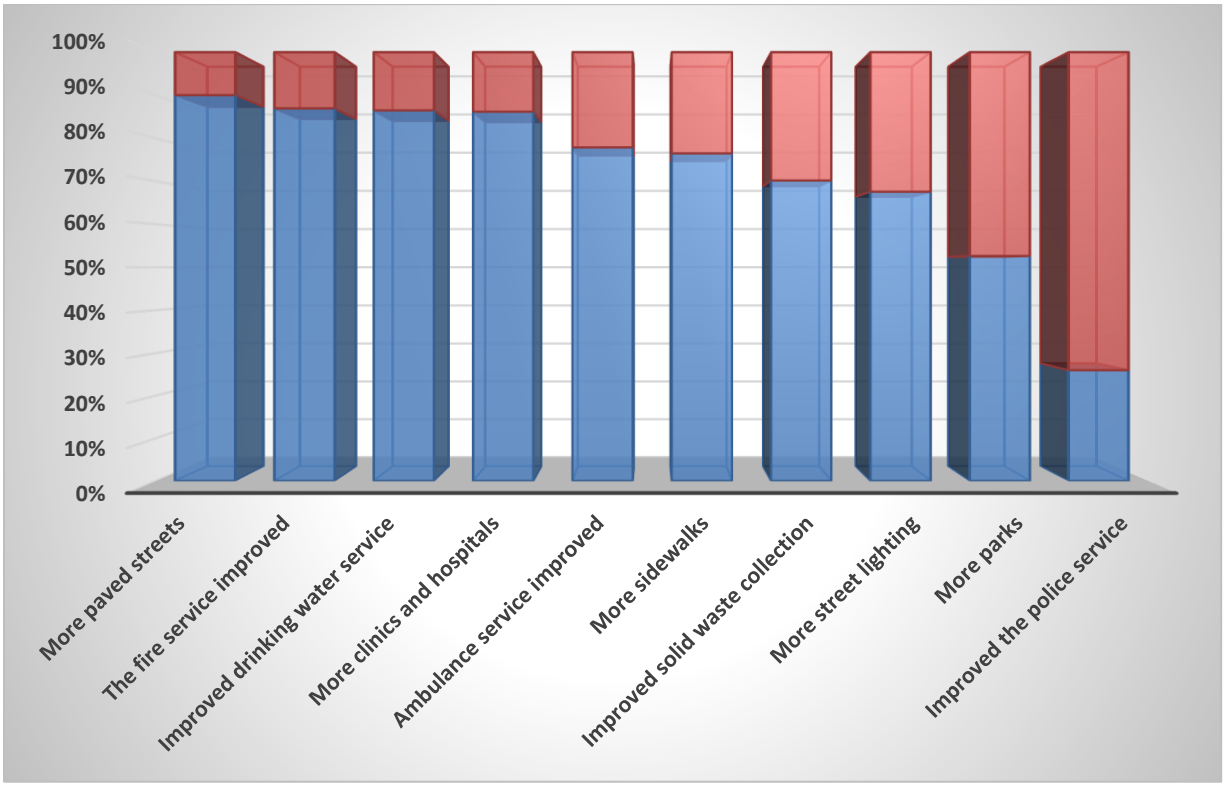
Map 12 shows georeferenced answers on this topic. In general terms, all the surveyed areas show a similar behavior; that is, each sector of the city has the same assessment in the responses. In summary, no spatial differentiation has been identified in the perception of the population of Nogales, Sonora regarding the impacts generated by the wastewater project on urban development.

Chart 12. Perception of Wastewater Project Impacts on Urban Development in Nogales, Sonora



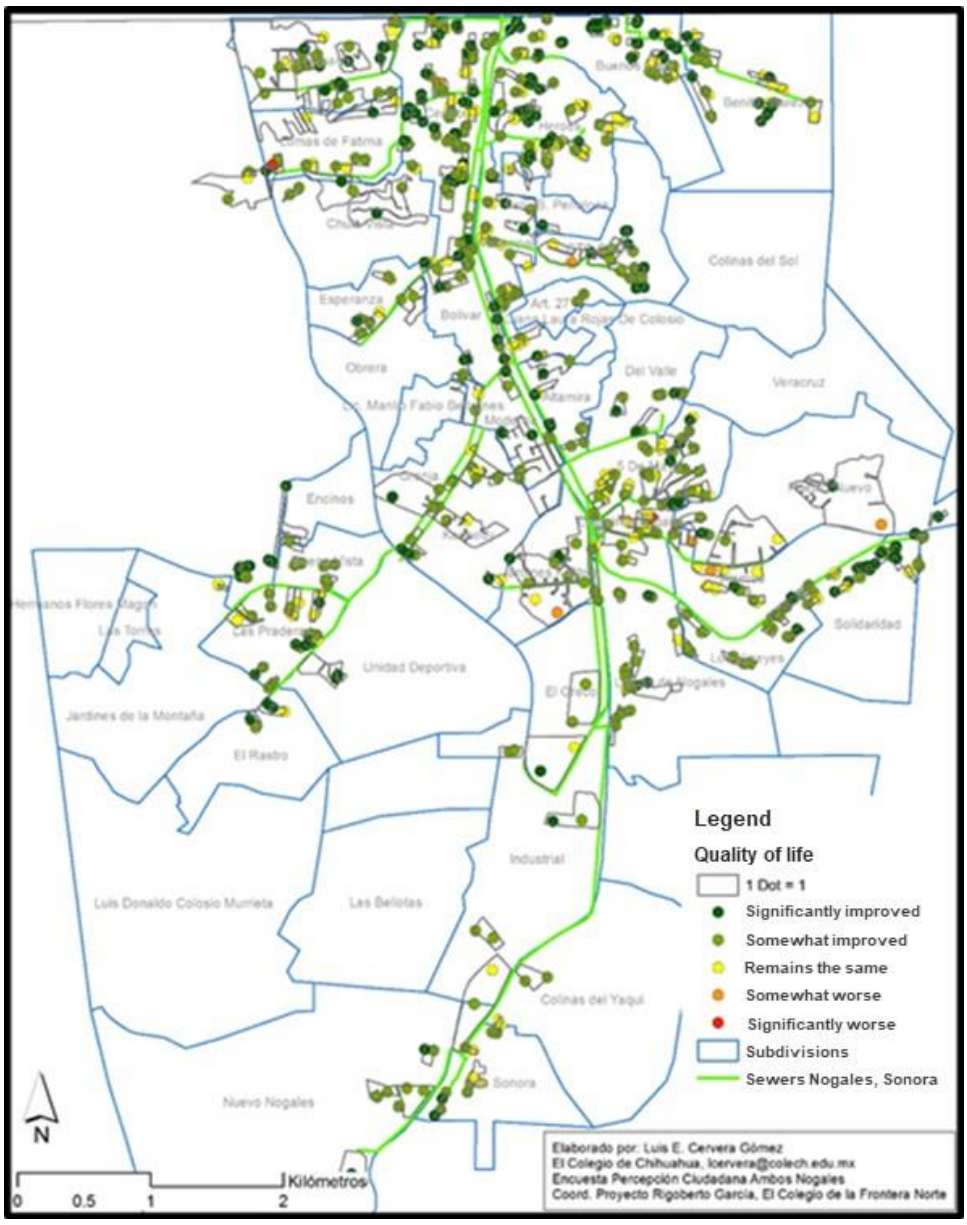
Source: Self-reported

Chart 13. Main Impacts on Urban Development Perceived by the Population of Nogales, Sonora



Source: Self-reported

Map 12. Spatial Representation of the Public Perception of Wastewater Project Impacts on Urban Development in Nogales, Sonora

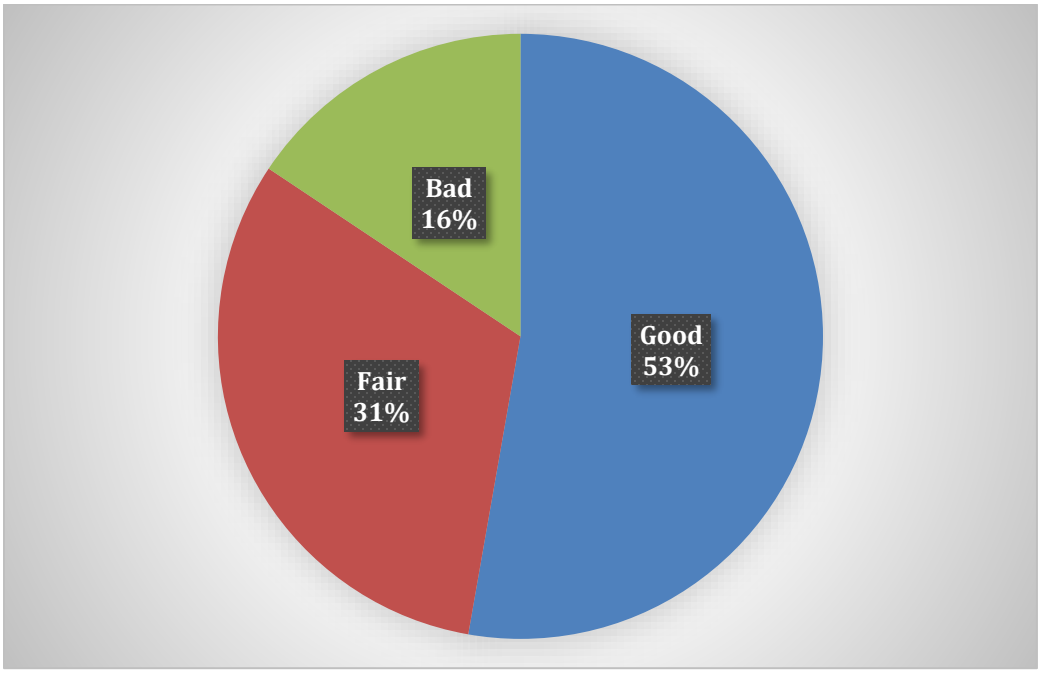


Source: Self-reported

Another component that can be associated with urban development is the environment. In general terms, respondents were more critical in evaluating this dimension, since 47% considered that this impact was moderate or negative, and only slightly more than half (53%) replied that the impact was positive (Chart 14). When asked about the types of impacts associated with the wastewater project (Chart 15), in all cases, the negative responses were the majority, i.e., most

of the population of Nogales, Sonora thinks that there was a reduction in the number of trees, birds, the amount of water in streams, and there was more flooding and more heat.

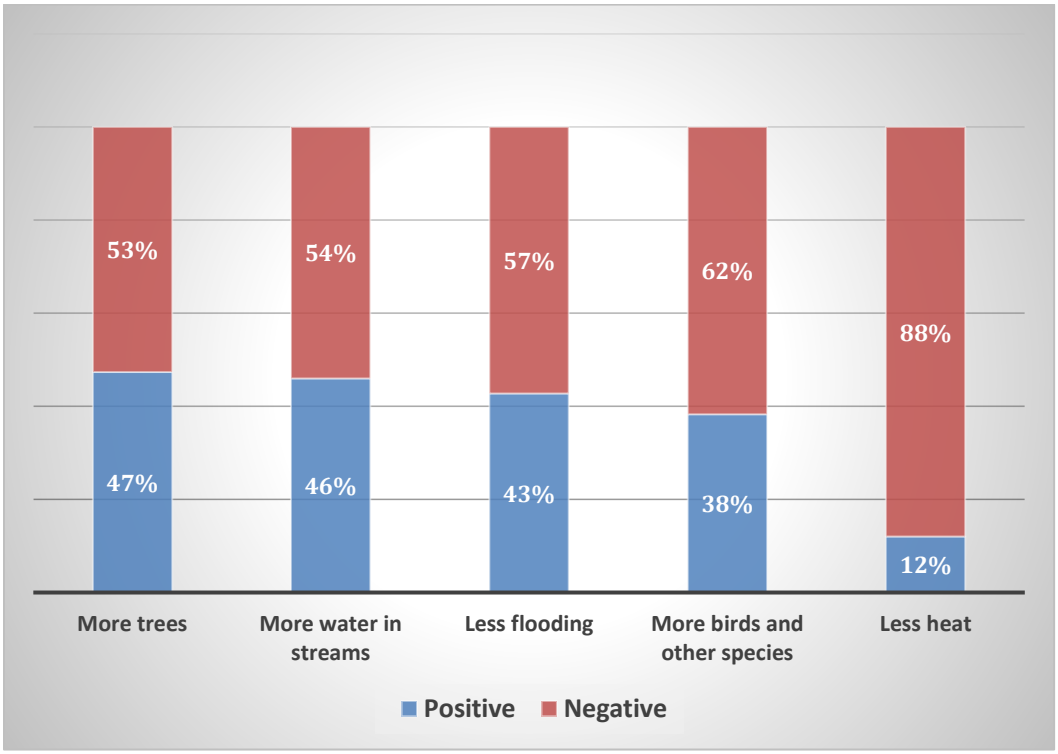
Chart 14. Perception of Wastewater Project Impacts on the Environment in Nogales, Sonora



Source: Self-reported

Map 13 shows the spatial distribution of these results. In this case, a significant spatial pattern is identified, since a significant number of responses rating the impact as moderate to very bad are concentrated in the southeast part of the city.

Chart 15. Main Environmental Impacts Perceived by the Population of Nogales, Sonora



Source: Self-reported

In summary, ten urban development indicators associated to Component 3 were built. All these indicators showed significant growth in the period analyzed (Table 7). However, it would be necessary to critically analyze the growth of the city´s urban area, given that, if this trend continues, a number of urban sustainability problems related to major issues such as home-to-workplace distance and travel time could arise and consequently, energy use and local and global emissions could increase. Another potential problem resulting from this situation would be the economic and financial burden that the municipal government would have to incur to provide the necessary service infrastructure to the city´s new urban areas.

Table 7. Urban Development Component Indicators

Dimension	Number	INDICATOR	INITIAL YEAR	VALUE	FINAL YEAR	VALUE	VARIATION (%)
Urban area and road infrastructure	1	Urban spot (Hectares)	2000	3,102.40	2018	4190	35.1
	2	Private homes	2000	37,249	2015	65265	75.2
	3	Area of paved roads respect to the total (square meters)	2010	3,989,109	N.D.	N.D.	N.D.
	4	Area of paved roads respect to the total (Percentage %)	2010	65	N.D.	N.D.	N.D.
Educational infrastructure	5	Educational centers (units)	2008	238	2018	283	18.9
	6	School enrollment (students)	2008	51,408	2018	77542	50.8
	7	Student-school ratio	2008	261	2018	274	5.0
	8	Student-teacher ratio	2008	20	2018	21	5.0
Public space	9	Public spaces (square meter per inhabitant)	2005	0.9	2012	3.1	244.4
	10	Green areas (square meter per inhabitant)	2008	0.9	N-D-	N.D.	N.D.

Source: Self-reported

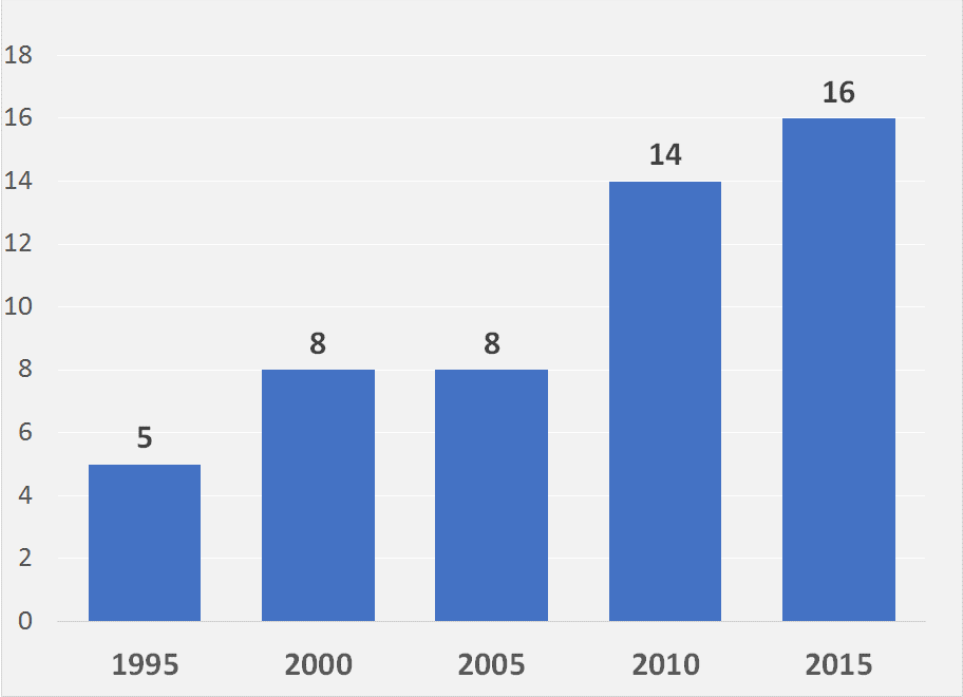
Regarding the public perception identified through the opinion survey, the results show in general terms that the population of Nogales, Sonora believes that the wastewater project is directly related to positive impacts on urban development, but not on environmental issues, regarding which they were more critical.

So far and in connection to what will be seen later about both Nogales, SON, and Nogales, AZ, it should be noted that, both hard data on coverage and socio-economic information and elements of public perception are expressions that indicate the direction of possible links between changing conditions in these cities, but do not necessarily reflect a quantifiable causal relationship with NADB projects. Rather, these indications of direction and magnitude are signs of the path that is being followed by the local reality.

Component 4: Health Indicators

The area of health care facilities, including clinics and public hospitals but excluding private institutions, shows a positive trend from 1995 to 2010 (Chart 16). It is important to highlight that from 1995 to 2000, only 3 health units were added, compared to an additional increase of 6 units in the 2005-2010 period. During that same period, the Ministry of Health (*Secretaría de Salud*, SS) significantly increased its number of health units (6 additional units).

Chart 16. Public Health Sector Units in Operation



Source: Prepared by the authors based on INEGI data (2006, 2011, 2016, y 2017)

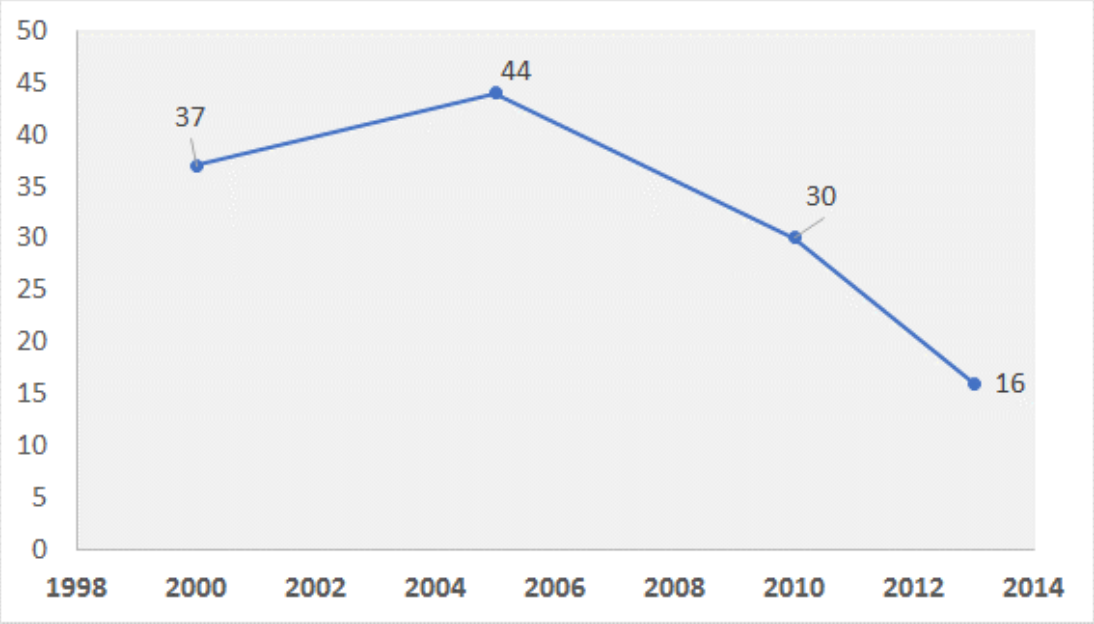
To a large extent, wastewater collection and treatment projects make possible and give viability to the construction and operation of hospitals and clinics. This has been evident in Nogales, Sonora, where the number of hospital facilities increased by more than 100% during the period in which the wastewater project was built, going from 8 in 2005 to 16 in 2015.

The impacts of wastewater projects on health should be reflected on problems such as gastrointestinal diseases associated with poor water quality, public exposure to untreated wastewater, or skin infections, among others.

Chart 17 shows the total number of hospital discharges (from public hospitals) of cases of diarrhea and gastroenteritis of suspected infectious origin. Hospital discharges were analyzed

because hospitalization involves an extreme condition related to these diseases. Between 2000 and 2013, there was a 57% decrease in this type of diseases. The analysis of this information shows that in 2000, 37 patients with diarrhea and gastroenteritis were discharged from hospitals, a figure that increased to 44 patients in 2005, and subsequently dropped to 30 patients in 2010 and 16 patients in 2013. This scenario shows a positive relationship with the implementation of the wastewater collection and treatment projects funded by the NADB in Nogales, Sonora, with respect to the 2000 period.

Chart 17. Diarrhea and Gastroenteritis Patients Discharged from Hospitals in Nogales, Sonora (2000-2013)



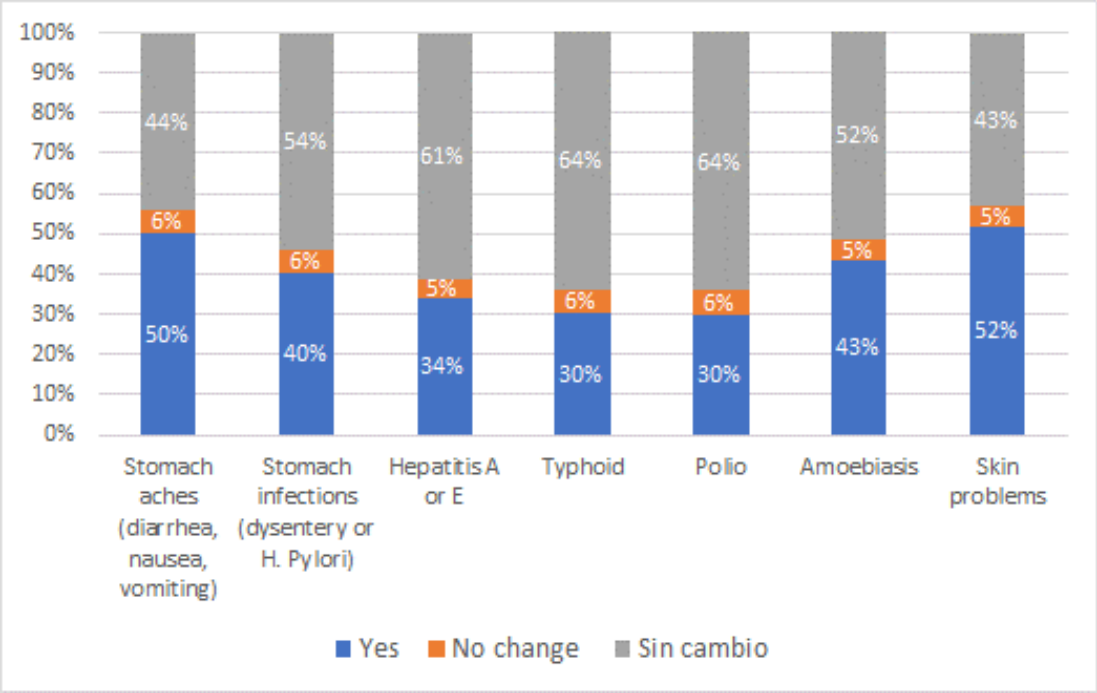
Source: Prepared by the authors based on Ministry of Health data

In summary, there is an indicative relationship with a positive direction between the implementation of the Nogales, Sonora wastewater collection and treatment system financed by the NADB, and indicators associated to water and wastewater components, economic behavior and urban infrastructure and health.

The public opinion survey data shows results similar to the above (see Chart 18); i.e., the greatest impacts are reflected on the decrease in indicators related to gastrointestinal disorders. Respondents were asked to indicate whether the incidence of these diseases had decreased in their families. The data show that the most frequently mentioned diseases with decreased rates of incidence include skin conditions, stomach disorders and amebiasis. These health indicators are related to the issue of sanitation. In summary, hard and subjective data are compatible.

Apparently, the wastewater collection and treatment infrastructure has had a positive effect on public health in Nogales, Sonora.

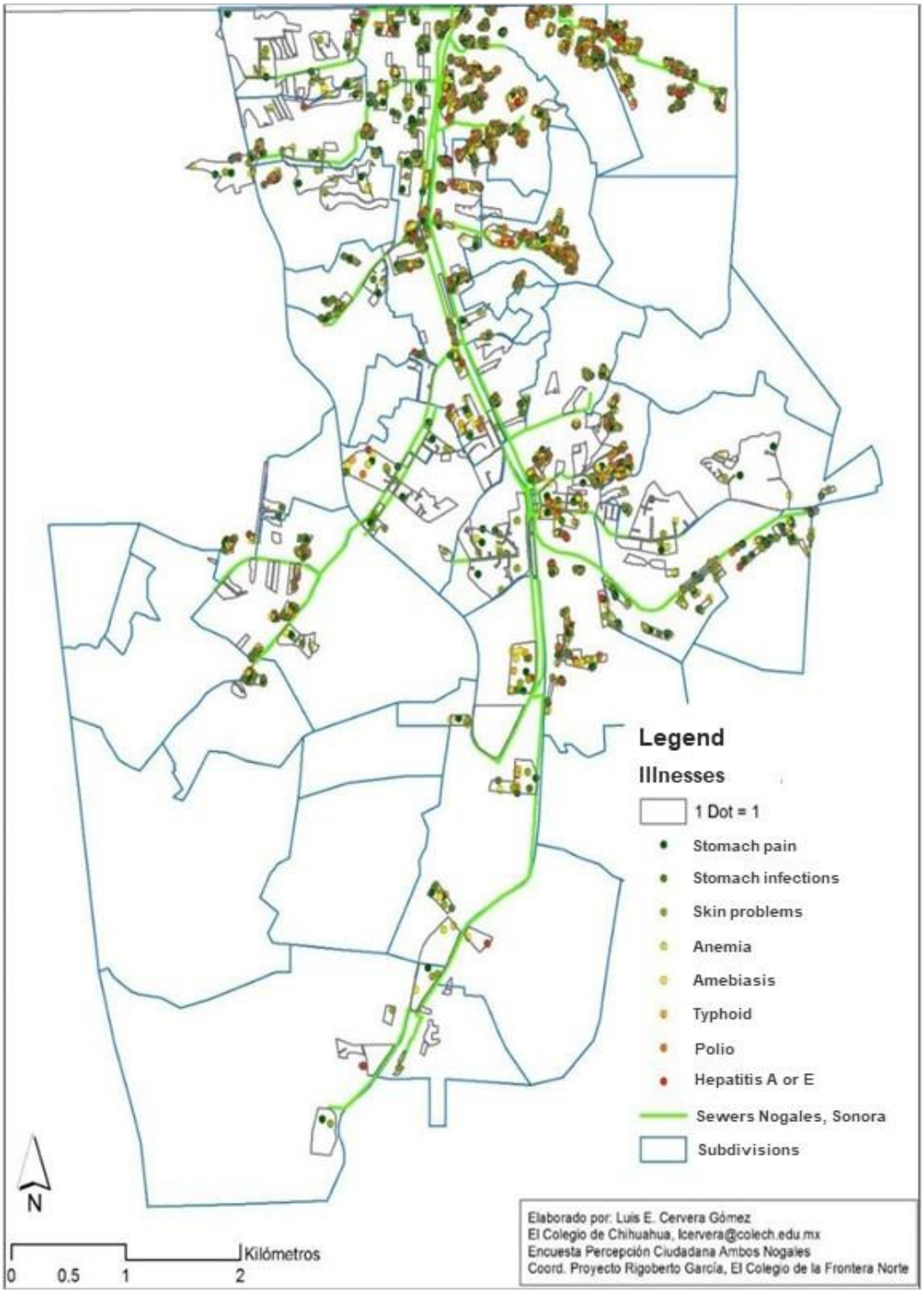
Chart 18. Impacts of Wastewater Treatment on Disease Rates



Source: Self-reported

Map 13 shows the spatial distribution of the public opinion regarding diseases in the surveyed areas. A spatial pattern of responses about diseases was not identified. Generally, the results emphasize the ubiquity of stomach disorders for which respondents indicated a reduced incidence. It is noteworthy that cases where the response was hepatitis A or E tend to concentrate towards the city´s northeast area, although not in a significant way.

Map 13. Spatial Distribution of the Public Opinion regarding Reduced Disease Rates Associated with Wastewater Projects



Source: Self-reported

Conclusions for Nogales, Sonora

The construction of 29 baseline indicators developed for the four components analyzed in this chapter (see Table 8), indicates that the wastewater project in Nogales, SON, was a factor that is likely to have significantly contributed to the best development of the city. It was also established that, in general terms, the perception of the majority of the population points in the same direction.

A great effort was made to obtain official data that could provide reliable statistical information for different periods of time, so that solid inferences could be made about multidimensional project impacts. However, as the scale is reduced to the local level, data becomes scarcer and more sporadic. For example, urban development data is generated only sporadically and is contingent on the needs that municipalities have to create or update their development plans and strategies. There is no systematic strategy to capture information periodically. However, it was found that the notable increase in wastewater collection coverage was accompanied by a positive evolution in the economic units, the number of employed persons, public areas, and hospital infrastructure in the city, a scenario that demonstrates the importance of the wastewater collection system for economic, social and urban development.

The perception of the majority of the population of Nogales, Sonora about the impacts of the wastewater project on their quality of life, economic development, environment, and binational cooperation, is positive overall. However, it was also discovered that there is a lack of public information about the wastewater infrastructure and its binational operation. That is, wastewater collection is an invisible project for many and therefore, there is not much awareness of it.

Table 8. Baseline Indicators of the Four Components for Nogales, Sonora

COMPONENT	Dimension	Number	INDICATOR	INITIAL YEAR	VALUE	FINAL YEAR	VALUE	VARIATION (%)
1. Basic infrastructure coverage	Services	1	Private inhabited houses	2000	37,545	2015	65,256	73.8
		2	Homes with sewer	2000	33,040	2015	63,951	93.6
		3	Houses with piped water	2000	31,538	2015	58,730	86.2
		4	Houses with electricity	2000	35,292	2015	64,603	83.1
	Environment	5	Wastewater treatment plants	2000	0	2015	1	N.D.
2. Socio-economic component	Total economic activity	6	Total gross production (millions of pesos)	2003	10,658	2013	18,240	71.1
		7	Economic units	2003	4,534	2013	6,121	35.0
		8	Employed personnel	2003	47,778	2013	73,196	53.2
	Wholesale trade	9	Total gross production (thousands of pesos)	2003	264,444	2013	1,197,400	352.8
		10	Economic units	2003	76	2013	196	157.9
		11	Employed personnel	2003	1,012	2013	1,192	17.8
		12	Persons employed by economic unit	2003	13	2013	6	-53.8
		13	Total gross production per economic unit (thousands of	2003	3,480	2013	6,109	75.5
	Retail trade	14	Total gross production (millions of pesos)	2003	1,055,457	2013	1,710,425	62.1
		15	Economic units	2003	2,269	2013	2,668	17.6
		16	employed personnel	2003	7,319	2013	9,561	30.6
		17	Persons employed by economic unit	2003	3	2013	4	33.3
		18	Total gross production per economic unit (thousands of	2003	465	2013	641	37.8
3. Urban development component	Urban area and road infrastructure	19	Urban spot (Hectares)	2000	3,102	2018	4,190	35.1
		20	Private homes	2000	37,249	2015	65,265	75.2
		21	Area of paved roads with respect to the total (square meters)	2010	3,989,109	N.D.	N.D.	N.D.
		22	Area of paved roads with respect to the total (%)	2010	65	N.D.	N.D.	N.D.
	Educational infrastructure	23	Educational centers (units)	2008	238	2018	283	18.9
		24	School enrollment (students)	2008	51,408	2018	77,542	50.8
		25	Student-school ratio	2008	261	2018	274	5.0
		26	Student-teacher ratio	2008	20	2018	21	5.0
	Public space	27	Public spaces (square meter per inhabitant)	2005	1	2012	3	244.4
		28	Green areas (square meter per inhabitant)	2008	1	N-D-	N.D.	N.D.
4. Health component	Health	29	Hospital discharges due to diarrhea and gastroenteritis	2000	37	2013	16	-56.8

Source: Self-reported

It should be noted that providing education about the importance of the NADB-financed wastewater project for the sustainable development of the city is a pending task that must be addressed promptly. It seems obvious that if residents are provided better environmental education and more accurate information regarding the operation of a project of this nature, they will have more elements to make choices about their environmental habits and behaviors.

In spatial terms, significant differences were observed on the level of awareness about the operation of the system during the rainy season, environmental impacts, and the location of treatment facilities. Conversely, no spatial differences were found regarding awareness of the impacts on the quality of life, economic development, urban development, and binational cooperation. In summary, the exercise carried out represents a valuable source of empirical knowledge, when comprehensively analyzed, shows that the wastewater project under study generated positive impacts for the population of Nogales, Sonora.

IMPACT ASSESSMENT OF THE WASTEWATER TREATMENT PROJECT IN NOGALES, ARIZONA

Introduction

This section presents the results of the four components considered for the construction of the baseline for Nogales, AZ, as explained in the methodology section. Additionally, the results of the public opinion survey are presented and, when relevant, the most important issues identified through interviews with key stakeholders are discussed. It is worth mentioning that, compared to other cities and counties in Arizona, there is a shortage of accurate statistical information for Nogales, Arizona and Santa Cruz County. The small size of the population in this county, along with its negligible level of economic activity, made it necessary to group the statistical information of this county at the state level in many cases. Given this scenario, which differs greatly from the case of Mexico with INEGI, a decision was made to build some of the baseline indicators using the public opinion survey, since the survey is representative of the situation at the city level. In addition, previously published reports and studies were consulted, and statistical and spatial information was generated through the University of Arizona´s Remote Sensing Center and the Google Earth platform.

Component 1 – Basic Infrastructure Coverage Indicators

This component includes indicators related to public service infrastructure, as well as drinking water coverage, wastewater collection coverage, existing wastewater treatment plants and capacities, percentage of wastewater treatment coverage, number of homes with latrines or similar disposal systems, and wastewater overflows to surface water bodies.

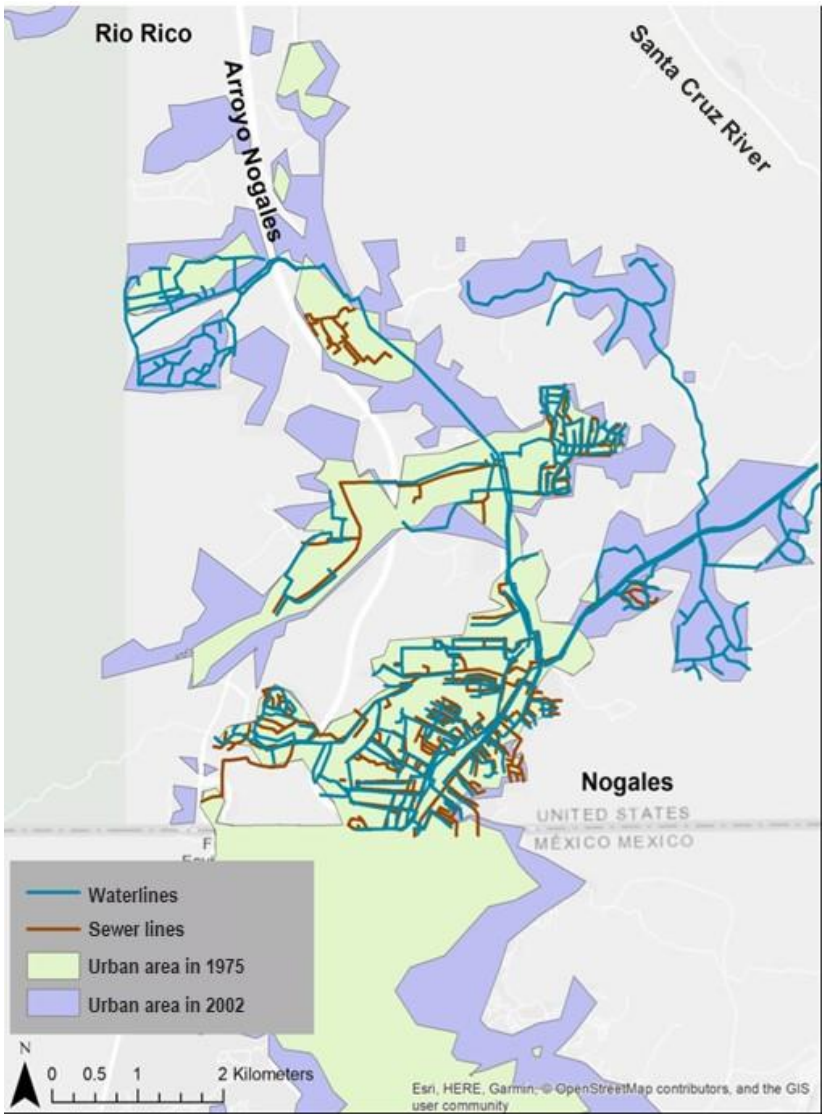
Regarding drinking water and wastewater collection coverage in Nogales, Arizona, Norman et al. (2006), based on data from the United States Geological Survey (USGS), found that these basic services were not available to the entire population. Although the oldest neighborhoods had both services back in 2006, this was not the case in the new subdivisions (Map 14). This suggests that a percentage of the population of Nogales, Arizona is not connected to the wastewater collection system, but may have another disposal system, such as septic tanks, as they are a very common and permissible system in the United States.

These data are consistent with the results of the public perception survey, since 75% of the respondents reported being connected to the wastewater collection system, while the remaining 25% indicated that they are not connected (Chart 19). The study also asked respondents if they have a septic tank, and it was found that all the homes that are not connected to the wastewater collection system do have a septic tank. This result makes sense because residents of Nogales,

Arizona have been connected to the sewer system for several decades, and those who are not, use septic tanks. The use of septic tanks is regulated by a law (Clean Water Act) that entered into force in the 1970s in the United States, which states that wastewater cannot be left untreated. It should be noted that none of the homes in Nogales, AZ use latrines.

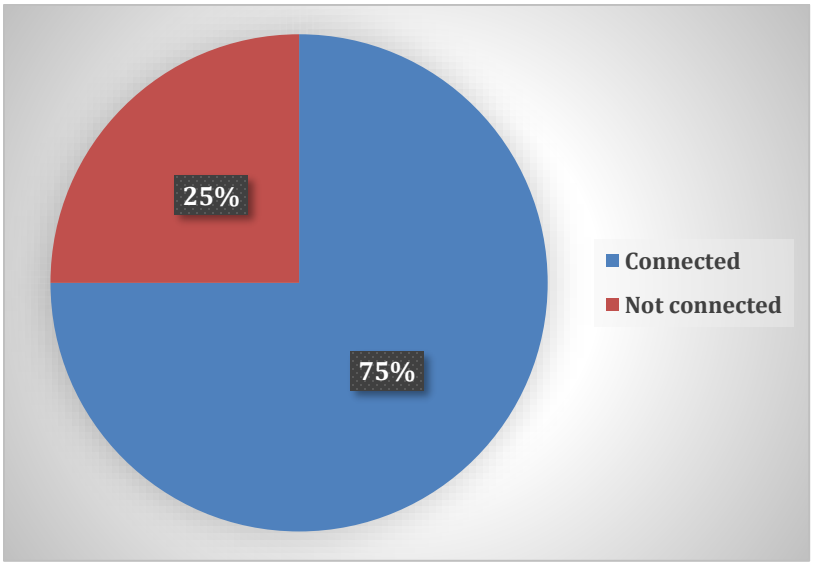
Regarding the possibility of not having sanitary sewage and discharging wastewater to the street, the vast majority of the respondents (69 percent) reported that they do not make wastewater discharges to the street, none reported having done so, and only one indicated not knowing. These results show that the vast majority of people in Nogales, Arizona know that their homes are connected to some type of system and know that their wastewater is not discharged onto the street.

Map 14. Urban Growth in relation to Wastewater Infrastructure



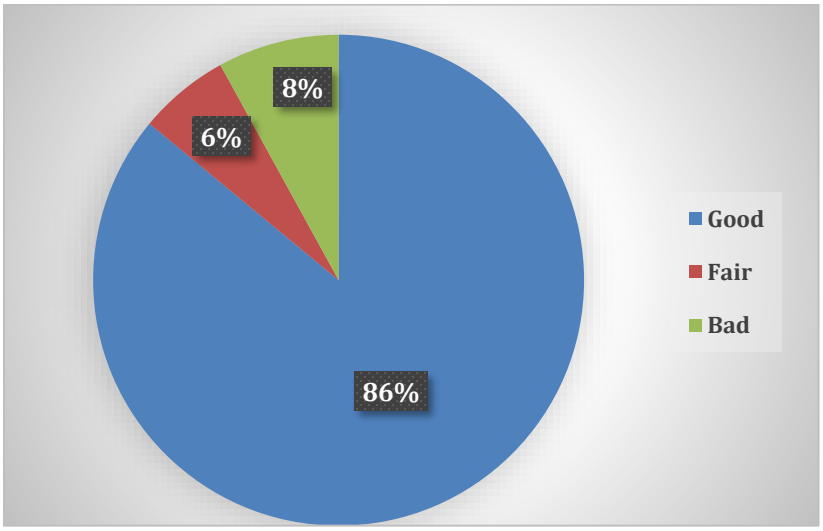
Source: Norman et al. 2006. Map by: A. Zúñiga

Chart 19. Report of Wastewater Collection System Connections in Nogales, Arizona



Source: Self-reported

Chart 20. Responses regarding the Perception of the Quality of Wastewater Collection Services in Ambos Nogales



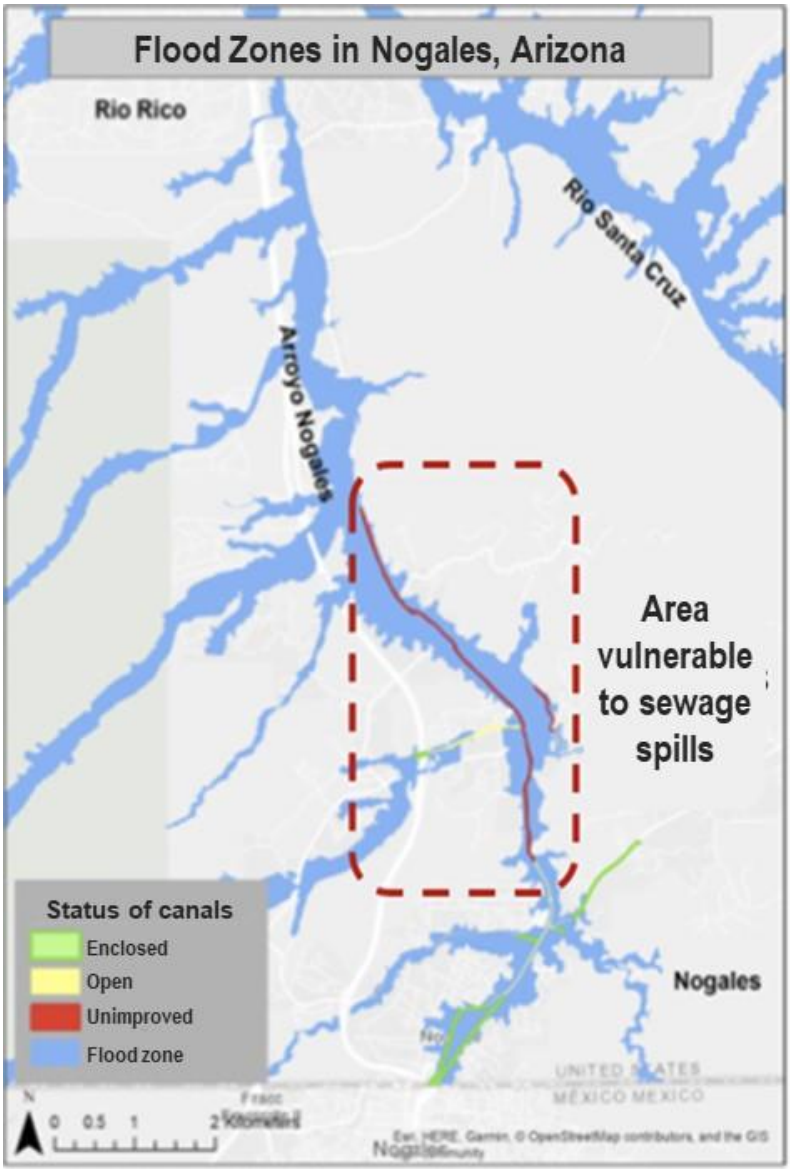
Source: Self-reported

Furthermore, although the WWTP in Rio Rico receives mostly wastewater from Nogales, Sonora, residents of Nogales, AZ, were asked about their perception of the operation of the wastewater collection system in Sonora and the wastewater treatment system in Arizona during the rainy season, considering the situation in their neighborhood.

The survey found that 86% of the population believes that the operation of the system is good; 6% consider it fair; and 8% consider it poor (Chart 20).

Regarding the capacity of the WWTP, based on Ghosh et al. (2017), it was found that the results of drought scenarios indicate optimal base flows of 21,840,540 cubic meters of wastewater. This amount is divided between the County of Santa Cruz, which contributes 9,895,729 cubic meters, and Mexico, which contributes 11,944,811 cubic meters. These volumes, however, vary greatly depending on the season and time of day.

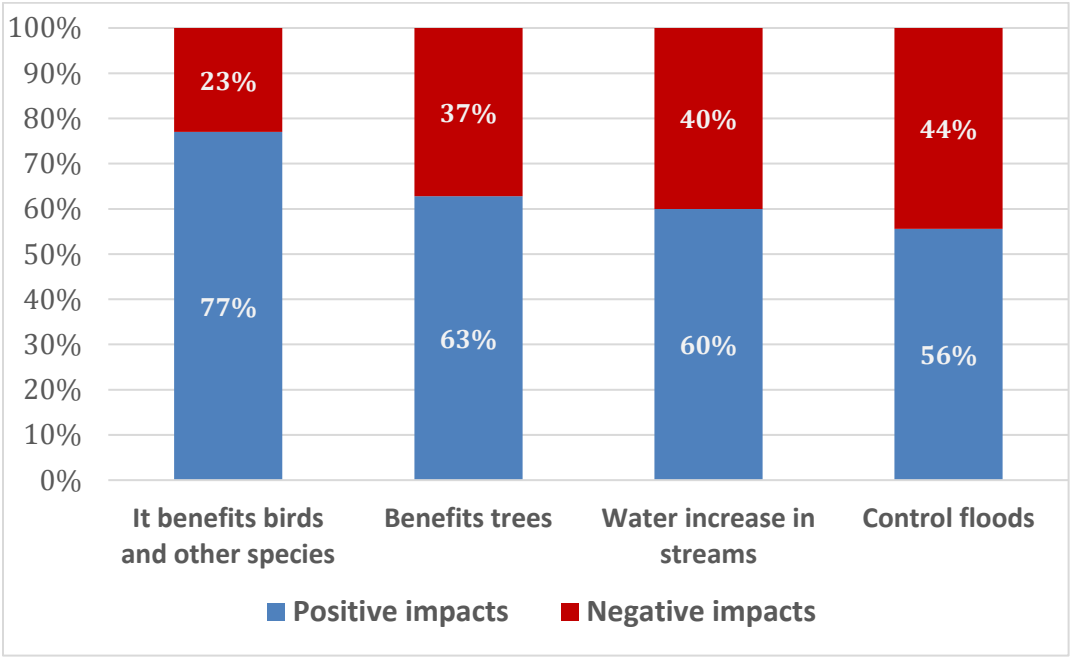
Map 15. Status of Canals with respect to Flood Areas in Nogales, Arizona



Source: TIGER, 2000 Census; map developed by A. Zuniga.

Regarding areas vulnerable to wastewater overflows, the spatial analysis shows that the unimproved IOI sits on major flood areas of the Nogales Wash. This situation directly impacts the well-being of the local population, since residents are exposed to the raw wastewater that overflows the arroyo during the rainy season. Using data from the 2000 Census, the area most vulnerable to wastewater spills was located spatially, based on the conditions of the outfall (IOI) tunnel (Map 15).

Chart 21. Survey Results regarding Impacts of the Wastewater Collection and Treatment Systems on the Environment

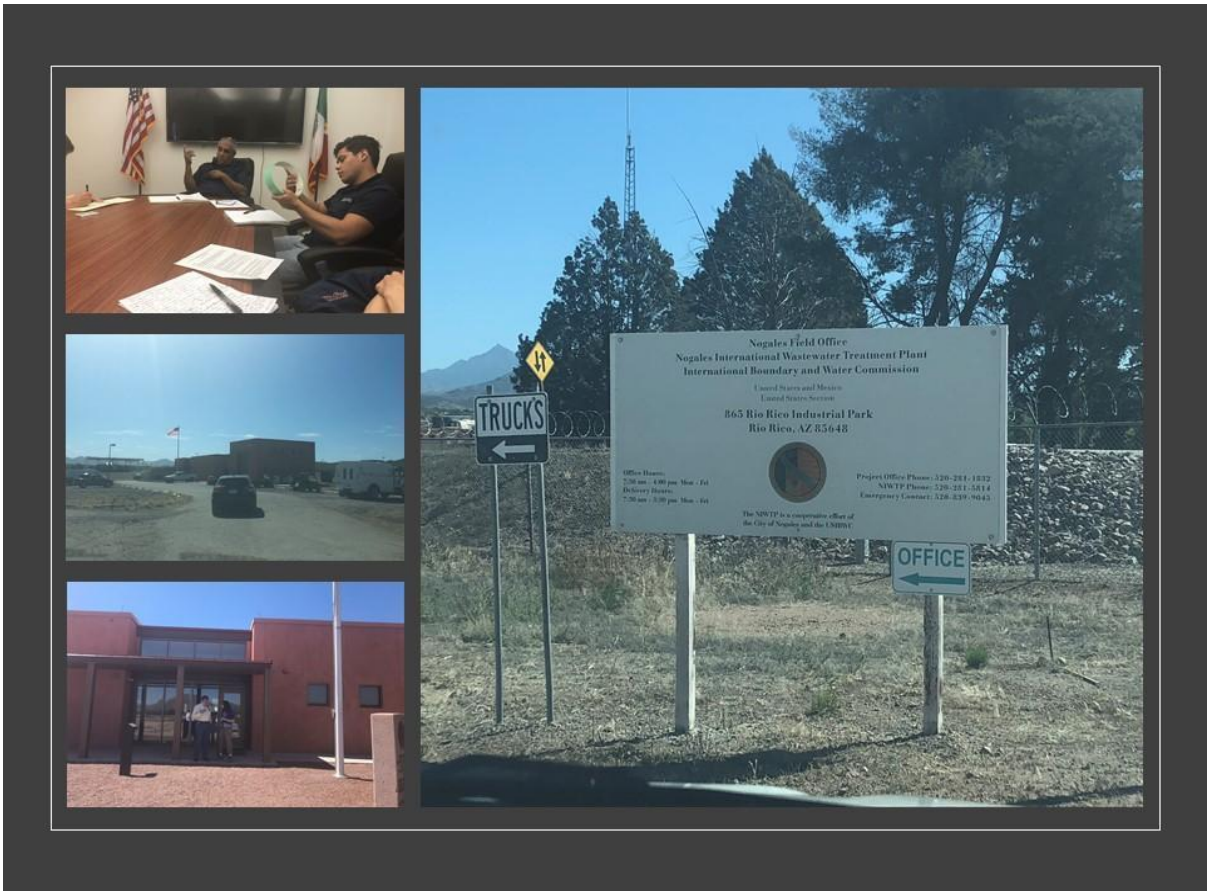


Source: Self-reported

These data are consistent with the results obtained by the opinion survey, since 56% of the respondents reported that there are fewer floods since the implementation of the wastewater collection system projects in Sonora and the wastewater treatment system in Arizona, but 44% of respondents stated that there are more floods (Chart 21). This scenario leads us to infer a direct relationship between the public perception of the number of floods and the distance between each home and the site of the IOI tunnel. That is, the closer a house is to the outfall, there is a greater perception of flooding and vice versa.

The information obtained through interviews with key stakeholders also confirms the above. In general, interviewees stated that there are environmental improvements to the north of the wastewater treatment plant in Rio Rico, where there is greening along the Santa Cruz River. These environmental improvements have boosted residential and commercial development north of the WWTP or downstream of the facility.

Figure 8. Field Visit to the Rio Rico, Arizona WWTP

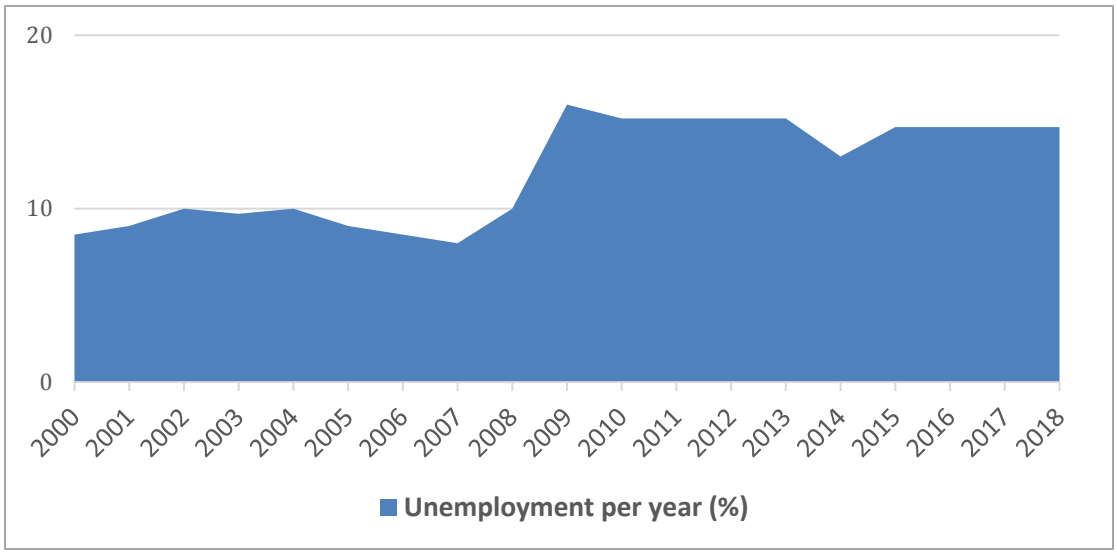


Component 2 – Socioeconomic Indicators

This component includes indicators related to the socioeconomic features of the region, such as population size, employment levels, household income, cost and/or reduction of household spending on drinking water vs. purchase of bottled water, land or property values, presence or addition of new housing developments, increase in the number of stores, etc.

With regard particularly to unemployment, this analysis found that Nogales, Arizona suffers from higher unemployment rates compared to the state. The level of unemployment in Nogales is 14.7%, while unemployment in the state of Arizona is 6.4% (less than half). Chart 22 shows how the increase in the unemployment rate coincides with the beginning of the 2008 crisis, when the country entered an economic recession, a situation that has remained unchanged for ten years. This suggests that while the rest of the state of Arizona is recovering from the 2008 economic recession, Nogales is at a standstill.

Chart 22. Unemployment Rates in Nogales, Arizona



Source: Data from http://www.city-data.com/city/Nogales-Arizona.html

Despite the high levels of unemployment in Nogales, Arizona, this city has a higher number of businesses per 10,000 residents compared to the state of Arizona. In Santa Cruz County, there is a higher number of grocery stores, as well as convenience stores, whether stand-alone or connected to gas stations. The survey also identified that there are more restaurants in this city per 10,000 residents than in the rest of the state. These data suggest that the geographic location of Nogales favors a high flow of people and products to and from Mexico, and infrastructure and businesses are needed to provide services to travelers (fuel, convenience stores).

Recognizing the asymmetries between the economies of Nogales, AZ and the state of Arizona in general, the following indicators show a relative improvement of the economy with respect to the rest of the state during the period analyzed:

1. Comparison of the per capita income in Nogales, AZ vs. the state of Arizona for the 2000-2016 period:[5]

    a. As of 2000, Arizona had an average per capita income of US $26,251; by 2016, this figure reached US $40,672 –a nominal increase of 44.47% in 16 years, i.e., a 2.7% annual growth.

[5] United States Bureau of Labor Statistics - Spanish translation on internet: https://www.linguee.com/english-spanish/translation/united+states+bureau+of+labor+statistics.html

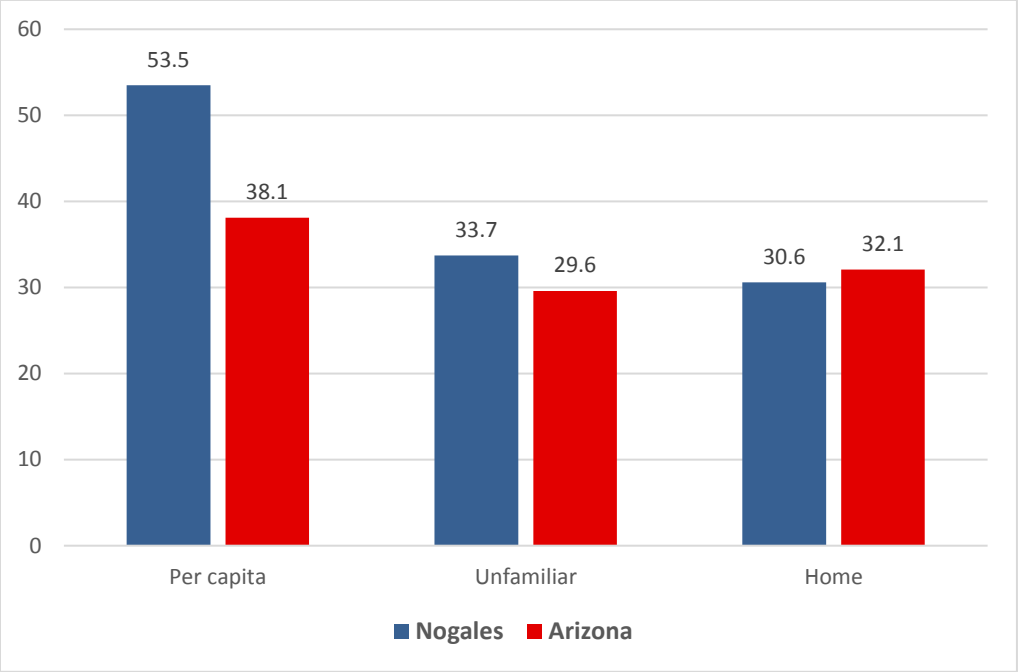
b. As of 2000, Nogales, AZ had an average per capita income of US $10,178; by 2016, this figure reached US $15,658.[6] This is a nominal increase of 53.54% in 16 years, i.e., a 3.3% annual growth.

2. Number of grocery stores: Santa Cruz County, 2.35/10,000 residents, compared with 1.38/10,000 residents in the state of Arizona.[7]
3. Number of convenience stores (including gas stations): Santa Cruz County, 4.24/10,000 residents, compared to 2.47/10,000 residents in the state of Arizona.[8]
4. Number of restaurants: Nogales, AZ., has 7.77/10,000 residents, compared to 6.21/10,000 residents in the state of Arizona.[9]

Chart 23 shows how the percentage change in per capita income between 2000 and 2016 grew by 53.5%, while in Arizona it grew by only 38.1%. Furthermore, between 2000 and 2016, the percentage change in median non-household income grew by 33.7%, while it grew only by 29.6% in Arizona. By contrast, the percentage change in the median household income increased by only 30.6% between 2000 and 2016, while in Arizona it increased by 32.1%.

[6] According to the U.S. Bureau of Labor Statistics, in 2016, the consumer price index was 39.4% higher than in the year 2000. In that period of 16 years, the dollar experienced an average inflation of 2.1% per year (3.36% in 2000 and only 1.26% in 2016), meaning that US $10,000 of the year 2000 was equivalent to US $13,937 of 2016.
[7] Source: www.city.data.com/city/Nogales-arizona.html
[8] Ibid.
[9] Ibid.

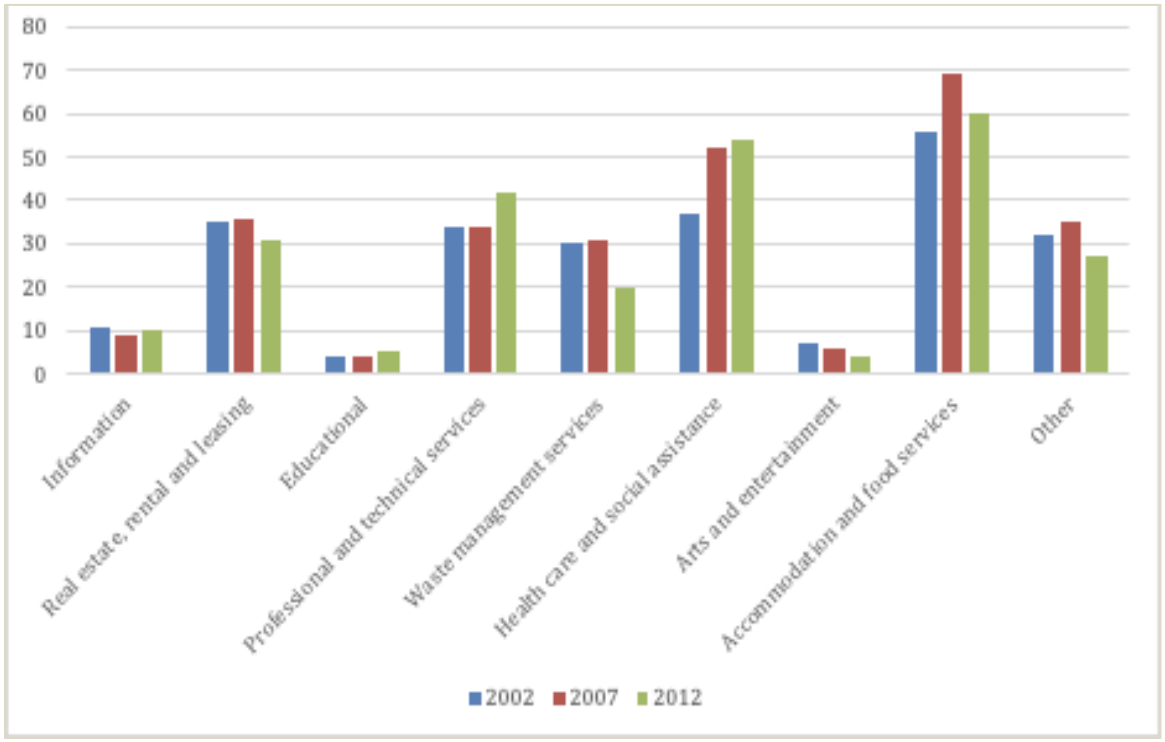
Chart 23. Percentage Change in Median Household Income in Nogales, Arizona (2000-2016)



Source: Prepared by the authors using information from City Data (2019)

As for the number of businesses that provide employment by type of industry, the U.S. Census Bureau reports different trends (Chart 24). Information, waste management, and art and entertainment businesses show a downward trend between 2002 and 2012. Conversely, businesses related to professional and technical services, as well as health care and social assistance, show a positive trend. Finally, businesses related to hospitality and food service, real estate and leasing, among others, show a rise in 2007 and a decline in 2012.

Chart 24. Businesses in Nogales, Arizona in 2002, 2007, and 2012

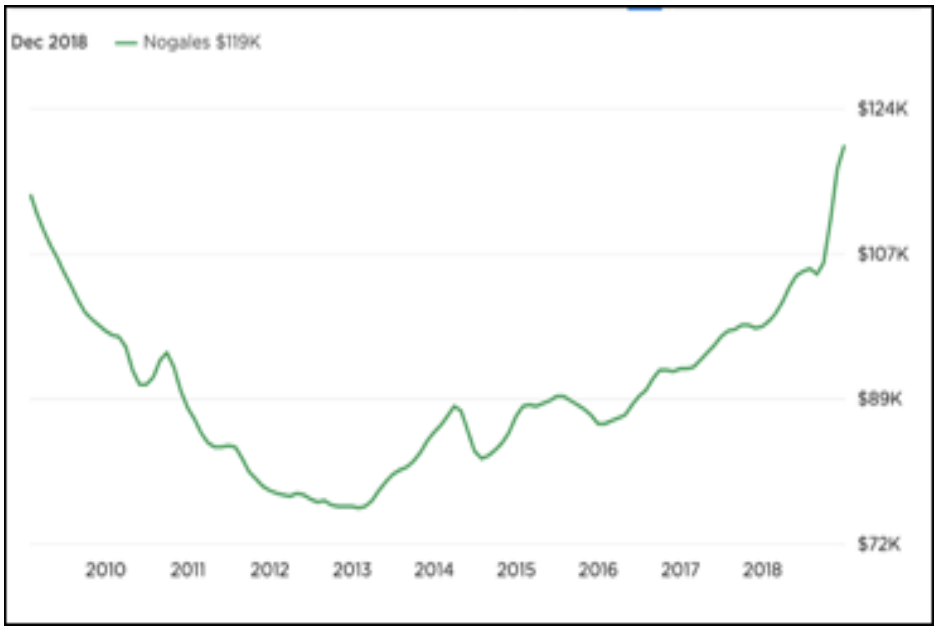


Fuente: Prepared by the authors using information from the U.S. Census Bureau

Property values for Nogales are below those for the state of Arizona but they have increased in recent years. The average value of a house or condominium in 2016 was US $133,387, while in the state it was US $205,900. This value in 2000 was US $85,100 (City-Data.com, n.d.). However, property values have recovered in recent years, as shown in Chart 25.[10]

[10] US census data confirmed the above (https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?fpt=table). According to the U.S. Census Bureau revenue from the real estate industry in Nogales, Arizona decreased from 2007 to 2012. Also, payroll income was reduced from 2007 to 2012 for both the real estate and leasing industries. Conversely, there was a slight increase in the revenue of real estate leasing industries between 2007 and 2012.

Chart 25. Average Property Values in Nogales, Arizona (2010-2018)



Source: Prepared by the authors using information from Zillow (2019)

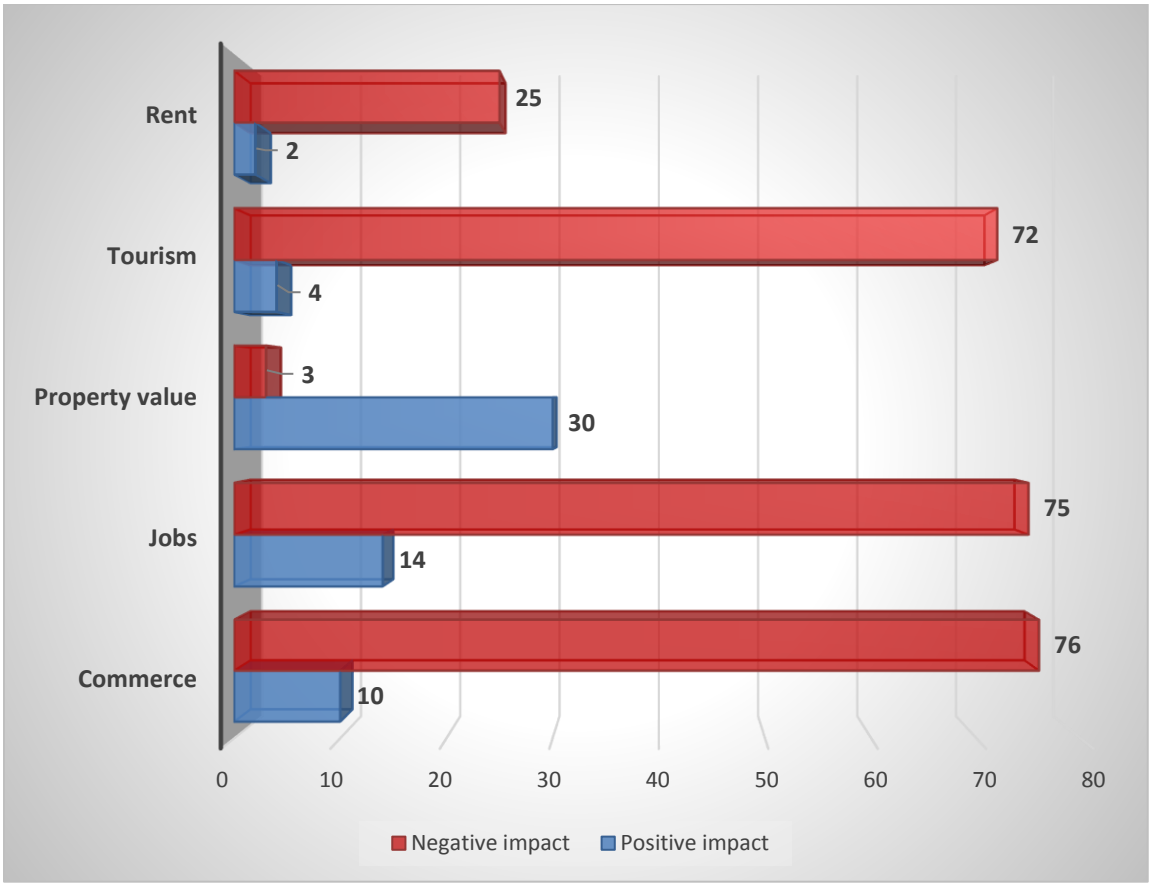
Despite the above official data—which reflect a moderate improvement at the local level in comparison with the state of Arizona—in several of its perceptions measured through the applied survey, the population of Nogales, AZ., does not visualize a completely positive scenario and reflects a highly critical stance throughout the analysis of its responses.

In several cases, perceptions are contradictory, since some of the survey items reflect more optimistic attitudes than other responses. There should be a certain degree of consistency, but it seems that the prevalence of problematic situations experienced by residents at the time of the survey overpowers their ability to detach from these situations and make a more objective review of past conditions. The above is evident when reviewing the answers provided regarding their perception of economic development and what they answered when discussing the issue of quality of life and urban development improvements.

A majority of respondents perceive a lack of employment opportunities in the city. 75% of the respondents pointed out that there are fewer jobs in Nogales, Arizona (Chart 26). In addition, 76% of the respondents reported that there are fewer stores and less trade in general in Nogales, Arizona. Also, most respondents reported that there are fewer tourists (72%), which is related to the food and lodging industry. The same applies to property values, where hard data showing an upward trend in recent years are confirmed by surveys. Finally, among other findings, a relationship was identified between the impacts of the WWTP and the local economy, due to the greening of the Santa Cruz River to the north (downstream) of the plant. According to Arizona

Public Media (2018), the habitat created by the greening of the Santa Cruz River attracts many bird species and, therefore, birdwatching enthusiasts, who bring US $21 million in revenue to Santa Cruz County.

Chart 26. Results of Public Perception Survey regarding Economic Development



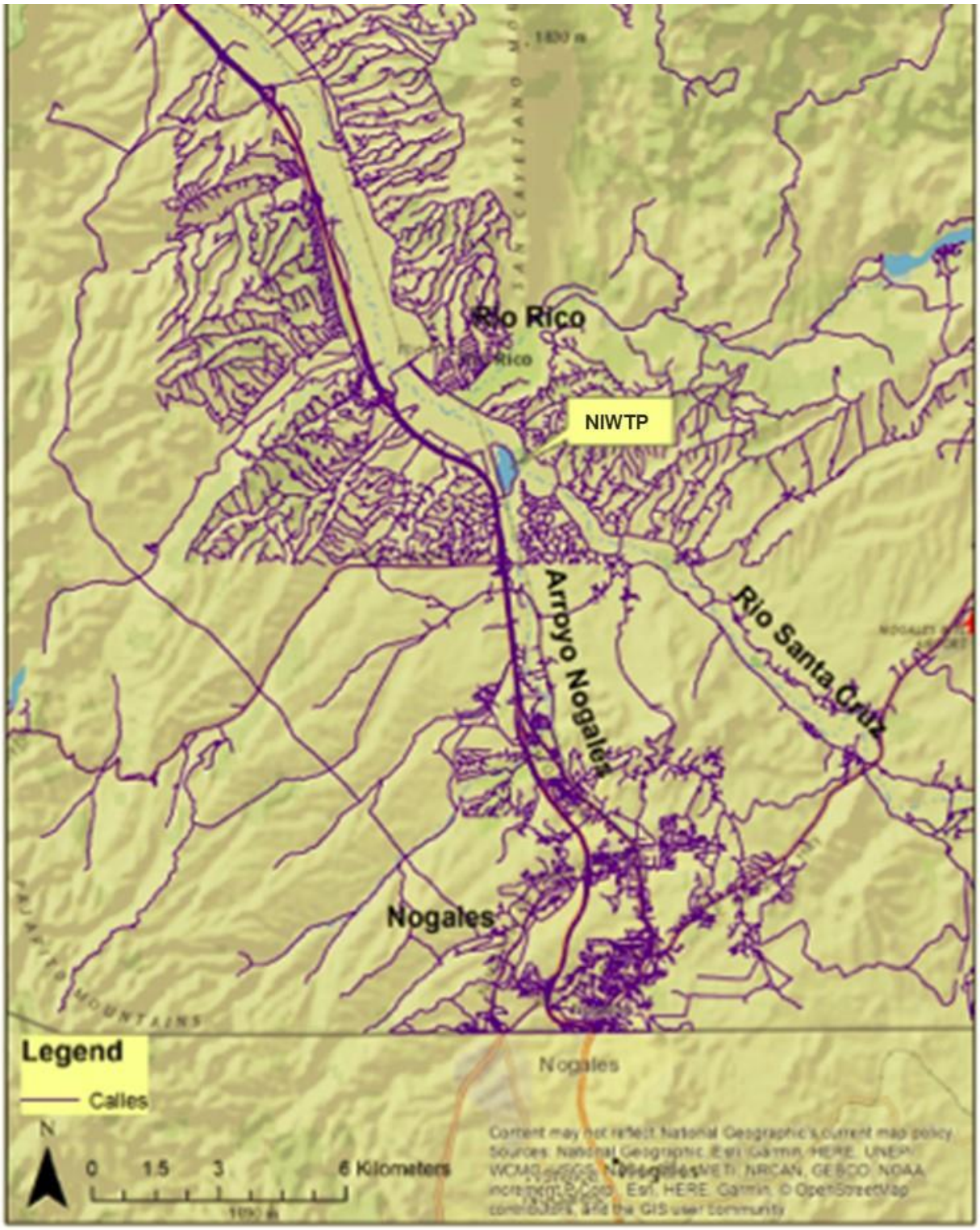
Source: Self-reported

Component 3 – Urban Infrastructure

Component 3 indicators refer to urban infrastructure and include public utility fees, street paving, street lighting, schools, public parks, improvements to urban fire safety, evolution of the urban area, etc.

On the U.S. side, the network of paved streets has grown significantly north of Rio Rico (Map 16). It is difficult to relate this urban growth in Rio Rico with the location of the WWTP, but an increase to the north of the facility can be clearly distinguished. It is inferred that this urban infrastructure can be related to the greening of the Santa Cruz River in this area, which may have attracted housing developers, as explained above.

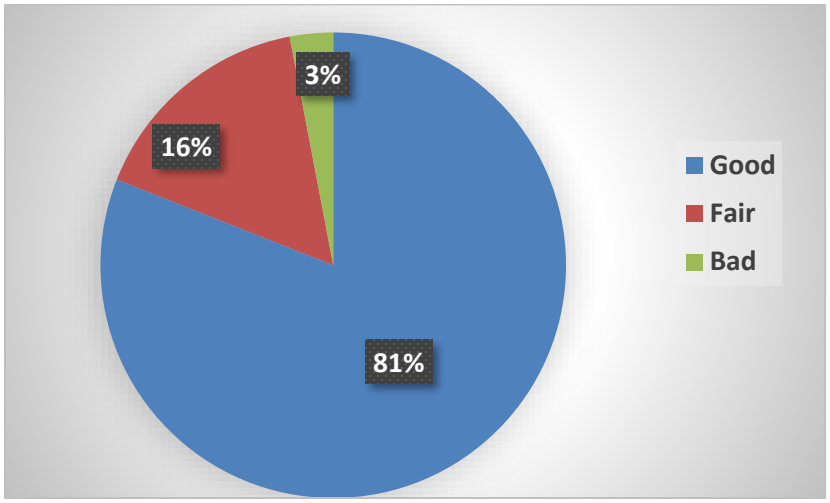
Map 16. Street Paving in Nogales, AZ.



Source: Information from Arizona State Land Department with TIGER data from the 2008 Census; map developed by A. Zuniga.

Regarding the link between urban development and the wastewater treatment system in Ambos Nogales, the general perception of Nogales, Arizona residents is good (Chart 27), since 81% of the population rated the impacts as good, 16% as fair, and only 3% as bad.

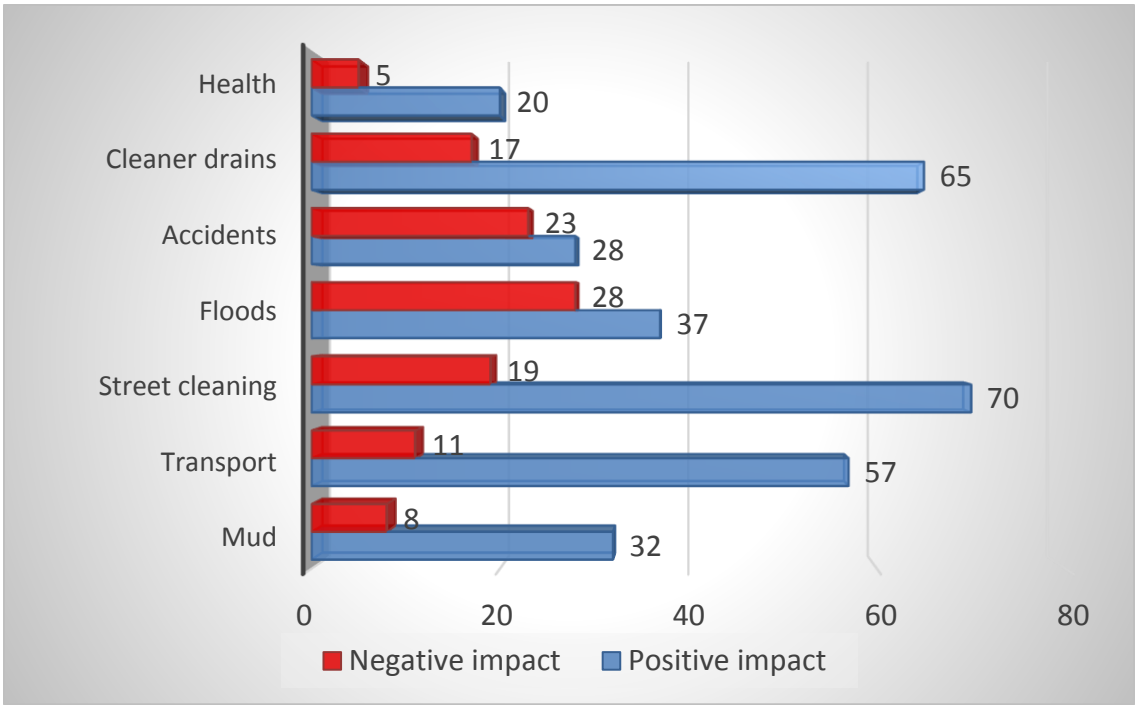
Chart 27. General Perception of Urban Development Impacts



Source: Self-reported

Interview data shows that, although Nogales, Arizona has paved streets, these are often in poor condition, i.e., potholes. The quality of the streets cannot be appraised using spatial hard data. Additionally, survey results indicate that people perceive that the streets are clean and there is less mud in the city (Chart 28).

Chart 28. Responses to Questions about Neighborhood Impacts



Source: Self-reported

Seventy percent (70%) of respondents reported clean streets, while 19% reported dirty streets. 32% reported less mud in the city, while 8% reported more mud in the city. Additionally, most respondents (57%) stated that traffic flow is smooth in the neighborhood, compared to 11% who stated otherwise.

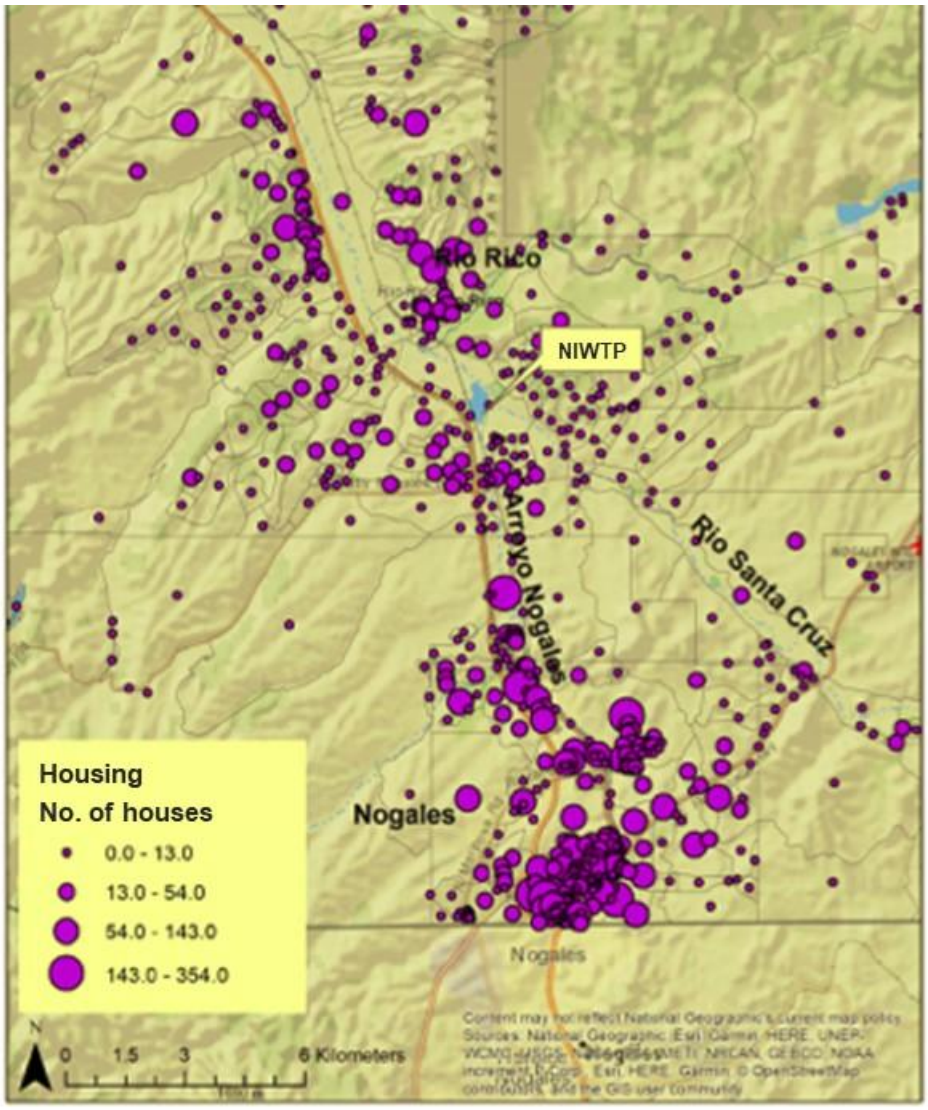
In addition to urban growth, there is demographic growth. This study found that housing growth on the U.S. side is denser in the Nogales area than in the Rio Rico area. This has to do with the age of the city, since Nogales is older and suburban housing had not been developed in the past. Nogales, therefore, has a denser urban configuration than Rio Rico (see Map 17).

The population of Nogales, Arizona, on the other hand, has a low-income level. About 25 percent of residents live on incomes below the poverty line (Latreille, 2018). According to data from the U.S. Census´ American Community Survey, in 2017, there were 7,397 households in the city living in poverty. The rate of unoccupied housing units was 13.9%, with an average income of US $532/month (2017 U.S. Census Bureau). The average house has 5 rooms and a value of US $114,600.

A distinction is made between Rio Rico and Nogales with respect to property data. In this case, the spatial analysis shows that there is a higher number of rental houses in Nogales than in Rio Rico (Map 18). This difference in the distribution of rental houses may be related to a higher

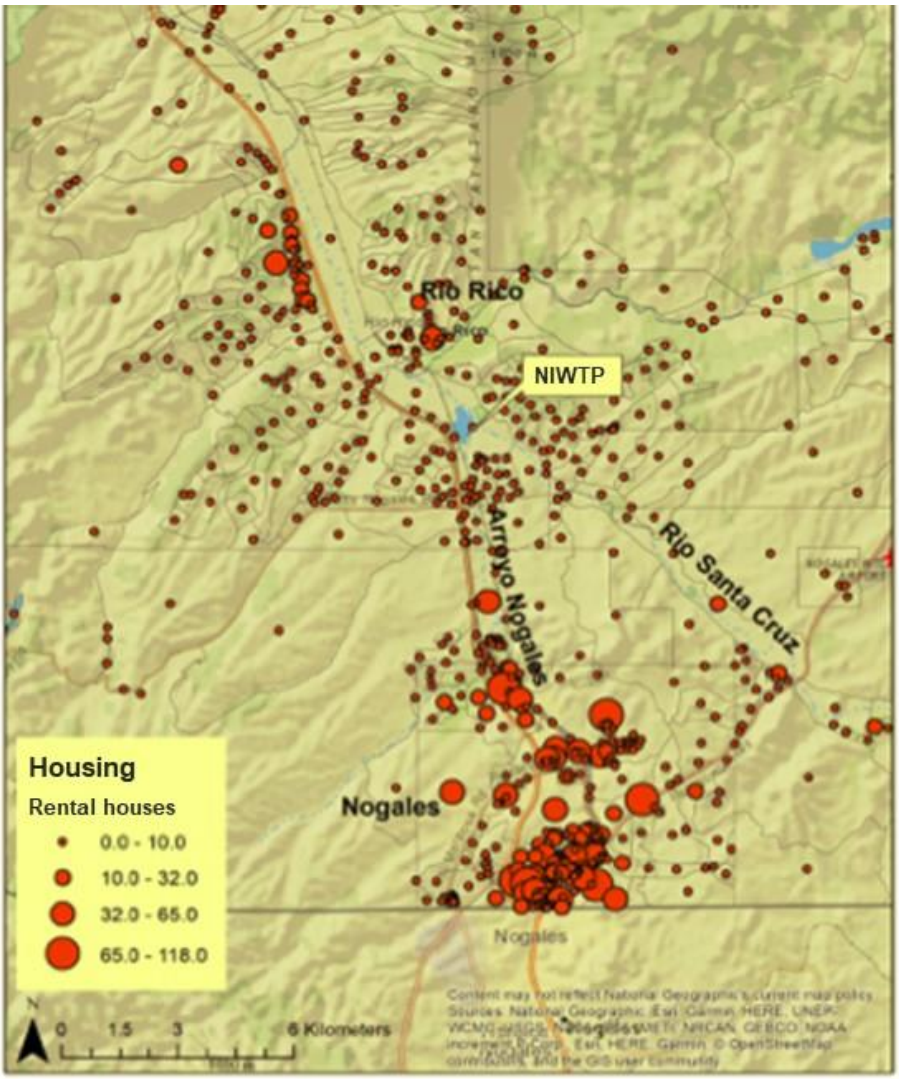
socioeconomic level in Rio Rico, a scenario that is linked to the greening of the Santa Cruz River downstream of the WWTP. The increase in property values around green areas has been documented in the literature (Immergluck & Balan, 2018).

Map 17. Number of Housing Units in Nogales, Arizona



Source: TIGER data from the 2000 Census; map developed by A. Zuniga.

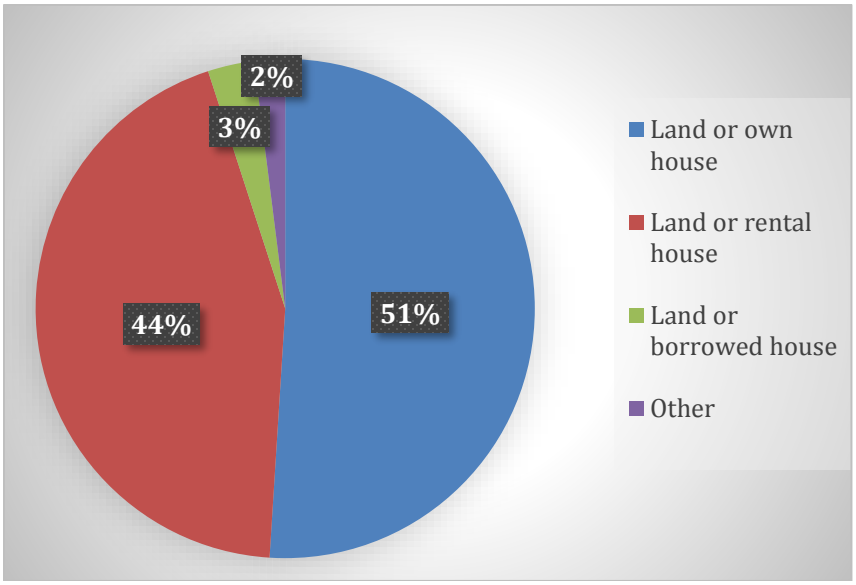
Map 18. Rental Housing in Nogales, Arizona



Source: TIGER data from the 2000 Census; map developed by A. Zuniga.

These official property data are also consistent with the results of the opinion survey. When asked: What type of property is the place where you live? 51% of the respondents reported living in their own homes, while 44% reported living in a rental house (Chart 29).

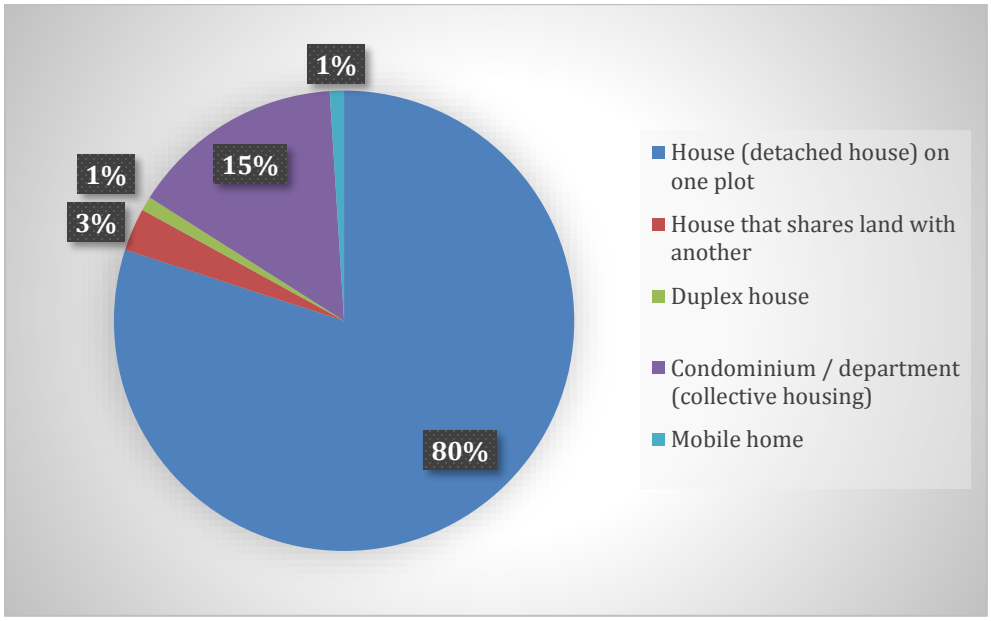
Chart 29. Public Perception Survey Responses to the Question about Property



Source: Self-reported

These data are also reflected in the public perception survey. The survey found that 80% of residents live in single detached houses, while 15 percent responded that they live in condominiums or apartments (Chart 30).

Chart 30. Public Perception Survey Responses to the Question about Type of Housing



Source: Self-reported

As for public schools, Nogales, Arizona was found to have two school districts –the Nogales Unified School District 1 and the Santa Cruz Valley School District 35. These districts have elementary, middle and higher education institutions for a total of 18 public schools, including two institutions of higher education (community college and university): Santa Cruz County Provisional Community College District and University of Arizona Santa Cruz.

In addition to public schools, Nogales has charter and/or private schools, for a total of 30 schools. The survey found that Nogales has three preschools, fourteen elementary schools, six middle schools, three high schools, four community/technical colleges, and one university.

Interviews with key stakeholders indicate that there is a high demand for schools in Arizona, as schools on the U.S. side also serve children living on the Mexican side. There are many cases of families in which the parents have been deported and cannot live in the United States, but the children are U.S. citizens and do have the right to attend schools in Arizona. In these cases, the parents drop off the children at the border and school buses pick them up and drive them to their respective schools. This situation suggests that, although it may seem that Nogales, Arizona has many schools in relation to its population size, the flow of people across the border reflects a different reality. Additionally, the interviews depict that there are no college or university degree options in Nogales, since the local university campuses only offer some courses, but not complete degree plans. Therefore, young high school graduates must leave the city if they want to pursue a higher level of education.

This situation is confirmed by the results of the surveys, which indicate that the majority of the population of Nogales, Arizona has a high school level education.

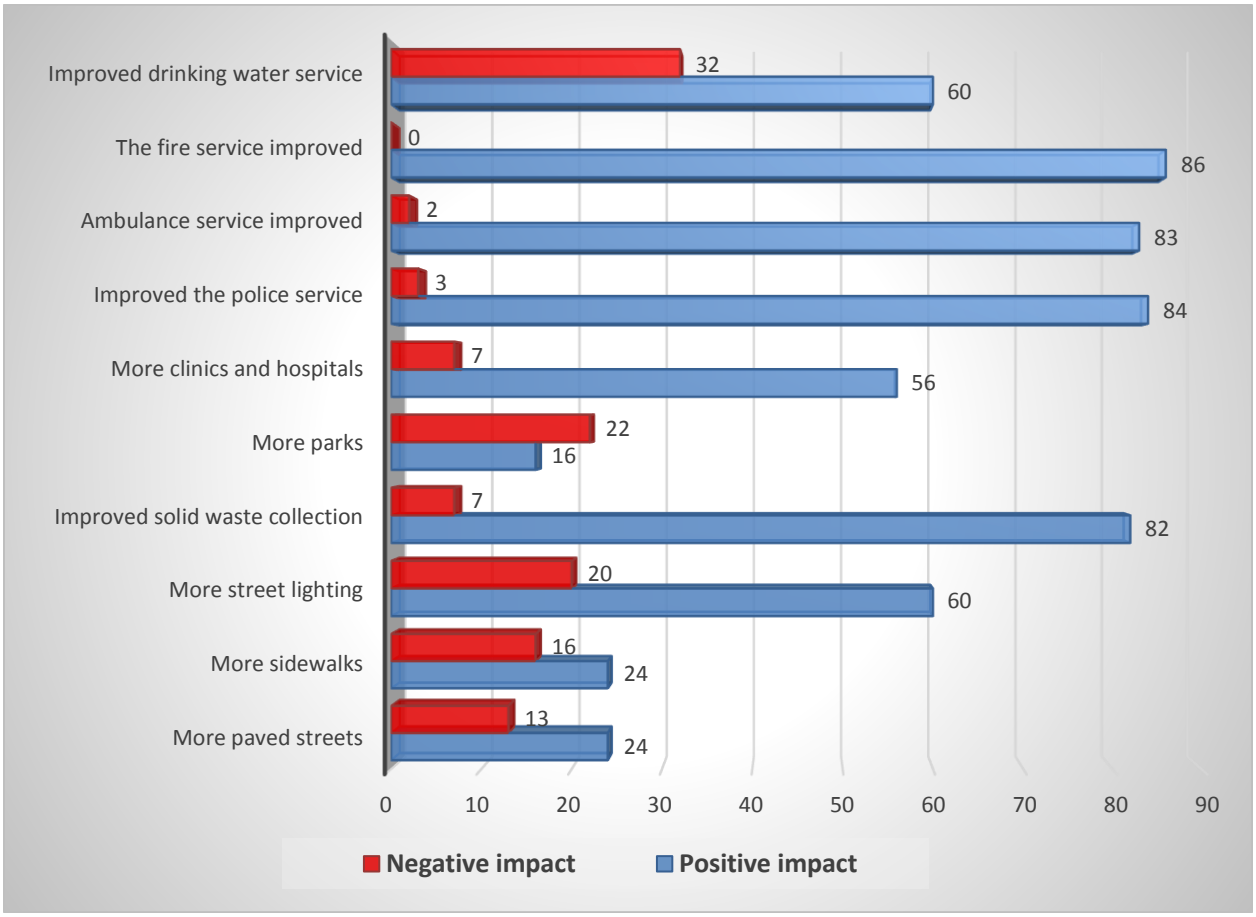
As for parks and sports facilities in Nogales, Arizona, the survey found that the city has 18 public recreational facilities, including eight recreational parks, two baseball fields, two pools, and a soccer field. The results of interviews with key stakeholders indicate that, although there are parks available in Nogales, Arizona, they only serve one sector of the population and others do not have availability to recreational areas.

An interviewee mentioned that parks in Nogales, Arizona are for students to practice sports, whether soccer, baseball, or even swimming, but there are not enough recreational parks where people can go to enjoy nature or just walk. This indicates that a sector of the population does not have access to recreational areas.

Regarding the fire safety, the City of Nogales, Arizona has a fire department with two stations, which is part of the municipal government. This department serves a population of approximately 20,000 residents living in an area of 21 square miles.

As mentioned above, the general perception of the respondents regarding urban development is also good. When the question was asked in detail, it was also found that most of the respondents perceive positive impacts on urban development (Chart 31). Local residents perceive positive impacts on drinking water, fire, ambulance and police services, as well as on the number of clinics and hospitals, the number of parks, garbage collection services, street lighting, sidewalks and street paving.

Chart 31. Perception of Impacts on Urban Development



Source: Self-reported

Component 4 - Health

This component comprises health-related indicators. These include hospitals or health centers, presence or reduction of waterborne diseases, skin diseases, hepatitis, etc.

As for hospitals and health centers, 25 facilities were found in the cities of Nogales and Rio Rico, Arizona. These include seven facilities offering medical consultations, two providing surgery and consultations, six dentists, a hospital, a medical emergency center, a nutrition center, and seven establishments that offer behavioral services. A spatial analysis using the Google Earth platform found that the number of hospitals and health centers has slightly increased in recent years, from 18 in the year 2000 to 25 in 2018, as mentioned above.

The Ambos Nogales region experienced inadequate living conditions in the 1980s, when high rates of diseases such as cholera and hepatitis A were documented, especially in communities along the border area that lacked potable water infrastructure and public sewage (Norman et al. 2006). After the signing of the 1983 La Paz Agreement and the creation of organizations that worked at the binational level, the federal governments of both countries developed the institutional capacity to work together to resolve urgent health issues (Norman et al. 2006) (Table 9). Norman and colleagues (2006) highlight the participation of NADB as a provider of funding to address the challenges created by uncontrolled population growth in the form of "colonias" that lacked public services.

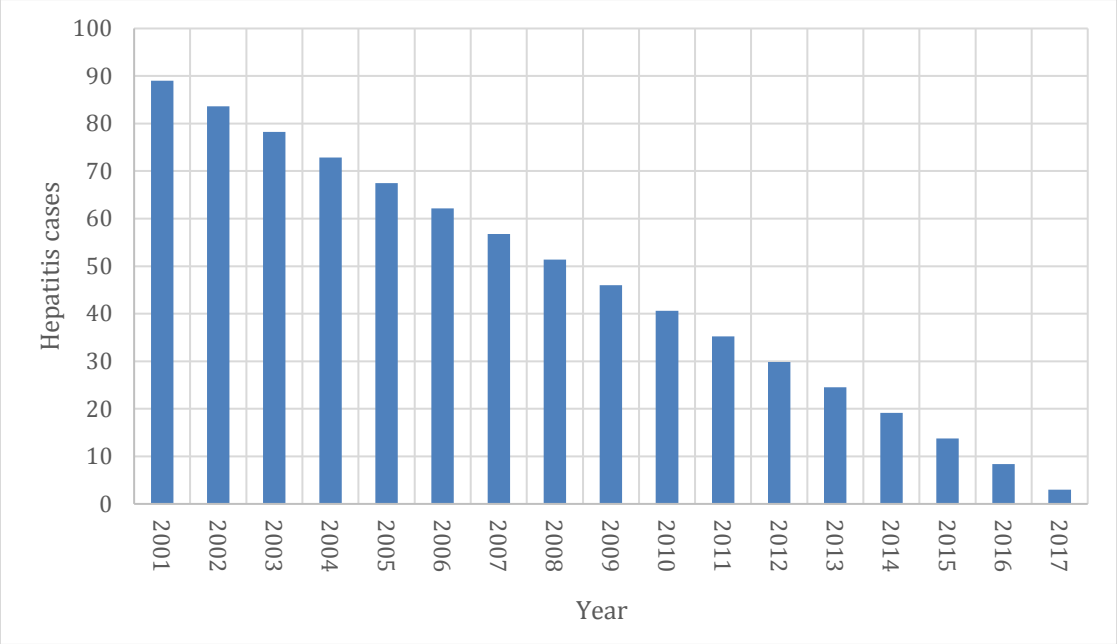
Table 9. Contagious Diseases in Santa Cruz County

Diseases	2001	2017
Amebiasis	**7.6**	**1**
Cholera	**0**	**0**
Campylobacteriosis	**n/a**	**13**
Hepatitis A	**88.6**	**3**
Hepatitis E	**0**	**0**
Polyomyelitis	**0**	**0**
Salmonella	**15.6**	**12**
Typhoid	**0**	**0**
Vibrio Infection	**0**	**0**
Giardiasis (parasites)	**0**	**1**

Source: Prepared by the authors based on information from Arizona Department of Health Services (2016)

The behavior of Hepatitis A is of great relevance, since this is a condition highly related to contact with raw or untreated wastewater. It is reasonable to assume that the projects in Ambos Nogales positively impacted public health in Nogales, AZ, since the number of Hepatitis A cases dropped from 89 in 2001 to only 3 cases in 2017 (Chart 32).

Chart 32. Hepatitis A Cases in Nogales, AZ (89 cases in 2001 to 3 cases in 2017)



Source: Prepared by the authors based on information from Arizona Department of Health Services (2016)

Access to drinking water is a health indicator on both sides of the border (Health in Americas, 2012). It is estimated that 88% of diarrhea cases are caused by contaminated water, poor water treatment, and leaks in the sanitary sewer system (CONAGUA, 2016).

Poor water quality can cause health issues such as skin diseases (rash, hives, dryness, irritation), stomach aches or pains (salmonella, cholera, campylobacteriosis, h.pylori) hepatitis A and E, typhoid, polio, amebiasis (worms, intestinal nematodes), and anemia. The availability of quality water is necessary to ensure a good quality of life, and it is reflected in a low incidence of many diseases (WHO, 2018).

In addition to contagious diseases, wastewater contains heavy metals. Metals that are critical for human (and environmental) health include cadmium, zinc, and chromium. Industrial wastewater represents a problem, as it contaminates the wastewater that reaches the WWTP.

Cadmium is a heavy metal that has harmful effects on human health. In recent decades, its accumulation has increased considerably as a result of industrial activities. One of the ways in

which humans can be negatively affected by cadmium is through the consumption of crops contaminated by this metal. Symptoms include abdominal pain, diarrhea, headache, nausea and vomiting.

Zinc causes abdominal pain, nausea and vomiting by skin contact (WHO 2005), as well as dry skin. Sources of zinc also include the plating industry, fertilizers, fungicides and insecticides, batteries and livestock growth stimulants. Additionally, zinc is naturally present in soils (Lenntech, 2018).

Chromium can cause respiratory and lung irritation, dermatitis, harmful effects on the kidneys and liver, cancer, and other effects (CDC Agency for Toxic Substances, 2011). In the industry, chromium and its compounds have a wide variety of applications that include, among others: tanning processes, textile pigments, alloys, catalysts, anticorrosive agents, batteries, fungicides, metallic coatings, electroplating, etc. (Source: aguas residuales.info).

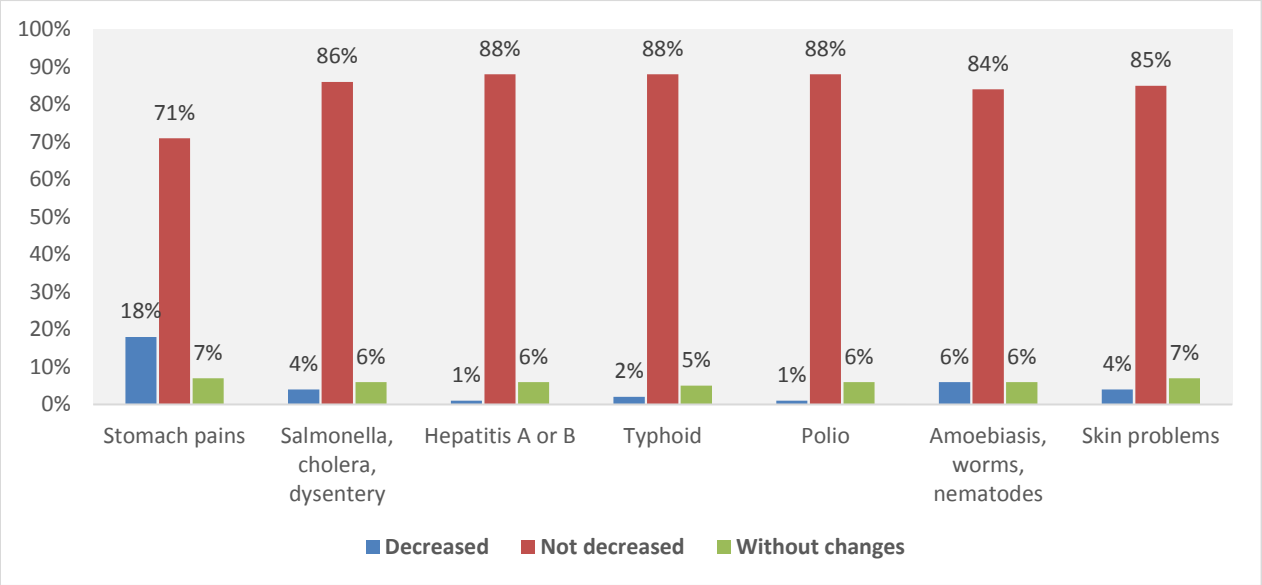
As for water quality in Nogales, Arizona, concentrations of Trichlorethylene have been found in breast milk and household water. This compound is associated with the electronics industry and is present in solvent paints and adhesives (Beamer et al., 2012).

This compound is listed at number 16 in terms of priority risk in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), for its threat to human health. People who are exposed to TCE show speech and hearing impairments, as well as liver, skin, diabetes, kidney, and blood disorders, immune system diseases and cancer (Beamer et al., 2012).

The results of the opinion survey do not reflect official data. As for the perception that diseases are caused by poor water quality, most of the population thinks that the prevalence of diseases has not decreased (Chart 33).

These results suggest that respondents on the U.S. side have been continually connected to some type of wastewater collection system (sewers or septic tanks) and therefore, do not perceive changes in related diseases.

Chart 33. Responses regarding Changes in Related Diseases in Nogales, Arizona



Source: Self-reported

Figure 9. Presentation of Preliminary Results at the Udall Center on February 20, 2019

Conclusions for Nogales, AZ.

The analysis of baseline indicators constructed with official data, in the four components considered, reveals that the wastewater infrastructure project is associated, in general terms, to positive economic, social and environmental impacts in Nogales, Arizona. It should be noted that most of the indicators of the infrastructure and urban development components did not evolve

significantly, since the city already had high service coverage rates at the beginning of the period under review. Based on the official data, the economic component showed a positive evolution in the dimension of total economic activity, and the same happened with the health component, although the perception of the community did not identify it as such at all (Table 10).

Table 10. Baseline Indicators of the Four Components Analyzed for Nogales, AZ

Component	Dimension	Number	Indicator	Initial year	Initial value	Final year	Value final year	Value variation (%)
1. Basic infrastructure coverage	Services	1	Households with sewer (%)	N.D.	N.D.	2018	100	N.D.
		2	Homes with latrine (%)	N.D.	N.D.	2019	0	N.D.
	Environment	3	Wastewater treatment plants (unit)	2000	1.0	2018	1	0
2. Socio-economic component	Total economic activity	4	Hourly earnings (dollars)	2000	$22,306	2016	$29,136	30.6
		5	Per capita income (dollars)	2000	$10,178	2016	$15,628	53.5
		6	Unemployment	2000	8.4	2015	14.7	75.0
		7	Population in poverty	N.D.	N.D.	2015	25	N.D.
	Commerce	8	Food stores (unit / 10,000 inhabitants)	N.D.	N.D.	2018	2.4	N.D.
		9	Convenience stores (without gas stations) (ur	N.D.	N.D.	2018	0.5	N.D.
		10	Convenience stores (with gas stations) (unit /	N.D.	N.D.	2018	4.2	N.D.
		11	Restaurants (unit / 10,000hab)	N.D.	N.D.	2018	7.8	N.D.
3. Urban development component	Urban area and road infrastructure	12	Property value (dollars)	2000	$85,100	2016	$133,387	56.7
		13	Uninhabited homes (%)	N.D.	N.D.	2017	13.9	N.D.
		14	Street paving (%)	N.D.	N.D.	2018	100	N.D.
	Educational infrastructure	15	Education Institutions (unit)	N.D.	N.D.	2018	48	N.D.
		16	Parks and sports facilities (unit)	N.D.	N.D.	2018	18	N.D.
		17	Fire Departments (unit)	2000	1	2018	1	0
		18	Hospitals and health centers (unit)	2000	18	2018	26	44.4
4. Health component	Health	19	Affected by amebiasis (people)	2001	7.6	2017	1	-86.8
		20	Affected by cholera (people)	2001	0	2017	0	0
		21	Affected by Campylobacter (people)	2001	N.D.	2017	13	N.D.
		22	Hepatitis A affected (people)	2001	88.6	2017	3	-96.8
		23	Hepatitis B affected (people)	2001	0	2017	0	0
		24	Affected by poliomyelitis (people)	2001	0	2017	0	0
		25	Affected by Salmonella (people)	2001	15.6	2017	12	-23.1
		26	Typhoid affected (people)	2001	0	2017	0	0
		27	Affected by giardiasis (people)	2001	0	2017	1	N.D.

Source: Self-reported

Based on the results obtained in the opinion survey, in general terms, the community expressed a positive assessment of the impacts of the wastewater project, and these opinions were consistent with the *hard indicators* constructed using U.S. official databases, or with the indicators built using the spatial analysis carried out by the research team.

COMPARISON BETWEEN CITIES

Introduction

After analyzing in the previous section, the main results obtained in the components baseline in Nogales, Sonora and Nogales, Arizona, and linking this information with the corresponding results in the public opinion survey, we will now proceed to compare the results obtained using a binational approach.

The key issue to explore here is to identify the relationship that exists in the socioeconomic conditions and, primarily, the perception of the impacts generated by the wastewater projects in Ambos Nogales. Additionally, a brief summary will be presented of the opinions expressed by the seven stakeholders interviewed regarding the current situation, within the framework of the binational operation of the wastewater system.

Sociodemographic Conditions

This section presents a brief comparative analysis of the socioeconomic variables included in the public opinion survey, which are:

1) Gender
2) Age
3) Education
4) Household size
5) Type of housing, and
6) Connection to the wastewater collection system

See Table 11.

The survey found that gender distribution, measured by identifying the sex of the respondents, is very similar in Ambos Nogales, since, in Nogales, Sonora 42% of respondents were male and 58% were female, while in Nogales, Arizona the results were 45% and 55%, respectively.

In terms of age, significant differences were observed in the low and high ends of the range, while in the middle age range the results were very similar. For example, in Nogales, Sonora 22% of the respondents are in the 18-30 age range, while in Nogales, Arizona, 41% are in the same age range. By contrast, 28% of respondents in Nogales, Sonora, and only 8% in Nogales, Arizona, are 60 or older. In the 40-59 age range, as mentioned above, the results are very similar, since 49% of respondents in Nogales, Sonora and 51% in Nogales, Arizona are in this category.

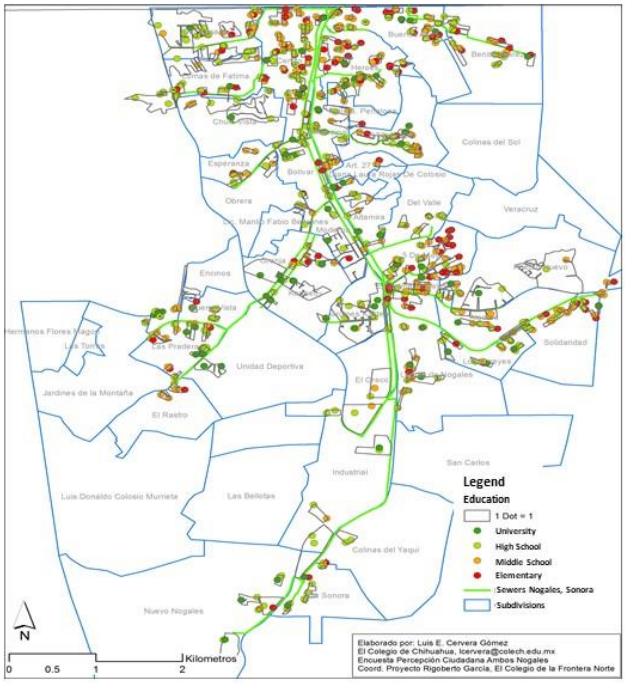
Table 11. Sociodemographic Conditions in Ambos Nogales

DIMENSION	VARIABLE	SONORA	ARIZONA
GENDER	Man	42%	45%
	Woman	58%	55%
	Total	100%	100%
AGE	18-20s	8%	17%
	30s	14%	24%
	40s	26%	31%
	50s	23%	20%
	60s	18%	7%
	70+	10%	1%
	Total	100%	100%
STUDY GRADE	Primary	18%	4%
	High school	31%	6%
	High school	39%	58%
	college	12%	32%
	Total	100%	100%
HOUSE SIZE	one	3%	11%
	2 to 4	62%	76%
	5 or more	36%	13%
	Total	100%	100%
TYPE OF HOUSE	House (detached house)	91%	80%
	House that shares land	8%	3%
	Duplex house	0%	1%
	Condiminio / department	1%	15%
	Mobile home	0%	1%
	Rooftop room	0%	0%
	Local not built for hab.	0%	0%
	Refuge	0%	0%
	Other	0%	0%
	Total	100%	100%
WASTEWATER COLLECTION	Yes	98%	73%
	No	2%	24%
	Doesn't know	0%	3%
	Total	100%	100%

Source: Self-reported

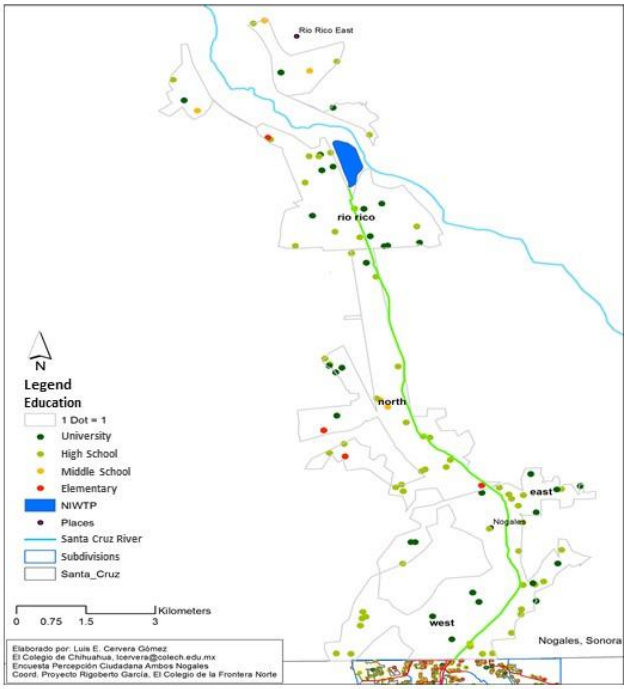
When examining the level of education, measured in completed levels of elementary, middle, high school, and university or postgraduate education, significant differences were also found in Ambos Nogales. In Nogales, Sonora, 18% of the respondents have completed the elementary school level, 31% have completed middle school, 39% high school, and only 12% have a university or postgraduate education; while in Nogales, Arizona, the respective results are 4% elementary school, 6% middle school, 58% high school, and 32% university or postgraduate education. These results clearly show that the education level of residents of Nogales, Arizona is significantly higher than the level in its twin city in Sonora.

Figure 10. Education Level in Ambos Nogales



The Southwest and Northwest areas have the highest level of education, with 65% and 57% of the population having high school and university studies, respectively.

The Northeast and Southeast areas have the lowest levels of education, with 59% and 52% of the population having primary or middle school educations, respectively.



The East and West areas have the highest level of education, with 96% and 100% of the population having high school and university studies, respectively.

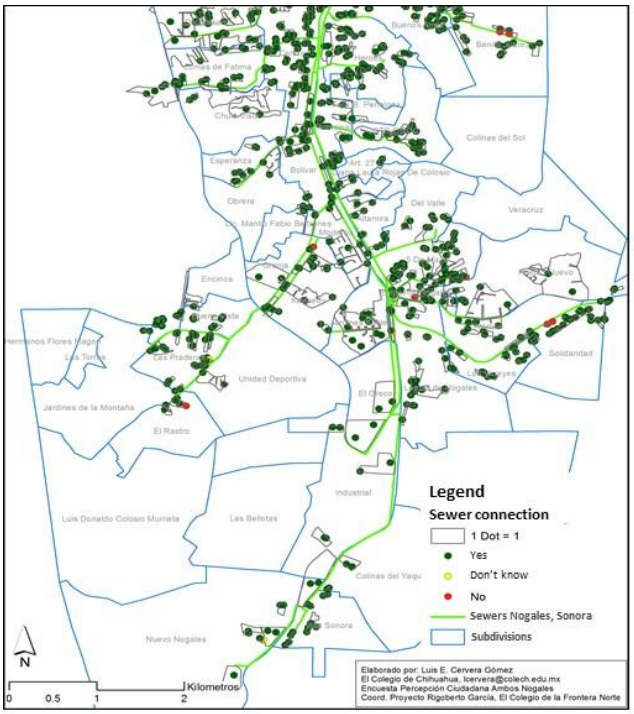
The North and Rio Rico areas have the lowest levels of education, with 18% and 13% of the population having primary or middle school educations, respectively.

The size of households also presents significant differences in Ambos Nogales. In Nogales, Sonora 1% of the households have one member, 62% have two to four members, and 36% have five or more; while in Nogales, Arizona, the situation is completely different, with a distribution of 11%, 76% and 12%, respectively.

The size of housing units also shows some important differences, since 91% of housing units in Nogales, Sonora are single-family homes, 8% share the lot with other homes, and 1% are apartments or condominiums; while in Nogales, Arizona, 80% are single-family homes, only 3% are on shared lots, and the biggest difference is observed in the proportion of apartments or condominiums, since 15% of the homes in this city are in this category.

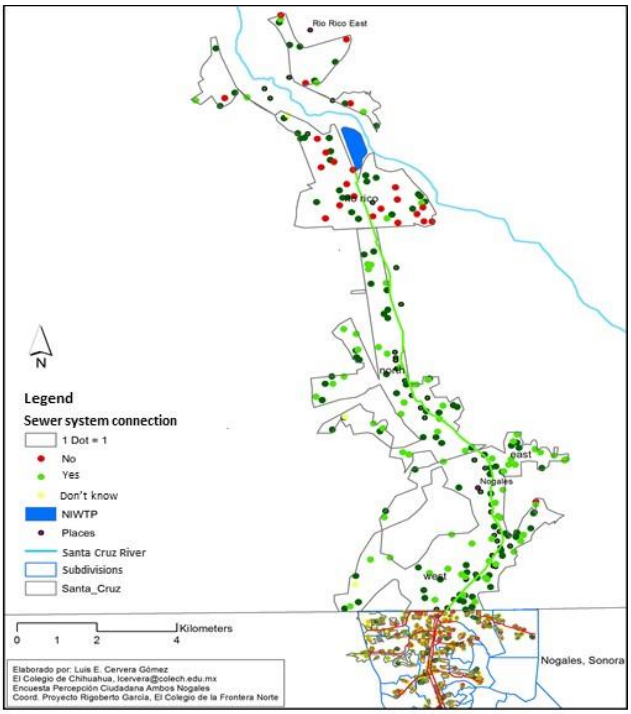
Finally, practically all of the homes in Ambos Nogales have wastewater collection, with the peculiarity that, although in Nogales, Arizona, 24% of the homes do not have wastewater collection connections, they do have septic tanks, which are sufficient to meet the sanitation conditions required by legal standards.

Figure 11. Connections to the Wastewater Collection System in Ambos Nogales



There is no spatial differentiation in Nogales, Sonora, since practically all homes (98%) are connected to the sewer system.

Homes not connected to the sewer system (2%) are located in the North, East and West Zones.



There is a clear spatial differentiation in Nogales, Arizona. Only 23% of homes in Rio Rico are connected to the sewer system, while the remaining 77% use septic tanks.

In the North, East and West Zones, all homes are connected to the sewer system.

In summary, the results of the public opinion survey show some significant differences between Ambos Nogales regarding sociodemographic conditions. Nogales, Arizona is a city with a younger population, a better level of education, a greater proportion of departments and condominiums, as well as single-person households than Nogales, Sonora.

Perception of the Wastewater Collection Infrastructure

The subjective perception expressed by residents of Ambos Nogales through the public opinion survey represents a dimension that complements the objective data found in official sources, with which the indicators of the four components that constitute the baseline were constructed. Based on these indicators, it was found that, since the construction and entry into operation of wastewater projects in Ambos Nogales, in general terms, there has been a positive evolution of the four components analyzed, although clear differences were observed in each of the sister cities. Given this scenario, the key issue here is to identify whether the perception of the community corresponds or not to what was measured and expressed by official indicators.

The subjective dimensions analyzed in this section are the impacts produced by the wastewater projects on:

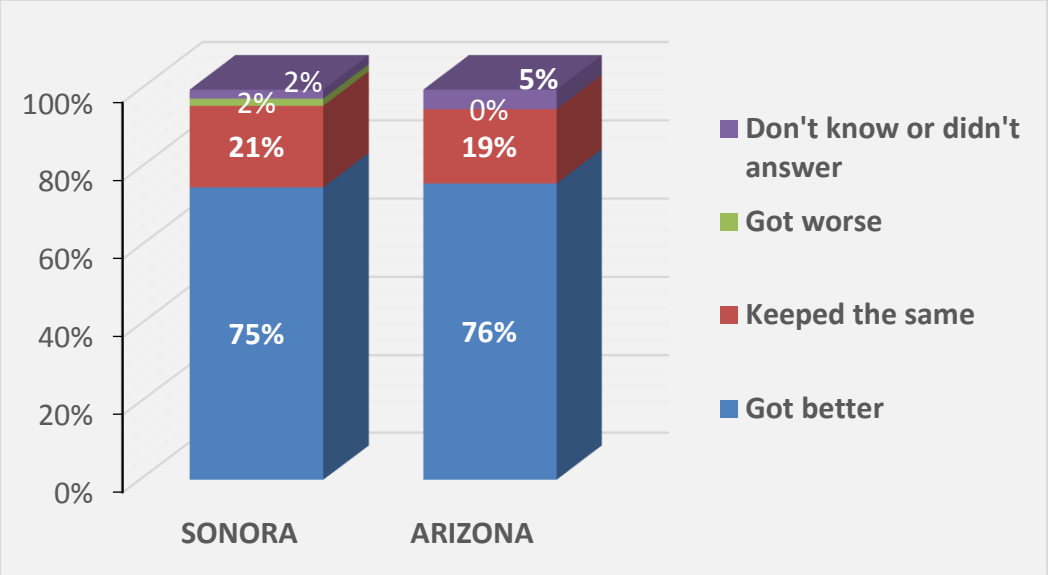
1) Quality of life
2) System operation during the rainy season
3) Economic development
4) Urban development
5) Binational cooperation
6) Awareness of the operation site
7) Binational impact
8) International cooperation, and
9) Potential reuse of treated wastewater

The main results obtained are described below. The first dimension corresponds to the quality of life, a complex concept due to the different factors involved in its definition. According to the World Health Organization (WHO), quality of life is measured on the basis of the perception that individuals have about their position in life, a definition that involves physical, behavioral, economic, social and cultural factors.

In this specific case, the study only considered the physical factor, understood as the health of individuals. The underlying assumption in this proposal is that the construction of the wastewater project, by expanding the wastewater collection system in Nogales, Sonora and increasing the volume of wastewater treated in Nogales, Arizona, has created the conditions to improve the health of individuals.

The results show that the vast majority of the population of Ambos Nogales perceives that their quality of life has substantially improved as a result of the construction of the wastewater infrastructure (Chart 34).

Chart 34. Impact on the Quality of Life in Ambos Nogales



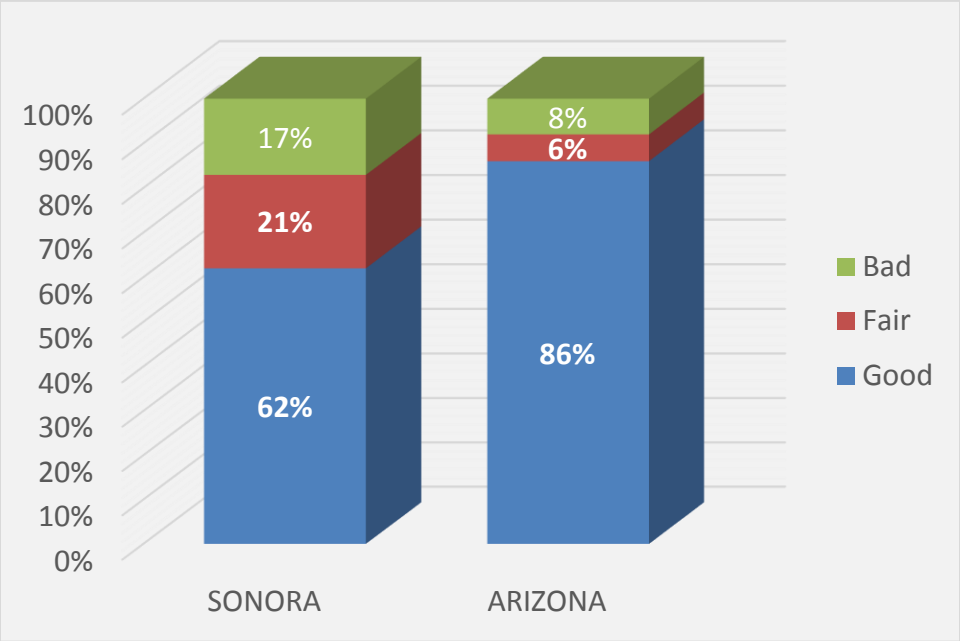
Source: Self-reported

In fact, the results are very similar in the two twin cities, since 75% of the population in Nogales, Sonora and 76% in Nogales, Arizona, think that their quality of life has improved; while 21% in Nogales, Sonora and 19% in Nogales, AZ, said that their quality of life remained the same. In other words, the scenarios found in Ambos Nogales are very similar.

The second dimension analyzed was the operation of the wastewater treatment system during the rainy season. The results show significant differences in Ambos Nogales (Chart 35). In general terms, the population of Nogales, Arizona has a more favorable opinion than the population of its twin city, since 86% of the residents perceives that the system works properly, 6% consider it fair, and 8% consider it inadequate. In Nogales, Sonora, conversely, the results are 62%, 21% and 17%, respectively.

It is crucial to analyze this issue and verify the results, since Ambos Nogales have historically experienced severe problems when extreme rain events occur. In Nogales, Sonora, it is common for the wastewater collection system to overflow due to the volume of rainwater that enters the system, and the same situation occurs with the Nogales, Arizona international outfall. For this reason, as mentioned above, a significant proportion of the population of Ambos Nogales perceives that the operation of the system is fair or inadequate.

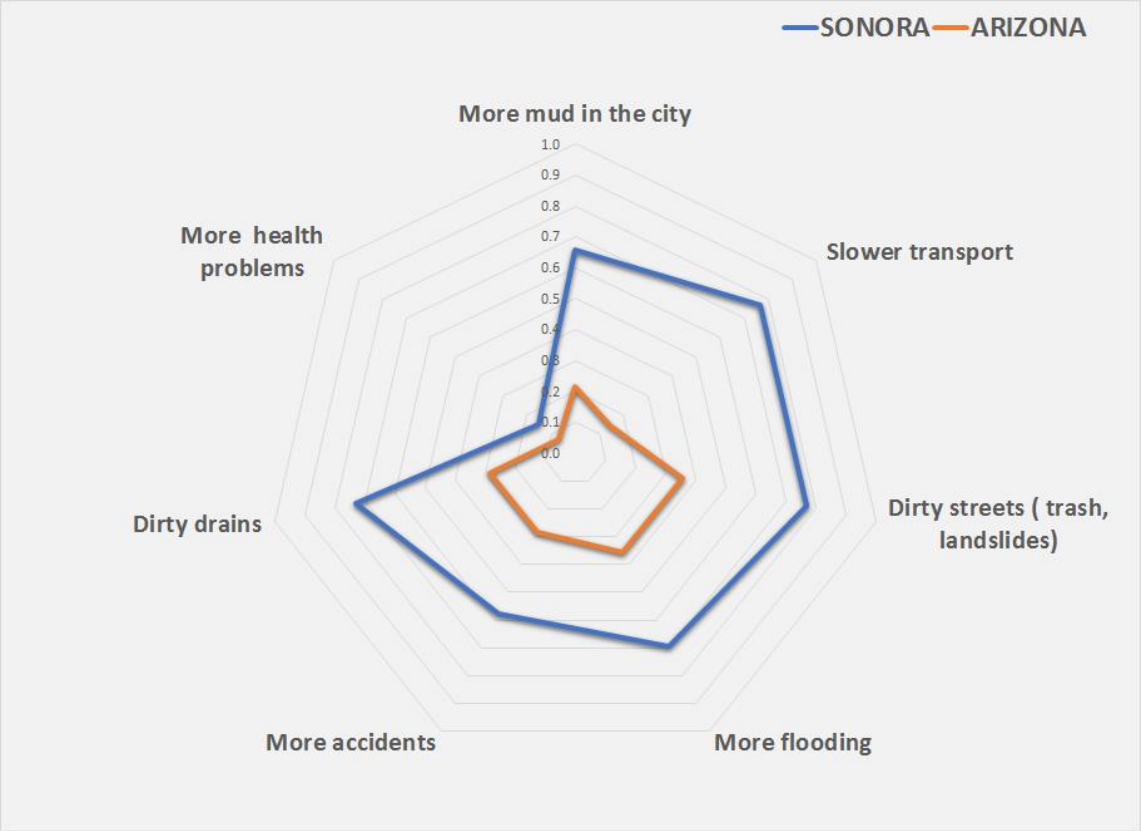
Chart 35. Operation of the Wastewater Collection and Treatment System during the Rainy Season



Source: Self-reported

The statements expressed in the previous paragraph are supported by the observation of the specific negative impacts that result from the inappropriate operation of the wastewater collection and treatment system (Chart 36). In Nogales, Sonora, the majority of the population that perceives an inappropriate operation of the system, associates it primarily with transportation issues (77%), dirty streets (77%), dirty canals (73%), floods (70%), presence of mud in the streets (66%), and more traffic accidents (53%); while a small proportion (15%) associates it with health issues. In Nogales, Arizona, with the exception of transportation issues, a similar scenario is observed, although the values are substantially lower than those of its twin city.

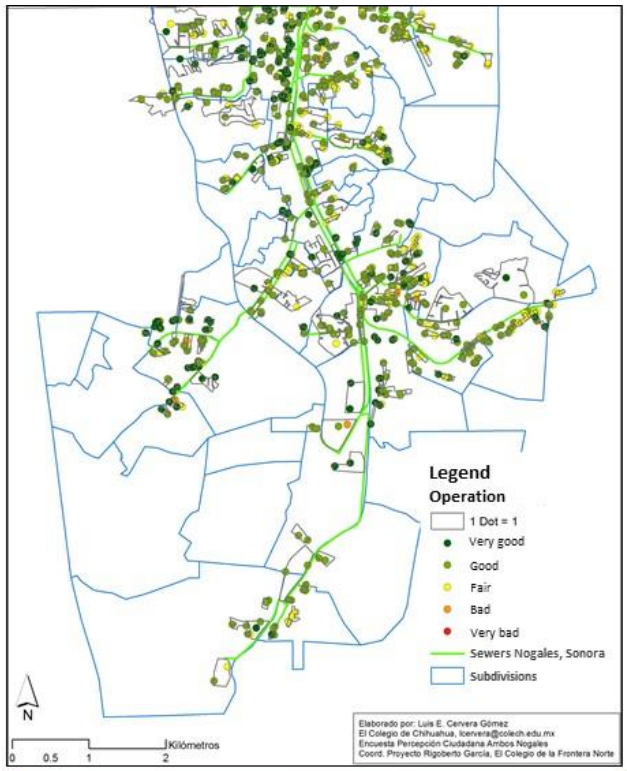
Chart 36. Negative Impacts Perceived in the Operation of the Wastewater Treatment System in Ambos Nogales



Source: Self-reported

This scenario reveals that the mere construction of the infrastructure necessary for wastewater collection and treatment in Ambos Nogales is not sufficient for said system to operate properly, at least in some sectors of these cities. It seems clear that it is necessary for the governments of both cities to undertake efforts to provide adequate maintenance to the systems, in such a way that ensures its proper functioning when extreme rains occur.

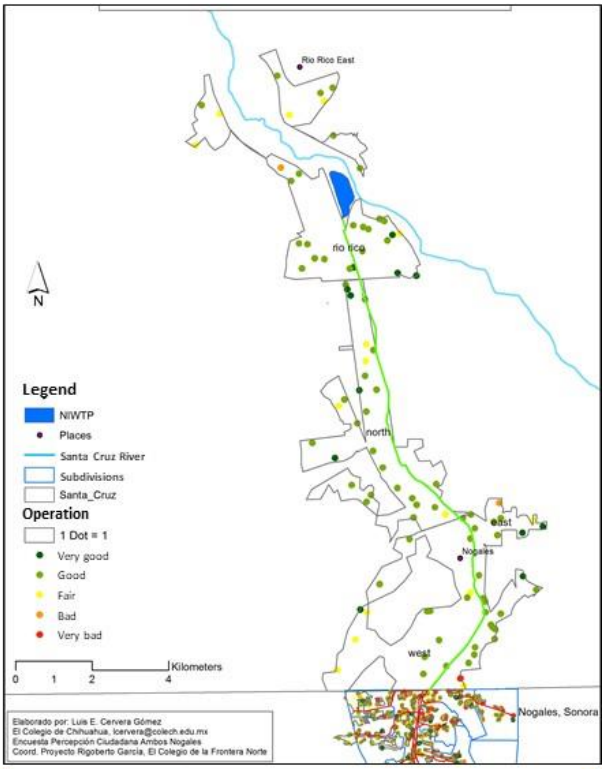
Figure 12. Wastewater System Operation in Ambos Nogales



There is no clear spatial differentiation in Nogales, Sonora.

In the Northeastern area 55% of the population perceives system operation as fair or bad. Flooding is more common in this area.

In the rest of the areas, the majority of the population perceives proper system operation: Northwest (75%), Southeast (67%) and Southwest (68%)



In all four zones, the majority of the population perceives proper system operation.

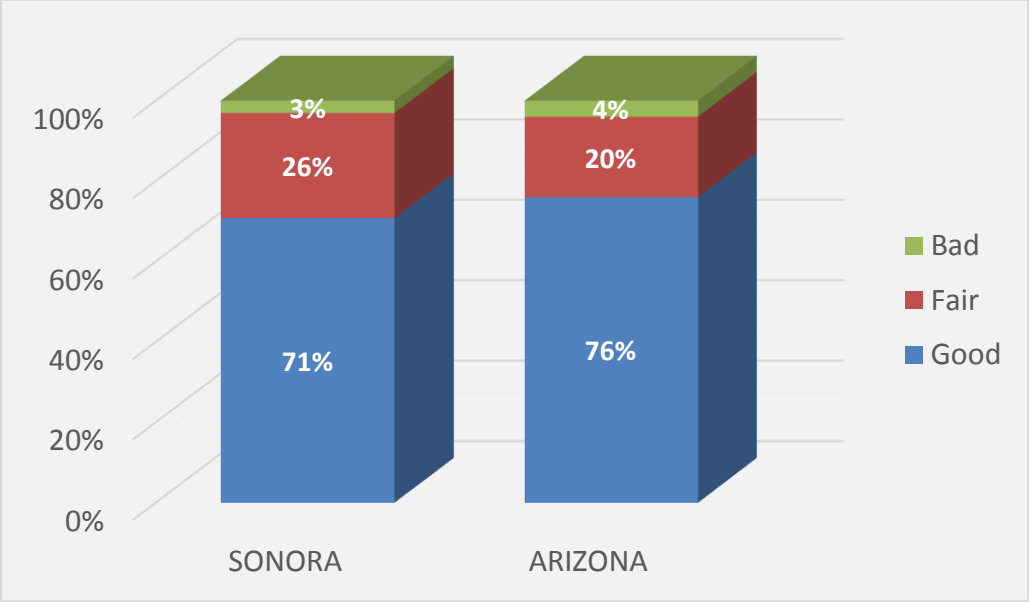
However, in the West Zone, 27% of the population perceives operations as fair or bad.

This situation shows a clear spatial differentiation.

The third dimension analyzed was the impact on economic development in Ambos Nogales, specifically in the area of influence where the wastewater infrastructure project was built. It is inferred that by increasing coverage and improving the wastewater collection system in Nogales, Sonora, and by expanding the main collector and increasing the capacity of the wastewater treatment plant in Rio Rico, favorable conditions have been created for the establishment of economic units, primarily in the trade and services sectors.

The following trends were observed in the responses provided in both cities to Question #14 of the questionnaire –How would you rate the impact of the wastewater collection (Sonora) or wastewater treatment (Arizona) systems on economic development in your neighborhood?

Chart 37. Impacts on Economic Development

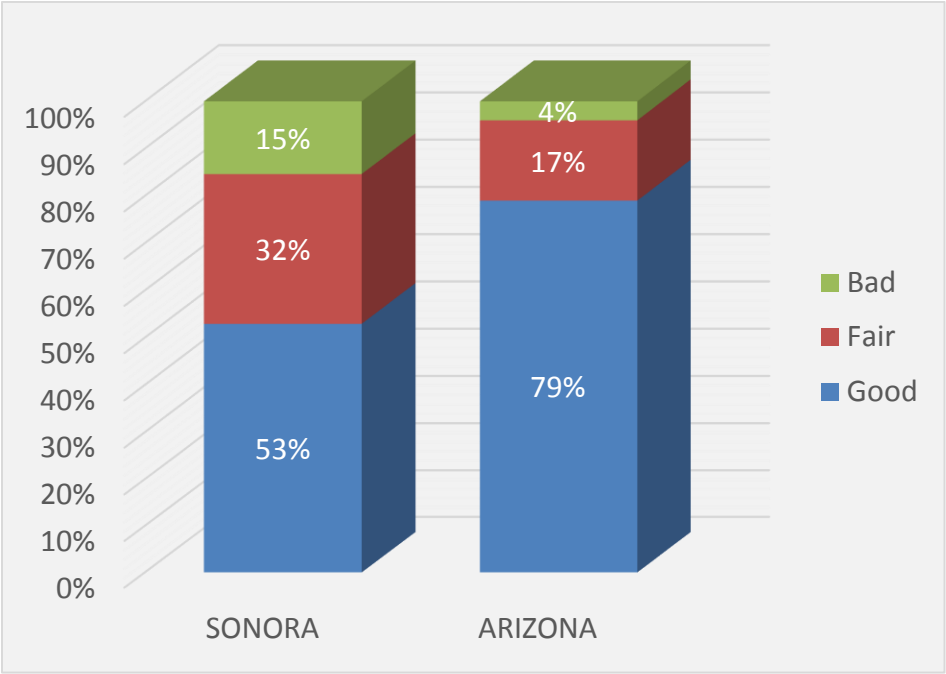


Source: Self-reported

The results show very similar scenarios in Ambos Nogales, with a positive perception. It is evident that the majority of the population in Nogales, Sonora (71%) and Nogales, Arizona (76%) perceives that the wastewater project had a positive impact on the economic development of both cities; while 29% of the respondents in Nogales, Sonora and 24% in Nogales, AZ, perceive a moderate or negative impact (see chart 37).

Regarding environmental and urban development impacts, which are the fourth and fifth dimensions analyzed in this study, similar scenarios are observed in Ambos Nogales, where the majority of the population perceives that these impacts are positive. In the case of environmental impacts, however, the differences between the two cities are significant, since 79% of the population of Nogales, Arizona perceives these impacts as positive and 21% think they are fair or negative; while, in Nogales, Sonora, the proportion was 53% and 47%, respectively (see chart 38).

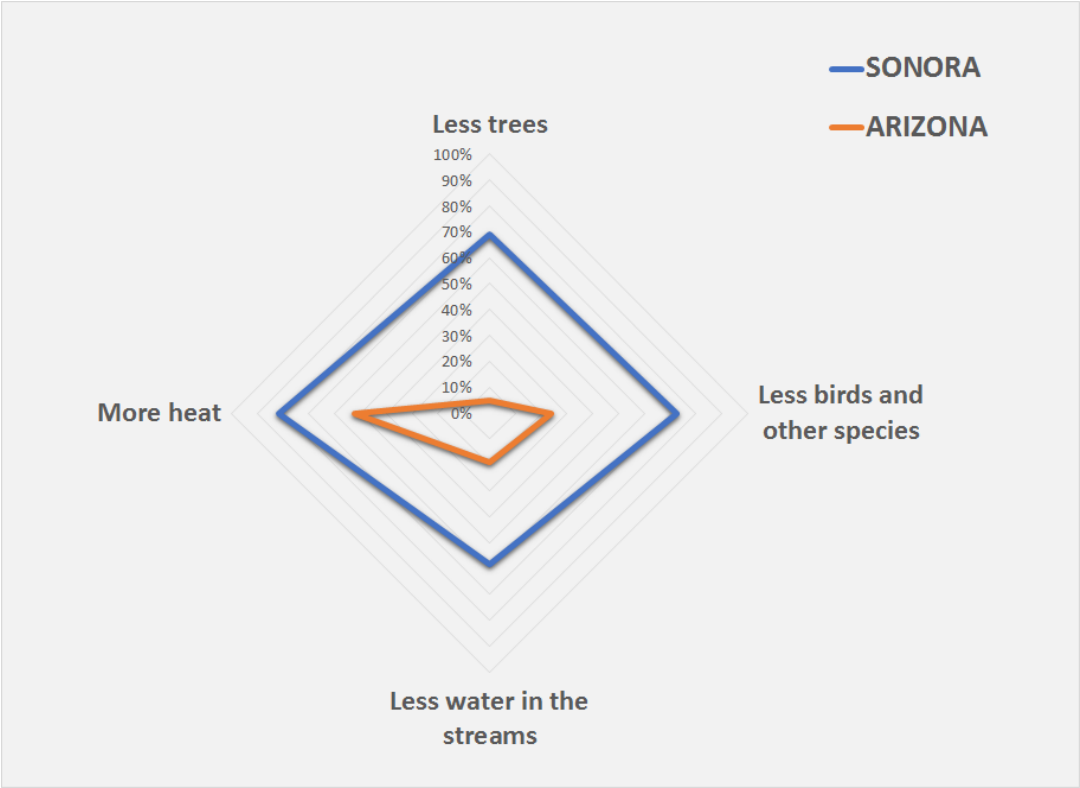
Chart 38. Impacts on the Environment



Source: Self-reported

It is appropriate to analyze the environmental aspect, since the construction of a wastewater project must be understood in a broad context of sustainability. In other words, it is inferred that the increase in wastewater collection coverage in Nogales, Sonora, as well as the increased capacity of the international outfall and the wastewater treatment plant, can generate positive environmental impacts that are reflected in enhanced local flora and fauna, primarily in areas adjacent to rivers and streams, which in turn can generate a better climate.

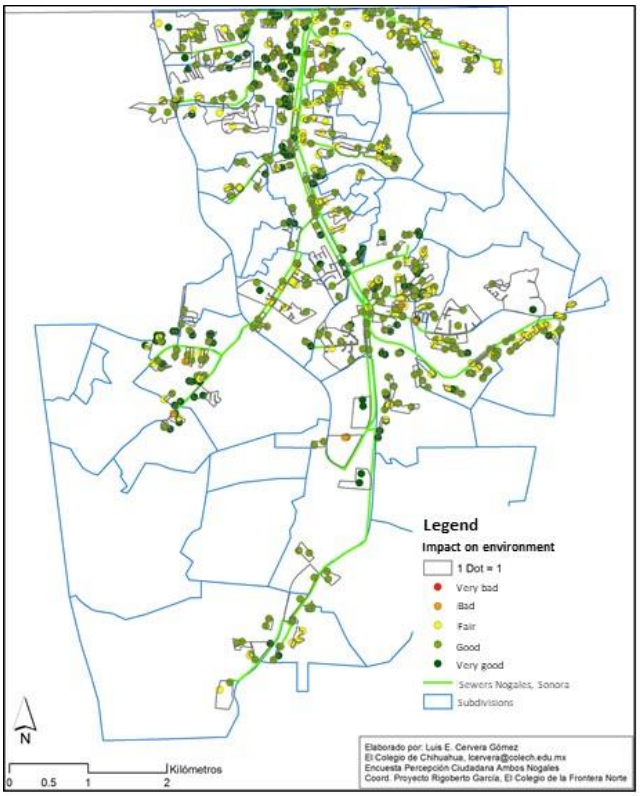
Chart 39. Main Impacts on the Environment Perceived by Residents of Ambos Nogales



Source: Self-reported

Taking into account that a significant part of the population perceives negative impacts on the environment, especially in Nogales, Sonora, the opinions gathered were investigated in more detail. Results are shown in Chart 39, and it is observed that the majority of the population of Nogales, Sonora that perceives negative impacts, believes that these impacts consist primarily of higher temperatures (81%), fewer birds (72%), fewer trees (69%) and less water in local streams (58%). In Nogales, Arizona, the situation is different, since the main perceived impact is more heat (52%), followed by fewer birds (24%), less water (19%) and to a lesser extent, fewer trees (5%).

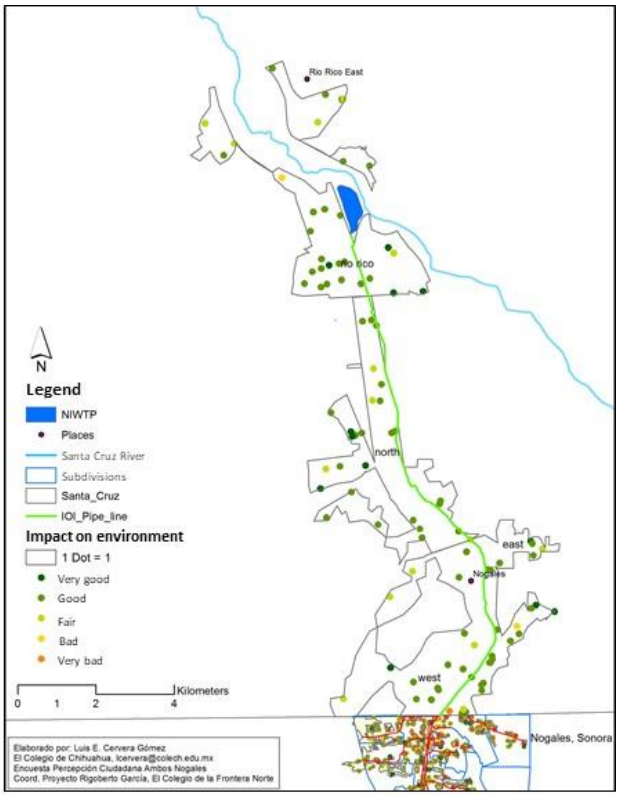
Figure 13. Impacts on the Environment in Ambos Nogales



There is a spatial differentiation in Nogales, Sonora.

In the Northeast and Northwest zones, 63% and 41% of the population, respectively, perceives regular or negative environmental impacts.

In the Southeast and Southwest zones the majority of the population (64% and 63%, respectively) perceives positive impacts.



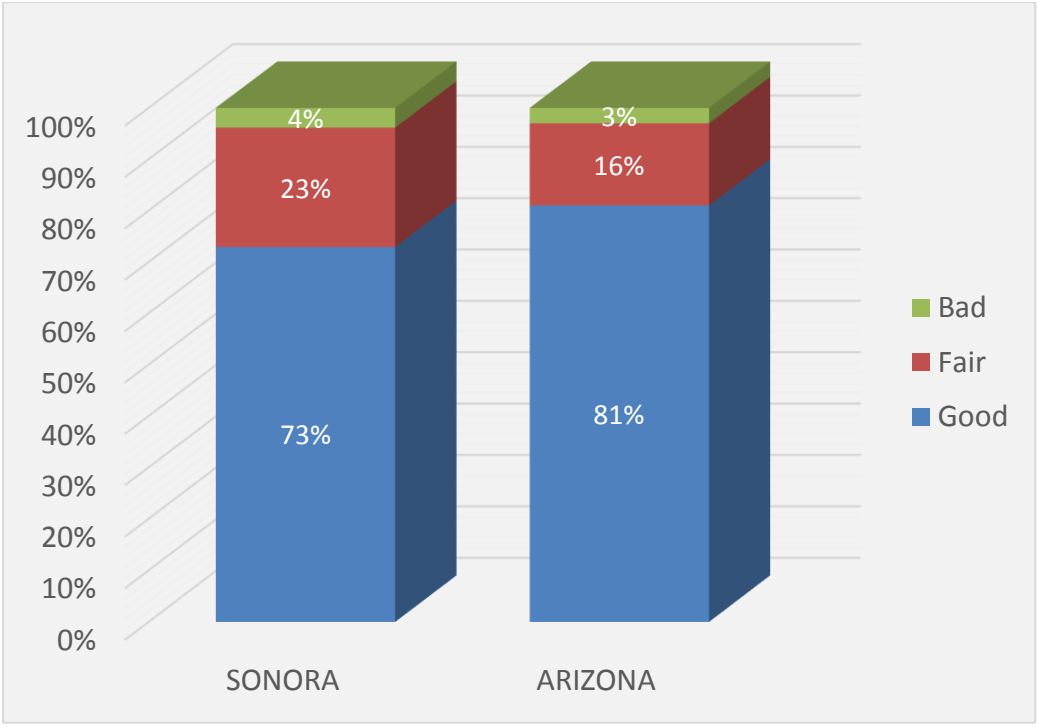
There is no spatial differentiation in Nogales, Arizona.

In all four zones the majority of the population perceives positive impacts.

However, in the West zone, a relatively significant proportion of the population (33%) perceives fair or negative environmental impacts.

On the area of urban development impacts (see Chart 40), as previously mentioned, the results are very similar in both cities. In Nogales, Sonora, 73% of the population perceives that the impacts were positive and 27% think that they were fair or negative; and in Nogales, Arizona, the results are 81% and 19%, respectively. It should be noted that the perception of positive impacts on urban development was an expected result, as the construction of wastewater infrastructure is a necessary condition to obtain a series of urban benefits that contribute to improving the quality of life and human development of local residents, such as street paving and sidewalk construction, which facilitate better intra-urban mobility, or improved street lighting, which contributes to greater safety.

Chart 40. Impact on Urban Development



Source: Self-reported

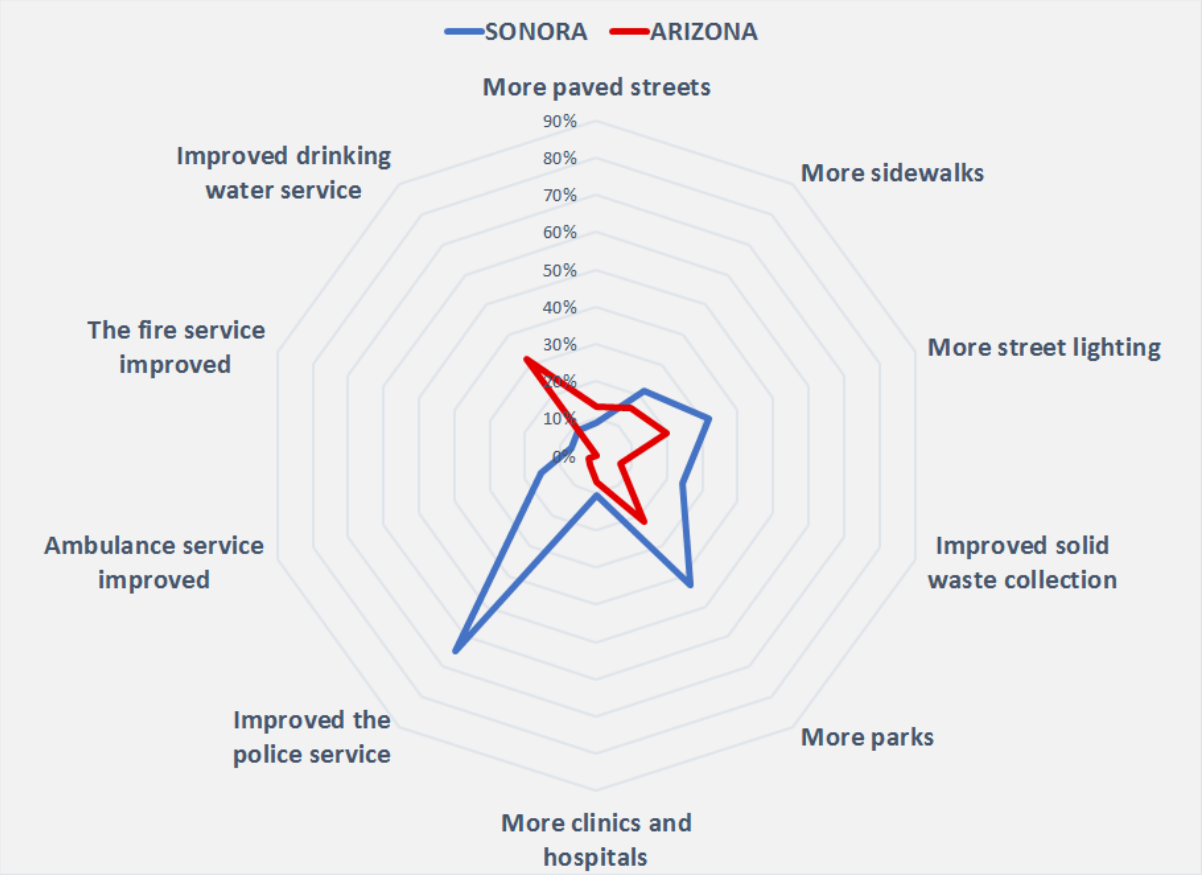
However, it stands out that approximately one fifth of the population in both cities perceives negative impacts. To better identify the reason for this situation, we proceeded to investigate which were the main negative impacts perceived by this segment of the population. The results are summarized in Chart 41. Significant differences were observed in Ambos Nogales, not only in terms of the proportion of the population that perceives the different impacts, but also in the types of impacts.

First, it was observed that, except for the operation of the fire service, the proportion of the population that perceives the different impacts in Nogales, Sonora, is greater. On the other hand, it is noticeable that in Nogales, Sonora, 81% of the people perceive that the wastewater project negatively impacted the operation of the pumping service. In this regard, the inference is that this result reflects the existence of the previously discussed issues of street flooding and the presence of mud when extreme rains occur, a situation that potentially interferes with the response time of firefighters in case of emergencies.

Additionally, the study found that the perception of the main negative impacts has to do with negative outcomes for parks, street lighting, garbage collection, and sidewalks.

In Nogales, Arizona, the main negative impact perceived is that there is less street lighting (35%), followed by negative outcomes for parks (25%), which may be linked to flooding that has occurred when the international outfall overflows. Finally, 25% of the population that perceives negative impacts considers ~~that~~ they also include the garbage collection service.

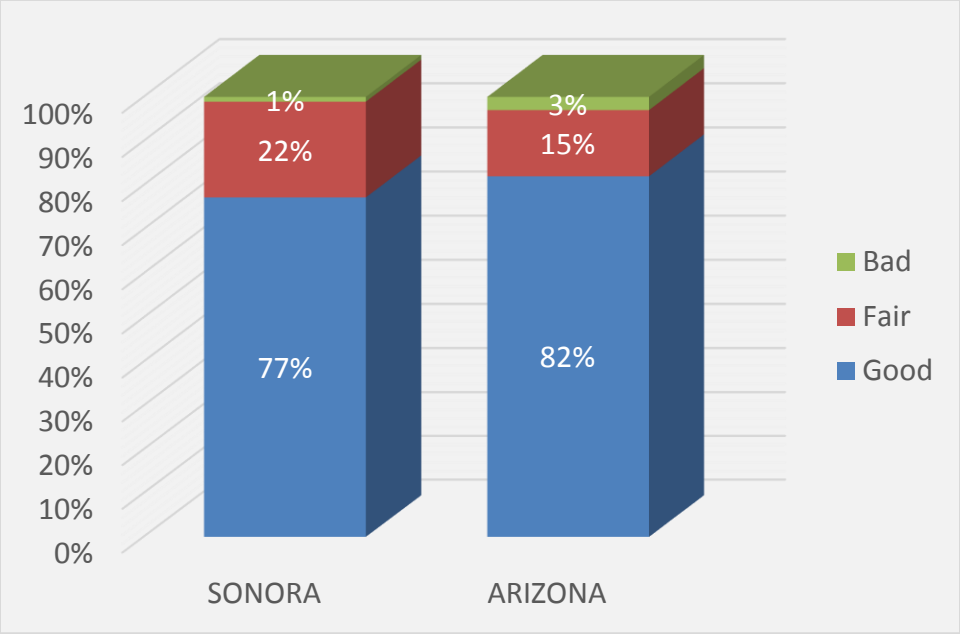
Chart 41. Main Impacts to Urban Development perceived in Ambos Nogales



Source: Self-reported

The following are the comparative results of four dimensions linked to the eminently systemic and binational operation of the wastewater system in Ambos Nogales: 5) Binational cooperation; 6) Awareness of the operation site; 7) Binational impact, 8) International cooperation and 9) Potential reuse of treated wastewater. It is appropriate to analyze them jointly, since the results obtained show inconsistencies that reflect the lack of familiarity of the population with the topic in question.

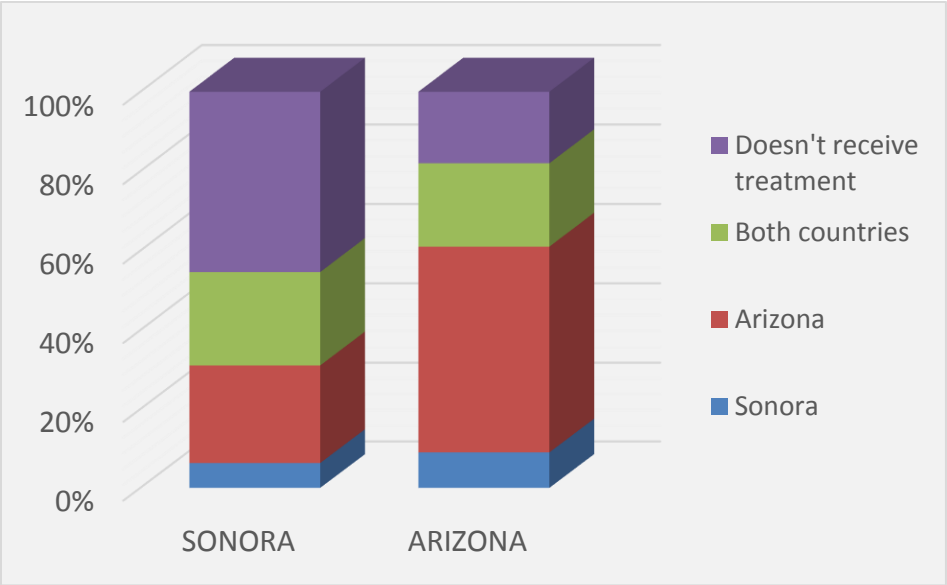
Chart 42. Impact on Binational Cooperation



Source: Self-reported

First, very similar scenarios are observed in the binational and international cooperation dimensions in Ambos Nogales. Most of the population of these twin cities thinks that the wastewater collection system (Sonora) and the wastewater treatment system (Arizona) have had positive impacts on binational cooperation, and practically all the population believes that international cooperation is necessary to protect existing water resources and their quality (Chart 42). However, there is a profound lack of awareness about the location where the wastewater treatment is carried out (Chart 43), and as to the degree of binational impact (see Chart 42).

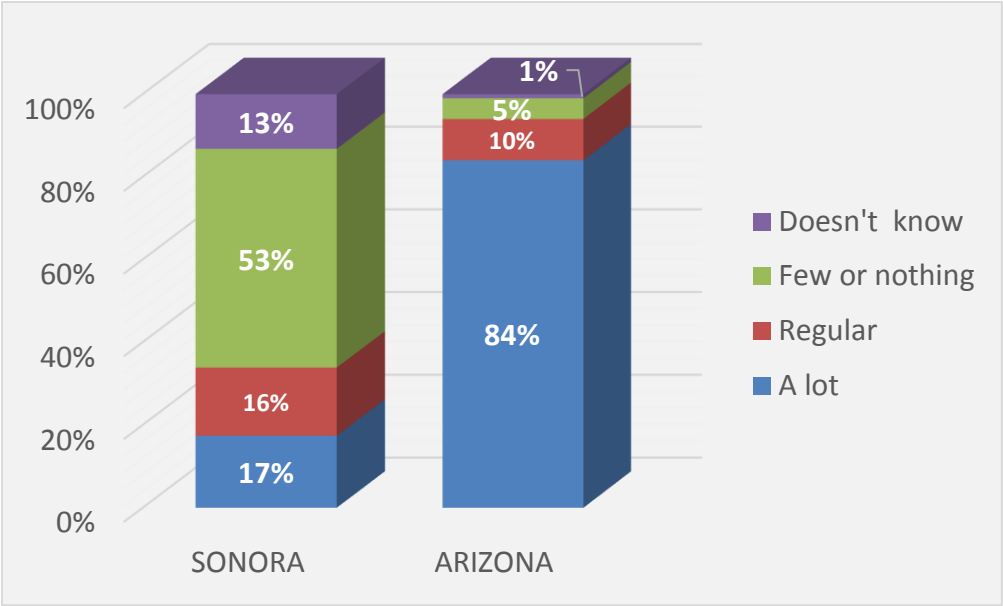
Chart 43. Wastewater Treatment Sites in Ambos Nogales



Source: Self-reported

The perceptions expressed below by the population of Ambos Nogales (Chart 43) and captured through the survey are noteworthy. For example, 45% of the population of Nogales, Sonora and 18% of the population of Nogales, Arizona think that the wastewater discharged by these cities receives no treatment at all, and only 24% in Nogales, Sonora and 21% of in Nogales, AZ responded that wastewater is treated in both cities. These results show that a substantial proportion of the population of Ambos Nogales is completely unaware of how the binational wastewater treatment system operates.

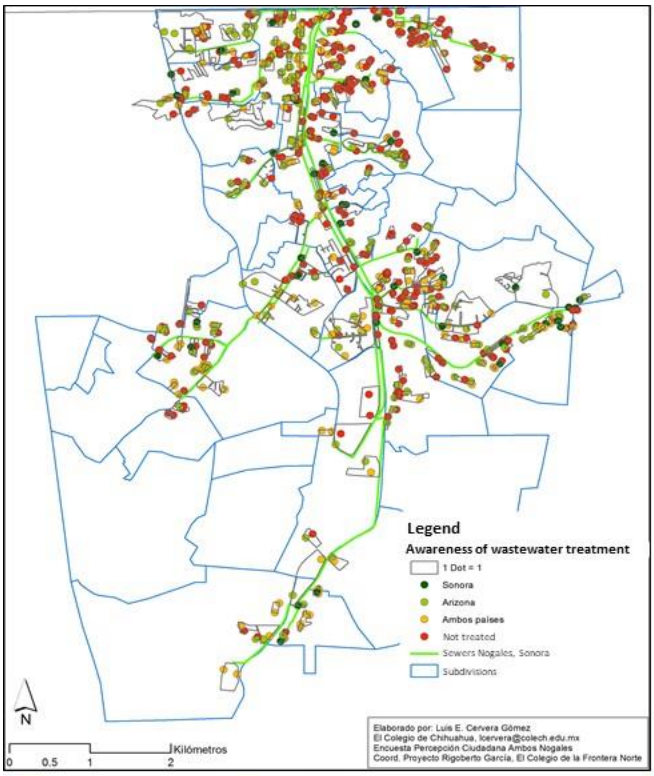
Chart 44. Perception of the Degree of Binational Impact in Ambos Nogales



Source: Self-reported

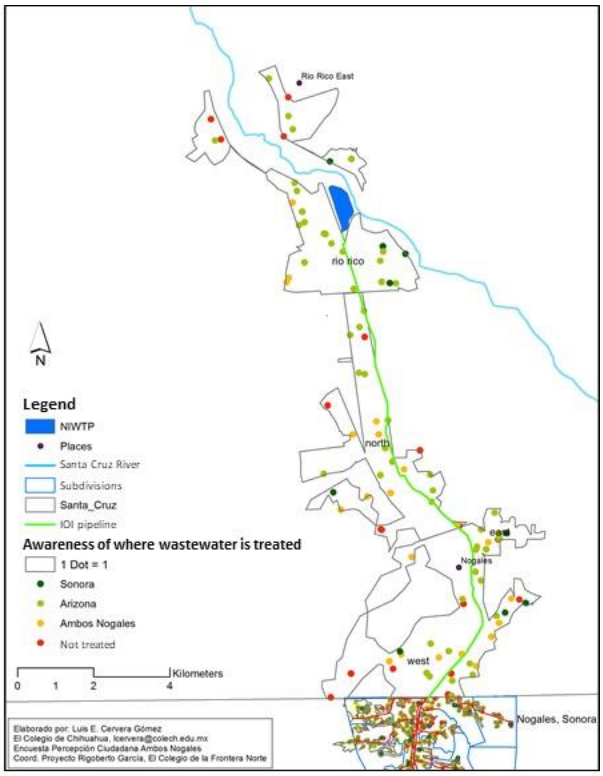
Regarding the degree of binational impact, a dimension that measures the public awareness of how the use of water by each city affects the other (see Chart 44), it is observed that most of the population of Nogales, Arizona (84%), perceives a high level of impact. However, the scenario in Nogales, Sonora is completely different, since only 17% of the population perceives a high level of impact, and 69% perceive that the impact is either moderate or null. It is evident then that most of the population of Nogales, Sonora, despite having benefited from the expansion of the wastewater treatment system, is unaware that this system operates under an eminently binational scheme.

Figure 14. Awareness of Treatment Site



There is a spatial differentiation in Nogales, Sonora.

Approximately 60% of the population living in the Northeast Zone does not know that wastewater is treated, followed by the Northeast Zone (41%), Southeast (38%) and Southwest (33%).



84% of the population of Nogales, AZ., knows where the wastewater is treated.

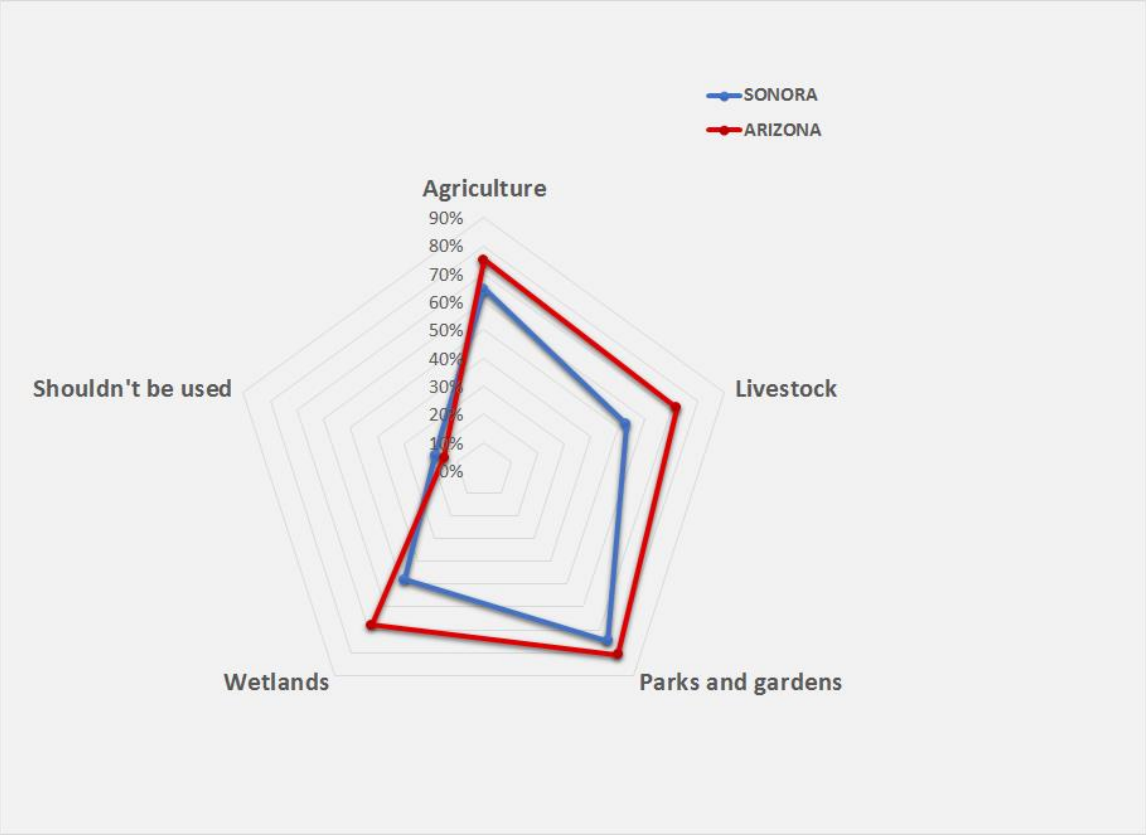
Finally, the ninth dimension analyzed is the potential reuse of treated wastewater. This issue has profound implications for the sustainable development of any city, and especially for Ambos Nogales, since the region that makes up the entire North of Mexico and the Southwestern United States is one of the regions with the greatest potential for disturbances due to the issue of global warming. It is anticipated that water stress will increase in the future, therefore, the reuse of treated wastewater is one of the most important actions that may be implemented to mitigate this type of impacts.

This means that treated wastewater can increasingly become a valuable resource, so it is crucial to analyze the potential uses of this resource in order to seek a more sustainable economic, social, environmental and urban development.

When the population of Ambos Nogales was asked what the main uses of this resource would be, the trend observed in both cities was practically identical, although the proportion of the population that supports the reuse of treated wastewater differs in the various sectors (Chart 45). In general terms, the study found that a greater proportion of the population of Nogales, Arizona supports these potential actions.

The most widely accepted option for wastewater reuse is using it for parks and green areas, since 75% of the population of Nogales, Sonora and 81% of Nogales, Arizona, support this option, followed by wastewater reuse for agriculture (65% and 75%), livestock farming (53% and 72%), and wetlands (48% and 68%). By contrast, the study found that 18% of the population of Nogales, Sonora, and 15% of Nogales, Arizona, does not support the reuse of treated wastewater.

Chart 45. Opinion on the Reuse of Treated Wastewater in Ambos Nogales



Source: Self-reported

After making a comparative analysis of the results of the public opinion survey in Ambos Nogales, the study concludes that, in general terms, the majority of the population perceives that the wastewater project was a factor that contributed to generating positive impacts on the quality of life, economic development, environmental conditions, urban development and binational

cooperation in Ambos Nogales. The scenarios observed in these dimensions, with some minor differences, were very similar in Ambos Nogales.

Furthermore, significant differences were found in the dimensions corresponding to the operation of the wastewater treatment system during the rainy season, as well as in the degree of awareness about the location of the operating system (wastewater treatment site) and the degree of binational disturbances. In all these cases, the population of Nogales, Arizona perceived more positive impacts than the population of Nogales, Sonora.

In spatial terms, significant differences were found in the perception of the operation of the wastewater system during the rainy season, the environment, and awareness of the treatment site. In Nogales, Sonora, the Northeast Area showed a mostly negative perception in these three dimensions; while in Nogales, Arizona, this negative perception was prevalent in the West area.

Input from Key Stakeholders

The third source of information used in this study to analyze the impacts of the wastewater project in Ambos Nogales, in addition to the review of secondary sources to build the baseline and the public opinion survey, was the consultation with key stakeholders who were familiar with the local context before and after the wastewater project entered into operation.

A key stakeholder is defined as a person who has thorough knowledge of the binational and transboundary nature of the wastewater collection and treatment systems and associated impacts and is familiar with the scenarios before and after the operation of said system. The information generated using this strategy is valuable, as it provides us a third viewpoint that compares the objective indicators constructed with the baseline, and the perception of the community identified through the public opinion survey.

The methodological strategy of this third option, based on what has just been mentioned, is eminently qualitative. Information was obtained through semi-structured interviews that were prepared on the basis of the following key themes: 1) Wastewater project impacts; 2) Binational cooperation; 3) Opportunities for improvement; 4) Potential wastewater reuse; 5) General opinion.

Table 12 summarizes in a sentence the opinion that each of the key stakeholders has regarding the different dimensions addressed. The main points identified through these interviews will be briefly described below.

Table 12: Summary of the Information provided by Key Stakeholders

STAKEHOLDER	KNOWLEDGE AREA	RESIDENCE	WASTEWATER PROJECT IMPACTS	BINATIONAL COOPERATION	OPPORTUNITIES FOR IMPROVEMENT	POTENTIAL WASTEWATER REUSE	GENERAL OPINION
1	Government official	AZ	Positive, especially in the area of health and environment in the region of Túbac and Tumacácori	Yes there is binational cooperation, however, Mexico has not paid its treatment fees in the last 10 years	It is necessary to increase the treatment capacity, as well as the capacity of the international collector. Greater supervision of the Mexican authorities is required since sometimes heavy metals are detected in wastewater	It is possible, but it is necessary to have a clear legal framework between Mexico and the United States.	The construction of this sanitation infrastructure work is very positive , but the issue of system maintenance must be addressed.
2	Government official	AZ	Positive in general terms, especially environmental impacts	Yes, exists cooperation, but it could be improved	Economic resources are required to improve system maintenance	The treated water has high quality, so it could be reused	Positive
3	Government official	Sonora	Very positive, especially the quality of water in Nogales, Sonora. The work led to greater social development as drainage coverage was significantly expanded	Yes, there is binational cooperation, especially when extreme rain events occur. However, the relationship is not equitable since treated Mexican water is used in Arizona.	The current pumping system can be improved to import water from the Santa Cruz basin to the Alisos basin. By this way Nogales, Sonora could take advantage of its treated wastewater	There are conditions for reuse in the agricultural sector, for irrigation of parks and gardens, as well as the creation of wetlands in the immediate vicinity of the Alisos treatment plant	Positive
4	Business Sector	AZ	Very positive, mainly in the Santa Cruz River north of Rio Rico, as bird tourism has proliferated. There are also negative impacts on the same river in the Nogales area	Yes, there is binational cooperation, but it can be substantially improved if a watershed approach is applied	Mexico must improve its infrastructure, since in extreme rain events, serious problems occur that affects both cities. The people of Rio Rico and Tumacácori could contribute to the maintenance and expansion of the system	Mexico has the right to reuse its waters, however such an action would imply a high energy cost that would negatively impact the environment, specifically to the North of Rio Rico	Positive, but with a great opportunity to improve the bi-national sanitation system
5	Business Sector	SON	The Wastewater treatment project has generated positive impact. The wastewater collection coverage has been improved	Binational cooperation does exist but must be improved	Nogales, Sonora has the necessary conditions to take advantage of a greater volume of water. It is required to build a system of dams and dikes to mitigate floods in the rainy season	The treated wastewater can be reused for irrigation of parks and green areas	Positive impacts
6	Business Sector	SON	The main positive impacts are social and environmental, but there are also serious negative impacts in the rainy season	He did not comment on this subject	There should be greater control of the government authorities about the wastewater discharged by the maquiladora industry. Nogales, Sonora can reuse its wastewater. The energy cost of the five pumping stations for importing this resource to " Los Alisos facility " is offset by greater water availability	The treated wastewater can be reused for crop irrigation	Positive impacts
7	Government official	AZ	Lack of feedback from IWBC Mexico when complaints of untreated sewage from Sonora arise; they are supposed to contact them. The chlorination of the Nogales stream by Mexico is problematic for environmental reasons.	Mexico has a debt of one million dollars to Nogales, Arizona for treatment costs from January 2017 to June 2018	Water users (consumers) in Nogales, Arizona should not pay for the Mexican wastewater treatment	Selling treated wastewater could be a possibility, as well as charging the cost to property owners along the Santa Cruz River for treated wastewater	Positive, if the IBWC Mexico fulfills its role to ensure fair financing of the WWTP and prevention of stream and water pollution

Source: Self-reported

Wastewater Treatment Project Impacts

Most stakeholders have a positive opinion about the impacts of the wastewater treatment project. In general terms, the study found that key stakeholders recognize that this wastewater project contributed to the sustainable development of Ambos Nogales, especially as to environmental issues, and to social welfare. Only one of the stakeholders (number seven), though recognizing the positive impacts of the wastewater project, emphasized that better communication between the authorities of both countries is needed to improve wastewater chlorination in the Nogales Wash, which is considered a serious environmental issue.

Binational Cooperation

On the issue of binational cooperation, all stakeholders consistently expressed that cooperation does exist but must be improved. On the U.S. side, both the first and the seventh stakeholders expressed their disagreement over the failure of Mexican agencies to pay for wastewater services and stated that debt amounts to approximately one million dollars. That is, these stakeholders made it clear that Mexico has not honored the commitments undertaken during the negotiations to build and operate the Rio Rico WWTP (See Background section). According to them, compliance with these agreements is necessary to improve binational cooperation. Conversely, on the Mexican side, the third stakeholder criticized that the Mexican wastewater treated in the WWTP is used in Arizona and stated that this situation must be addressed to improve binational cooperation.

Opportunities for Improvement

The third issue addressed in the interviews with key stakeholders was the identification of opportunities for improvement. It should be noted that this was the topic that drew the greatest degree of participation by the different stakeholders. Four major opportunities for improvement were identified.

The first opportunity, as noted by the first and second stakeholders (both from the U.S.), has to do with improving the operation and maintenance of the WWTP, for which they propose increasing the treatment capacity, improving maintenance practices in the facility, and improving oversight by the Mexican authorities, so that the wastewater of Nogales, Sonora can meet the minimum standards for heavy metals.

The second opportunity involves the potential for the reuse of treated wastewater by the Mexican agencies. The third, fifth and sixth stakeholders (all three from Mexico) clearly stated that treated wastewater is a valuable resource that can be used to improve water availability in Nogales, Sonora.

The third stakeholder proposed to reactivate the current pumping system in Nogales, Sonora, which sends approximately 80 liters per second of wastewater to the Los Alisos plant located south of the city. It should be noted that this system currently operates using only one pumping unit, while the complete system would use five pumping units.

The fifth stakeholder expressed an opinion very similar to that of the U.S. stakeholder, stating that Nogales has the necessary conditions to maximize the use of treated wastewater, and even proposed building a new wastewater treatment plant in the vicinity of the international boundary for this purpose.

The sixth stakeholder supported the idea of reactivating the current pumping system, ensuring that the cost of the energy needed for this pumping system to operate at maximum capacity (using the five pumping units) would be offset by the greater availability of water for the city.

The third opportunity has to do with the need for Mexican agencies to improve the water and wastewater infrastructure in Nogales, Sonora to mitigate the negative effects resulting from extreme rain events, since the city's stormwater system usually collapses, and this situation could affect people's health. Additionally, infrastructure improvements should help to contain the excess volumes of water that enter Nogales, Arizona when these events occur. It should be noted that practically all stakeholders identified this problem as an area of opportunity to improve the binational wastewater treatment system.

Finally, the third and seventh stakeholders highlighted that the population of Ambos Nogales has failed to leverage the significant environmental benefits produced by the wastewater project. These stakeholders pointed out that these benefits have improved the area north of the WWTP, mainly in Tumacacori and Rio Rico, a situation that has advanced different economic sectors, especially birdwatching tourism and the lodging services sector. Both stakeholders mentioned that agencies in Tumacacori and Rio Rico should contribute financially to improve the operation and maintenance of the binational wastewater treatment system.

Wastewater Reuse

Regarding the potential reuse of treated wastewater, all stakeholders said that wastewater is a valuable resource that should be reused for different purposes, whether in the agricultural sector, for the irrigation of parks and green areas, or for the creation of artificial wetlands. The first stakeholder warned that, in order to maximize the use of this resource, the existing regulatory and legal framework needs to be improved and updated, as the international management of treated wastewater is a complex issue.

Finally, all the stakeholders believe that the Ambos Nogales wastewater collection and treatment project has generated positive impacts in the region, i.e., their opinion is eminently favorable. However, the stakeholders also mentioned, in some way and with different degrees of relevance, a series of critical points that they have observed since the system became operational.

These points have to do with improving communication between the authorities of both countries; the lack of full compliance of the financial commitments undertaken for the operation of the WWTP by the Mexican authorities; the existing perception about the permissible level of local pollutants (mainly heavy metals) in Nogales, Sonora wastewater.

The perception of key Mexican stakeholders about the use of Mexico´s wastewater in Arizona; the potential use of wastewater in Nogales, Sonora, as well as the need to invest in infrastructure to pump and convey wastewater to the Los Alisos facility; the need to consider various mechanisms in order to improve the operation and maintenance of the binational wastewater system; as well as the potential reuse of treated wastewater in various economic sectors, or for the irrigation of parks and green areas[sic].

Summary

The comparison exercise carried out in this section provides a binational vision –appropriate for the sister cities– of the impacts generated by the construction and operation of the wastewater project in Ambos Nogales.

Upon comparing the socioeconomic indicators, substantive differences were found between the two sister cities. Nogales, Sonora is a city with a younger population than its Arizona counterpart. Additionally, significant differences were also found in the level of education, since Nogales, Arizona has a significantly higher proportion of population with high school, professional and postgraduate education levels than Nogales, Sonora.

The types of housing is a variable that significantly differentiates both cities, since Nogales, Sonora is mainly characterized by having single family homes and, although most of the houses in Nogales, Arizona are of this type, the difference is that this city has a high proportion of apartments and condominiums. Finally, no significant differences were observed between the two cities in the rest of the socioeconomic variables.

A future study effort could be undertaken to analyze the potential relationship between the differences in the socioeconomic conditions found in Ambos Nogales and the public perception of the impacts produced by the wastewater project. In this regard, three main trends were identified in the perception of these impacts. The first one reflects that the majority of the population perceives that the wastewater project produced positive impacts in all the dimensions analyzed. The second has to do with a homogeneous scenario, with very few differences in the perception of how the project improved the quality of life and the economic and urban development of both cities, as well as binational cooperation. Conversely, the third trend shows that there are significant differences in the perception of the impacts on the operation of the wastewater system, the environment and the level of awareness of the location of the binational wastewater treatment system.

Finally, all stakeholders provided input indicating that the wastewater project generated positive impacts for the community of Ambos Nogales, although they highlighted a number of critical points that should be addressed promptly and that reflect tension between the public and the authorities of both cities regarding binational communication, the non-compliance with financial commitments undertaken for the operation of the system, the potential reuse of treated wastewater, the potential use by Nogales, Sonora of a greater volume (or even the totality) of the wastewater, the environmental impacts generated outside the Ambos Nogales area, as well as the need to improve the comprehensive maintenance of the binational wastewater system.

CONCLUSIONS: TOWARDS A BINATIONAL VISION

Introduction

Based on the conceptual and contextual framework applied in this study, this section describes the main conclusions drawn, which are related to the management and operation of the wastewater treatment system in Ambos Nogales, which requires a binational and transboundary vision, both by the general public and by the main stakeholders and agencies involved in the issue. The analysis of the impacts produced by the wastewater collection and treatment infrastructure projects in Ambos Nogales, through the four components considered in the previous section, as well as the results of the public opinion survey and interviews with key stakeholders, prompts a reflection that is constructed with five themes or main pillars, as explained below.

Positive and Differentiated Impacts on the Sister Cities

First, as to the baseline indicators built for the infrastructure, socioeconomic development, urban development and health components, it was found that most of these indicators evolved positively during the periods before and after the construction of the wastewater collection and treatment infrastructure. However, there were significant differences in both cities, since the social and economic conditions, as well as the levels of urban development of the two cities, were significantly different before the construction of the NADB-funded wastewater collection and treatment infrastructure project.

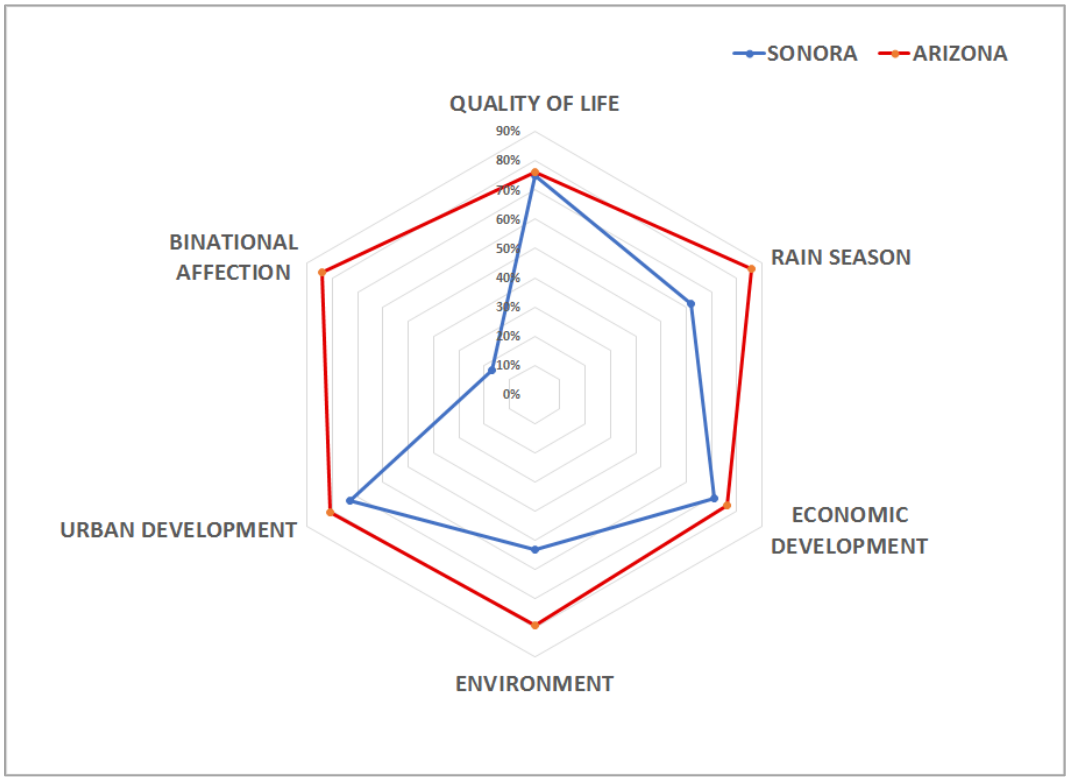
- Nogales, Sonora improved significantly, since the wastewater collection project implemented in 2004 helped to increase wastewater infrastructure coverage from 88% to 99% between 2005 and 2015, thus achieving almost total coverage. This scenario led to better living conditions for the population, since by having this type of basic infrastructure, conditions were created to improve the city's economy (maquiladora industry, businesses and services), urban development and residents´ health.

- In Nogales, Arizona, at the beginning of the period under review, the conditions evaluated for the four components considered were better than those of its Mexican twin city, except for the issue of uncontrolled raw wastewater overflows coming from Sonora. Therefore, none of the sectors reported changes in evolution as significant as those on the Mexican side.

Thus, when considering these sister cities as a system, it is clear that it is a heterogeneous and differentiated system because the cities belong to two countries with marked economic, social,

cultural and political disparities. This idea of positive but differentiated impacts can be seen more clearly when analyzing the results of the public opinion survey (Chart 46).

Chart 46. Comparison of the Public Perception of the Impact of the Wastewater Projects on Ambos Nogales



Source: Self-reported

In general terms, the results obtained regarding quality of life, economic development and urban development are similar in the two sister cities. However, significant differences were observed in the perceived impact on the environment during the rainy season and, above all, on the binational connection and influence of the wastewater treatment system.

As to the perceived impact during the rainy season, it was observed that 62% of the population of Nogales, Sonora thinks that the wastewater collection and treatment project had a good impact; while in Nogales, Arizona, the percentage is even higher, as 86% of the population thinks the impact is good.

This result is consistent with what was expressed by the key stakeholders interviewed in both cities. The slightly less positive perception of the Nogales, Sonora population, (62%) is due in part to the fact that the city experiences serious floods during the rainy season because the excess water collected causes the collapse of the wastewater collection system implemented with the NADB project. This situation impacts the population that lives along roadways that literally become arroyos when this condition occurs, but it does not affect the entire city. Hence, the result obtained in the public opinion survey is consistent with this situation.

Regarding the environmental impacts, significant differences were found between both cities. Almost half of the population of Nogales, Sonora perceives that the wastewater project has produced negative impacts on the environment. Although this result seems paradoxical and contradictory, the key stakeholders interviewed pointed out that the public has this perception due to the flood issues discussed above. Disturbances to the flora and fauna resulting from the floods seems to be a logical reason to infer why this result was obtained.

As mentioned above, the point where the greatest differences were found was binational connection and influence. It is noteworthy that only 44% of the population of Nogales, Sonora perceives that the city´s wastewater collection system is linked to the Nogales, Arizona wastewater treatment system. There is great unawareness about the way in which the binational wastewater treatment system works. In the case of Nogales, Arizona, by contrast, the vast majority of the population perceives a strong connection between the two systems.

Main Environmental and Economic Impacts

One of the most remarkable findings of this study was the environmental and economic impact generated by the wastewater collection and treatment projects in an area removed from the sister cities that comprise the area of influence of Ambos Nogales. This more explicitly identified environmental impact has been observed in the towns located north of Rio Rico, following the path of the Santa Cruz River, primarily in the communities of Tumacacori and Tubac.

Based on comments made by key stakeholders in Nogales Arizona, as well as on field visits conducted by the research team along the Santa Cruz River, in the stretch of river that runs along the international boundary and the community of Tubac, Arizona, the team identified the economic and environmental significance of Mexican wastewater treated in Arizona.

In the section [of the river] that goes from the international boundary to the Rio Rico WWTP, the Santa Cruz River runs completely dry during most of the year. Only during the rainy season, there are days when the river carries a considerable volume of water. This situation has negatively impacted the local ecosystem, as many trees and flowers in general have dried up on that path.

Conversely, to the north of Rio Rico, just after the site where WWTP discharges the treated wastewater, the picture changes radically. From this point on, the Santa Cruz River carries a considerable volume of water (between 500 and 950 liters per second, depending on the time of day and time of the year), of which 90% is water that comes from Mexico.

Figure 15. Environmental Impact of the Rio Rico WWTP

This means that the environmental benefits, reflected on the ecosystem located along the area of the Santa Cruz River north of Rio Rico, are the result (for the most part) of Mexico's wastewater.

The benefits to the ecosystem of the above area are extremely valuable. Every year, millions of songbirds migrate from their wintering grounds in Mexico and Central America to their summer breeding habitats in Canada and the northern United States. In particular, they move along the Bravo, Colorado, Santa Cruz and San Pedro rivers. In the case of the Santa Cruz River, this generates significant tourist activity, which produces around US $21 million dollars annually.

The public perceives that Nogales, Arizona does not benefit from this revenue generated by birdwatching tourism, which in turn results from the presence of wastewater from Ambos Nogales. The topic has gained notoriety since, in the social imaginary of the community of Nogales, Arizona, the beneficiary communities (mainly Tubac and Tumacacori) do not contribute anything to the maintenance and operation of the WWTP, however, they obtain financial and environmental benefits from the wastewater treated at this facility.

Need for an Outreach Strategy

While it is true that the NADB does not have the explicit mandatory responsibility of promoting among the beneficiaries of its projects a better understanding of the binational efforts it makes on the U.S.-Mexico border, there is a critical window of opportunity for establishing an institutional policy that would advance this function, at least in its area of jurisdiction.

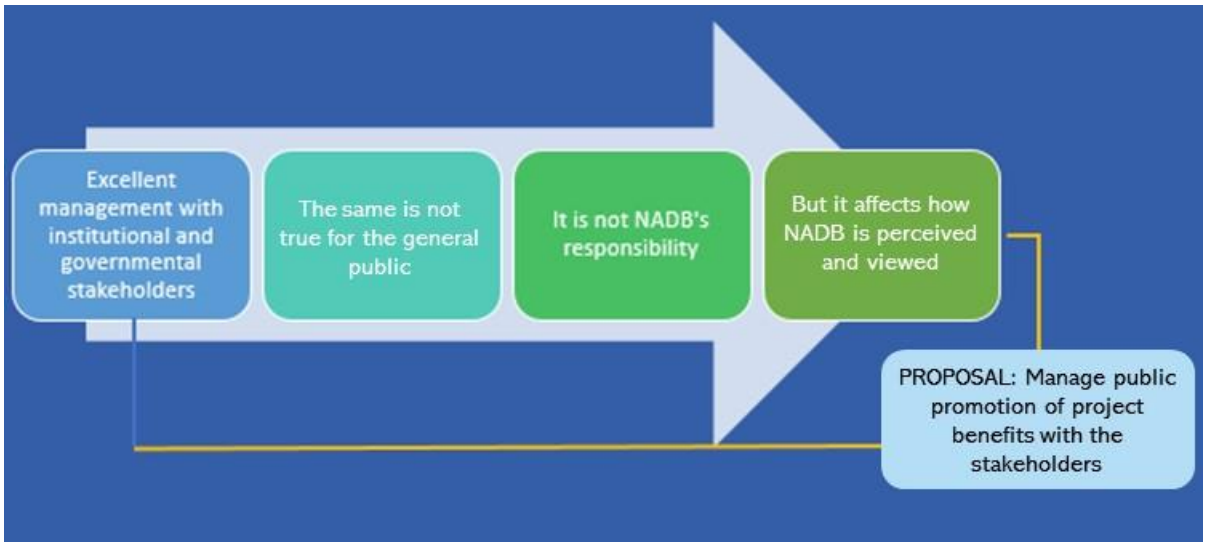
There are two issues in Ambos Nogales that deserve to be addressed, as pointed out in the above comments. The first is the remarkable unawareness of most of the population of Nogales, Sonora regarding the binational or transboundary operation of the wastewater treatment system. The second is the perception of almost half of the city residents regarding the unfounded negative impacts generated by the wastewater system during the rainy season on the environment and urban development.

First, unawareness of the inherently binational and systemic operation of the wastewater treatment system also implies unawareness of the different strategies that could be implemented to ensure the optimal operation of the system, and above all, their economic cost. Wastewater management will be increasingly important in the future in the face of the issue of water stress in the region, so Mexican authorities will most likely have to assess different strategies to maximize the use of a resource that belongs to Mexico and that, at present, is largely unexploited.

The second issue, which has to do with the public perception of unfounded negative environmental impacts, can also be explained by the public´s unawareness of the lack of adequate infrastructure in Nogales, SON, to maximize the use of excess water collected during the rainy season. As the key stakeholders interviewed consistently mentioned, this has to do with the fact that the population associates these infrastructure problems with the environmental impacts observed. That is, the wastewater collection system was improved, more streets were paved, more businesses were established, the overall quality of life improved, but the collapse of the wastewater collection system due to the lack of stormwater infrastructure brings about environmental damages.

In this regard, NADB took significant steps with institutional and governmental stakeholders at all levels to address a critical environmental issue—the treatment and conveyance of wastewater in Ambos Nogales. However, it also seems clear that the benefits and impacts generated by these projects are not perceived equally on either side of the border, especially with regard to binational connection and environmental benefits. Although this situation is not the responsibility of the NADB, it would be necessary to critically question the fact that the population of Nogales, Sonora is unaware of the operation of a system so crucial for urban sustainability as is the management of treated wastewater.

Figure 16. Proposed Actions to Improve Infrastructure Project Outreach



To address this lack of awareness on the part of residents of Nogales, Sonora and, considering the importance of implementing wastewater projects of this nature to advance the social development and well-being of the population, an outreach strategy needs to be implemented to communicate the scope and limitations of this type of projects. For this purpose, it would be appropriate for the municipal authorities of Ambos Nogales to jointly implement such a strategy.

Additional Infrastructure Projects

According to some of the key stakeholders interviewed in Mexico, the Ambos Nogales wastewater system requires additional large-scale projects to optimize its operation.

Five additional infrastructure projects are proposed:

1) Dikes and reservoirs
2) Artificial wetlands
3) Rehabilitation of arroyos in Nogales, Sonora and green infrastructure
4) Implementation of renewable energy for the operation of the WWTP

Dikes and Reservoirs

As mentioned earlier, the city of Nogales, Sonora faces serious problems when heavy rains occur, as large volumes of water enter the wastewater system, causing its collapse. In connection with this, one of the projects that for many years has been considered as a solution to this problem, is the construction of a system of levees and dams to contain excess water during the rainy season.

The preliminary design of this project was completed in 2008 and included two reservoirs and 10 flood-retaining dikes, all positioned in strategic locations. Although four flood-retaining dikes have been built to date, the opinion of the key stakeholders interviewed is that these dikes were not built in the proposed sites, due, among other things, to the refusal by people who had settled in these locations illegally. Thus, the original location of these projects was changed, a situation that affected the goal established in each case, since the places where the projects were built were not optimal for retaining the largest volume of water.

The key stakeholders mentioned that this project is critical to control the wastewater flowing from Ambos Nogales, but in order to achieve the established goals, the project must adhere to the original location proposed for all dams and reservoirs.

Artificial Wetlands

Another infrastructure project proposed by some of the key stakeholders interviewed is the construction of artificial wetlands in the area adjacent to the Los Alisos WWTP. This project would be directly linked to a project (expensive but feasible) to maximize the use of wastewater from Nogales, Sonora, that is currently conveyed to Arizona. This would be achieved by diverting wastewater from its original course to the Los Alisos WWTP.

In this regard, artificial wetlands could help Nogales, Sonora to use wastewater for the benefit of local residents. Artificial wetlands can be used to treat wastewater from urban communities under a decentralized and small-scale scheme. Treated wastewater can be used in nearby facilities for green areas such as parks that fight urban heat islands.

Rehabilitation of Arroyos in Nogales, Sonora and Green Infrastructure

In addition to artificial wetlands along the Nogales Wash, another infrastructure project has been proposed for Nogales, Arizona –the rehabilitation of arroyos in Nogales, Sonora–. It is inferred that many of the binational issues that impact these sister cities exist because streets in Nogales, Sonora were laid out and paved above existing arroyos. Although these arroyos are dry most of the time, during the storm season, they carry quite a bit of runoff. As they have been paved over, arroyos behave differently than they would be in their natural state, so that runoff is more abundant, faster, stronger, and more dangerous.

As previously described, the paving of arroyos or streets in Nogales, Sonora, causes frequent flooding. Open drainage sewers and uncovered manholes cause a number of complications on the other side of the border.

However, a strategy that is being submitted for consideration –although more drastic and radical– is to redesign the streets of Nogales, Sonora, which were drawn over the arroyos, so that they become hybrid streets. Under this proposal, sections of each street (1-2 lanes) would operate as what they are: arroyos. This way, streets would run alongside the arroyos, allowing for the infiltration of runoff, the natural retention of sediments, and an environmentally-friendly operation in general. These arroyos/streets would have trees and plants to help slow down the runoff and therefore, the number of fatal accidents in the city. Also, this strategy would support the beautification of the city, which is estimated to significantly improve the quality of life of local residents. The greening of the city would also help reduce heat and adapt to climate change. NADB has strongly promoted this type of green infrastructure. Nogales, Sonora would be a suitable location to promote these projects that are well-known in Arizona, where NADB a few years ago promoted a related pilot project and symposium.

Implementation of renewable energy for the operation of the WWTP

According to key stakeholders interviewed on the U.S. side, 60% of the WWTP´s operating costs are for energy. This makes the overall operating costs high and the payments of both sister cities for the use of the WWTP difficult to cover. An infrastructure project focused on solving this issue is needed.

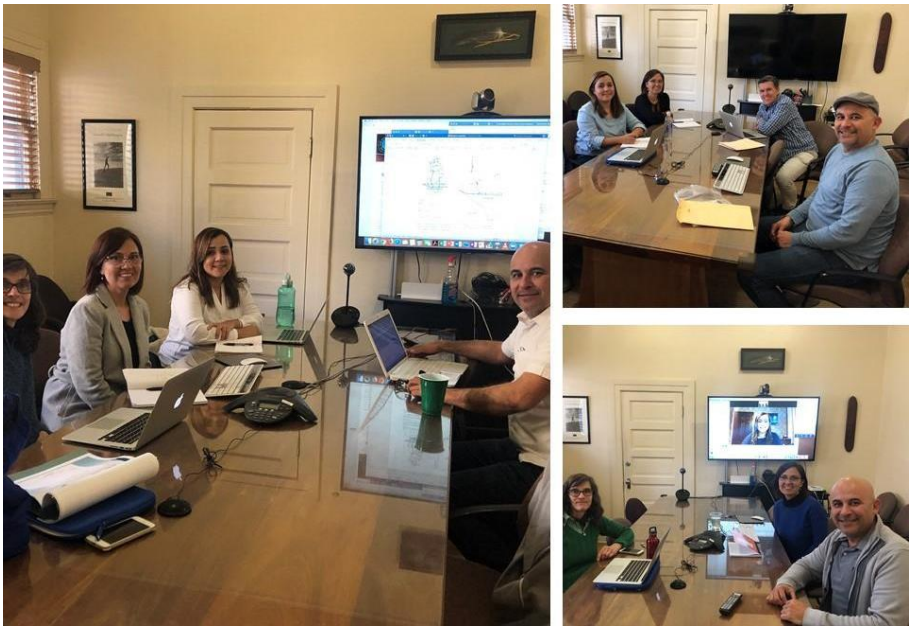
A suggestion has been made to install photovoltaic solar panels on buildings and land adjacent to the WWTP. The panels can lower the costs of the energy required for water treatment and the operation of WWTP buildings. Instead of having to pay the electricity network for their energy, the project would have its own energy source. The entire WWTP project would be more sustainable because the energy would come from a renewable source that does not release carbon to the atmosphere.

Final Comments

The sister cities of Nogales Sonora and Nogales, Arizona have a very close relationship in terms of hydrology and the management of water resources. Therefore, binational cooperation at the local level is a necessity and has advanced the shared management of wastewater treatment infrastructure throughout the cities´ history. However, there is still a long road ahead.

NADB finances binational-level projects for these wastewater collection and treatment infrastructure systems. However, demographic and economic growth prospects in Ambos Nogales, as well as the projected effects of climate change that impact the region (e.g., more frequent and intense storms), are creating new challenges that complicate the operation and maintenance of the existing infrastructure... Efforts must continue.

Figure 17. Work Team Meetings



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APPENDIX 1

PUBLIC PERCEPTION SURVEY

GENERAL INFORMATION

The purpose of this survey is to capture the public's perception of the impacts that have resulted from the construction of wastewater collection lines in Nogales, SON, and from the implementation of the wastewater treatment plant in Rio Rico, AZ.

Questionnaire Number		
Address		
Date (dd/mm/yr)		
Socioeconomic level	( ) High ( ) Medium ( ) Low	
F1: Respondent´s age	_____ years old *** (If 20 >, continue the interview)**	
F2: Length of residence in area	_____ years *** (If 15 years or more in Sonora or 10 years or more in Arizona, continue the interview)**	
Location	Subdivision:	Geostatistical code:

Address	
Main street	
Nearest cross street	
Street and Apt. number	
Zip code	

Contact: For any questions or clarifications related to the study and/or questionnaire, please contact: [Insert contact]

SECTION I: RESPONDENT AND HOUSEHOLD INFORMATION

1. Sex	a. Male ( ) b. Female ( )
2. Age	a. 18-20 ( ) b. 30s ( ) c. 40s ( ) d. 50s ( ) e. 60s ( ) f. 70s or older ( )
3. Education	a. Elementary ( ) Middle School ( ) b. High School ( ) c. College ( )
4. Total number of people regularly living in the house	1 ( ) b. 2 to 4 ( ) c. 5 or more ( )

5. Number of years living in the subdivision	a. De 1 a 5 ( ) b. De 6 a 10 ( )	c. De 16 or more ( )
6. Type of housing unit	a. _____ House on single plot (single family home) b. _____ House on shared plot c. _____ Duplex house d. _____ Condominium/Apartment (multi-housing unit) e. _____ Mobile home f. _____ Rooftop room g. _____ Non-residential property h. _____ Shelter i. _____ Other (Specify):_____	

SECTION II: GENERAL HOUSING DATA

7. What type of property is the place where you live?	___ Own land/house ___ Rented land/house ___ Other; specify:
8. Is your home connected to the municipal WASTEWATER COLLECTION (sewage) system?	Circle the answer: ( ) Yes ( ) No ( ) Does not know
If yes, since when?	( ) < 1 year ( ) 1 to 3 years ( ) > 3 years
¿If no, does it have a septic tank?	( ) Yes ( ) No ( ) Does not know
¿If no, does it have a latrine?	( ) Yes ( ) No ( ) Does not know
¿Does it discharge to the street?	( ) Yes ( ) No ( ) Does not know

SECTION III. IMPACTS ON THE QUALITY OF LIFE

9. Are you aware of the existence of a wastewater treatment plant in Nogales, Sonora?
   a. ___ Yes
   b. ___ No

10. How much do you think the quality of life in your neighborhood has improved as a result of the wastewater treatment plant (in Arizona) and the wastewater collection system (in Sonora)?
    c. ___ Significantly improved
    d. ___ Somewhat improved
    a. ___ Remains the same
    b. ___ Somewhat worsened
    c. ___ Significantly worsened

    Explain: _____

PUBLIC HEALTH

11. As a result of the construction of the wastewater collection system in Nogales, Sonora in 2004 and the treatment plant in Rio Rico, Arizona in 2009, have you or some of the members of your family experienced a decrease in the following diseases? (Select all applicable answers).
    a. ___ Stomach aches or pains (diarrhea, nausea, vomiting)
    b. ___ Stomach infections such as salmonella, cholera, dysentery, or H. pylori,
    c. ___ Hepatitis A or E
    d. ___ Typhoid
    e. ___ Polio
    f. ___ Amebiasis/ worms / intestinal nematodes
    g. ___ Anemia
    h. ___ Skin problems (rash or hives, dryness, itching, or irritation)
    i. ___ Other. Specify: _____
    j. ___ No change in health condition
    k. ___ Does not know

WATER MANAGEMENT

12. How would you rate the operation of the wastewater collection system (Sonora) or the wastewater treatment system (Arizona) in your neighborhood during the rainy season?
    a. ___ Very good
    b. ___ Good
    c. ___ Fair
    d. ___ Bad
    e. ___ Very bad

13. Select the impacts that you believe are present in your neighborhood during the rainy season as a result of the wastewater collection (Sonora) and wastewater treatment (Arizona) systems.

Positive Impacts	**Negative Impacts**
a. ___ Less mud in the city	i. ___ More mud in the city
b. ___ Smoother traffic flow	j. ___ Traffic backups
c. ___ Cleaner streets (no trash, mudslides)	k. ___ Dirtier streets (trash, mudslides)
d. ___ Less flooding	l. ___ More flooding
e. ___ Fewer accidents	m. ___ More accidents
f. ___ Clean canals	n. ___ Dirty canals
g. ___ Fewer health issues	o. ___ More health issues
h. ___ Other	p. ___ Other
Explain_____	Explain_____

ECONOMIC DEVELOPMENT

14. How would you rate the impact of the wastewater collection (Sonora) or wastewater treatment (Arizona) systems on economic development in your neighborhood?
    a. ___ Very good
    b. ___ Good
    c. ___ Fair
    d. ___ Bad
    e. ___ Very bad

15. Select the economic development impacts that you have seen in your community as a result of the wastewater collection system projects (Sonora) and wastewater treatment projects (Arizona) (Check all that apply).

Positive Impacts	Negative Impacts
a. ___ More stores and trade in general b. ___ More jobs c. ___ The value of my property increased d. ___ There are more tourists e. ___ My rent is lower f. ___ Other Explain_____	g. ___ Fewer stores and less trade in general h. ___ Fewer jobs i. ___ The value of my property decreased j. ___ There are fewer tourists k. ___ My rent is higher l. ___ Other Explain_____

ENVIRONMENT

16. How would you rate the impacts of the wastewater collection (Sonora) and wastewater treatment (Arizona) systems on the environment?
    a. ___ Very good
    b. ___ Good
    c. ___ Fair
    d. ___ Bad
    e. ___ Very bad

17. Select the environmental impacts that you have seen in your community as a result of the wastewater collection (Sonora) and wastewater treatment (Arizona) systems (Check all that apply).

Positive Impacts	Negative Impacts
a. ___ More trees b. ___ More birds and other species c. ___ More water in streams d. ___ Less flooding e. ___ Less heat f. Other Explain_____	g. ___ Fewer trees h. ___ Fewer birds and other species i. ___ Less water in streams j. ___ More flooding k. ___ More heat l. ___ Other Explain_____

URBAN DEVELOPMENT

18. How would you rate the impacts of the wastewater collection (Sonora) and wastewater treatment (Arizona) systems on urban development?
    a. ___ Very good
    b. ___ Good
    c. ___ Fair
    d. ___ Bad
    e. ___ Very bad

19. Select the urban development impacts that you have seen in your community as a result of the wastewater collection (Sonora) and wastewater treatment (Arizona) systems (Check all that apply).

Positive Impacts	**Negative Impacts**
a. ___ More paved streets	l. ___ Fewer paved streets
b. ___ More sidewalks	m. ___ Fewer sidewalks
c. ___ More street lighting	n. ___ Less street lighting
d. ___ Improved trash collection service	o. ___ Worsened trash collection service
e. ___ More parks	p. ___ Fewer parks
f. ___ More clinics and hospitals	q. ___ Fewer clinics and hospitals
g. ___ Improved police service	r. ___ Worsened police service
h. ___ Improved ambulance service	s. ___ Worsened ambulance service
i. ___ Improved fire service	t. ___ Worsened fire service
j. ___ Improved water service	u. ___ Worsened water service
k. Other	v. Other
Explain_____	Explain_____

SECTION IV. IMPACTS ON BINATIONAL COOPERATION

20. How would you rate the impacts of the wastewater collection (Sonora) and water treatment (Arizona) systems on binational cooperation?
    a. ___ Very good
    b. ___ Good
    c. ___ Fair
    d. ___ Bad
    e. ___ Very bad

21. Where is the wastewater from Nogales, Sonora, treated?
    a. ___ Sonora
    b. ___ Arizona
    c. ___ Both countries
    d. ___ Not treated

22. How much do you think that what happens to wastewater in Nogales, Sonora impacts Nogales, Arizona and vice versa?
    a. ___ A great deal
    b. ___ Considerably
    c. ___ Moderately
    d. ___ Slightly
    e. ___ Not at all

23. Select potential uses of wastewater
    a. ___ Agriculture
    b. ___ Livestock farming
    c. ___ Irrigation of parks and green areas
    d. ___ For species found in streams
    e. ___ Wastewater cannot be used

24. Select the most important cooperation actions between law enforcement and the public in Ambos Nogales
    a. Flooding assistance
    b. Public safety
    c. Migrant assistance
    d. Wastewater management
    e. Fires
    f. Chemical spills
    g. Humanitarian aid
    h. Combating drug trafficking
    i. Business issues
    j. First responder training (firefighters, police officers)
    k. There is no cooperation