CASE

Growing opportunities for Mexico City to tap into the Tula aquifer (Mexico)

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Supporting case for Business Model 21	
Location:	Mezquital Valley, Mexico; Mexico City
Waste input type:	Urban wastewater
Value offer:	Agricultural and potable wastewater use
Organization type:	Public and private partners
Status of organization:	Irrigation since 1912; new treatment plant since 2016; potable reuse expansion to Mexico City under review
Scale of businesses:	Large
Major partners:	National Water Commission (CONAGUA), local, state and federal Government; Mezquital Valley Farmers and Water User Associations

Executive summary

This business case describes the double value proposition of (i) producing annually crops worth USD 400m through wastewater irrigation; and (ii) generating nearly potable water through the combination of conventional and natural wastewater treatment (aquifer recharge).

The Mezquital (or Tula[1]) Valley of Mexico is well-known for its large-scale wastewater irrigation on about 90,000 ha and its time (over 100 years) of operation which make the case in many textbooks a unique example of wastewater use in the global context. Until recently, the water was to 90% untreated depending on natural treatment processes which could not eliminate risks for the environment and human health. This situation has now been improved through the construction of new wastewater treatment plants, including the 800 million gallon-per-day (35m^3/s) Atotonilco mega plant which is one of the largest in the world, cleaning about 60% of the urban wastewater released from a population equivalent of 10.5 million people of the Greater Mexico City.

Although the value of irrigated food production received so far most attention, the significant rise of the groundwater level in the valley is shifting the attention to the use of its aquifer for supplying aside local communities in the valley also Mexico City with water. The city faces a long severe water crisis, and is running out of cost-effective options for its freshwater supply. The government's allocation of USD 255 million for tapping into the Tula aquifer to reduce the water deficit of Mexico City will make the city its own downstream water user to the direct and indirect benefit of several million urban dwellers.

KEY PERFORMANCE INDICATORS (ONLY ATOTONILCO WWTP, STATUS 2016)						
Land use:	159 ha (plant area)					
Water use:	35m³/s wastewater treated					
Capital investment:	USD 786 million (numbers vary with source and reference year)					
O&M:	USD 81m per year					
Output:	Up to 90,000 ha of irrigated fodder and food crops, aside large-scale wastewater driven aquifer recharge of about 25–39m³/s, which is retrieved in the valley for different purposes including domestic water supply (6.2m³/s envisioned for Mexico City)					
Potential social and/or environmental impact:	Job creation along the value chain, savings for advanced treatment, increased soil fertility and water supply for addressing urban food needs; nutrient recycling (reducing additional N and P fertilizer needs), aquifer recharge and the provision of drinking water within the valley and for Mexico City					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR (Atotonilco):	14.2	Gross margin:	N.A.

Context and background

About 70% of the 21 million urban dwellers of Mexico City depend on groundwater as a source of drinking water. Overexploitation of groundwater by at least 117% resulted within the city in soil subsidence at the rate of 5–40cm annually, increasing the cost of water supply and urban drainage, affecting transport (metro) and built infrastructure. Alternative options to improve urban water supply are long-distance water import and a large-scale leakage control program. Both options face their own challenges, making wastewater reuse, either directly after treatment, or after use in irrigation from the recharged aquifer, cost-effective complementary measures (Jimenez, 2014). Already today, the Tula aquifer, which derived to 90–100% from former wastewater, supplies the local population with drinking water (17%), while supporting agriculture (38%), industry (33%) and other uses (12%).

Irrigation, especially with water rich in nutrients and organic matter, is in high demand as the climate is semi-arid and soils are poor. On the request of local farmers around 1920, the government supported a complex irrigation system in the valley, which constituted recognition, although informal, of the use of non-treated wastewater to irrigate crops. Later, the farmers requested the concession of 26m³/s of Mexico City's wastewater – the entire quantity available at that time. Consent was granted by the President in 1955 (Jiménez, 2009). The use of wastewater quickly became a source of livelihoods as it enabled crops to be grown all year round. Land with access to wastewater costs more than twice the rent (USD 1,000/ha) than land with access to rain water (USD 400/ha) only.

Irrigation water quality in the valley varies regionally, with about 10,000 ha using raw wastewater, 35,000 ha diluted wastewater, 25,000 ha partially treated wastewater, and other areas benefitting from aquifer recharge (Navarro et al., 2015). These shares will change towards increased safety with the newly installed treatment capacity which can absorb 60% of Mexico City's wastewater and will release 23m³/s directly for irrigation, while 12m³/s will support indirect reuse, local reservoirs and the environmental flow of the Tula river.

Due to the high irrigation rate as well as storage and transport of wastewater in unlined dams and channels, the aquifer is unintentionally being recharged on a vast area at a rate between 25 and 39m³/s which is exceeding natural recharge 13 times, and led to an increase of the groundwater level between 1938 and 1990 by 15–30m with new springs appearing and a higher water volume in the Tula river through groundwater inflow (Jimenez, 2014).

Market environment

There are two complementary water markets, Mexico City and the Tula Valley. While the valley needs the urban wastewater for its economy, the city needs the valley to absorb with limited costs its effluent.

a) According to Jiménez (2014), Mexico City uses about 86m^3/s of water derived from local wells (57m^3/s), long distance transfer (20m^3/s), surface water (1m^3/s) and is using all its reclaimed water (7.7m^3/s). Water consumption is mostly for domestic use (74%), local irrigation (Mexico Valley, 16%) and industrial and other uses (3%). For 2010, a water deficit of 15–38m^3/s was estimated to supply the increasing population and control soil subsidence within the city. Among the measures to close the gap are a long-term leakage control program and the careful protection of the inner-urban aquifer. Additional long distance supply will remain a critical component but is increasingly opposed by local population at the source, or faces very high pumping costs, not because of the distance, but 1,000–1,500m differences in altitude to reach Mexico City. Extending wastewater reuse from the Tula aquifer would offer at much lower vertical difference, and is increasingly considered a feasible and cost competitive option, although post-treatment is required to eliminate remaining water quality concerns (Jiménez, 2014; Navarro et al., 2015).
b) The Tula Valley receives on average about 60m^3/s of Mexico City's wastewater. Irrigation to supply Mexico City with food is the economic backbone of the area, as the additional water allows to grow two to three crops instead of one, and achieves 67–150% higher yields compared to freshwater irrigation. Direct and (via aquifer recharge) indirect wastewater use in the valley supports also other economic activities. Although water quality from the Tula aquifer appears in large better than of conventional wastewater treatment, the newly commissioned WWTPs are expected to further reduce gastrointestinal diseases (Contreras et al., 2017), and support market demand.

Both (rural and urban) markets are not mutually exclusive if the extraction points are well distributed, given that groundwater recharge is exceeding local water needs. The transfer of about 5m^3/s consisting of groundwater from the Mezquital (Tula) Valley to Mexico City has been initiated under Mexico's National Infrastructure Program and was in February 2017 under review (CONAGUA, 2017). If successful, higher water volumes are available.

Macro-economic environment

One of the main aims of Mexico's current National Water Program is to treat and reuse wastewater. In recent years, the percentage of collected wastewater that is treated has risen from 23% to 36%, and the goal is to reach 100% of municipal wastewater by 2020 and industrial wastewater by 2025. The gap is not caused by missing water demand, but treatment capacity. The use of **un**treated wastewater for irrigation is already supporting the livelihoods of several hundred thousand people. Agricultural production for 2011–2012 in the two main irrigation districts of the Tula Valley generated about USD 400 million in crop outputs (CONAGUA, 2013). To replace untreated with treated wastewater, the government catalyzed a multi-billion US Dollar investment program to improve urban water supply, drainage and wastewater treatment. Currently, Mexico City is using 100% of its reclaimed wastewater, making the city in relative terms one of the global reuse leaders. The new investments are paving the way to become also in absolute numbers a global leader given that the new treatment plants will multiply the amount of reclaimed water of immediate use in the Tula Valley. The additional allocation of USD 255 million for tapping into the Tula aquifer to reduce the urban water deficit makes Mexico City its own downstream water user. Aside water imports from Mezquital, also transfer from other basin remains important, but is increasingly objected due to negative local impacts like reduced irrigation areas.

Business model

The main 'value proposition' was and is the use of wastewater for crop production, turning an unwanted discharge into a resource which is mobilizing annually a value of several hundred million US Dollar (see above). A small part of these revenues is spent on O&M of the irrigation infrastructure, complemented by CONAGUA subsidies.

With 90–100% of the valley's aquifer being formed by Mexico City's wastewater, groundwater use for various economic activities offers a second waste-based value proposition. The treatment provided by the Atotonilco plant will support surface and groundwater quality, although for potable reuse further membrane filtration before reuse has been suggested.

Supplying Mexico City with groundwater from Tula could generate about USD 150m/year based on the upper water tariff, which is however unlikely to cover the operational costs, while the expected economic benefits will be far beyond this value. Taking as example the Gutzamala long-distance water transfer, which however requires more energy for a much higher difference in elevation, its annual operational cost is covered to 48% through user fees and 52% by federal funds. Without changes in water tariffs, the business model (Figure 251) will remain foremost a social one, subsidized by the municipal and federal governments, which is however well justified by the magnitude of reduced externalities, like damages to buildings, streets, sidewalks, sewers, storm water drains and other infrastructure due to land subsidence, as well as the magnitude of community benefits due to appropriate water supply.

Value chain and position

The traditional value chain of transforming urban wastewater into an agricultural asset, involving local farmers, water user associations and traders, is since decades common reality in the Tula Valley (Figure 252). To transport water from the replenished aquifer back to Mexico City appears cost effective and is under review (CONAGUA, 2017). It could potentially face institutional obstacles in view of water entitlements (FAO, 2010) although in general all goods found beneath the surface in Mexico belong to the country according to the Mexican Constitution, with CONAGUA in charge of groundwater management. While in other remote areas where CONAGUA is sourcing water for Mexico City, water competition is increasing and so local resistance, there should be less reason for competition in view of the boosted Tula aquifer.

Institutional environment

Mexico's National Water Law, passed in 1992, provides the legal framework for water management in Mexico. It states that the use of the nation's water or the right to discharge wastewater will be carried out by concessions from the Federal Executive Branch, through the National Water Commission (CONAGUA). CONAGUA also allocates the water-related budget for the 32 states in Mexico. The budget for water is approximately 60% of the total environmental budget in Mexico. One of the states is the State of Mexico, which includes the large majority of Greater Mexico City (Mexico City Metropolitan Area) with its 21 million people that is composed of 16 Municipalities, as well as a larger number of adjacent municipalities. Governmental responsibilities are complex given the stakes of the Federal Government, the government of Mexico City, and the government of the State of Mexico, resulting in fragmented responsibilities[2]:

- The Federal government is in charge of regulating the use of water resources, contributing to the financing of investments and supplying bulk water from other basins through CONAGUA.
- CONAGUA which is operating under the Ministry of the Environment and Natural Resources is also responsible for upstream parts of the wastewater irrigation infrastructure in the Tula Valley and its operation, while local water user associations (WUA) are in charge of downstream irrigation management and user tariffs.

FIGURE 251. BUSINESS MODEL CANVAS – WASTEWATER FOR IRRIGATION AND GROUNDWATER RECHARGE

KEY PARTNERS

- National and State Water Commissions
- Municipalities
- Farmers and their WUAs
- SACMEX
- ATVM
- Banks

KEY ACTIVITIES

- Wastewater transport and treatment
- Reclaimed water distribution, post-treatment and sale

KEY RESOURCES

- Urban wastewater
- Finance
- High level engineering skills
- Positive public perception

VALUE PROPOSITIONS

- Turning wastewater into water for irrigation and potable reuse at scale

CUSTOMER RELATIONSHIPS

- Formal agreements between all partners
- Automatic billing of domestic water users

CHANNELS

- Water delivery through pipes and irrigation canals
- Water bills can be paid at most banks, major grocery stores, some convenience stores, or the water company

CUSTOMER SEGMENTS

- Farmers located in the Mezquital Valley
- Urban dwellers in the Valley and of Mexico City

COST STRUCTURE

- Capital investment and O&M of water treatment, long distance transport and irrigation schemes
- Health risk monitoring and reduction costs

REVENUE STREAMS

- Bulk water sales to WUAs, and fees charged to individual farmers
- Bulk water sales to municipal water suppliers, and household charges via water bill

SOCIAL & ENVIRONMENTAL COSTS

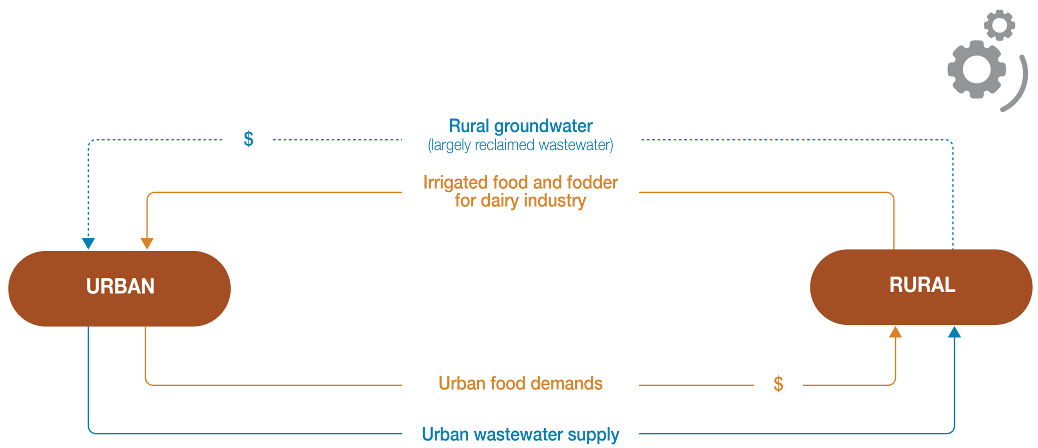
- Likely health cost for farmers and potentially also for consumers through diseases derived from unremoved contaminants transferred via the food chain or reclaimed water
- Risk of long term soil contamination (e.g. by heavy metals)

SOCIAL & ENVIRONMENTAL BENEFITS

- Benefits for rural and urban food and water security with value generation across sectors and value chains
- Reduction in public health expenditure through increased conventional and natural wastewater treatment and water availability
- Improvement in livelihoods and ecosystem services

- In Mexico State, the State Water Commission (CAEM) buys bulk water from CONAGUA, transmits it through its own bulk water infrastructure and sells it on to its municipalities. CAEM also monitors water quality, operates wastewater pumping stations and several wastewater treatment plants.
- The municipal governments in the State of Mexico and Hidalgo are in charge of water distribution and sanitation for their constituents. In Mexico City, for example, the water operator (Sistema de Aguas de la Ciudad de México or SACMEX) provides potable water, drainage, sewerage, wastewater treatment and water reuse services.

FIGURE 252. RURAL-URBAN LINKAGES BETWEEN THE MEZQUITAL VALLEY AND MEXICO CITY



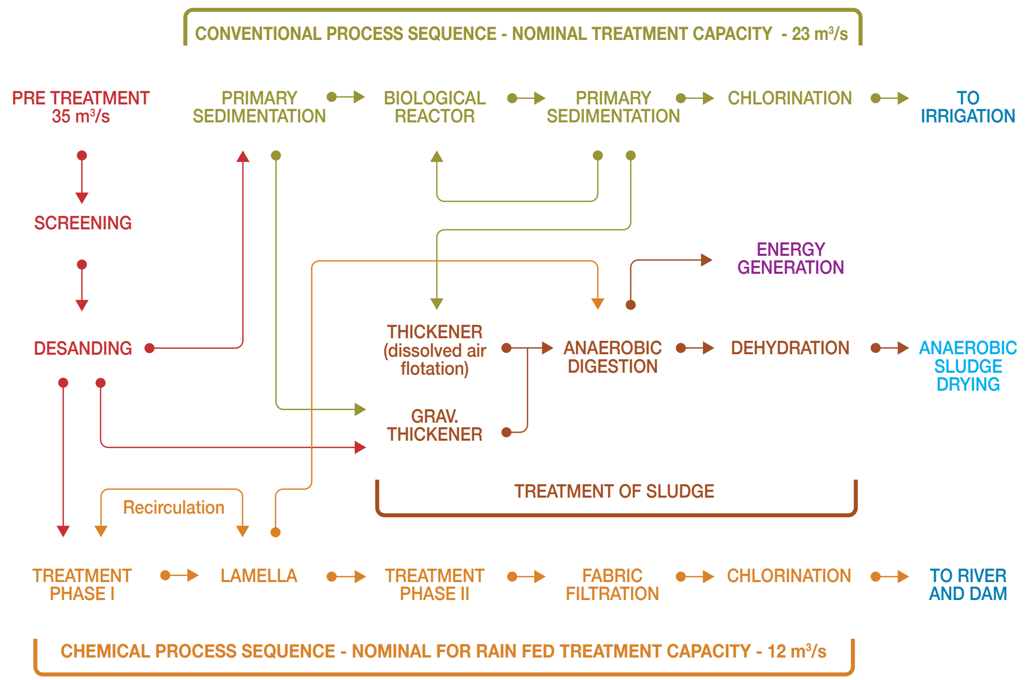
The major program governing recent water developments is the Water Sustainability Program of the Valley of Mexico, which envisages a series of infrastructure investments supported by the drainage, water supply and wastewater treatment to serve the Mexican capital. The program is supported the National Infrastructure Program but relies heavily on private sector funding. One target is to increase the city's water supply by $14m^3/s$ with about $5m^3/s$ consisting of groundwater from the Tula Valley, at an estimated cost of USD 255 million[3]. The second-largest source of additional water will be mobilized through an exchange of treated wastewater for clean water at present used for green area irrigation ($4m^3/s$), at a cost of 140 million. Another $3m^3/s$ is envisioned to be gained through rehabilitation measures (Cutzamala system) and $2m^3/s$ would be made available from the Guadelupe dam in Mexico state[4]. The Sustainability Program governs also the construction of the Emisor Oriental (Western Sewer) and the Atotonilco wastewater treatment plant. The plant has been constructed and will now be operated by the Aguas Tratadas del Valle de Mexico (ATVM) private sector consortium.

Technology and processes

Discharge of wastewater from the Greater Mexico City into its sewer network is estimated around 41 to 44 m^3/s. Considering rainfall, the total average flow managed by the sewer system in the Metropolitan Area is around 60 +/– $15m^3/s$. This wastewater is sent by gravity and pumping via five artificial exits to the Tula Valley. The latest tunnel, the East Emitter (Emisor Oriente) which was end of 2016 still in construction has a capacity of $150m^3/s$ and is 62 km long. Discharge from the tunnels will be primarily treated at the Atotonilco wastewater treatment plant which has a total treatment capacity of 35 m^3/s (Figure 253), with an additional hydraulic capacity of 20% to manage storm water that mixes with the wastewater, giving a maximum capacity of 42 m^3/s in rainy periods. Till the East Emitter is operational, the plant receives the flows from the older Central Emitter.

The treated water will support direct and indirect wastewater irrigation, and based on farmers' request try to limit the removal of crop nutrients during wastewater treatment. The sludge produced by the Atotonilco plant will be stabilized by anaerobic digestion and the gas produced will be used for power cogeneration, providing according to different sources 60–80% of the plant's own electricity requirements. The plant has an estimated lifespan of 50 years. There are also several smaller wastewater treatment plants in construction which together will add another $10m^3/s$ treatment capacity.

FIGURE 253. DIAGRAM OF THE ATONONILCO TREATMENT PROCESS.



Source: CONAGUA, 2017.

Due to unlined water reservoirs and irrigation channels, the Tula aquifer is unintentionally being recharged at a rate of (more than) 25m³/s, exceeding natural aquifer recharge multiple times. Aside local groundwater use, a part of the excess groundwater has been proposed to be pumped from twelve batteries of extraction wells in the Mezquital Valley over 80 km and an altitude difference of about 500 m back to Mexico City. Flow rate of extraction will be about 6.4m³/s, and at the destination at least 4.2m³/s (CONAGUA, 2017). Treatment before reuse to address potential health risks is highly recommended, especially if the water is used like in this case for potable purposes.

Funding and financial outlook

Local financing for water infrastructure comes from federal, state and municipal resources. CONAGUA which channels federal (governmental) funding to municipal and rural projects, and the National Bank of Public Works (BANOBRAS) which provides financing, subordinated debt and capital. States, municipalities and local authorities have very limited financing capacity for new infrastructure. CONAGUA is also a fiscal authority, charging duties for the use of Mexico's water resources which includes water supply as well as (the use of water receiving) wastewater discharges.

Irrigation: CONAGUA manages irrigation water supply across Mexico through local WUAs or smaller operators which are charging their farmers for O&M of the irrigation infrastructure. The tariff is to be calculated every year to cover O&M costs of the irrigation system. Fees are assessed by total area, by irrigated area, by type of crop, and by cultivated area, and only in a few cases by water volume. A part of the fee supports CONAGUA's maintenance of upstream infrastructure, which remains otherwise subsidized.

Rural-urban water supply: After construction of the planned pipeline, its operation might be – like in similar cases – with the Mexico Valley basin agency (OCAVM) for CONAGUA, supplying CAEM and SACMEX with water for the supply of communities and households. Water tariffs are set locally by the authorities of each municipality depending on the provisions of each state's legislation, and include fixed costs, proportional costs according to the water used, with or without costs for sewerage and wastewater treatment and taxes.

Wastewater treatment: The Atotonilco project was assigned by CONAGUA to a private sector consortium for a design-build-operate-transfer (DBOT) contract, with a 25-year construction and operating period. The ATVM consortium partners financed 20% with equity, and 31% with credit from BANOBRAS, while the National Development Fund of Mexico (FONADIN) contributed a subsidy of 49%. The winning bid was chosen on the basis of the lowest consumer tariff requested. The concessionaire is repaid, however, from CONAGUA's budget. CONAGUA is charging water use and discharge duties and is paid for the provision of bulk water, which the municipalities supply to households. The household water bill usually includes a share for sanitation/wastewater management (Figure 254). These tariffs are generally not sufficient to cover the costs of providing the services.

More information on financing water services (capital and operational costs) can be found in CONAGUA (2010).

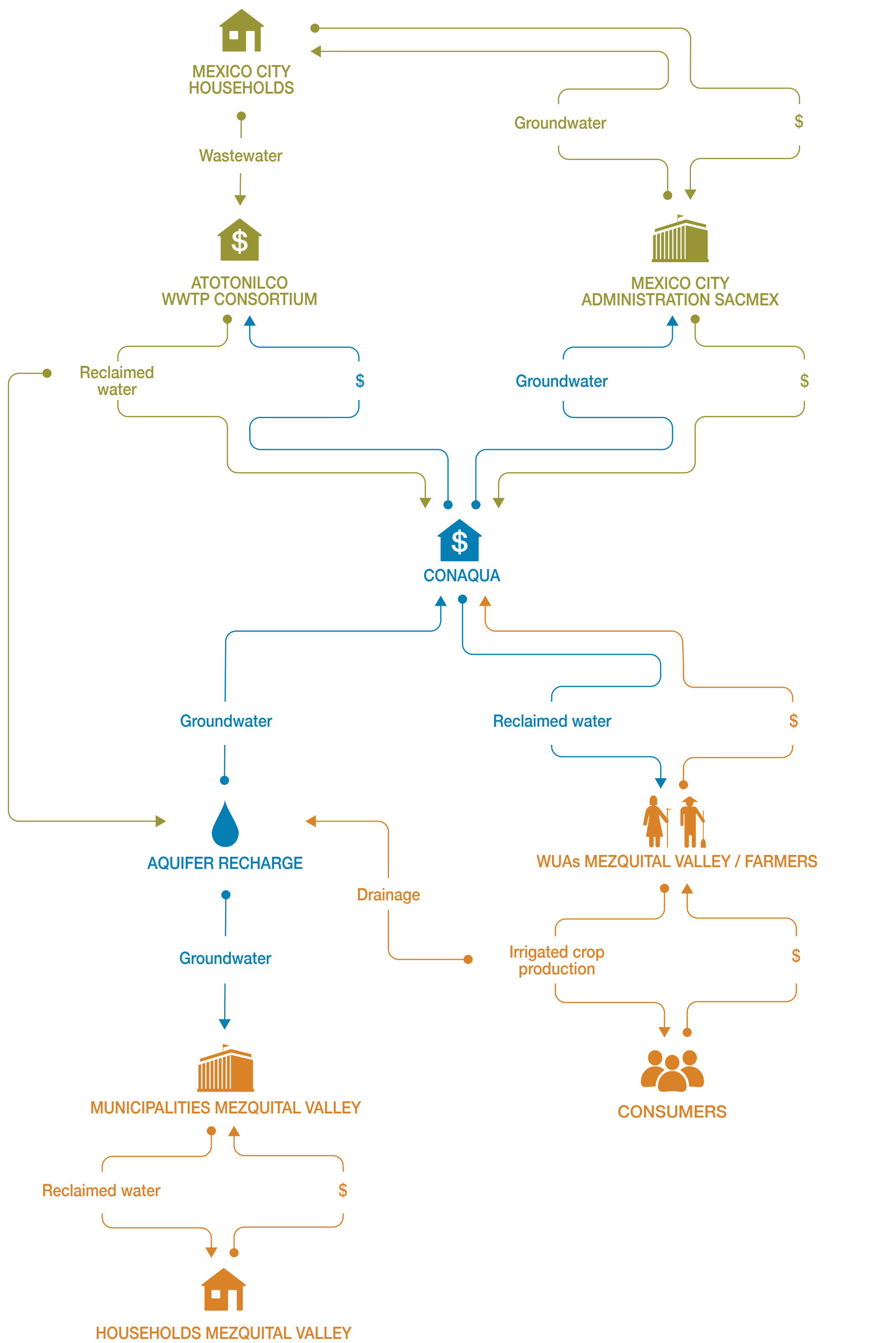
Socio-economic, health and environmental impact

Mexico City was for over a century taking advantage of natural wastewater treatment in the Tula Valley, saving costs otherwise required for treatment infrastructure. This system appeared in large as a win-win situation as the city got rid of the water while the local economy in the Tula valley transformed the wastewater in an economic asset via additional crop harvests, higher yields per hectare, etc. To control possible health risks, legislations requesting crop restrictions are in place, though with limited enforcement, resulting in a long history of increased diarrheal diseases linked to water exposure (Contreras et al., 2017). Risks will also remain after the Atotonilco wastewater treatment plant is fully operating as it will only treat 60% of the wastewater released in the valley. However, it is a giant step forward given that before only 6–11% were treated. The treatment plant is supposed to benefit 700,000 people in the Mezquital valley, of which 300,000 live in irrigation.

Especially for aquifer recharge, natural land treatment will remain important. So far, the water passing the soil and unsaturated zone above the Tula aquifer is resulting in groundwater of a quality exceeding the one of conventionally treated wastewater. The higher groundwater table and the appearance of new springs are supporting different economic sectors including potentially several million households back in Mexico City once the long-distance transfer is in place. Water extraction from the Tula aquifer can also positively influence groundwater induced soil salinity in the valley. However, soil characteristics and hydro-geology vary regionally and so their filter characteristics. In fact, it is not known when the natural filter system might reach saturation. There is also the risk that the new treatment plants will remove organic matter from the wastewater which is needed to absorb contaminants when passing the soil. There could also be safety concerns due to the use of agro-chemicals by farmers. Thus, for potable use, additional membrane filtration has been recommended, especially in view of 'emerging contaminants', such as pharmaceutical or pesticide residues with so far unknown threshold values (Navarro et al., 2015).

Finally, in line with the recommendations of the National Water Plan (2012–2018), the Atotonilco wastewater treatment plant is covering to a large percentage its own water (92%) and energy (60–80%) needs and reducing greenhouse gas (GHG) emissions by an average of 400,000 tons of CO_2e per year.

FIGURE 254. RURAL–URBAN WATER AND WASTEWATER TRANSACTIONS BETWEEN MEXICO CITY AND THE MEZQUITAL VALLEY (SIMPLIFIED)



The project is investing in reforestation using native plant species, with the aim of recovering and improving the quality of environmental services on the site.

Scalability and replicability considerations

This business case describes a rural-urban win-win situation with a double value proposition of (i) producing annually crops worth USD 400 million through the use of unwanted wastewater; and (ii) generating nearly potable water through the combination of conventional and natural wastewater treatment (aquifer recharge), resulting potentially in USD 150 million revenues through the water tariff.

The key drivers for the business which are also common in other regions are:

- Rapid urbanization resulting in large volumes of unwanted wastewater discharge and groundwater recharge.
- Water scarcity resulting in high demand for surface and groundwater for multiple financial and economic benefits.

Other drivers which are not always common:

- Governmental capital investments and subsidies based on expected large economic benefits.
- Government consent in providing farmers with (untreated or partially treated) wastewater and irrigation infrastructure.
- Vast aquifer with very high natural recharge rate.
- Scale of reuse making it a powerful economy.
- Alternative options for upgrading urban water supply face increasingly challenges.
- Significant research on health risks and options for risk reduction.
- World class engineering (wastewater treatment and long-distance/high elevation water transfer).

A major issue associated with this model is the continuous use of in part untreated wastewater for irrigation and groundwater recharge. However, there are various options to limit related risks for human health, which can be tailored to the actual water use and its quality requirements.

Summary assessment – SWOT analysis

The described model is very promising because water is in high demand in both the Mezquital Valley and Mexico City and both locations are short in alternative options to direct or indirect wastewater use. Minimizing possible health risks will be the key to a sustainable rural–urban partnership where the economic benefits of water for domestic use, agriculture, industry and the environment will easily justify the capital investment as well as O&M costs. Figure 255 shows a condensed SWOT analysis for this business case in Mexico.

FIGURE 255. SWOT ANALYSIS FOR WASTEWATER REUSE INCLUDING RURAL–URBAN WATER TRANSFER FROM THE MEZQUITAL VALLEY, MEXICO

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Supply of large amounts of wastewater secured ▪ Farmers, authorities and legislations value wastewater ▪ Strong water demand from rural and urban users ▪ Financial support from the government available ▪ High engineering capacity	**WEAKNESSES** ▪ Wastewater treatment not covering all generated wastewater and types of contaminants ▪ Farmers' concerns that further treatment will remove crop nutrients ▪ High absolute cost of water transport and treatment
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Lower costs to supply Mexico City than via other long distance/high altitude transfers ▪ Strong and growing urban demand for expanding business ▪ Likely health risks for water consumers can be controlled ▪ Reduced soil salinization through groundwater use	**THREATS** ▪ Remaining health risks for farmers, consumers and potable water users have to be controlled to protect market demand ▪ Potential conflict due to unclear wastewater use rights ▪ Future competition for water reuse if acceptance grows

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Case descriptions are based on primary and secondary data provided by case operators, literature, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2016/17. As business operations are dynamic data can be subject to change.

Note

1 The Mezquital valley is located in the Tula Valley in the State of Hidalgo, 100 km north of Mexico City. In this case study the name Tula valley is mostly used except where a distinction is required.
2 https://en.wikipedia.org/wiki/Water_management_in_Greater_Mexico_City (accessed 12 Sept. 2016).
3 ibid.
4 ibid.