PRE-FEASIBILITY STUDY

WASTEWATER TREATMENT PLANT FOR THE CITY OF METAPÁN, SANTA ANA

SEPTEMBER 2012

This publication was produced by Tetra Tech for the United States Agency for International Development.
CREDITS:
Authors: Fernando Román, Julián Monge, Magdalena de Aguilar and Miguel Franco
Photographs, schematics and editing: Julián Monge
Cover photograph: José Cruz, 2002

ABOUT THE AUTHORS:

Fernando Román: Vice President, Tetra Tech; expert in drinking and wastewater treatment. San Antonio, Texas, USA.

Julián Monge: Local specialist in wastewater treatment; experience in design, construction and maintenance of wastewater treatment systems. San Salvador, El Salvador.

Magdalena de Aguilar: Local specialist in wastewater treatment; experience in wastewater treatment and laboratory analysis. San Salvador, El Salvador.

Miguel Franco: Team Leader of Tetra Tech consulting team; experience in industrial wastewater treatment and biogas generation, recovery and use. Arlington, Virginia, USA.
PRE-FEASIBILITY STUDY

WASTEWATER TREATMENT PLANT FOR THE CITY OF METAPÁN, SANTA ANA

SEPTEMBER 2012

DISCLAIMER
The views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.
TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS ........................................................................................................ V
EXECUTIVE SUMMARY ........................................................................................................................ VII

1.0 INTRODUCTION ........................................................................................................................................... 1

2.0 OBJECTIVES .................................................................................................................................................. 3
  2.1 GENERAL OBJECTIVE ............................................................................................................................ 3
  2.2 SPECIFIC OBJECTIVES ............................................................................................................................ 3

3.0 BACKGROUND ........................................................................................................................................... 5
  3.1 DESCRIPTION OF THE METAPÁN MUNICIPALITY, METAPÁN LAKE, GUIJA LAKE AND SAN JOSÉ RIVER ........................................................................................................................................ 5
    3.1.1 Municipality of Metapán .................................................................................................................. 5
    3.1.2 Metapán Lake ............................................................................................................................... 5
    3.1.3 Guija Lake ...................................................................................................................................... 6
    3.1.4 San José River .............................................................................................................................. 6
  3.2 GEOGRAPHY, HYDROLOGY, GEOLOGY AND GENERAL DEVELOPMENT TRENDS ........................................................................................................................................ 6
    3.2.1 Physical Geography ....................................................................................................................... 7
    3.2.2 Hydrology ..................................................................................................................................... 7
    3.2.3 Current Land Use .......................................................................................................................... 7
    3.2.4 Agricultural Structure ................................................................................................................. 7
    3.2.5 Rural Electrification ..................................................................................................................... 7
    3.2.6 General Development Trends ....................................................................................................... 7
    3.2.7 Ecosystems .................................................................................................................................... 8
  3.3 BACKGROUND ON THE WASTEWATER TREATMENT PLANT FOR THE CITY OF METAPÁN ........................................................................................................................................ 8

4.0 METHODOLOGY ......................................................................................................................................... 9

5.0 STUDY RESULTS ..................................................................................................................................... 11
  5.2 ASSESSMENT OF THE TREATMENT OPTIONS AND CREATION OF A MATRIX FOR COMPARING TECHNICAL, FINANCIAL AND ORGANIZATIONAL CONSIDERATIONS ........................................................................................................................................ 16
    5.2.1 Treatment Options ......................................................................................................................... 18
    5.2.2 Appropriate Technology ............................................................................................................... 26
    5.2.3 Description of the Wastewater Treatment Plant with UASB + Trickling Filter ........................................................................................................................................ 26
  5.3 DEFINITION OF THE DESIGN POPULATION AND THE CONVENIENCE OF DEVELOPING THE PROJECT IN LONG-TERM PHASES ........................................................................................................................................ 32
    5.3.1 Definition of Design Population and Design of Wastewater Flowrates ................................... 32
5.3.2 Is It Preferable that the Project be Constructed in Full or in Stages? ....35

5.4 DETERMINATION OF THE EFFLUENT DISCHARGE POINT AND THE FINAL DISPOSAL OF THE TREATED SLUDGE .................................................................36
   5.4.1 Determination of the Effluent Discharge Point ........................................36
   5.4.2 Determination of the Final Disposal Point of the Treated Sludge ........37
   5.4.3 Local Experience in Sludge Disposal from Domestic Wastewater Treatment Plants .................................................................38

5.5 IDENTIFICATION OF OPTIONS FOR RECOVERING OPERATIONAL AND MAINTENANCE COSTS .................................................................39
   5.5.1 Development of the Operation Budget .................................................39
   5.5.2 Cost Recovery Mechanisms ..................................................................41

5.6 DETERMINATION OF THE CAPACITY OF THE MUNICIPALITY FOR LONG-TERM OPERATION AND MAINTENANCE OF THE TREATMENT PLANT ..........42
   5.6.1 Municipal Finances ...............................................................................43
   5.6.2 Technical and Financial Support by ANDA ..........................................43
   5.6.3 Qualified Personnel .............................................................................43
   5.6.4 Protection of the Sewage System .........................................................44
   5.6.5 Municipal Capacity to Operate the System ...........................................44

5.7 IDENTIFICATION OF THE NECESSARY INFORMATION FOR THE FEASIBILITY AND/OR FINAL DESIGN STUDIES, IN CASE ALTERNATIVES ARE FOUND ..........44
   5.7.1 Preliminary Design ...............................................................................44
   5.7.2 Final Design .........................................................................................45

5.8 ASSESSMENT OF THE RISK OF DELAYING THE PROJECT OF SEPARATION OF STORM WATER AND WASTEWATER, TO BE EXECUTED BY THE CITY OF METAPÁN AND ANDA, AND POSSIBLE IMPACTS TO THE PLANT’S PROJECT ...45
   5.8.1 Separation of Storm Water and Wastewater to be Executed by the City of Metapán and ANDA .................................................................45
   5.8.2 Assessment of the Risk of Delaying the Project of Separation of Storm Water and Wastewater, to be Executed by the City of Metapán and the Ministry of Public Health, and Possible Impacts to the Plant’s Project ......................................................47

5.9 ASSESSMENT OF THE HEALTH, ENVIRONMENTAL AND ECONOMIC BENEFITS RESULTING FROM THE WASTEWATER TREATMENT PLANT PROJECT ..........47
   5.9.1 Health Benefits .................................................................................47
   5.9.2 Environmental Benefits ......................................................................48
   5.9.3 Economic Benefits .............................................................................48

5.10 DEVELOP PROJECT TIMELINE AND COST ESTIMATES ..................................................48
   5.10.1 Timeline of Project .........................................................................48
   5.10.2 Project Costs .......................................................................................49

5.11 HOW THE ACTIVITY FITS WITH USAID’S BIODIVERSITY CODE CRITERIA ......51

5.12 EL SALVADOR EXPERIENCES WITH TREATMENT PLANTS THAT WERE CONSTRUCTED WITH THE TECHNICAL AND ECONOMIC SUPPORT OF INTERNATIONAL INSTITUTIONS ..................................................53
   5.12.1 San Juan Talpa Municipality’s Treatment Plant, La Paz Department ......53
   5.12.2 San Pablo Tacachico Municipality’s Treatment Plant, Department of La Libertad .................................................................54
   5.12.3 Wastewater Treatment Plants in the Municipalities of San José Las Flores in Chalatenango and Nejapa in San Salvador ...................................55
ACRONYMS AND ABBREVIATIONS

ANDA
Administración Nacional de Acueductos y Alcantarillados

°C
Degrees Celsius

CESSA
Cementos de El Salvador

CONACYT
Consejo Nacional de Ciencia y Tecnología

COSUDE
Agencia Suiza para el Desarrollo y la Cooperación

BOD5
Five-day Carbonaceous Biochemical Oxygen Demand

COD
Chemical Oxygen Demand

DW
Drinking Water

EMASA
Empresa Municipal Administradora Suchitotense de Agua Potable y Alcantarillado

FANTEL
Fondo Especial de los Recursos Provenientes de la Privatización de ANTEL

FISDL
Fondo de Inversión Social para el Desarrollo Local

FODEC
Fondo Contravalor de Desarrollo El Salvador-Canadá

Holcim
Holcim El Salvador, S.A de C.V.

KFW
Kreditanstalt für Wiederaufbau (Credit Bank for Reconstruction)

km²
Square Kilometer

KWh
Kilowatt Hours

l/s
Liters per Second

l/pd
Liters per Person per Day

m²
Square Meter

m³/d
Cubic Meter per Day

m³/h
Cubic Meter per Hour

m³/s
Cubic Meter per Second

MARN
Ministerio de Medio Ambiente y Recursos Naturales

mg/l
Milligrams per Liter

ml
Meters above Mean Sea Level

PROCOSAL
Programas Comunitarios para El Salvador
Convenio de RAMSAR  \textit{Convención Relativa a los Humedales de Importancia Internacional Especialmente como Hábitat de Aves Acuáticas}

RAFA  Reactor Anaeróbico de Flujo Ascendente

SNET  \textit{Servicio Nacional de Estudios Territoriales}

TSS  Total Suspended Solid

UASB  Upflow Anaerobic Sludge Blanket or RAFA in Spanish

UCA  Universidad Centroamericana “José Simón Cañas”

USAID  United States Agency for International Development

WW  Wastewater
EXECUTIVE SUMMARY

USAID contracted Tetra Tech to conduct a pre-feasibility study for a wastewater treatment plant project for the City of Metapán, El Salvador. Previously, the committee for the construction of the wastewater treatment plant at Metapán, formed by representatives from the City of Metapán, ANDA, MARN, Plan Trifinio and Holcim, had discussed four treatment alternatives for the city, all of which are based on the use of an upflow anaerobic sludge blanket (UASB, or RAFA in Spanish) with different secondary treatment options. Of the four options (trickling filter, activated sludge, wetlands and facultative ponds), the committee selected the use of trickling filter.

Tetra Tech’s task was to evaluate the treatment options within the expectations of the process and the legal framework of El Salvador. The scope of the study also included an assessment of options to minimize future costs, minimize the generation of sludge and establish the simplest process that would yield the expected results and ensure its sustainability. The assessment tasks included evaluating if the land previously acquired by the municipality is adequate and the best alternative relative to other potential sites.

The pre-feasibility study concluded that the wastewater treatment plant in Metapán is feasible and that the installation of a UASB with trickling filter is the best technical option to meet the needs of the city, particularly considering that the reduction of solids by the UASB minimizes the quantity of resulting sludge and the trickling filter ensures, for the most part, the successful treatment of the wastewaters. Factors involving the location of the plant also were analyzed, such as the distance to the discharge point for wastewaters, distance to the point of effluent discharge, topographic characteristics, access, availability of electricity and analysis of risks and impacts to neighbors. It was concluded that the land acquired by the city is adequate and represents the best option among other available sites in the area.

The plant’s capacity was calculated from census information and with ANDA water use factors. It was projected that by the year 2034, the wastewater inflows to the plant will be approximately 5,300 m$^3$/d. As such we recommend that the plant be constructed with a capacity of 5,500 m$^3$/d, and that construction be phased. It is recommended that the treated effluent initially be discharged directly to the San José River (in compliance with CONACYT regulation NSO 13.49.01:09), and that other disposition options be evaluated, including reuse, once the plant is constructed. Similarly, the production of methane gas at the plant must be quantified under real conditions and, if there is interest and it is shown to be feasible, a project to use the gas for internal energy production at the plant could be developed.

Two tasks must be undertaken as soon as possible to ensure that the project proceeds. One involves the separation of stormwater and wastewater flows (now combined) to ensure maximum reliability of the preliminary discharge data for design of the plant. The second task is to characterize the wastewater in order to optimally design the biological process.

The plant’s monthly operating budget is estimated at $8,000 to $9,000 for the first ten years of life. This figure includes labor, chemicals, electricity, spare parts and a contingent reserve budget for major costs. The estimate is in current 2012 dollars, and the future final budget should include appropriate inflation factors. The estimated construction cost of $2,530,000 is apparently sufficient for the construction of the project. Tetra Tech’s team estimated a cost of $2,666,586, without contingencies, based on a conceptual predesign. An additional amount should be added if more intense mechanization of the plant is desired and if it is to be constructed in a modular form.

Very ambitious targets have been set for executing the project, including termination of construction by 2014. To take immediate actions to initiate the project, it is recommended that the institutions involved in the process execute a Memorandum of Understanding (MOU). The MOU should define the roles,
responsibilities and commitments of the parties; establish a process for collecting funds for the project and for contracting the required technical services to develop the project. The signatories should be, at a minimum, the City of Metapán, ANDA, MARN, Plan Trifinio, FISLD and Holcim.
1.0 INTRODUCTION

This document presents the findings and recommendations of the consultancy performed prior to the construction of a wastewater treatment plant at the site; it describes the location of the plant, treatment alternatives, sludge disposal and the plant’s long-term sustainability.

The study is part of the framework of the United States Agency for International Development (USAID) Cooperative Agreement and the consulting company Tetra Tech in cooperation with the private-public committee formed by the City of Metapán, the Ministerio de Ambiente y Recursos Naturales de El Salvador (MARN, Ministry of Environment and Natural Resources of El Salvador), the Administración Nacional de Acueductos y Alcantarillados (ANDA, Administration of Water and Sewage) and the Comisión Trinacional del Plan Trifínio (Plan Trifínio, Trinational Commission of the Trifínio Plan.)

This work includes the consultation, collection and evaluation of existing documents; the implementation of meetings and interviews with the persons or contact parties of the institutions above mentioned; the collection of information in situ and analysis of prior experiences related to this topic.
2.0 OBJECTIVES

2.1 GENERAL OBJECTIVE

To define the feasibility of a wastewater treatment plant in the City of Metapán.

2.2 SPECIFIC OBJECTIVES

- Evaluate the proposed technology/treatment options.
- Evaluate the site and/or location of the treatment plant.
- Evaluate the critical factors of the design.
- Investigate the options for the disposal of effluents and sludge.
- Investigate sustainability aspects.
- Prepare a list of project benefits.
3.0 BACKGROUND

3.1 DESCRIPTION OF THE METAPÁN MUNICIPALITY, METAPÁN LAKE, GUIJA LAKE AND SAN JOSÉ RIVER

3.1.1 Municipality of Metapán

The name Metapán originates from the náhuatl o pipil language. Met translates as maguey or American agave, and apán as river. The full meaning is Agave River or Agaves River. Metapán is located in the western zone of the Santa Ana Department; it is the municipality with the most land in the department (668.36 km²), has a population of 59,004 inhabitants (VI population census and V housing census of 2007) and is subdivided into 24 cantones and 227 neighborhoods. The municipality has the following boundaries: to the north and west, the Republic of Guatemala; to the east, the municipalities of Citalá and La Palma and to the south, the municipalities of Agua Caliente, Nueva Concepción, Santa Rosa-Guachipilín Masahuat, Texitepeque and San Antonio Pajonal.

Since this municipality shares the Montecristo Forest with Guatemala and Honduras, contains the Guija and Metapán lakes and has the only cement factory in the area, it has been identified as a zone of potential development.

3.1.2 Metapán Lake

Metapán Lake is located northeast of Guija Lake, 3 km southwest of the city between the Las Piedras and Tecoman cantones (Municipality of Metapán) and in Santa Ana Department. It is located between coordinates 14° 17’ N and 89° 27’ W. The water surface in the rainy season (from June to November) covers about 4 km², with a varying depth of up to 6 m. During the dry season, it shrinks to 1 km² with depths between 0.6 and 1 m. The water levels in the lake have seasonal fluctuations, and the resulting flood plains are used by the communities for agriculture, grazing and tourism (Thesis UES). This lake, one of the municipality’s natural resources, is used as a work and food source. The lake is not of volcanic origin and lies in a valley formed by lava currents surrounded by small volcanoes (Moisa 1994).
3.1.3 Guija Lake

Guija Lake is shared by Guatemala and El Salvador. It is located along the northeast boundary of El Salvador and the east boundary of Guatemala, between de Santana and Jutiapa departments at an altitude of 430 meters above sea level. The surface area of the lake is approximately 45 km². The tributaries to this fresh water body are the Ostúa, Angue and Cusmapa rivers. The lake discharges on the right margin of the Lepa River via the Desagüe River where the Guajoyo Hydroelectric Dam is located. The lake has two large peninsulas. The islands of Teotipa, Cerro de Tule and Iguatepec are located on the Salvadoran side (approximately 32 km²), where excavations in 1924 discovered numerous pre-Columbian artifacts. The lake is surrounded by the volcanoes Mita, San Diego and Cerro Quemado (now extinct.)

3.1.4 San José River

The San José River begins at the Montecristo Forest, is 6.4 km long, is fed by other rivers and discharges into Lake Metapán. In 1975, Tage and Heymans reported this river to be torrential. The basin is characterized by dendritic drainage with a density of 1.41km/km² and a fourth order river network.

The main stem of the river is 17 km long, with a difference in elevation of 1.72 m, and with an average slope of 10%. The annual flow rate is of 533 mm (the general flow coefficient is 0.31), which causes a sediment transport of 9,000 m³ though the river; these sediments tend to deposit in the lower part of the City of Metapán, diminishing the river’s capacity. The river has changed watercourse over time and in the rainy season it causes floods.

3.2 GEOGRAPHY, HYDROLOGY, GEOLOGY AND GENERAL DEVELOPMENT TRENDS

Metapán has many favorable attributes that can contribute to the development of the northeastern portion of the country, such as: good geographic location for commercial activities, natural resources, high quality agricultural lands, transportation services hydroelectric energy sources, and a flourishing mineral industry. It is located on the boundary of Guatemala. Its calcareous soils (high in limestone) are scarce in the country. It has the Metapán and Guija lakes and important rivers like the San José, Angue and Desagüe. The zone covers an area of 9,656 km², which includes the municipalities of Metapán and San Antonio Pajonal of the Santa Ana Department; Metapán is located 480 m above sea level with an average precipitation of 1,556 millimeters. Its dry season is from November to April, and its rainy season is from May to October. There is an average annual precipitation of 1,700 millimeters in the northern and southern borders of the area, and 1,300 millimeters in the central section.
3.2.1 Physical Geography

The oldest rocks of El Salvador are probably in Metapán, from the Metapán Formation of the Superior Jurassic and Inferior Cretaceous eras. This formation contains layers of sandstone, shale, loam and limestone, with occasional strata of tufa and breccia. There is dolomitic limestone in the north, in the mountains east of the Lempa River and near the boundary with Honduras. The central part of the zone has a flat to rippled formation with alluvial deposits. This area is surrounded by hills and high mountains.

3.2.2 Hydrology

Surface runoff of the area and the Ostua and Angue rivers discharge in the Guija, Metapán and San Diego lakes. The Desagüe River carries water from the Guija Lake to the Lempa River. The discharge from Guija Lake is regulated by the hydroelectric dam and supplements the Guayabo Reservoir. Like in all the country’s rivers, the ones in this zone have high amounts of suspended solids. Deforestation in the zone has resulted in accelerated erosion endangering cities, infrastructure works, and agricultural lands. Thus, it is advisable to establish conservation areas.

3.2.3 Current Land Use

The zone produces cantaloupes, watermelons, tomatoes, beans, corn and “maicillo” (a special corn variety). Cantaloupe plantations make up the majority of the cultivated area.

3.2.4 Agricultural Structure

According to the predominant land tenure patterns, land in both municipalities in the zone is mostly leased. The zone’s population density is low.

3.2.5 Rural Electrification

The hydroelectric dam at Lake Guija, produces 15,000 kilowatts of that supplies the region. 44 kilowatts transmission lines serve Metapán and 115 kilowatts transmission lines serve the south. These lines connect with the distribution system for the central part of country. However, the rural electrification system in the rural regions is not complete.

3.2.6 General Development Trends

Although the development and industrialization of resources is very evident in the region, abundant land and water resources are conducive to a productive agricultural sector. The area’s soils have potential for good production capacity, but often flood. This is due to the fact that the good soils are located in low lands with mild slopes and poor drainage of surface water. However, they have good infiltration capacity, medium texture, good depth and are apparently fertile. These lands could improve with drainage systems, and have the potential to produce fruits and vegetables for commercialization in fresh or processed forms. Its proximity to international boarders opens the possibility for international markets.

The topography of the region, with hills to lower ridges, differs from the rest of the country, offering the opportunity for varied forestry production, particularly of the broadleaf type. In light of the zone’s development, most importantly in the north, conservation of higher lands and of the hydrologic basins should be considered. Not doing so would threaten the lower lands with landslides and sedimentation of the water conveyance and drainage systems.
3.2.7 Ecosystems

“Ecosystems change gradually not only due to time but also to space. This is why zones of influence are important due to the close relationships between neighboring ecosystems, which take place even at the soil level. The richness of an ecosystem is determined by the degree of biodiversity in a territory; this richness not only refers to birds, fish and mammals, but also to insects and microscopic organisms that are the base of the food chain. Therefore, when an ecosystem is altered, those neighboring it become less stable” (Corporación Andina Nacional para la Defensa del Ecosistema Manglar del Ecuador [C-CONDEM], 2001).

The Guija Complex, recognized as the 5th RAMSAR Site of International Importance, consists of the Metapán, Clara, Verde, Teconalá and Guija lakes. This lake complex also includes the San Diego, Vega de Caña, Masatepeque and El Tule volcanoes. It sustains endangered species that appear on the International Union for the Conservation of Nature’s Red List, such as the prickly iguana (garrobo espinoso), the rough voice parakeet (perico ronco), the yellow nape parakeet (loro nuca amarilla) and the tigrillo. The complex also houses fish such as the fresh water bivalve, which is very scarce in the country. With its designation as a RAMSAR Site, the Guija Complex is 1924th on RAMSAR’s list of “Important International Wetlands.”

3.3 BACKGROUND ON THE WASTEWATER TREATMENT PLANT FOR THE CITY OF METAPÁN

1. In 1995, PROCOSAL conducted a study on the “Design of the Wastewater Treatment Plant of Metapán” study that describes the project, its budget and an estimate of the dimensions of the treatment plant based on other Salvadoran examples, including the Suchitoto treatment plant in the Department of Cucatlán.

2. The Central American University of José Simeon Cañas (UCA), through the Department of Technological Processes and Environmental Sciences, conducted the “Preliminary Estimate of the Capacity of a Treatment Plant of the Wastewater Discharged to the San Jose River by the City of Metapán” in May 2010 based on water consumption data of the Aministración Nacional de Acueductos y Alcantarillados (National Administration of Aqueducts and Sewers) and the statistical projections of the Dirección de Estadísticas y Censos 2004 (Office of Statistics and Census 2004). The purpose of this study was to use these data for the design of a treatment system.

3. Fundación CESSA, through Dutch consultant Klaas Vissheer, in June 2011 conducted the “Wastewater Treatment Project of Metapán” (“Proyecto de Tratamiento de Aguas Residuales de Metapán”) study based on relevant information and studies and on anaerobic treatment experience in Bolivia. The study recommended the treatment system and provided cost estimates.

4. The Committee for the Construction of the Wastewater Treatment Plant at Metapán met in December of 2011 to define the “Preliminary Design of the Treatment of Wastewaters in Metapán” (“Pre Diseño de Tratamiento de Aguas Residuales en Metapán”). Four proposed treatment alternatives were discussed: 1) upflow anaerobic sludge blanket (UASB) with trickling filter; 2); UASB with activated sludge; 3) UASB with wetlands; and 4) UASB with Facultative Oxidation Ponds. Advantages and disadvantages of each treatment alternative were discussed, and the final selection was No. 1: Upflow anaerobic sludge blanket followed by a trickling filter with a secondary sedimentation tank (also referred to as settling tank).
4.0 METHODOLOGY

The following activities were carried out as part of the consultancy:

1. Introduction of the Tetra Tech consultant team and finalization of the work plan for the pre-feasibility study. The team was to focus on interviews and meetings with members of USAID, the Committee for the Construction of the Wastewater Treatment Plant of Metapán and governmental institutions directly or indirectly involved.

2. Field visits to the City of Metapán, with the representatives of the city and ANDA (the west and metropolitan regions) to visually inspect the important project sites: San José River, Metapán Lake and the proposed property for the construction of the treatment plant.

3. Research of pertinent information from the institutions involved in order to collect, analyze and utilize available data.

4. Conduct of working meetings to discuss how the project was advancing and identification of critical points and missing information and research.
5.0 STUDY RESULTS

A summary of the study results follows. The different activities performed were:

1. Assessment of the most strategic location of the wastewater treatment plant through field visits and determination of the suitability of the land acquired by the municipality for the treatment options considered.

2. Assessment of the treatment options and creation of a matrix for comparing technical, financial and organizational considerations.

3. Definition of the design population and the feasibility of designing the project in long-term phases.

4. Determination of the final points of effluent and sludge disposal.

5. Identification of options for recovering operational and maintenance costs.

6. Determination of the municipality’s capacity to ensure the long-term sustainability of the performance and maintenance of the treatment plant.

7. Identification of the necessary information for the feasibility study and/or the final design if a final alternative is found.

8. Evaluation of the risks of delay for the project to separate storm water and wastewater runoff by the Metapán municipality and ANDA, and the impact thereof on the treatment plant project.

9. Evaluation of the health, economic and environmental benefits resulting from the project.

10. Creation of a project timeline and estimation of costs.

11. Determination of how this activity agrees with USAID’s Biodiversity Code.


The City of Metapán’s sewage system covers approximately 70% of its territory. This system is located between the two principal tributaries to the San José River. The part of the city without a sewage system is made up of a large number of dwellings with septic tanks, conventional tanks or no wastewater disposal options. Because of the topography of the land, the dwellings on the west of the city could be connected to the treatment plant when the sewage network is extended. The east zone could be connected via a pumping station.

Figure 1 shows the plan provided by city staff who, together with Tetra Tech technicians, defined zones with and without sewage service. As indicated in the figure the wastewater treatment plant should be located as close to discharge two as possible.
The first visit to the City of Metapán was conducted on May 24, 2012, the purpose of which was to collect information and visit the two wastewater discharge points. At this time, the team also inspected the site acquired by the municipality for the construction of the treatment plant, which would service the department’s headwaters and Metapán Lake. The trip was made with representatives of USAID (Rubén Alemán and Christine Katin), ANDA (Thelma Sandoval de Arévalo), Metapán (Virginia Sanbria, Naún Gonzalez and Roger Edmundo Calidonio) and Tetra Tech (Magdalena de Aguilar and Julián Monge).
On June 6, local consultants, with Fernando Román (Tetra Tech consultant) and city technical personnel, Naún Gonzalez and Roger Edmundo Calidonio, carried out an exhaustive trip to the wastewater discharge points, the land acquired by the municipality, the land located by the San Antonio River downstream from the discharge points and Metapán Lake to assess the topography and the best possible location for the construction of the treatment plant.

During the site inspection, the team observed that the land’s topography to the southeast of Wastewater Discharge Point Number 2 is such that 50% of it does not flood and is very irregular (with steep slopes), and that the construction level of the plant is 20 to 30 meters above the level of Discharge Point Number 2 on the San José River. The land northwest of this discharge point is flat but at a high flood risk. The land adjacent to the acquired site has the same characteristics as the one purchased, thus considering it as an option is irrelevant. The maximum surface water level in the event of a flood would be 3 meters above this discharge point.

After the trip and after analyzing properties adjacent to the San José River, revising the flood risk maps of the City of Metapán provided by SNET and consulting with the technicians of Metapán, it was clear that the land adjacent to and across the river from the property acquired for the treatment plant had the same topographic characteristics as the property acquired and that the land located downstream is flat and at risk for flood (see Figures 2 and 3).
One of the tasks of the study was to determine the suitability of the property acquired by the city. From the field visit information and interviews with city staff, it was determined that the acquired land is the best option, based on the following questions:
1. **Is there a location where pumping needs would be minimized?**

As Figure 2 shows, the land adjacent to that acquired by the municipality has no major elevation differences (+/- 5m) and those that have less elevation difference are located more than one kilometer downstream from the discharge point.

2. **If there are other candidate sites, are these located outside of the flood zone?**

According to Figures 2 and 3, lands in the vicinity of the acquired site also are in the flood zone. Lands outside of the flood zone are located downstream and thus further of discharge point 2.

3. **Given that the purchased land is the closest to the discharge, would the purchase price and cost to extend infrastructure to other candidate sites be less than the present value of cost savings from reduced pumping requirements at the acquired site.**

Assuming electricity costs of $0.16/kWh and energy consumption at maximum plant capacity, the energy savings attributable to a difference in elevation of five meters is $685/month. Thus, assuming an interest rate of 5% over a 50-year period, the net present value of energy savings is $150,142. Assuming further that the cost to purchase five manzanas [a manzana is approximately 1.7 acres] is $125,000, then the $150,142.00 in energy savings would largely go to purchase the land. Even if the property were donated and there were no acquisition costs, and assuming a cost of $316/m of new sewer collector, the $150,142 in savings would only permit construction of 475 meters of new pipe, which is not sufficiently long enough to reach other potential sites, as indicated in figures 2 and 3.

Other criteria to consider include the evaluation of flood risks, landslides and earthquakes, as well as the potential impact of odors, noise or activities that would alter substantially the quality of life for neighboring areas. The team verified that the purchased property is outside of the flood zone. During the visit of June 6, it was observed that reforestation was taking place on the higher areas of the land, which will diminish the risk of landslides. Independently of the latter, the plant will have to be constructed with foundation banks to impede the movement of the structures. Proper seismic design will ensure that damage due to earthquakes is minimized.

Impacts to neighbors will be insignificant since the closest dwellings are located 300m from the site. In comparison, in Texas, USA, the regulation (which is the same as in El Salvador) requires a minimum distance of 50m between the wastewater treatment plant and the closest dwelling. The use of chlorine, if chosen as a disinfectant, always implies a public health risk. An acute health risk could be posed within a 100m radius of the tank in the event of a massive leak. This would require the population to be evacuated to a minimum distance of 300m downwind. That said, chlorine gas is a common material and with a conservative design and adequate operator training, the risk of leaks would be substantially minimized. Environmental impacts can include erosion caused by low-quality fill material in the construction ditches of the “impulsion” lines or by a poor storm water drainage design. Another potential risk is methane gas leaking from pipes or if the gas burner extinguishes. From this analysis, the team determined that the site elected is the best option, thus it is suggested that the land acquired by the municipality be used (see Figure 4).
5.2 ASSESSMENT OF THE TREATMENT OPTIONS AND CREATION OF A MATRIX FOR COMPARING TECHNICAL, FINANCIAL AND ORGANIZATIONAL CONSIDERATIONS

A special component of this pre-feasibility study was to evaluate available technologies for wastewater treatment for the City of Metapán and to find an alternative that would respond to the requirements of the project:

1. Comply with the current regulation (NSO 13.49.01:09, CONACYT);
2. Minimize operation costs;
3. Minimize sludge production;
4. Be appropriate to the technical and administrative level of the city; and
5. Be sustainable.

Latin America has experience with low-impact wastewater treatment plants, like facultative oxidation pond systems, as well as technologies with diverse degrees of mechanical implementation and complexities. In order to compare technologies, research was conducted on experiences in wastewater treatment in developing countries. Among those researched, a noteworthy article is that by the Brazilian researchers Silvia C. Oliveira and Marcos von Sperling, entitled “Performance Evaluation of Different Wastewater Treatment Technologies Operating in Developing Countries.”
This article presents a comparative chart of the principal quantifying performance indices of treatment plants in 166 plants, and it compares capacities with respect to various parameters under real working conditions. The conclusions of the article favor the use of UASB (or RAFA in Spanish) with Post-Treatment, which is the type analyzed by the inter-institutional committee of the Metapán project.

**TABLE 1: SUMMARY OF THE CONCLUSIONS OF THE BRAZILEAN RESEARCHERS**

<table>
<thead>
<tr>
<th>Process</th>
<th>% Average Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBO5</td>
</tr>
<tr>
<td>Septic Tank with Anaerobic Filter</td>
<td>59</td>
</tr>
<tr>
<td>Facultative Oxidation Ponds</td>
<td>75</td>
</tr>
<tr>
<td>Anaerobic and Facultative Oxidation Ponds</td>
<td>82</td>
</tr>
<tr>
<td>Activated Sludge</td>
<td>85</td>
</tr>
<tr>
<td>UASB</td>
<td>72</td>
</tr>
<tr>
<td>UASB with Post-Treatment</td>
<td>88</td>
</tr>
</tbody>
</table>

1 Silvia C. Oliveira and Marcos von Sperling, IWA January 2011.

The removal efficiencies of the Five-day Carbonaceous Biochemical Oxygen Demand (BOD5, or simply BOD) and Total Suspended Solids (TSS) make the UASB with Post-Treatment process desirable. However, it has to be verified if the 88% average removal is appropriate for the conditions in Metapán. The next chart presents a BOD removal graph for different inflow conditions with the goal of obtaining an effluent with 50 mg/l of BOD (the regulation requires a BOD of 60 mg/l).

As shown in Graphic 1, if the inflow of Metapán is 600 mg/l, a 50 mg/l of effluent quality can be expected if the plant operates in the highest removal efficiency ranges, as reported in the literature. However, an inflow of up to 420 mg/l of BOD could be comfortably treated with an average efficiency of 88% as reported by Oliveira. Therefore, the UASB with post-treatment technology is recommendable from a technical standpoint.

Other variables to consider are the financial and administrative requirements of each technology. For discussion purposes, the natural systems were analyzed as one group (the anaerobic filters or any other type of pond that is not mechanized), the low mechanized systems in another group (of which the UASBs are part) and the highly mechanized with activated sludge plants in a third group.
5.2.1 Treatment Options

The treatment options considered by the inter-institutional committee for the construction of the treatment plant in Metapán in the document “Pre-design of the Wastewater Treatment Plant of Metapán,” dated December 6, 2011, evaluate advantages and disadvantages of four viable alternatives. Common to all the alternatives is the use of an Upflow Anaerobic Sludge Blanket. The four options are:

1. Upflow Anaerobic Sludge Blanket (UASB) + Trickling Filter;
2. Upflow Anaerobic Sludge Blanket (UASB) + Activated Sludge;
3. Upflow Anaerobic Sludge Blanket (UASB) + Wetlands; and
4. Upflow Anaerobic Sludge Blanket (UASB) + Facultative Oxidation Ponds.

UPFLOW ANAEROBIC SLUDGE BLANKET

UASB is a form of anaerobic digester used in wastewater treatment. The reactor is a methanogenic digester (it produces methane gas). The upflow anaerobic process consists of an upside down Imhoff tank. In it, the chambers of anaerobic decantation and digestion are overlaid, and there is a gas-liquid-solid separating system in the upper part. The methane gas can be used to produce electric energy or to cook after a purification process. The hydraulic detention time is six to 24 hours, depending on the process’ temperature.
5.2.1.1 UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) + TRICKLING FILTER

The trickling filter, which runs after the UASB as secondary treatment, has been utilized in Guatemala and El Salvador. It is a system that works with anaerobic and aerobic phases. The aerobic phase puts the settled wastewaters into contact with biological cultures and oxygen where the microorganisms convert the complex substances in the water, primarily organic, into cellular living material or in simpler or more sedimentable materials. Depending on the filter, electricity might not be needed and the system can work by gravity.

The complete treatment system has the following elements (see Figure 6):

a. Pre-treatment or preliminary treatment: Screen chamber, grit removal, flowrate meter and grease and/or oil trap;

b. Primary treatment: Upflow anaerobic sludge blanket;

c. Secondary treatment: Biological filter and secondary sedimentation tank; and

d. Sludge treatment: Sludge digester (works as a reservoir of the secondary sedimentation tank) and drying lagoons for the digested sludge.

Because of the elevation difference required (approximately 10 m) for this system to work by gravity, the land acquired by the municipality is ideal as it has the topography required for its implementation without problems. Technically it is the best option since its operation and efficiency is well known and the biogas can be utilized.

The cost of the operation and maintenance can be relatively low if the system works by gravity.
5.2.1.2 UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) + ACTIVATED SLUDGE

This process is widely used in economically and technologically more developed countries for the treatment of large wastewater flows. The systems use millions of microorganisms to treat the water. The feeding, growing and reproduction of these organisms remove waste materials diluted or suspended in the water. This system uses electromechanical equipment that requires a lot of energy, and its operation and maintenance call for highly trained personnel. The activated sludge is a treatment process in which the wastewater and microbial cultures are mixed in an aeration tank. The biological flocks formed in this process settle in a sedimentation tank and then re-circulate to the aeration tank.

In the activated sludge process, the microorganisms are completely mixed with the organic material of the wastewater, which in turn provides them with food. The mixing occurs through mechanical means (e.g., superficial aerators and diffusers) that serve dual purposes: to mix the materials together and to add oxygen to enable the process to develop.

This system can be constructed on the land purchased by the city, if built in levels. However, it is not economically viable due to construction costs, equipment and operation and maintenance.

The full treatment system contains the following elements (see Figure 7):

a. Pre-treatment or preliminary treatment: Screen chamber, grit removal, flowrate meter and grease and/or oil trap;

b. Primary treatment: Upflow anaerobic sludge blanket;

c. Secondary treatment: Aeration tank and secondary sedimentation tank; and

d. Sludge treatment: Sludge digester and drying lagoons of digested sludge.
In Tegucigalpa, Honduras, a treatment plant of this type was donated by the European Union. The quality of the water is good, but the plant’s electric energy consumption is high.

5.2.1.3 UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) + WETLANDS

There is little wetland treatment experience in El Salvador due to the need for a large, flat, extended land sites. There are two treatment plants constructed in the municipalities of San Jose Villanueva (Department of Chaltenango) and Nejapa (Department of San Slavador) that utilize the wetland system. These systems have
an Imhoff tank (similar to the UASB, but with a horizontal flow) with one wetland, but the experience has not been good: the Imhoff tanks, because of their horizontal flow and low residence time, have low efficiencies and the wetlands are blocked. This has resulted in poorly treated wastewater.

This system could improve removal efficiency if implemented with other units such as grease/oil traps and UASBs instead of Imhoff tanks, and could be used in small communities with fewer than 1000 inhabitants and with available large flat land.

The full treatment system has the following elements (see Figure 8):

a. Pre-treatment or preliminary treatment: Screen chamber, grit removal, flowrate meter and grease and/or oil trap;

b. Primary treatment: Upflow anaerobic sludge blanket;

c. Secondary treatment: Wetlands; and

d. Sludge treatment: Drying lagoons of digested sludge (a sludge digester is not required).

Figure 8: Schematic of a UASB and Wetlands System

5.2.1.4 UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) + FACULTATIVE PONDS

Oxidation ponds are small-depth excavations in which microbiotic populations consisting of bacteria, algae and protozoa are developed that eliminate, in a natural form, the pathogens present in wastewater. There are different types of oxidation ponds for the treatment of wastewater: facultative ponds, maturation ponds, anaerobic ponds (without aeration) and high-rate aeration ponds.

Facultative oxidation ponds are the most widely used and can be of two types: primary ponds that receive raw wastewater, and secondary ponds that receive wastewater that had undergone sedimentation though some type primary process (usually the effluent of an anaerobic pond, a sediment tank or a UASB). They are designed to remove BOD by means of a low organic superficial load that would allow the development of active algae populations. Algae produce the oxygen required by the heterotrophic bacteria, which in turn
removes the soluble BOD. The normal hydraulic detention time to remove Helminth eggs in ponds is at least 10 days.

This system is very good for the removal of pathogens, but it is not recommended because it requires a large flat surface and the land acquired by the city is highly uneven and significant earth movement would be necessary.

The full treatment system contains the following elements (see Figure 9):

a. Pre-treatment or preliminary treatment: Screen chamber, grit removal, flowrate meter and grease and/or oil trap;

b. Primary treatment: Upflow anaerobic sludge blanket;

c. Secondary treatment: Facultative ponds (a minimum of two in parallel); and

d. Sludge treatment: Drying lagoons of digested sludge.

**Figure 9: Schematic of a UASB and Facultative Oxidation Pond System**
<table>
<thead>
<tr>
<th>Wastewater Treatment Systems</th>
<th>Removal %</th>
<th>Removal Log Cycles</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>UASB + Trickling Filter</td>
<td>70 to 90</td>
<td>70 to 90</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>60 to 95</td>
<td>60 to 95</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>60 to 90</td>
<td>60 to 90</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td>UASB + Activated Sludge</td>
<td>60 to 90</td>
<td>60 to 90</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>60 to 95</td>
<td>60 to 95</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>60 to 90</td>
<td>60 to 90</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td>UASB + Wetlands</td>
<td>60 to 90</td>
<td>60 to 90</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>60 to 95</td>
<td>60 to 95</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>60 to 90</td>
<td>60 to 90</td>
<td>2 to 2</td>
<td>2 to 2</td>
</tr>
<tr>
<td>UASB + Oxidation Ponds</td>
<td>70 to 90</td>
<td>70 to 90</td>
<td>2 to 2</td>
<td>2 to 2</td>
</tr>
<tr>
<td></td>
<td>70 to 95</td>
<td>70 to 95</td>
<td>4 to 6</td>
<td>4 to 6</td>
</tr>
</tbody>
</table>

One cycle $\log_{10} = 90\%$ removal; 2 cycles = $99\%$; 3 cycles = $99.9\%$. 
<table>
<thead>
<tr>
<th>COMPARISON CRITERIA</th>
<th>N° 1 UASB + TRICKLING FILTER</th>
<th>N° 2 UASB + ACTIVATED SLUDGE</th>
<th>N° 3 UASB + WETLANDS</th>
<th>N° 4 UASB + PONDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be constructed on the purchased land, which has an elevation difference of ±20.00m?</td>
<td>3 YES: Needs ±10.00m in elevation difference.</td>
<td>3 YES: Can be constructed on level or uneven land.</td>
<td>1 NO: Wetlands can only be constructed on level land.</td>
<td>1 NO: Ponds, can only be constructed on level land.</td>
</tr>
<tr>
<td>Is the DBOs good?</td>
<td>3 YES: Above 90%</td>
<td>3 YES: Above 90%</td>
<td>3 YES: Above 90%</td>
<td>3 YES: Above 90%</td>
</tr>
<tr>
<td>Operative complexity</td>
<td>2 MEDIUM</td>
<td>1 HIGH</td>
<td>2 MEDIUM</td>
<td>3 LOW</td>
</tr>
<tr>
<td>Will it need electricity to operate electromechanical equipment?</td>
<td>2 YES: For the recirculation between the filter and the sedimentation tank.</td>
<td>1 NO: All work with electricity.</td>
<td>3 NO: All work by gravity, only needed for pumping.</td>
<td>3 NO: All work by gravity, only needed for pumping.</td>
</tr>
<tr>
<td>Spear parts easily available?</td>
<td>2 NO: Pumping equipment</td>
<td>1 NO: Pumping equipment and other mechanical parts</td>
<td>2 NO: Pumping equipment</td>
<td>2 NO: Pumping equipment</td>
</tr>
<tr>
<td>Operation and maintenance costs?</td>
<td>2 MEDIUM: Electricity (minimal mechanization)</td>
<td>1 HIGH: Electricity (complete mechanization)</td>
<td>3 LOW: Pumping equipment</td>
<td>3 LOW: Pumping equipment</td>
</tr>
<tr>
<td>Can treated water be used for agriculture?</td>
<td>3 YES: For ornamental plants and pasture</td>
<td>3 YES: For ornamental plants and pasture</td>
<td>3 YES: Large pathogen reduction</td>
<td>3 YES: Large pathogen reduction</td>
</tr>
<tr>
<td>National experience?</td>
<td>3 YES: Plant with the two units</td>
<td>3 YES: Plant with the two units</td>
<td>1 NO: Only UASB</td>
<td>2 YES: Each unit separately</td>
</tr>
</tbody>
</table>

**THE LARGEST TOTAL IS THE BEST ALTERNATIVE**

Because of their relatively simple operational requirements, pond systems have been used widely. However to function properly they require relatively level land which is not available in Metapán. Because of this and because of the experience in El Salvador in UASB with trickling filter, the team agrees with the Committee for the Construction of the Treatment Plant for the City of Metapán that this alternative is preferable. Most importantly, this option is the one that is most adaptable to the land purchased by the city.
5.2.2 Appropriate Technology

It is important to consider appropriate technologies in technical, institutional, social and economic frameworks. Technically and institutionally, the lack of appropriate technologies has been identified as one of the principal reasons that systems fail. Wastewaters are a hostile media for electronic and mechanical equipment. The maintenance must be constant and requires spare parts, laboratory analysis, qualified technicians, specialized technical assistance and adequate budget. In developed counties, the systems are chosen and designed based on the type of maintenance required. In developing countries (where some components might be missing), this should be the first consideration when selecting technologies for successful treatment plants and pumping stations.

5.2.3 Description of the Wastewater Treatment Plant with UASB + Trickling Filter

TREATMENT PLANT ELEMENTS

5.2.3.1 WASTEWATER PUMPING STATION

The best site on which to construct the pumping station is on the land directly above Discharge Point No. 2 because this collector is approximately 2m deep. To place pipes through the river, protection works are necessary and the lower sections of the land purchased (near the river) gets too deep. The fact that under flood conditions the water elevation is about a meter above the elevation of the station must be taken into account. In the case of winter, many variables must be carefully considered during the design phase so as to reduce soil clogging, flooding or overworked pumps due to water filtrating to the station.

A pre-treatment system that retains large objects and sands that can damage the pumps must precede the pumping station. Three pumps and ancillary equipment should be installed: one for normal discharge, a second for maximum discharge and a third to be on stand-by for maintenance or emergencies.

To prevent water hammer check valves must be utilized. The station will have a wet well with 3 submersible coupling pumps with automatic operation, with guide rails for the submersible pumps and float switches to
transmit a start/stop signal to the pump controller. The hydraulic design of the well must include a brim and drainage.

**Figure 10: Schematic of the Factors Involved in the Design of the Pumping Plant for the Metapán City Wastewater Treatment Plant**

The design and construction of the station must have adequate ventilation and light, and safe working conditions.

### 5.2.3.2 PRE-TREATMENT

The pre-treatment of the wastewater is required prior to it being pumped to the treatment plant. Pre-treatment consists of the:

a. Screens;

b. Grit chamber or channel with velocity and cleaning measuring devices;

c. Parshall flowrate meter; and

d. Grease trap.

The objective of pre-treatment is to remove as much material as possible that could cause harm to the treatment plant or is difficult or impossible to accommodate such as non-biodegradable materials. This includes sands, stones, plastics, solids with diameter larger than two inches and any other foreign elements that can be retained by the grit chambers.

**a. SCREENS**

This is the first operation in the treatment process whereby wastewater flows through screens to remove large elements that would affect the process. Adjacent to the screen and at a higher elevation, a perforated slab must be installed to act as draining surface where the objects separated by the screens will be temporarily deposited and allowed to dry before being taken to disposal pits.

**b. GRIT CHAMBER**
Wastewater has elements that may cause maintenance and operational problems in the plant. Thus, the construction of a grit chamber is a necessity.

The elements with greater specific weight, called discrete particles, can settle to the floor of the chamber. This is made possible by designing a chamber with a hydraulic section that operates with a velocity that allows the sand to sediment, thus decreasing the accumulation of heavy deposits downstream in the pipes. Moreover, this decreases the cleaning requirement of the UASB, the percolating filter and the secondary sedimentation pond.

c. **PARSHALL FLOWRATE METER**

A Parshall flume will be used with a throat channel with \( W = 9" \) (22.9 cm) that allows the measurement of flows ranging between 2.55 l/s and 251 l/s, an acceptable range in the plant’s operating processes. The dimensions of the Parshall flume are defined by the throat width (\( W \)). The flowrate is calculated measuring the water depth (\( H \)) in the measuring well adjacent to the channel using the equation:

\[
Q = 0.5038 \times H^{3/2}
\]

where:

\( Q = \) flowrate m\(^3\)/s

\( Q = 0.5038 \times H^{3/2} \)

\( H = \) water depth in m

d. **GREASE CHAMBER**

The primary function of a grease trap is to hold greases that, as in the case of sand, are present in wastewater and interfere with the biological processes at the UASB and the percolating filter.

5.2.3.3 PRIMARY TREATMENT

Following pre-treatment, biologic treatment begins with an UASB. This system is recommended because of its high removal capacity of organic loading with efficiencies of 50% to 70%. It operates at ease in peak loads and has a stabilizing capacity for toxic elements, common in wastewater, that can be detrimental in the next treatment phase (trickling filter), thus protecting the filter’s biological equilibrium.
This structure is a completely sealed tank with gas exhaust pipes. The pipes are connected to ventilation ducts, which eliminate for the most part odor problems typical of anaerobic processes. There already are plants constructed with this type of ventilation.

5.2.3.4 SECONDARY TREATMENT

The objective of the secondary treatment stage is the degradation and stabilization of the organic matter still present in the reactor’s effluent and its final clarification.

a. Biological or trickling filter

b. Dortmund type secondary settling tank

a. BIOLOGICAL OR TRICKLING FILTER

In the bio-percolating process, the effluent from the reactor is introduced to an array of filters through sprinkler channels, the purpose of which is to guarantee an even distribution of water over the supporting material or filtrating medium. The use of seven to 10 cm diameter volcanic ash is recommended because of its form, composition and texture (plastic material can also be used), on which a superficial biologic film of a large array of aerobic microorganisms will grow. These in turn will absorb and mineralize the substances in the residual water. The biological film, or zooglea, is formed by unicellular (ciliated) and multicellular (rotatory, nematodes, insect larvae) organisms. The efficiency of the filter depends on the feeding capacity of such organisms. This phase is expected to achieve a final treatment efficiency of more than 85%.

Photograph 10: Parshall flume flow measuring device prefabricated with a calibrated ruler for the direct measurement of flow.

Photograph 11: Maintenance staff cleaning a grease trap. Mejicanos, San Salvador.

Photograph 12: Construction of an upflow anaerobic sludge reactor (tank’s top slab). Chalatenango.
b. DORTMUND TYPE SECONDARY SEDIMENTATION (OR SETTLING) TANK

The thickness of the biological film, or zooglea, in the trickling filter increases gradually during the percolation process to the point where it detaches and flows with the effluent due to the hydraulic load. Because of this process, it is necessary to remove this zooglea in a final clarification structure. A secondary Dortmund sedimentation tank will be constructed for this purpose. The final treatment efficiency at this point would be higher than 90%.

5.2.3.5 SLUDGE TREATMENT

Final disposal of the sludge involves storing, digesting and dehydrating the sludge. The elements of this stage are the following:

a. Sludge digester storage basin (which can be avoided if returned to the UASB)

b. Drying beds
a. SLUDGE DIGESTER

The sludge digester will store and thicken the digested sludge that flows from the UASB to the settling tank, from which it should be purged at least twice a day.

b. DRYING BEDS

These beds are common in treatment plants. Their objective is sludge dehydration. The digested sludge is placed on the permeable beds; the thickness of the sludge on the beds should be between 15 and 30 cm. To speed up the process, it is recommended that the beds be located in an area exposed to air and sun.

For the dehydration of sludge in cities with a population higher than 20,000 inhabitants (as in the case of Metapán), other alternatives should be considered. These include band filters or filter presses to increase operation and maintenance costs.
5.3 DEFINITION OF THE DESIGN POPULATION AND THE CONVENIENCE OF DEVELOPING THE PROJECT IN LONG-TERM PHASES

5.3.1 Definition of Design Population and Design of Wastewater Flowrates

Population and wastewater flow projections for the City of Metapán were based on the study entitled “Estimación preliminar de una planta de tratamiento de las aguas residuales descargadas al Río San José por la Ciudad de Metapán” (“Preliminary Estimation of a Wastewater Treatment Plant Discharged to the San José River by the City of Metapán”) by the Department of Process Technology and Environmental Sciences at UCA. The Tetra Tech team also analyzed the 2010 Statistical Bulletin entitled “Boletín Estadístico 2010 de la Administración de Acueductos y Alcantarillados ANDA,” the Sixth Population Census and the Fifth Housing Census (“VI Censo de Población y V de Vivienda”) prepared by the General Institute of Statistics and Census. As presented in table 7 the projected wastewater flow for the year 2029 is 5,452 m³/d, rounded to 5,500 m³/d.

<table>
<thead>
<tr>
<th>No.</th>
<th>Municipality Supplied by ANDA</th>
<th>Number of Urban Connections</th>
<th>Population with Urban Coverage (%)</th>
<th>New Urban Services</th>
<th>Monthly Consumption (x1000 m³) (CM)</th>
<th>(b) Urban Population (PU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Metapán</td>
<td>6,513</td>
<td>4,521</td>
<td>100.0</td>
<td>87.3</td>
<td>164</td>
</tr>
</tbody>
</table>

|                | Water | Sewage | Water | Sewage | Water | Sewage | 113.2 | 20,719 |


From Table 5, we obtain the drinking water consumption per person: \( CP = \left( \frac{CM}{PU} \right) / 30 \text{ days} \times 1000 \)

Where: \( CP \) = consumption per person in liters/ person * day

\( CM = \text{Monthly consumption} \)

\( PU = \text{Urban population with aqueduct service} \)

\( CP = [(113,200 \text{ m}^3/20,719 \text{ habitants})/30 \text{ days}] \times 1000 \)
CP = 182.12 l/pd

There are dwellings that pay low cost rates and other that are illegal (water theft), making the actual monthly consumption bill collected by ANDA less than the real consumption.

According to ANDA standards “Normas Técnicas para Abastecimiento de Agua Potable y Alcantarillados de Aguas Negras” (ANDA, 1998), the minimum consumption of residential drinking water ranges from 80 to 125 l/pd, the medium ranges from 125 to 175 l/pd and the maximum ranges from 175 to 350 l/pd. The average has been calculated as 220 l/pd, including all urban infrastructure (restaurants, markets, dwellings etc.). Industry and business in the city are smaller, thus the figure of 200 l/pd can be used (UCA uses this number) with the resulting wastewater contribution of 80% of the drinking water, i.e., 160 l/pd. The designer of the wastewater treatment plant must refine these data.

<table>
<thead>
<tr>
<th>DEPARTMENTS AND MUNICIPALITIES</th>
<th>TOTAL</th>
<th>URBAN</th>
<th>RURAL</th>
<th>M</th>
<th>URBAN %</th>
</tr>
</thead>
<tbody>
<tr>
<td>08 - METAPÁN</td>
<td>59,004</td>
<td>19,356</td>
<td>39,648</td>
<td>89.3</td>
<td>32.8</td>
</tr>
</tbody>
</table>

Ministry of Economics, General Direction de Statistics and Census, 6th Population and fifth Housing 2007, pg. 33

Using the urban population of Metapán from the VI Population Census of 2007 (Table 6), the population increase was projected with the following equation:  

\[ P_n = P_o (1 + r)^n \]

Where:  
\( P_n \) = Population in year \( n \)  
\( P_o \) = Population at base year  
\( r \) = Annual growth rate  
\( n \) = Difference between year \( N \) and the base year

For the year 2010:  
\[ P_{2010} = 19,356 \times (1+0.258)^{2010-2007} \]

\[ P_{2010} = 20,893 \text{ inhabitants}. \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Pop. (Inhab.)</th>
<th>AN (m³/d) with 150 l/pd</th>
<th>Year</th>
<th>Pop. (Inhab.)</th>
<th>AN (m³/d) with 158.7 l/pd</th>
<th>Year</th>
<th>Pop. with Serv. DW (100%)</th>
<th>Pop. with Serv. WW (87.3%) (ANDA)</th>
<th>Dwellings with Serv. of WW</th>
<th>WW (m³/d) with 160 l/pd</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>27,823</td>
<td>2010 21,163</td>
<td>2010</td>
<td>20,893</td>
<td>18,240</td>
<td>2010</td>
<td>2,918</td>
<td></td>
<td>3,231</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>33,222</td>
<td>2016 24,661</td>
<td>2016</td>
<td>24,343</td>
<td>21,252</td>
<td>2016</td>
<td>3,400</td>
<td></td>
<td>3,400</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>34,218</td>
<td>2017 25,298</td>
<td>2017</td>
<td>24,971</td>
<td>21,800</td>
<td>2017</td>
<td>3,488</td>
<td></td>
<td>3,488</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>38,513</td>
<td>2021 28,014</td>
<td>2021</td>
<td>27,650</td>
<td>24,138</td>
<td>2021</td>
<td>3,862</td>
<td></td>
<td>3,862</td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>39,668</td>
<td>2022 28,738</td>
<td>2022</td>
<td>28,363</td>
<td>24,761</td>
<td>2022</td>
<td>3,962</td>
<td></td>
<td>3,962</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>40,858</td>
<td>2023 29,480</td>
<td>2023</td>
<td>29,095</td>
<td>25,400</td>
<td>2023</td>
<td>4,064</td>
<td></td>
<td>4,064</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>42,084</td>
<td>2024 30,241</td>
<td>2024</td>
<td>29,846</td>
<td>26,055</td>
<td>2024</td>
<td>4,169</td>
<td></td>
<td>4,169</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>43,347</td>
<td>2025 31,022</td>
<td>2025</td>
<td>30,616</td>
<td>26,728</td>
<td>2025</td>
<td>4,276</td>
<td></td>
<td>4,276</td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>44,677</td>
<td>2026 31,823</td>
<td>2026</td>
<td>31,406</td>
<td>27,417</td>
<td>2026</td>
<td>4,387</td>
<td></td>
<td>4,387</td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>46,094</td>
<td>2027 32,645</td>
<td>2027</td>
<td>32,216</td>
<td>28,124</td>
<td>2027</td>
<td>4,500</td>
<td></td>
<td>4,500</td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>47,601</td>
<td>2028 33,488</td>
<td>2028</td>
<td>33,047</td>
<td>28,850</td>
<td>2028</td>
<td>4,616</td>
<td></td>
<td>4,616</td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td>49,207</td>
<td>2029 34,353</td>
<td>2029</td>
<td>33,900</td>
<td>29,594</td>
<td>2029</td>
<td>4,735</td>
<td></td>
<td>4,735</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>50,903</td>
<td>2030 34,774</td>
<td>2030</td>
<td>34,774</td>
<td>30,358</td>
<td>2030</td>
<td>4,857</td>
<td></td>
<td>4,857</td>
<td></td>
</tr>
<tr>
<td>2031</td>
<td>52,700</td>
<td>2031 35,671</td>
<td>2031</td>
<td>35,671</td>
<td>31,141</td>
<td>2031</td>
<td>4,983</td>
<td></td>
<td>4,983</td>
<td></td>
</tr>
<tr>
<td>2032</td>
<td>54,597</td>
<td>2032 36,592</td>
<td>2032</td>
<td>36,592</td>
<td>31,945</td>
<td>2032</td>
<td>5,111</td>
<td></td>
<td>5,111</td>
<td></td>
</tr>
<tr>
<td>2033</td>
<td>56,524</td>
<td>2033 37,536</td>
<td>2033</td>
<td>37,536</td>
<td>32,769</td>
<td>2033</td>
<td>5,243</td>
<td></td>
<td>5,243</td>
<td></td>
</tr>
<tr>
<td>2034</td>
<td>58,561</td>
<td>2034 38,504</td>
<td>2034</td>
<td>38,504</td>
<td>33,614</td>
<td>2034</td>
<td>5,378</td>
<td></td>
<td>5,378</td>
<td></td>
</tr>
</tbody>
</table>

From Table 7 we can observe the following:

1. The population data calculated by UCA and Tetra Tech differ due to the fact that the former uses 2004 population data and the latter 2007.
2. The contribution of wastewater increases by 1.3 l/pd, from 158.7 l/pd to 160 l/pd. The last number can also be obtained using 200 l/pd and 80% as drinking water consumption, 80% of that contributing to wastewater.

3. To obtain the wastewater flowrates of Table 7, UCA considered 100% sewage coverage. According to ANDA information, Metapán has an 87.3% sewage coverage, which means that theoretically the wastewater treatment plant is being over-dimensioned. It is suggested to use Tetra Tech’s data for the final design.

4. Flowrates are calculated to the year 2034 because it is estimated that the treatment plant will be constructed in 2014.

5. ANDA provided the drinking water consumption in Metapán for the year 2012, namely 114,468 m³/month, or 3,342 m³/d. Tetra Tech estimated that consumption is 3,071 m³/d for 2012 (91.9% of ANDA’s figure).

Graph 2: Comparison of Projected Design Flowrate: PROCOSAL, UCA and Tetra Tech

Since the data is theoretical, it is suggested that as work goes on in both collectors, detecting connections where wastewater is mixed with storm water, real flowrates can be measured in order to obtain field data and compare it with theoretical data. There are several methods and measurement systems to obtain flowrate data in situ such as “V” notch meters, Venturi meters, magnetic flowrate measuring devises and calibrated Parshall measuring devices or use of the wetted perimeter method for circular pipes.

5.3.2 Is It Preferable that the Project be Constructed in Full or in Stages?

As Table 7 shows, the design flowrate projected for Metapán is considerably high; the constructed treatment plant must be capable of treating this flow.
The treatment plant must be designed for a minimum of 20 years. Taking into consideration all the necessary stages until construction begins, it is expected that the plant will be in operation by 2014; therefore, the plant’s capacity should be designed for 2034.

There are two options for constructing the plant:

1. Construct the plant for the design capacity (design flowrate) of 2034, which implies a full initial capital expenditure with an extra potential operating flowrate of 1,350 m³/d, thus operating with extra capacity during the first 10 years of operation.

We recommend that the pumping station be built to full capacity and not in stages. Three sets of pumps will be required at the onset, the capacity of which can be increased in year 10 to meet future flow requirements.

Construct the treatment plant in phases or stages, designing it in modules of equal capacity. These modules would be constructed as needed up until 2034.

### TABLE 8: FLOWRATE ESTIMATES OF WW FOR THE CITY OF METAPÁN EVERY FIVE YEARS BETWEEN 2014 AND 2034

<table>
<thead>
<tr>
<th>Year</th>
<th>Pop. Inhab. with (100%) DW Serv.</th>
<th>Pop. Inhab. (87.3%) WW Serv. (according to ANDA)</th>
<th>Projection of Dwellings with WW Service</th>
<th>Wastewater (m³/d) using 160 l/pd</th>
<th>Wastewater (m³/h) using 160 l/pd</th>
<th>Number of modules with 1,350 m³/d or 8,438 Inhabitants</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>23,134</td>
<td>20,196</td>
<td>5,048</td>
<td>3,231</td>
<td>134.63</td>
<td>2.7 (3)</td>
</tr>
<tr>
<td>2019</td>
<td>26,277</td>
<td>22,939</td>
<td>5,734</td>
<td>3,670</td>
<td>152.92</td>
<td>3.1 (3)</td>
</tr>
<tr>
<td>2024</td>
<td>29,846</td>
<td>26,055</td>
<td>6,512</td>
<td>4,169</td>
<td>173.71</td>
<td>3.3 (4)</td>
</tr>
<tr>
<td>2026</td>
<td>31,406</td>
<td>27,417</td>
<td>6,853</td>
<td>4,387</td>
<td>182.79</td>
<td>3.3 (4)</td>
</tr>
<tr>
<td>2029</td>
<td>33,900</td>
<td>29,594</td>
<td>7,397</td>
<td>4,735</td>
<td>192.29</td>
<td>3.5 (4)</td>
</tr>
<tr>
<td>2034</td>
<td>38,504</td>
<td>33,614</td>
<td>8,402</td>
<td>5,378</td>
<td>224.08</td>
<td>4.0 (4)</td>
</tr>
</tbody>
</table>

Analyzing Table 8 and taking as base modules with 1,350 m³/d of capacity, three modules need to be constructed for 2019 and 2024 (five and 10 years down the road), and four modules for 2029 and 2034 (15 and 20 years down the road). Therefore, construction could be planned in two stages: three modules can be constructed for the first ten years (until 2024) and in 2026, after the twelfth year, the fourth module could be constructed. Considering previous (30-year) experiences, the concrete infrastructure holds well (seen for the plants in Chilama [ANDA] and Puerto de la Libertad), which is an advantage that justifies this option. Constructing in stages will reduce the initial investment by $239,629.69. Another advantage of constructing by module is that if one module fails, the others keep working while the first is being fixed. Final decision will depends on the financial availability and the proposed design.

### 5.4 DETERMINATION OF THE EFFLUENT DISCHARGE POINT AND THE FINAL DISPOSAL OF THE TREATED SLUDGE

#### 5.4.1 Determination of the Effluent Discharge Point

In order to release treated water into a body of water or for agricultural uses, the treated effluent has to comply with CONAYT’s norm NSO 13.49.01.09, detailed in Table 9.
The two alternatives to dispose of the treated water are:

1. Discharge to the San José River, which then flows into Metapán Lake; or

2. Utilization for agricultural irrigation. The volume is limited to 4,500 m$^3$/d, which represents a daily application of 5 mm of water to 127 blocks of land, but the pumping and pipe investment to bring the water to the land can be high.

The agricultural irrigation option should be considered as an independent project using financial sustainability as principal criteria. Important considerations when making this decision include distance from the plant to the land, difference in elevation between the plant and the land, instantaneous and total water required, service requirements of the pipe network and all the contractual aspects to finance the project (e.g., the requirement that water be paid for whether used or not).

Treated water can be used for grassland, fruit trees and ornamental plants. Its use for edible plants is restricted because of a potential contamination with coliforms or other pathogens.

It is recommended that initially the wastewater be discharged to the San José River and that plans for its reuse be developed with interested parties. Such parties most likely do not have irrigation water during the summer, would be able to use treated water depending on the crop and should be able to pay for the installation of equipment and piping.

### 5.4.2 Determination of the Final Disposal Point of the Treated Sludge

The final sludge disposal depends on its use, and can be carried out either in the liquid phase or in the solid phase.

#### 5.4.2.1 LIQUID PHASE

a. Irrigation of grassland for livestock. This alternative requires the construction of a sludge irrigation system that could rotate in designated areas. Its use is very intensive and the nutrient and metal deposits has to be monitored to prevent exceeding desired rates. Just as in the alternative of using treated water as irrigation supplement, the use of sludge should be considered independent of the treatment plant construction project because the requirements for its financial sustainability should be met (with an interested client willing to finance the project and pay the operative costs). The plant must have an alternative method of sludge disposal because in winter the sludge demand would be low and the city will have to solve this problem.
5.4.2.2 SOLID PHASE

a. Temporary in situ storage for interested parties. Dehydrated sludge improves soil quality by improving its porosity and nutrient content in limited quantities. ANDA has positive experiences in the county: in San Juan Talpa and San José Villanueva, sludge is distributed to interested parties who pick it up with their own means. This is a low-cost alternative with social benefits.

b. Landfill transfer. If the private distribution of sludge is not enough, the city will have to transfer it to a landfill. The construction of the landfill in Santa Ana will minimize the transportation costs but landfilling will have to be paid by the ton.

c. Creation of an in situ sludge landfill. From the environmental standpoint, this is a complicated alternative. A sludge landfill requires a specific design with geo-membranes and leachate extraction. For a project of this scale, an in situ landfill would be prohibitive.

d. Compost. This is a very desirable alternative where the dehydrated sludge cannot be randomly distributed. The mixture of sludge and amendments (with carbonaceous material such as branches and agricultural waste) produces an inert compost with excellent properties for soil amending. Composting requires a source of amendment material, an area for mixing and maturation and equipment to move large quantities of material. This option costs more than that of disposal of dehydrated sludge alone, and would be done if the latter were not implementable.

It is first recommended that a mix of sludge and soil be used for landscape and the other for agriculture, as in San Juan Talpa (depending on the type of crop). If the sludge volume is excessive, alternatives b and d should be implemented.

According to the study “Study of Valorization of Sludge from Urban Sewage Plants” (“Estudio de valorización de lodos de estaciones depuradoras de aguas residuales urbanas”) conducted by the Las Palmas Municipality, one person produces between 15 and 20 kg of dry sludge per year. Taking as base that one metric ton is equal to a cubic meter of water or 1,000 kg, Table 10 shows the theoretical quantity of sludge that the treatment plant will produce annually and monthly.

<table>
<thead>
<tr>
<th>TABLE 10: ASSESSMENT OF TREATMENT PLANT SLUDGE PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SLUDGE ASSESSMENT IN M$^3$</strong></td>
</tr>
<tr>
<td><strong>YEAR</strong></td>
</tr>
<tr>
<td>2014</td>
</tr>
<tr>
<td>2018</td>
</tr>
<tr>
<td>2022</td>
</tr>
<tr>
<td>2026</td>
</tr>
<tr>
<td>2030</td>
</tr>
<tr>
<td>2034</td>
</tr>
</tbody>
</table>

5.4.3 Local Experience in Sludge Disposal from Domestic Wastewater Treatment Plants

The treatment plants of San José Villanueva and San Pablo Tacachico, both cities in the La Libertad Department, and the treatment plant of San Juan Talpa in La Paz started operations in 1997. The three were designed and constructed for 6,000 inhabitants and all but the last one have pumping stations. The KFW and the Government of El Salvador financed the plants.

The experiences gained from these plants are many, from the treatment process to digestion and dehydration, and to final disposal of sludge. In El Salvador anaerobic digestion is used due to the high temperatures. About 60 days are required to stabilize or digest the mixture of liquids and solids in the digester in order to be taken to the dehydration beds. This operation is generally conducted every 15 days. The mixture takes the longest to dehydrate in the summer.
There have been no problems with the final disposal of sludge because production has been low. A maximum of 30.0 m$^2$ of drying beds is needed for every 1,000 inhabitants (normally with a thickness of dry sludge of 5.0 cm, corresponding to 1.5 m$^3$/1,000hab*month). Two drying beds were constructed in the San Pablo Tacachico and San Juan treatment plants. Three drying beds were constructed in San José Villanueva. All had a smaller bed for storage. In San Juan Talpa, the sludge is used for the landscape surrounding the plant and for a football field adjacent to the plant. In San José Villanueva, the neighbors take the sludge during the night when the operator of the plant is not present and use it as amendment for different crops. For this reason, there is no accumulation of sludge in the plants.

Note that these cities are small (San Juan Talpa and San Pablo Tacachicoa population of about 6,000 inhabitants each), and there is no formal industry.

5.5 IDENTIFICATION OF OPTIONS FOR RECOVERING OPERATIONAL AND MAINTENANCE COSTS

5.5.1 Development of the Operation Budget

The operation and maintenance costs of the treatment plant can be classified as fixed and variable. The fixed costs incur independently of the wastewater flow to be treated, the variable costs depend exclusively on the treated flow. Typically the fixed costs include all administrative costs such as salaries, benefits, third party contracts and capital cost amortization.

The variable costs generally include the process’ electricity and chemicals. Some repairs, like replacement of pump blades, could be cataloged as variable since the wear is proportional to the use. However, in order to simplify the budget, it is considered as a fixed cost.

This section presents costs calculated for an estimated flowrate of 4,500 m$^3$/d, which, according to Tetra Tech projections, corresponds to the population for the year 2024. The costs are expressed in 2012 dollars, so to prepare yearly operation budgets, costs have to be increased with the pertinent adjustment factors. Table
11 lists monthly operative costs. Utilizing the values and assumptions explained in following sections of this document, the budget of the initial years, in which the treated flow will be lowest, can be calculated with the following equation:

**Operative budget: $3,788 + $1.00 per each m³/d of expected flow + desired reserve**

### TABLE 11: PROJECTED COSTS FOR 2014 THROUGH 2027, WHEN THE DEMAND REACHES MAXIMUM INSTALLED CAPACITY

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Flowrate m³/d</th>
<th>FIXED COST $/MONTH</th>
<th>MONTHLY COSTS, $/MONTH</th>
<th>VARIABLE COST</th>
<th>RESERVE</th>
<th>MONTHLY COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>3,231</td>
<td>3,788</td>
<td>3,231</td>
<td>702</td>
<td>7,721</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>3,315</td>
<td>3,788</td>
<td>3,315</td>
<td>710</td>
<td>7,813</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>3,400</td>
<td>3,788</td>
<td>3,400</td>
<td>719</td>
<td>7,907</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>3,488</td>
<td>3,788</td>
<td>3,488</td>
<td>728</td>
<td>8,004</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>3,578</td>
<td>3,788</td>
<td>3,578</td>
<td>737</td>
<td>8,103</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>3,670</td>
<td>3,788</td>
<td>3,670</td>
<td>746</td>
<td>8,204</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>3,765</td>
<td>3,788</td>
<td>3,765</td>
<td>755</td>
<td>8,308</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>3,862</td>
<td>3,788</td>
<td>3,862</td>
<td>765</td>
<td>8,415</td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>3,962</td>
<td>3,788</td>
<td>3,962</td>
<td>775</td>
<td>8,525</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>4,064</td>
<td>3,788</td>
<td>4,064</td>
<td>785</td>
<td>8,637</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>4,169</td>
<td>3,788</td>
<td>4,169</td>
<td>796</td>
<td>8,753</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>4,276</td>
<td>3,788</td>
<td>4,276</td>
<td>806</td>
<td>8,870</td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>4,387</td>
<td>3,788</td>
<td>4,387</td>
<td>818</td>
<td>8,993</td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>4,500</td>
<td>3,788</td>
<td>4,500</td>
<td>829</td>
<td>9,117</td>
<td></td>
</tr>
</tbody>
</table>

Cost estimates were made with the following assumptions: four full-time employees with an average monthly salary of $480 per person and benefits equivalent to 40% of their salary, and payment to external local electricians and mechanics of $10 per hour. Cost of spare parts is estimated to be $450/month. This is based on the assumption that 15% of the total construction costs of the plant ($1,800,000) is for electromechanical equipment (that is $270,000), and that maintenance for these systems is approximately 2% of this cost; that is 2% of $270,000 of $5,400/year or $450/month.) The amortization of a vehicle (to be used by operators) was done based on an initial cost of $15,000 and a five-year lifespan.

The electricity cost was estimated based on the mean flowrate of 4,500 m³/d and the recirculation in the trickling filter equivalent to 100%, 12 hours per day and a cost of $0.16kWh. Chemical costs were estimated assuming a dosage of 10 mg/l of chlorine gas at a cost of $0.75/kg. Because of the risks in managing pressurized gases, the chloride gas could be dosed with solutions of calcium or sodium hypochlorite, but the cost would increase by more than 300%.

A budget reserve of 10% was established to strengthen the capacity of the city to confront major maintenance. During the first years of the plant’s operation, the wear on the equipment is limited, but at some point, it will require replacement, the cost of which may be out of budget. An example is a motor that could cost around $10,000. If local accounting rules permit, the reserve not utilized could accumulate separately for infrequent uses.

Cost estimates do not include the cost of equipment to capture gas generated for the production of electricity for internal use at the plant. The economic benefits of gas capture equipment and the decrease reliance on external energy sources must be evaluated against the increased operation and maintenance cost of these equipment.
5.5.2 Cost Recovery Mechanisms

Although a wastewater treatment plant will have positive impacts on human and environmental health in Metapán, there are costs associated with these improvements. These costs could be allocated in several ways depending on the legal framework and inter-government agreements, but typically this is done through taxes or user fees.

The use of taxation implies that costs are captured broadly in municipal or national budgets and that the population as a whole contributes. The collected taxes can be earmarked to support the specific service for which the tax is levied; care should be taken to ensure that these funds are not co-mingled with other funds or directed to other municipal or national services and functions, particularly as this tax increment would not have occurred had this service (e.g., wastewater treatment) not existed.

At the municipal level, taxes are typically levied on property; at the federal level, however, taxes can be levied on income, commercial transactions or other income-generating activities. One disadvantage of taxation is that, unless the collected funds are used for a specific purpose, taxation could impact persons not directly related to the activity (that is, citizens that do not benefit directly from the wastewater treatment plant). However, within the realm of public health and environmental protection, treating wastewater benefits the entire population, thus general taxation could be justified. Such reasoning is used for other government services in which funds are used for projects of a national common good, without regards to geographic location or level of regional use.

In spite of the above, it is possible to develop mechanisms that allocate financial impacts directly to project beneficiaries. In many countries, sanitation is an attribution and responsibilities of local governments. In such a situation, municipalities are owners of the infrastructure and responsible for its operation and maintenance, with all the fiscal powers required to independently collect funds and create maintenance budgets. Under this approach, the user of the service, not the general taxpayer, is responsible for paying the costs according to the use incurred.

Currently there is a government tariff structure for cost of wastewater conveyance only. ANDA has established a rate proportional to drinking water use that varies from zero (exempt) for use less than 10 m$^3$/d to $5.00 for consumption over 500 m$^3$/month. Given the population characteristics of Metapán, as many as 7,030 dwellings are expected to use ANDA services by design year 2027, which would generate a revenue of $6,679, assuming that less than 50% of the population will use less than 20 m$^3$/d and that they would pay $0.10 per month, and that the other 50% would be above that level of consumption paying a monthly contribution of $1.80.

ANDA’s rate does not include treatment costs, and it is recommended for future studies that ANDA’s real costs be analyzed as part of its management in Metapán, to determine if part of these funds could be channeled for wastewater treatment.

If the cost of wastewater treatment were to be completely recovered through the Metapán users, the monthly cost per user in the year 2027 would be $1.30. However, the impact would be higher in the initial years, as can be seen in Table 12.

| TABLE 12: MONTHLY TREATMENT COST PROJECTION PER DWELLING FOR THE PERIOD 2014 TO 2027 |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| **YEAR** | **SEWAGE** | **TREATMENT** | | |
| | **Number of payees** | **Estimated revenue (1)** | **Monthly cost** | **Cost per person (2)** |
| | **$/month** | **$/month** | **$/month** | **$/month** |
| 2014 | 5,048 | 4,796 | 7.27 | 1.53 |
| 2015 | 5,178 | 4,919 | 7.81 | 1.51 |
| 2016 | 5,312 | 5,046 | 7.90 | 1.49 |
| 2017 | 5,449 | 5,177 | 8.00 | 1.47 |
### TABLE 12: MONTHLY TREATMENT COST PROJECTION PER DWELLING FOR THE PERIOD 2014 TO 2027

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SEWAGE</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of payees</td>
<td>Estimated revenue (1) $/month</td>
</tr>
<tr>
<td>2018</td>
<td>5,589</td>
<td>5,310</td>
</tr>
<tr>
<td>2019</td>
<td>5,734</td>
<td>5,447</td>
</tr>
<tr>
<td>2020</td>
<td>5,882</td>
<td>5,588</td>
</tr>
<tr>
<td>2021</td>
<td>6,033</td>
<td>5,731</td>
</tr>
<tr>
<td>2022</td>
<td>6,189</td>
<td>5,880</td>
</tr>
<tr>
<td>2023</td>
<td>6,349</td>
<td>6,032</td>
</tr>
<tr>
<td>2024</td>
<td>6,512</td>
<td>6,186</td>
</tr>
<tr>
<td>2025</td>
<td>6,680</td>
<td>6,346</td>
</tr>
<tr>
<td>2026</td>
<td>6,853</td>
<td>6,510</td>
</tr>
<tr>
<td>2027</td>
<td>7,030</td>
<td>6,679</td>
</tr>
</tbody>
</table>

**Note:**  
(1) Assumes: 50% of the payees will consume less than 20 m³/d and contribute $0.10 per month.  
(2) Assumes a homogeneous distribution among payees.

The objective of the discussion of estimated revenue vs. operation costs is to estimate the impact to users in case ANDA funds are available, but this does not represent a recommendation. The appropriate authorities are to decide which funding avenue to use. Impacts to the users can be analyzed under two scenarios: one where taxes are increased as a percentage of drinking water and sewage costs, and another as a function of the mean family income.

The first case implies an increase of 1.53% per month in the ANDA rate for a family with consumption of 20 m³/d, which represents a 34% increase over the current water and sewage rate of $4.49 ($2.29 minimum + $0.21 for every additional m³ + $0.10 for sewage). For a family that consumes 30 m³/month, the increase is 30% over its normal rate of $10.47 ($2.29 + 20*0.319 + 1.80). When an increase in rates affects more low-income people than those with higher incomes (as in this case), it is said that the impact is regressive and the distribution has to be corrected to reflect an equitable contribution. This analysis is beyond the scope of this study.

Even if the increase is high, it must be considered that the charge is for an additional service. An essential element in cost recovery is public education. The challenge is to make the population aware of the expected health benefits so that the economic impact of treated wastewater can be understood and accepted. The government should use all means available to make the public understand that they have to acquire a commitment in the environmental health of their area.

### 5.6 DETERMINATION OF THE CAPACITY OF THE MUNICIPALITY FOR LONG-TERM OPERATION AND MAINTENANCE OF THE TREATMENT PLANT

The sustainable operation of the treatment plant depends on a number of fundamental factors:

1. Healthy municipal finances (adequate operative budgets);
2. Technical and financial support by ANDA;
3. Qualified staff;
4. Sewage protection system; and
5. Municipal capacity to operate the system.
5.6.1 Municipal Finances

The plant’s operating budget must be sufficient to maintain a motivated and qualified staff, provide the energy that the process requires, monitor the process and perform repairs and improvements on time and with quality. Operating a biological process requires that optimal conditions be provided for the microorganisms to work at maximum efficiency. To achieve this, the plant must be in biological equilibrium; the best way to manage this is through operations protocols. For example, the maintenance of the recirculation system and regular intervals of sludge extraction require a protocol. Moreover, many plants fail because of insufficient resources to manage the flow of solids. Some management and sludge disposal costs are inevitable and cannot be postponed. The operations budget must cover the plant’s requirements in full.

The Metapán wastewater treatment project will depend, as all projects do, on the political will to assign resources for operation and maintenance, be they federal or municipal resources. The City of Metapán will need to demonstrate this willingness by including a line item in their budget for operation and maintenance.

One of the critical factors in a program designed to lower pollution is the continued support of subsequent administrations. A change to an administration not committed to environmental sanitation could bring a subsequent lack of interest and, therefore, abandonment of the installations. How can Metapán assure future political commitment? One possible incentive is the prospect that a clean and healthy lake becomes a tourist. Additionally increasing environmental awareness and conservation around the lake can further serve to attract investment.

5.6.2 Technical and Financial Support by ANDA

ANDA has plenty of experience in the operation of similar systems and will be an invaluable support for the city. From plants constructed in the past, at least six have been built with international aid. These plants are: San Juan Talpa, San Pablo Tacachico, and San José Villanueva with funds from ANDA and KFW; Suchitoto financed by USAID, FISDL and the city; Juayua with funds from ANDA and FODEC and Nejapa and San José Las Flores with Swiss funds (COSUDE).

The experiences of the above-mentioned plants are not the same, as some plants do not operate efficiently. It is recommended to study one or two successful plants and one with lower efficiency in order to learn lessons applicable to the Metapán project. As far as financial support, ANDA’s support will reduce the tax obligations. ANDA’s help can be in the form of resources, technical support, monitoring and lab support, and training.

5.6.3 Qualified Personnel

The selected treatment process is not difficult to operate but requires qualified personnel and opportunities for training to maintain their skills to date. The operator must also have access to external technical resources in the event that he/she cannot handle an operational or maintenance situation. All staff, from the engineers to the operations and maintenance personnel, should be properly trained.

Technical resources must not always be part of the municipal payroll; external personnel can be contracted for specific operation conditions, training or maintenance. In Metapán, qualified staff that services Holcim are a fundamental part of the sustainability of this project. These staff are not on Holcim’s payroll, but are an important group of small property owners that have been trained in mechanical, electrical, instrumentation and control abilities to support Holcim, and will be an important resource in the maintenance of the treatment plant.
5.6.4 Protection of the Sewage System

In spite of the fact that the plant is designed to treat domestic wastewater with some quality variability, it is important to maintain the wastewater integrity within expected ranges. Storm water that flows into the wastewater system, whether accidental or intentional must be avoided. For the plant to work within the designed range, the wastewater flow must be separated from storm flow, to allow for biological equilibrium under design conditions. This applies to any biological process.

Another necessary action is the pre-treatment of commercial, institutional and industrial influents that could affect the system. Those who generate them must screen acids, metals and other substances that would inhibit the biological process, e.g., excess fats can cause blockage in the sewage system and the pumping stations.

5.6.5 Municipal Capacity to Operate the System

As the City of Metapán does not currently have responsibilities for managing wastewater systems, it will have to train current staff or contract trained staff to operate that proposed treatment plant. The municipality’s engineers have the capacity and are willing to take part in the project. Their involvement would be beneficial especially if they are given training and the opportunity to visit projects with similar complexity and magnitude. Currently no municipal staff member has the required minimum experience to handle the mechanical equipment. It will be necessary to select and train personnel who are willing to learn for this job.

According to the mayor of Metapán, Mr. Juan Umaña Samayoa, the city has the capacity to pay the treatment plant’s operation and maintenance costs without raising municipal taxes. The representative of the cement factory, Holcim, stated that the factory pays about $4,000 in taxes annually. Therefore, the team is of the opinion that the costs of operation and maintenance are guaranteed without raising taxes. Moreover, the mayor had expressed that the city will assume responsibility for the treatment plant, Holcim will provide some collaborative technical support and ANDA will provide laboratory analysis support.

5.7 IDENTIFICATION OF THE NECESSARY INFORMATION FOR THE FEASIBILITY AND/OR FINAL DESIGN STUDIES, IN CASE ALTERNATIVES ARE FOUND

5.7.1 Preliminary Design

The pre-feasibility (also referred to as preliminary design) study team determined that the project formulated by the city is feasible and can proceed to the next stage. In the next stage, the project’s concepts must be developed to detail sufficient to understand the different design options. For example, there are two places for locating the pre-treatment and pumping stations, one on the land purchased by the city and the other on a site across the river, but both areas are subject to flooding. Analysis of both sites will show substantial differences, and the advantages and disadvantages should be analyzed by the designer. If the option to use the land across the river is selected, the city must be notified immediately.

Two of the most important design criteria at this stage are the definition of influent measurement and characterization of the flow. Both criteria are critical in the dimensioning of the processes. The measurement of flow rates in Discharge Point No. 1 appears straightforward since the structure is in good condition. For Discharge Point No. 2, however, the situation is more complicated, thus it is recommended that a working plan be elaborated and the city alerted if there is a need for equipment and construction material to partially reconstruct the discharge. It is obvious that rainwater will be a factor in the wintertime, affecting the characteristics of the water quality and its measurement.
The preliminary design phase requires that the topography of the site chosen be well-defined in order to locate the different process units and estimate the hydraulic head of the pumping station for the affluent. With the topography and a soil mechanics study, the embankments that will prevent landslides around the plant can be calculated.

Modular design alternatives must be presented and recommendations made on which units should be constructed for the total plant’s capacity and which can be constructed in modular form. The disadvantages and advantages of trickling filters should also be studied in order to make informed decisions. Costs of the project must be re-estimated in detail once final design decisions are taken.

The environmental impact statement must be taken to MARN with a conceptual design so that assessors can understand the intent of the project and its design. The conceptual design must be prepared in the preliminary design phase. The agency responsible for the electricity service must be notified of the electricity demands of the plant. This could be one of the factors that alters the budget or delays construction.

5.7.2 Final Design

The final design can be initiated once the environmental impact study confirms that the land could be used without problems. However, if the initial analysis suggests considerable environmental issues, it is suggested to limit the design to activities that have no risks of being re-designed.

5.8 ASSESSMENT OF THE RISK OF DELAYING THE PROJECT OF SEPARATION OF STORM WATER AND WASTEWATER, TO BE EXECUTED BY THE CITY OF METAPÁN AND ANDA, AND POSSIBLE IMPACTS TO THE PLANT’S PROJECT

5.8.1 Separation of Storm Water and Wastewater to be Executed by the City of Metapán and ANDA

The City of Metapán’s sanitary sewage coverage is 87% (Statistical Bulletin 2010 of ANDA). It is estimated that 60% of the city is covered by a storm water system that includes culverts, storm water collectors. In the rest if the city storm water flows superficially to rivers and ravines.

According to the Metapán technicians, the city has already defined sectors for the separation of waste- and storm waters. A pilot project was initiated with the help of the Ministry of Public Health and Social Assistance (Ministerio de Salud Pública y Asistencia Social) to visit every house in a pilot sector to detect crossed connections. The technicians discharged colored water through toilets, sinks and rainwater drains, and the team then looked for the colored wastewater.
water in the sewage and storm water systems.

The City of Metapán has programmed this project and is ready to execute it. The method used in the pilot project has been often used in the country with good results. The sector selection was performed with city plans that identified each neighborhood and scheduled visits. It is important to publicize the project in written and radio media so the population is accepting of visits. The visiting employee must bring a proper identification of the institution he/she represents.

**Figure 11: Plan of the North Area of the City of Metapán (Red Lines Represent the Storm Water Drainage System)**

This project should begin soon and should be finished prior to construction of the wastewater treatment plant. Depending on the number of workers utilized, it may take one year to complete. During this time, progress on the treatment plant project would include: preliminary design studies, preparation of environmental impact studies, final design of the plant, permits and financing. It will be important to insure that hospital and industrial waste receive some form of pretreatment prior to discharging to the municipal sewage; this to ensure that hazardous, toxic or other contaminated wastes do not reach the treatment plant. It will be necessary to train technicians in detection and repair of connections as well as in customer service.

It is also recommended that the detection program include capacity for the correction of connections, i.e. the separation of wastewater and storm water flows.
5.8.2 Assessment of the Risk of Delaying the Project of Separation of Storm Water and Wastewater, to be Executed by the City of Metapán and the Ministry of Public Health, and Possible Impacts to the Plant’s Project

If the program to separate crossed connections of waste- and storm water flows is delayed, storm flow in winter could substantially increase the volume of diluted wastewater in the sewage network, and summer wastewater flowing through the storm flow collector could generate undesirable smells. Without separating the flows, the construction of the treatment system (pumping station and treatment plant) would have to be designed for a higher capacity (to handle the increased flows).

If the wastewater pumping station required a higher capacity in terms of volume (larger cisterns) and pumping power, the result would be increased electricity consumption and, thus, overall higher costs. An alternative would be to construct a bypass of excess water with the consequent pollution of the San José River and Metapán Lake. Ultimately, the system and pumping equipment will fail because of the large volumes of water that would have to be handled.

5.9 ASSESSMENT OF THE HEALTH, ENVIRONMENTAL AND ECONOMIC BENEFITS RESULTING FROM THE WASTEWATER TREATMENT PLANT PROJECT

This document identifies some of the problems that could arise around the wastewater treatment plant project. Examples are separation of storm- and wastewater and direct discharge of the wastewater into the San José River. The construction of the wastewater treatment plant will allow a better development and expansion of the City of Metapán. Some of the benefits follow.

5.9.1 Health Benefits

The most important benefit of the wastewater treatment plan will be the decrease in gastrointestinal, respiratory and skin diseases caused by trash, dust, wind, polluted waters and bad odors. In addition to a considerable reduction in medical attention required and deaths, the general population’s quality of life will notably improve.
5.9.2 Environmental Benefits

The decrease of nutrient loadings and contamination in the water bodies will improve substantially water quality. This will especially be true in the San José River and Metapán Lake, which are directly affected by the discharge of the municipality’s wastewater. Consequently, the biodiversity of these ecosystems will improve.

5.9.3 Economic Benefits

The construction and maintenance of the treatment plant will not yield economic benefits or recovery since, according to Mr. Juan Umaña Samayoa, current mayor of Metapán, the population will not be taxed and the city will assume the maintenance costs. The projected benefits are related to more and better work sources, decrease in the public health costs with reduction in gastrointestinal, pulmonary and skin diseases and the possible increase in ecotourism.

5.10 DEVELOP PROJECT TIMELINE AND COST ESTIMATES

5.10.1 Timeline of Project

The total execution time for the project is two calendar years, which can be shortened in the preliminary phases (creation and approval of the environmental impact statement [Estudio de Impacto Ambiental, or EIA], and the treatment plant’s preliminary and final designs). Activities will begin on September 2012 with the submission of the pre-feasibility study, and construction will end on July 2014. The process following the pre-feasibility study is as follows:

1. **Environmental Studies**: Bidding of services, environmental formulation, document preparation, revision and approval.
2. **Design**: Project bidding, conceptual design, preliminary design, revision of the preliminary design, final design.
3. **Bidding Process**: Company prequalification, construction bidding.
4. **Construction**: Construction of the treatment plant and start of operations.

The project’s critical path is comprised of technical and coordination activities. A timeline is critical because the project is being financed by multiple agencies. The project’s calendar assigns one month for examining options and determining which agency will lead the project. It is critical to determine if funds from USAID will be solicited, as this requires detailed work and takes time. Likewise, intergovernmental agreements and the alliance with Holcim need to be immediately delineated. If decisive actions are not taken, this 30-day period will not be sufficient.

The next step on the critical path relates to environmental management. To prepare the environmental impact statement, the project must be further conceptualized and supporting information supplied. This can be done immediately with the already available information. Environmental and engineering consultancies must be contracted immediately. The first consultancy contracted will be for preparation of the EIS. The contractor should have a reputation for good performance and timely delivery. Engineering services are also needed immediately since they will give the necessary support to the environmental impact study’s development. It is not an impossible task to complete the construction of the plant in two years, but strong leadership will be required. If the environmental study and official revisions are done in a timely manner, the time needed to complete this phase could be shorter.

In summary, an action plan with recommended preliminary activities follows:
1. **Confirm resources:**
   - Construction
   - Source of operative resources (already confirmed by the city)

2. **Establishment of the lead agency authorized to execute the project:**
   - Establish budget for services to be contracted
   - Outline bidding requirements

3. **Speed up contracts:**
   - Environmental consultancy
   - Engineering services

4. **Start the following activities immediately:**
   - Feasibility study and conceptual design
   - Environmental management

Table 13: The following Gantt chart presents the time and activities required to complete the Project. The red bars indicate the project’s critical path.

![Gantt Chart](image)

5.10.2 **Project Costs**

The assessment of construction costs was prepared by analyzing and reviewing the following documents: Budget and Design of the PROCOSAL Treatment Plant, 2006; Klaas Visscher cost estimates, June 2011 and cost estimates of the committee in charge of the construction of the plant, December 2011. Table 14 presents
an estimate based on similar plants; estimates can vary according to the type of construction materials and degree of mechanization desired. The final official budget will be determined in the final design.

<table>
<thead>
<tr>
<th>TABLE 14: ASSESSMENT OF PROJECT COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROJECT COST: THE COST OF THE TREATMENT PLANT HAS BEEN ESTIMATED AT $1.3 MILLION, THE TOTAL FOR THE PROJECT IS $ 2,665,586 (SEE DETAIL)</strong></td>
</tr>
<tr>
<td><strong>TOTAL ESTIMATES</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>--------------------------------------</td>
</tr>
<tr>
<td><strong>A) STUDIES AND DESIGN</strong></td>
</tr>
<tr>
<td>Studies and design</td>
</tr>
<tr>
<td><strong>B) CONSTRUCTION OF COLLECTOR Ø 4” TO PUMPING STATION (INCLUDES PROTECTION)</strong></td>
</tr>
<tr>
<td>Construction of collector Ø 24” to pumping station (includes protection)</td>
</tr>
<tr>
<td><strong>C) PUMPING STATION</strong></td>
</tr>
<tr>
<td>Pre-treatment (screen, grit, prefab. Parshall)</td>
</tr>
<tr>
<td>Grease trap (includes screen and tubing)</td>
</tr>
<tr>
<td>Pumping cistern (includes underwater excavation)</td>
</tr>
<tr>
<td>Control panel</td>
</tr>
<tr>
<td>Pumping equipment</td>
</tr>
<tr>
<td>Impellent line Ø 6” HoFo, with accessories (pumping plant)</td>
</tr>
<tr>
<td>Electric line and electric station</td>
</tr>
<tr>
<td>Land purchase for the pumping station</td>
</tr>
<tr>
<td>Exterior works (embankment and others)</td>
</tr>
<tr>
<td><strong>D) TREATMENT PLANT</strong></td>
</tr>
<tr>
<td>Primary settling tank</td>
</tr>
<tr>
<td>Primary treatment (upflow anaerobic sludge blanket)</td>
</tr>
<tr>
<td>Secondary treatment (trickling flow + secondary settling tank)</td>
</tr>
<tr>
<td>Sludge digester</td>
</tr>
<tr>
<td>Sludge drying beds</td>
</tr>
<tr>
<td>Storage and burner of methane gas</td>
</tr>
<tr>
<td>Septic tank (for leachate in drying beds)</td>
</tr>
<tr>
<td>Security station (includes showers and toilet, tool room, product storage, office)</td>
</tr>
<tr>
<td>Exterior work (access roads, storm water drainage, etc.)</td>
</tr>
<tr>
<td>Chlorination</td>
</tr>
<tr>
<td>Hydraulics</td>
</tr>
<tr>
<td><strong>E) SEPARATION OF RAINWATER AND WASTEWATER</strong></td>
</tr>
<tr>
<td>SG</td>
</tr>
<tr>
<td><strong>F) LAND PURCHASE</strong></td>
</tr>
</tbody>
</table>

50  PRE-FEASIBILITY STUDY: WASTEWATER TREATMENT PLANT FOR THE CITY OF METAPÁN, SANTA ANA
The principal objective of the cost estimate is to understand the larger construction items. In general, the costs presented are calculated from preliminary dimensions of the plant and updated unit costs. These costs could change if the mechanical components increase substantially.

Another item that must be analyzed once the City releases information is the cost of separating the stormwater flow from the wastewater flow. The $420,000 assigned can be sufficient if new piping is installed adjacent to the storm flow collectors, but the data has yet to be analyzed.

Finally, the design budget excludes the following:

1. Engineering related to disconnecting the systems;
2. Design of effluent disposal structures except those associated with the discharge to the San José River;
3. Design of sludge disposal structures in addition to the drying beds; and
4. Design of methane gas electric generation system.

In conclusion, the costs of the project seem sufficient for the scope of the project.

### 5.11 HOW THE ACTIVITY FITS WITH USAID’S BIODIVERSITY CODE CRITERIA

The conclusions of this Pre-Feasibility Study for the Wastewater Treatment Plant of the City of Metapán in Santa Ana, as well as the activities required for its implementation, fit with USAID’s Biodiversity Code.

First, the project’s framework explicitly states a biodiversity objective. The project, sponsored by Holcim through a public-private alliance that oversees the preliminary study prepared by Holcim entitled: “Improving the Conservation of the Biodiversity Through the Construction of a Primary Wastewater Treatment Plant in Metapán” specifically focuses on improving the state of the region’s biodiversity; the project also expects to improve the public health and the economic growth of the region.

Second, project activities must be identified based on a biodiversity risk analysis. The Central American University (Universidad Centro Americana, UCA) conducted a wetland environmental study in Metapán and confirmed the strong impact that wastewater has on the San José River. The San José River connects with the Chimalapa River, which becomes the Trapichito River, which is the only tributary to Metapán Lake. UCA measured the contamination levels of the lake, and found high levels of organic material, which negatively impact the ecosystem, in particular, the biodiversity of the region. The domestic wastewater discharge problems detected in the zone are:

1. Deterioration of the water quality;
2. High coliform levels; and

### TABLE 14: ASSESSMENT OF PROJECT COSTS

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Cost ($)</th>
<th>Sub Total ($)</th>
<th>TOTAL ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G) SUPERVISION: STUDY, DESIGN AND CONSTRUCTION</td>
<td>month</td>
<td>20</td>
<td>5,000.00</td>
<td>100,000.00</td>
<td>100,000.00</td>
</tr>
<tr>
<td>H) CAPACITATION</td>
<td>month</td>
<td>3</td>
<td>5,000.00</td>
<td>15,000.00</td>
<td>15,000.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,666,586.75</td>
</tr>
</tbody>
</table>

The principal objective of the cost estimate is to understand the larger construction items. In general, the costs presented are calculated from preliminary dimensions of the plant and updated unit costs. These costs could change if the mechanical components increase substantially.
3. High nutrient content in the water (due to the adjacent agricultural lands and the domestic wastewater discharges of Metapán), which generate water hyacinths.

Part of the environmental impact study, required for the construction of the wastewater treatment plant of Metapán, should be to evaluate the principal risks to biodiversity, as well as the value/importance of such resources in the region.

**Third, the program must monitor biodiversity conservation indicators.** Part of the environmental impact study must include identification and monitoring of biodiversity conservation indices. Possible indices to utilize are:

1. Levels of organic matter in Lake Metapán measured as biochemical oxygen demand and chemical oxygen demand.

2. Nutrient level (N, P) in the water of Lake Metapán.

3. Coliform levels in the water of Lake Metapán.

4. Dissolved oxygen levels in the water of Lake Metapán.

5. Biological state of the waters of Lake Metapán (e.g., macro-invertebrates, plants, fish populations, algae).

Finally, the program’s intention should be to positively impact the biodiversity in areas of biological importance. Lake Metapán is part of the Guija Complex, which was declared in El Salvador as a wetland of international importance (under RAMSAR). Thus the wastewater treatment plant project of the City of Metapán focuses on the protection and conservation of the biodiversity of the Metapán and Guija lakes.
5.12 EL SALVADOR EXPERIENCES WITH TREATMENT PLANTS THAT WERE CONSTRUCTED WITH THE TECHNICAL AND ECONOMIC SUPPORT OF INTERNATIONAL INSTITUTIONS

El Salvador has several treatment plants in different municipalities that were constructed with the technical and economic support of international institutions. Some of those projects are:

1. **Italia District, Tonacatepeque**: Constructed with Italian Cooperation funds in 1989.
2. **San Juan Talpa, La Paz**: Constructed with ANDA and KFW funds in 1996.
3. **San José Villanueva, La Libertad**: Constructed with ANDA and KFW funds in 1996.
4. **San Pablo Tacachico, La Libertad**: Constructed with ANDA and KFW funds of in 1996.
5. **San José Las Flores, Chalatenango**: Constructed by the Swiss Cooperation, COSUDE, in 2000.
7. **Suchitoto, Cuscatlán**: Constructed with USAID, FISDL and municipality funds in 2002.
8. **Apaneca, Sonsonate**: Constructed with ANTEL and FANTE (national) funds in 2004.

All treatment plants worked well for several years, and they still work, but the majority have experienced deficiencies due to the following problems: bad design, bad construction or minimal operation and maintenance. Maintenance and operation problems are the most common in all treatment plants. No municipality charges for wastewater treatment services because there is no law or municipal norm to do, so and the operators are responsible for operation and maintenance costs. Some examples and experiences of attributes and deficiencies of plants follow, which should be taken into consideration in the design of the Metapán project.

5.12.1 San Juan Talpa Municipality’s Treatment Plant, La Paz Department

This plant was constructed with ANDA and KFW German funds and was design by a German company. It is operated and maintained by ANDA, and operations were initiated in 1996. The plant works by gravity and has pre-treatment, two settling tanks, one trickling filter and sludge treatment. Because the plant used to work well and is near the capital city, ANDA used it as an example of a successful treatment system yielding good treated water quality, with low maintenance and operation costs.
For a long time, the plant received preventive and corrective maintenance; it finally began to deteriorate because of a lack of anticorrosive paint. One person currently maintains it.

5.12.2 San Pablo Tacachico Municipality Treatment Plant, Department of La Libertad

This treatment plant, like those in San Juan Talpa and Jose Villanueva, was constructed with ANDA and KFW funds, and was also designed by a German company. It is operated and maintained by ANDA and operations were initiated in 1996. The pumping station was constructed on the lower lands of the city. Unfortunately, the sewage inflow lacks pre-treatment, the station has no emergency generator and the system works with one pump. Therefore, the station suffers constant failures because the pump clogs and the cistern overflows during power outages. Grit, plastics and metallic objects obstruct and wear down the pump blades.
As in the San José Villanueva plant, this system is operated and maintained by the municipality, and it requires pumping from the primary settling tank to the trickling filter. The plant has a pre-treatment system, two settling tanks, one trickling filter and sludge treatment. Since this system is electricity-dependent and does not have a generator, it has had problems since the beginning. Under normal conditions, however, the quality of the treated water is good.

For several years, the plant received full maintenance; later, the metallic structures began to deteriorate. Only one operator now works in the plant and the pumping station.

The difference in elevation of the land between the secondary settling tank and the discharge point is more than 10 m. The trickling filter could have been constructed at a lower elevation and thus worked by gravity with improved efficiency.

Another structural problem was that the sludge drying beds were constructed without a brim at relatively high elevations, and they were flooding in winter. This problem was solved by constructing a ditch around them.

5.12.3 Wastewater Treatment Plants in the Municipalities of San José Las Flores in Chalatenango and Nejapa in San Salvador

The treatment plants of San José Las Flores and Nejapa were designed and financed by the Swiss Cooperation (COSUDE), the first in 2000 and the second in 2001. Both systems have an Imhoff tank and a wetland. As in the majority of the new plants, they worked well for several years. The San José plant started to have clogging problems in the filtrating medium of the wetland in 2005.
The treatment plant in the municipality of Nejapa, being bigger than the one in San José Las Flores, has more problems: the Imhoff tank does not work properly, the drying beds are too small and are not used and the wetland is clogged. The municipality operates it.

Due to the lack of maintenance of the Imhoff tank, the upper part contains floating material, which has not been removed in a long time. The tank is full of sludge, thus has little water capacity, with minimum detention time and very low efficiency. As previously mentioned, the filtrating medium (volcanic ash) of the wetland is totally clogged. Therefore, the water from the Imhoff tank flows superficially through the wetland and is not treated.

5.12.4 Wastewater Treatment Plant of the Municipality of Suchitoto, Cuscatlán

The wastewater treatment plant of the City of Suchitoto was constructed in 2002 with funds from USAID, FISDL and the municipality. As with San Juan Talpa, it has pre-treatment, two settling tanks, one trickling filter and sludge treatment. Initially, the quality of the treated water was good, but in less than a year, problems begun. The sludge digester was not well-designed and started to overflow because it lacked an overflow pipe system. Due to this, the sludge of the settling ponds could not be purged, solid material began to accumulate and overflow. This material would flow from the primary tank to the trickling filter to the secondary sedimentation tank and to the final discharge point. As a consequence, the efficiency was very low and a filter fly infestation resulted.
When the problem was corrected, the plant worked normally and produced a good quality effluent. By 2011, during a visit with technicians of USAPA, it was observed that the plant lacked preventive and corrective maintenance. The City of Suchitoto, through the decentralized organization EMASA, operates this plant.

5.12.5 Wastewater Treatment Plants of the Municipalities of Apaneca and Juayua in Sonsonate, Puerto El Triunfo in Usulután and El Lago in Chalatenango

The Apaneca plant was constructed with funds from ANTEL and FANTEL (national funds) in 2004; it works well because it was over-dimensioned and the treatment flow is minimal. The Juayua plant was constructed with funds from ANDA and FODEC in 2008; the Puerto El Triunfo Plant in Usulután was financed by the Spanish Cooperation and ANDA in 2008 and the La Laguna Plant in Chalatenango was constructed with funds from FISDL, the European Community and the municipality. All were designed using the Suchitoto plant as their model.

We can conclude that these treatment plants operated successfully during the contractual period with international finance. This contract forced the operators to work with good continuous operation and maintenance so the investment was met. When the period concluded, so did the good operation of the plants.
These plants’ failures began after the international contractual agreements ended; they have been deteriorating due to lack of proper operation and maintenance; there is no legal fee for the wastewater treatment service, therefore ANDA and the municipalities cannot charge for the service and the costs in materials, equipment, tools and salaries have to be absorbed by the system’s operator. For this reason, some plants have been abandoned.

**When a treatment system is constructed, the following should to be considered:**

a) **For the design:**

- Minimize the degree of mechanization: If mechanization is minimal, the electric consumption reduces substantially.

- Design by modules: If a one-module plants fails, the plant stops work completely; if the plant has several modules, the plant continues to work if one module fails or needs to be repaired.

b) **For the construction:**

- Treatment units and devices must be done according to plans: During construction, plans should be strictly followed. The designer should be consulted about any modifications.

c) **For the operation and maintenance:**

- As indicated by the operations and maintenance manual, operation and maintenance should be continuous and of good quality, to impede the deterioration of treatment units and their devices in time. This requires that the institution in charge assign a yearly budget for the plant.

- Periodic laboratory analysis must be done, and develop permanent training program for treatment plant staff.
6.0 CONCLUSIONS

Guided by the analysis presented in this document, the Tetra Tech team concluded that the wastewater treatment plant project for Metapán is feasible. From a technical standpoint, the team determined that the installation of a UASB and trickling filter is the best option because: 1) the reduction of solids in the reactor via anaerobic digestion minimizes the subsequent sludge disposal requirements; and 2) the trickling filter, with successful performance worldwide, offers a solid technical base that ensures that the wastewaters will be treated appropriately.

The traditional factors for selecting land on which to locate the plant were analyzed: costs related to the distances between plant and wastewater discharge points and plant and point of effluent discharge, topographic characteristics, access, availability of electricity and analysis of risks and impact to neighbors. The team concluded that the land purchased by the city is adequate and represents the best option among the candidate plots available in the area.

The design population was calculated based on drinking water connection and flow rate information, as well as population data from the 2007 Census. According to the analysis, the capacity required for the year of construction (2014) is 3,231 m³/d; for the tenth year (2024), the capacity required would be 4,169 m³/d and for the year 2034, the capacity required would be 5,378 m³/d. Therefore, it is recommended that the plant be constructed with a capacity of 5,500 m³/d.

Ideally the plant should be constructed in modules; however, since 60% of the plant must be constructed initially, there is not much room for a modular project. Nevertheless, a modular project could be formulated in such a way that two modules could be constructed initially covering 75% of the final plant capacity of 5,500 m³/d, and a third module would be constructed in the future. It must be observed that the costs of a modular system are higher compared to a non-modular system due to higher construction costs. In order to make the most of the current project’s momentum and to minimize long-term costs, the technical team recommends that the plant be constructed in full if the funds are available.

Initially the effluent will be discharged into the San José River. This effluent could be used for agricultural activities in the summer season if farmers are willing to pay the costs associated with the effluent’s reuse. In effluent recycling projects, it is best to first develop markets and then look for investment.

The disposal of the dehydrated sludge could be done locally to allow farmers to use it to improve their soil. This has been ANDA’s experience in other wastewater plants, which would be beneficial to all parties, as the municipality could save on transportation and landfill costs.

The monthly operating budget of the plant ranges from $8,000 to $9,000 during the first 10 years. This includes labor, chemicals, electricity, spare parts and a contingent reserve for major expenditures. The cost estimate is presented in constant 2012 dollars, and its use in the future should include appropriate adjustment factors.

At a meeting on July 3, 2012, the City of Metapán expressed its commitment to cover operation costs for the project. An important factor for the feasibility of this project is the financial contribution of Holcim to the city, which makes the city’s commitment feasible. ANDA will support the city with technical assistance through technical consultations and laboratory analysis.

From the institutional standpoint, the city has staff committed to the project who have excellent technical qualifications and are willing to work; adequate training would make them an excellent resource. The presence of Holcim in the area facilitates the two following aspects: 1) a constant, predictable revenue for the city; and 2) the development of a critical mass of trained technicians in the region, key for the proper performance of...
the plant. Another important element is ANDA’s experience in wastewater treatment and its commitment to support the City of Metapán.

One of the most important factors in the implementation of this project is the separation of wastewater and storm water. If this project were delayed, storm water flow would overcome the plant’s capacity and would affect the plant’s processes. The city has collected extensive information for the “separation” project, and work is expected to start as soon as the project begins.

The most relevant assumption is that of the design flowrate, which can be improved with real time field measurements of wastewater flows and representative sample characterization. This will prove invaluable in the dimensioning of the treatment plant.

The estimated cost of $2,530,000 is adequate for the project’s execution. Tetra Tech’s team estimated $2,666,586 without considering contingencies or reserves, but it must be clear that the estimate was based on a conceptual pre-dimension of the plant, with information from previous studies and assuming a non-modular construction. The accuracy of costs will improve in the Feasibility Study.

The project’s execution program is very ambitious, with completion expected by the middle of 2014. In order to achieve this, it will be necessary to define the financing resources and initiate environmental and design operations/requirements.

Based on the above, we conclude that the project has merit and is feasible.
7.0 RECOMMENDATIONS

7.1 NEXT STEPS

a. It is recommended that the institutions involved sign a Memorandum of Understanding that identifies immediate actions necessary to proceed with the project. Such actions include: defining roles, responsibilities and commitments of each party; and establishing a process for collecting funds for the project and for contracting the required technical services to develop the project. The signatories of the Memorandum should at least be the City of Metapán, ANDA, MARN, Plan Trifinio, FISDL and Holcim.

b. It is recommended that the application procedures to request financing by USAID be taken immediately. Those in charge of the document should have the experience and capacity to generate all the supporting information thereof.

c. It is recommended that the necessary environmental and project design consultants be contracted. The environmental impact statement studies and all information for its creation should begin immediately. The contracting of consultants for this as soon as possible will speed up the process.

7.2 TECHNICAL RECOMMENDATIONS

a. It is important to proceed with the project of separating wastewater and storm water connections. It is recommended that the City of Metapán contract a specialist in sanitary engineering to delineate as soon as possible a detailed plan of action and costs of this project.

b. Begin the separation of drainage collectors immediately. A delay in the separation of pipes for storm water and wastewater flows would result in an overutilization of the plant or would directly damage the treatment plant.

c. Define the location of the preliminary treatment station. It is suggested that it be located on the land immediately upstream of Discharge Number 2 because it presents more advantages than the land purchased by the city.

d. Locate the construction of the treatment plant on the land purchased by the city because this site is more suitable than the other options analyzed.

e. Characterize the influent (the flow rate), considering the differences in winter and summer flow conditions. To validate theoretical estimates, field data should be collected.

f. Design and construct a treatment process with UASB, a trickling filter and secondary sedimentation tank (also referred to as settling tank).

g. Initially discharge the effluent to the San José River and develop a reuse alternative for the future.

h. If the reuse alternative of treated water for agricultural purposes is not possible in the short or medium term, the city should consider the implementation of a small pond with nymph control, the objective of which would be to control the nutrient content that discharges in Metapán Lake. This issue could be further developed at the feasibility study stage considering land availability and pumping requirements. It would be ideal to use the ammonia content of the effluent for habitat growth.
i. To reduce the initial investment, the plant could start up with three units of UASB and trickling filter instead of four. The investment of the fourth unit could be made in 2026, thus reducing the initial investment by $239,629.69.

j. Initially burn the resulting methane gas and, depending on the quantity of biogas generated, pursue the option of its reuse.

7.3 INSTITUTIONAL RECOMMENDATIONS

a. In order to slowly recover the water bodies in the area (rivers and lakes), it is necessary to organize cleaning activities in coordination with nongovernmental organizations, local governments and private companies.

b. The local government and institutions involved in environmental aspects should organize and get the commitment of communities around water bodies via environmental education so that they understand the appropriate management of solid waste and use of agrochemicals.

c. Create a legal enforcing office that would sanction entities/persons that pollute the water bodies.

d. When city staff in the area of urban development are requesting permits for new construction or expansion of construction, they should be careful to review the project and make field visits so that discharges of wastewater are not disposed of in any water body or rainwater collector.
8.0 GLOSSARY

- **Anaerobic**: Condition where air or oxygen is not present.
- **Biological Oxygen Demand (BOD)**: Water constituent that measures the amount of oxygen required to stabilize organic matter biologically under specific temperature and time conditions. A BOD₅ measurement is done in 5 days at 20°C.
- **Chemical Oxygen Demand (COD)**: Water constituent that measures the amount of oxygen required to oxidize chemically organic and inorganic substances thus stabilizing the waste completely.
- **Coliform organism**: A bacteria group with specific biochemical characteristics. It is of relevant importance because it is more numerous and easily tested for and therefore is commonly used as indicator organism.
- **Digestion**: Biological decomposition of organic matter (sludge) in wastewater.
- **Discharge**: Wastewater that is disposed of in the sewage system, or the measurement of flow.
- **Effluent**: Liquid flowing out of a system.
- **Grit chambers**: Chamber designed to reduce the velocity of wastewater inducing sedimentation and removal of mineral solids such as sands and others.
- **Infiltration capacity**: Capacity of a medium (soil) to percolate a liquid (water).
- **Inflow/Influent**: Water or other liquid that flows into a reservoir, treatment plant or treatment process.
- **Primary treatment**: Process where solids in water are screened and allowed to settle or sediment.
- **Secondary treatment**: Process where water undergoes biological (aerobic or anaerobic) and physicochemical (flocculation) treatment to reduce a great amount of BOD.
- **Sewage system**: Water works system that evacuates and disposes of wastewaters, from collectors, pumping stations to wastewater treatment systems.
- **Sludge dehydration**: Process where water is removed from sludge.
- **Suspended solids**: Fraction of solids (mostly organic matter) that do not settle in two hours in the Imhoff cone.
- **Tertiary treatment**: Also known out advanced treatment, this is the process dedicated to the final reduction of BOD, heavy metals, specific chemical contaminants, pathogens and parasites.
- **Treatment**: The process or series of processes for eliminating pollutants of wastewater that are harmful to the sewage systems or do not comply with environmental regulations.
- **Trickling or Biological Filter**: Filter used to purify water; it has a porous medium through which the liquid flows.
- **UASB Reactors**: An Upflow Anaerobic Sludge Blanket, is a type of unit (reactor) that operates continually and flows in an upward direction. “Water enters in the bottom of the reactor. The
wastewater flows through a sludge blanket composed of biologically formed granules or particles. Treatment occurs when the wastewater enters in contact with the granules. The gases produced under anaerobic conditions (principally methane and carbon dioxide) cause internal circulation, which helps the formation and maintenance of biological granules … free gas released … is captured in gas collection domes located in the top of the reactor” (Metcalf & Eddy, 1997).

- **Wastewater:** Water that results from any use of water (domestic, commercial, industrial, agricultural operations) or processes that require water.

- **Water pollution:** Is the alteration of the physical, chemical, biological or radioactive quality of water.
9.0 BIBLIOGRAPHY


12. “Preinforme estudio de valorización de lodos de estaciones depuradoras de aguas residuales urbanas (I.e.d.a.r.u.),” Municipio de Las Palmas de g.c., España, 2008.


16. Universidad José Simón Cañas (UCA), departamento de Tecnología de Procesos y Ciencias Ambientales, “Estimación Preliminar de La Capacidad de una Planta de Tratamiento de Las Aguas Residuales Descargadas al Río San José por la Ciudad de Metapán,” May 2010.


1.1. The conference will be sponsored by UNAMA and has the theme of the Vision of the next 20 Years for Herat.