The Report Committee for Robin Shaw Lynch
Certifies that this is the approved version of the following report:

A GIS-based Estimation of Steady-State Non-Point Source Bacteria Pollution in the Lower Rio Grande below Falcón Reservoir

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ______________________________
Daene C McKinney

Co-Supervisor: ______________________________
David J Eaton

A GIS-based Estimation of Steady-State Non-Point Source Bacteria Pollution in the Lower Rio Grande below Falcón Reservoir

by

Robin Shaw Lynch, B.S.C.E.

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degrees of

Master of Science in Engineering

&

Master of Public Affairs

The University of Texas at Austin

May 2012

Acknowledgements

I would like to thank David Eaton, Ph.D. and Daene McKinney, Ph.D. for their help and comments for this report. I would like to thank the Texas Commission on Environmental Quality for financially supporting part of my work on this research. I would like to thank Steve Niemeyer for his guidance, Roger Miranda for his ideas and help collecting data, Eddie Moderow, Ross Pumfrey, Victor Valenzuela, Gina Posada, Victor Wong, Claudia Lozano for their sharing of knowledge, and James Michalk for providing insight with the use of QUALTX models. I would like to thank Marcel Dulay of Parsons Corporation for providing insights into performing watershed studies. At the United States Geological Survey, I would like to thank Kimberly Jones, Karen Hanson, and Tony Litschewski. At the Instituto Nacional de Estadística y Geografía, I would like to thank Rogelio Mondragon and Maricela Bugarin. At the International Boundary and Water Commission, I would like to thank Gilbert Anaya. At the Texas Parks and Wildlife Department, I would like to thank Eric Garza and Alan Cain.

Abstract

A GIS-based Estimation of Steady-State Non-Point Source Bacteria Pollution in the Lower Rio Grande below Falcón Reservoir

Robin Shaw Lynch, MSE, MPAff

The University of Texas at Austin, 2012

Supervisors: Daene C McKinney, David Eaton

This report estimates the steady-state, non-point source bacteria pollution along the international river system of the Lower Rio Grande / Río Bravo between Falcón Reservoir and the Gulf of Mexico. The results from this report may be used by environmental agencies in the United States and México in order to develop a steady-state water quality model of the bacterial load in this river system. This report creates a GIS-based estimation of the steady-state, non-point source pollution from sources such as failing septic tanks, untreated sewage, grazing animals, and wildlife in the watershed. This report also provides recommendations for environmental agencies when developing the water quality model. The results and methodology developed for this report may be used as part of the Lower Rio Grande / Río Bravo Watershed Initiative, a binational pilot project to develop a plan to restore and protect the quality of the Rio Grande/Río Bravo.

Table of Contents

Chapter 1: Introduction

The United States and México share responsibility in preserving the quantity and quality of their international river system, the Rio Grande/ Río Bravo. Several international treaties govern the quantity of water each country must give and take.[1] No treaty establishes joint standards for the quality of the river, which is important for the people and wildlife that use the water. For this reason, the federal and state environmental agencies in both the U.S. and Mexico are participating in the Lower Rio Grande/Río Bravo Watershed Initiative (the Initiative), a binational pilot project to develop a plan to restore and protect the quality of the Rio Grande/Río Bravo. This pilot project focuses on the part of the Rio Grande/Río Bravo below Falcón Reservoir to the Gulf of Mexico, but it will be used as a model for developing bi-national watershed protection plans in the other sections of this international river system. To protect water quality, it is necessary to understand the pollution sources, which involves modeling the river. Any model must be transparent, and use equations and data acceptable to both countries. The Initiative is likely to develop a steady-state model to consider low-flow conditions on a constant basis, without adding the complexity of storm water flow. Steady-state models are used frequently for point sources, stationary sources of pollution such as factories, or wastewater treatment plants that produce a constant flow of contaminated water. Such steady-state models rarely account for non-point sources of pollution that are not attributable to a single source, such as septic system failures or animal defecation. This report develops an estimation of the non-point source pollution that enters the Rio Grande/Río Bravo below Falcón Reservoir on a steady-state basis in order to assist in the development of the Initiative's water quality of model of pollution attributable to non-point sources.

The methodology used in this report is adapted from the dissertation of Stephanie Lynn Johnson, Ph.D., titled "A General Method for Modeling Coastal Water Pollutant Loadings."[2] This report is also based on the methodology on several Total Maximum Daily Load reports created to satisfy the requirements of section 303(d) of the Clean Water Act.[3,4,5] The method depends on combining geographic data with census data in a GIS environment to create an estimate for the fecal coliform bacteria that contaminates the Rio Grande/ Río Bravo.

The results of this study are designed specifically for use as input files into a QUALTX model, the style of steady-state water quality model created for the Texas Commission on Environmental Quality (TCEQ) that is used for water quality regulations by both México and the U.S.[6] This methodology could be used for any other steady state water quality model, such as LAQUAL or QUAL2K. The results are computed using a HydroNetwork created with the ArcHydro add-in for ESRI's ArcGIS software. The results are segmented into sections called "Reaches" using the previous water quality models completed by TCEQ. In total, there are 48 reaches, starting at Falcón Dam and continuing to the Gulf of Mexico.

This study looks at the non-point sources of pollution that enter the river on a constant basis, such as septic system failure, untreated wastewater, and animals defecating directly into the river and contributing streams. This study does not include the runoff caused by storm events. This study differs from some research of the past, that seek to estimate non-steady state flow[7], which includes the runoff from storm events. This study seeks to quantify the non-steady state bacteria contamination that enters the river. For an example of the difference, consider a cow that defecates on open land. The bacteria from that defecation will not enter the river until a rainstorm washes the defecation into the river. Some research papers seek to estimate the impact of that defecation after it is washed into the river. This research does not include rainfall runoff contributions from rain-induced defecation. This study considers the bacteria that would enter the river if the cow was to defecate directly into the river while it was drinking water. Non-steady state models are important, as non-steady state flows are a significant contribution of bacteria contamination in a river. However, the data and modeling expectations for a non-steady state model would require information which is not readily available for the Rio Grande/ Río Bravo, and so is beyond the scope of this research. A steady-state model estimates a different type of pollution, the type which would occur in times when the river is in low flow conditions.

This report uses several equations for the calculation of fecal coliform load in the watershed. These equations are presented in Table 1, the Table of Equations. For the purposes of using these equations, it is necessary to make many assumptions in the process of estimating the total bacteria load that reaches the Lower Rio Grande/ Río Bravo. Table 2 presents the Table of Assumptions, which lists all of the assumptions used in this study. This report is divided into four chapters.

Chapter 2 develops the methodology of how the analysis is performed. Chapter 3 of this report presents the results of this analysis. The results are divided among 48 sections of the river, called "Reaches." These results are designed for use as inputs into steady-state water quality models. Chapter 4 of this report provides recommendations for government agencies on the measures they should take, such as additional studies and surveys, when improving this analysis for the use in water quality models of the Rio Grande/ Río Bravo.

Table 1: Table of Equations

Equation	Subject	Details
(1)	First order decay of fecal bacteria	Calculates the decay of bacteria for the exposure time between the source of the bacteria and reaching the Rio Grande/ Rio Bravo. Uses a first order rate a decay.
(2)	Exposure time of bacteria	Calculates the exposure time of the bacteria for use in Equation (1).
(3)	Velocity of river based on flow	Calculates the velocity of the river, using the flow rate and coefficients for the hydraulic conductivity of the river.
(4)	Number of people in each locality with and without drainage	Calculates the number of people in each locality with and without drainage, using INEGI data for the number of households as well as the average number of people per household.
(5)	Flow of wastewater produced per day per each locality	Calculates the flow of wastewater produced per day per each locality, using the number of people found from Equation (4) and the average amount of wastewater produced per person.
(6)	Number of people with failing septic tanks in each subwatershed	Calculates the number of people with failing septic tanks per each subwatershed, using the denisty of septic tanks, the area of the riparian corridor in the subwatershed, and a failure rate.
(7)	Total grazing animals in each subwatershed	Calculates the total number of grazing animals in each watershed with the average density of animals and the area of appropriate land use.
(8)	Fecal coliform load for grazing animals, per sub-watershed	Calculates the fecal coliform load from grazing animals, using the total grazing animals in the watershed from Equation (6) and the average fecal coliform load per animal.
(9)	Fecal coliform load for wild animals, per sub-watershed	Calculates the fecal coliform load for wild animals, using the average density of animals and the average fecal coliform load per animal.

Table 2: Table of Assumptions

Assumption	Subject	Details
1	Delineation of watershed	The delination of watersheds in Figure 1 accurately represents the watershed that drains into the Rio Grande. These watersheds are still topics of discussion between USGS and INEGI as of March 2012.
2	NHD data	The NHD data avialable accurately represent the rivers and streams in the watershed. The NHD data are still topics of discussion between USGS and INEGI as of March 2012.
3	DEM data	The DEM data available represent the true topography of the watershed.
4	Decay rate (1)	Bacteria in this watershed decays at first order rate.
5	Decay rate (2)	The decay rate of bacteria is a constant through the whole watershed.
6	Decay rate (3)	At low decay rates, the decay rate of E.Coli and Fecal Coliform are approximately equal.
7	Velocity of river	The velocity of the river can be related to the flow rate according to the equations and constants used in prevoius QUALTX models of the Rio Grande.
8	Travel distance from bacterial source to reach	When calculating the distance travelled of bacterial load from the source to its respective reach, aggregating all sources into subwatersheds and using the distance from the centroid of the subwatershed to the reach adequately estimates the distance travelled.
9	Rural connections to public sewers	In order to distribute percentage of septic tanks and public sewage access in the Mexican side of the watershed, it was assumed that people in rural areas did not have access to public sewer systems.
10	Number of people without sewage	In the Mexican side of the watershed, the number of people without sewage can be estimated by multiplying the number of households without sewage by the average number of residents per household in each locality.
11	The "other" category	People in the "other" category regarding access to sewage in the INEGI census can be equally distributed between urban and rural localities in the municipality.
12	Access to sewage	People with access to public sewage are assumed to not contaminate the rivers or streams. Finding the percentage of sewage collected but is not treated is beyond the scope of this report.
13	Septic contamination	Households with septic systems are assumed to contaminate the rivers and streams when the septic system is failing.
14	Septic failure rate	The septic failure rate found on the U.S. side of the watershed is applicable on the Mexican side as well.
15	Septic riparian corridor	Septic systems outside a 500 meter riparian corridor are assumed to have no pollution reaching the rivers or streams.
16	Distribution of sewage in urban areas	The distribution of sewage in urban areas, when dividing an urban area across subwatersheds, is proportional to the % of area in each subwatershed.
17	Estimation of wastewater produced per person	The estimation of wastewater produced per person per day accurately represents the wastewater produced by people on each side of the watershed.
18	Lack of wastewater treatment in red colonias	Households in colonias labeled as 'red' lack access to wastewater treatment.
19	Fraction of time livestock spend in rivers and streams	The percentage of time livestock spend in streams, as used in this study, accurately represents the true time spent in streams.
20	Livestock land uses	Livestock are distributed equally across forest, shrub, and grass/pasture land uses, except in the municipalities of Rio Bravo, Valle Hermosa, and Matamoros, in which they are also on agricultural land. The exception is due to the fact that these municipalities are almost completely agricultural.
21	Wildlife riparian corridor	A riparian corridor of 300 feet accurately represents the wildlife that contribute bacteria to the rivers and streams.
22	Deer and feral hog land uses	Deer and Feral Hogs are distributed equally across forest, shrub, grass/pasture, agriculture, and wetlands land uses.
23	Deer density	The density of deer found by the Texas Parks and Wildlife in Resource Management Unit 8 can be attributed across the whole watershed.
24	Feral hog density	The density of feral hogs found by the Institute of Renewable and Natural Resources at Texas A&M University accurately represents the distribution of feral hogs in the watershed.
25	Waterfowl distribution	Waterfowl are distributed evenly across the wetland and water land uses.
26	Distribution From Rio Grande Delta	The distrubtion of waterfowl is inversely related to the distance from the Rio Grande Delta. This study recommends that more complete surveys of waterfowl be completed.

This chapter has provided an introduction of the purpose of this study as well as a table of the equations and assumptions used in the following methodology. Chapter 2 presents the methodology used for the study, divided into sections based on the type of data and methods used.

---

[1] United States Government Printing Office, *Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande: Treaty Between the United States of America and Mexico* (Washington D.C: GPO, 1946), http://www.ibwc.gov/Files/1944Treaty.pdf, 9-11.

[2] Stephanie Lynn Johnson, "A General Method for Modeling Coastal Water Pollutant Loadings," (PhD diss., The University of Texas at Austin, 2009).

[3] The United States Environmental Protection Agency, "Impaired Waters and Total Maximum Daily Loads," http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/, (Accessed on March 7, 2012).

[4] James Miertschin & Associates, Inc, *Final Modeling Report for Fecal Coliform TMDL (Total Maximum Daily Load) Development for Leon River Below Proctor Lake, Segment 1221: Project Area 2 – Baisn Groups D & E Bacteria Impairments Work Order #5* (Austin, TX: Texas Commission on Environmental Quality, November 2006).

[5] Chief Engineer's Office, Water Programs, TMDL Section, *One Total Maximum Daily Load for Bacteria in the Guadalupe River Above Canyon Lake* (Austin, TX: Texas Commission on Environmental Quality, July 2007).

[6] George H. Ward, Jr. and Jennifer Benaman, *Models for TMDL Application in Texas Watercourses* (Austin, Texas: Texas Natural Resource Conservation Commission, December 1999), http://www.crwr.utexas.edu/reports/pdf/1999/rpt99-7.pdf, 169.

[7] Stephanie Lynn Johnson, "A General Method for Modeling Coastal Water Pollutant Loadings," 249.

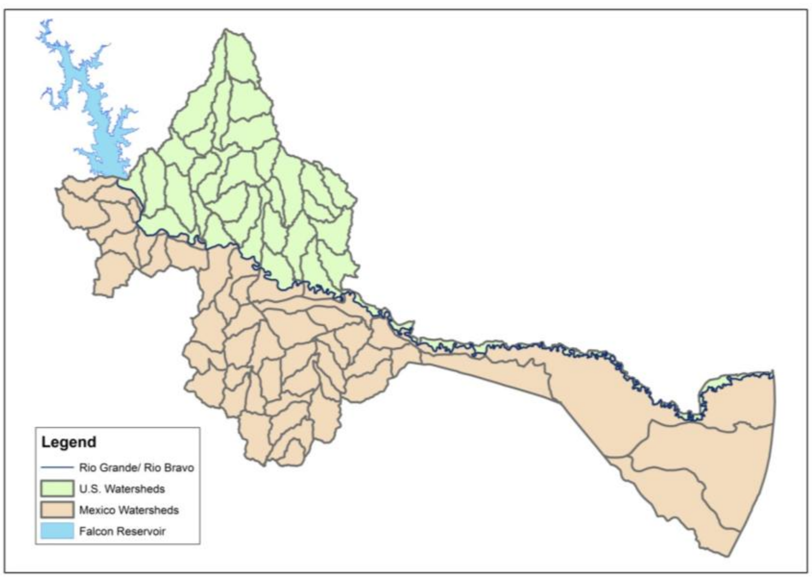
Chapter 2: Methodology

Three challenges for developing a model for the steady-state, non-point source effluents for a river are to decide what is the river, what are the sources of several different effluents, and how to convert the activities in the river into a mass-balance flow of effluents. To account for these challenges, Chapter 2 is divided into seven sections. The first section describes the creation of the watersheds, or the spatial area within which all the water bodies drain to one point. The second section explains the political subdivisions of municipalities and counties, because these subdivisions are often the level at which census data are available. Because much of the data are available at the municipality and county level, understanding the intersection of these political boundaries with the watershed boundaries is a key aspect to the way this methodology was developed. The third section presents the land use data. These land use data classify every part of the watershed into the way the land is used, such as for agriculture, forest, shrub, etc. Each use of the land leads to a bacterial load on the river. For example livestock and wildlife spend their time on specific types of land use, and their steady-state bacterial loads reflect assumptions about their behavior. The fourth section develops a decay rate to use when bacteria travels from its source to the points along on the Rio Grande/ Río Bravo of interest. The bacteria decays significantly over the period of time it travels along the river. An analysis could use the decay rate to estimate the quantity of decay of the bacteria. The fifth section looks at untreated wastewater in Mexico and the U.S. This untreated wastewater originates either from households that have no access to public sewage or from households on failing septic systems. The sixth section looks at the bacteria contribution from animal grazing. Only the bacteria contribution from direct defecation into the stream is considered, as that is the only contamination that will enter into the river on a constant basis. Both cattle and horses contribute to the bacteria contamination of rivers and streams from direct defecations. The seventh section estimates the bacteria contribution from wildlife, such as deer, feral hogs, and migratory fowl. While this source of bacteria is not one that government agencies can do much to control, wildlife still contributes a significant load of bacteria to the river system.

WATERSHED DELINEATION

The watershed for the Rio Grande/Rio Bravo represents the surface area that drains to the river. The watershed is divided into basins and sub-basins according to the Hydrologic Unit Code (HUC). Figure 1 below illustrates the watersheds for the lower Rio Grande/Río Bravo.[8,9] The watersheds for the U.S. side are taken from the National Hydrography Dataset (NHD) website of the USGS.[10] The watersheds from the Mexico side are preliminary watersheds that, as of February 2012, are still topics of discussion between the United States Geological Survey (USGS) in the U.S. and its counterpart in Mexico, the Instituto Nacional de Estadística y Geografía (INEGI).[11] A watershed will end at a reservoir, such as the Falcón Reservoir on the international border as well as the reservoirs created by the Las Blancas and Marte R. Gómez dams in Mexico. These watersheds, shown in Figure 1, define the area of the land that contributes to the end point of each watershed. The delineation of these watersheds provides the analysis with a way of defining the land area that contributes to the bacteria load in different sections of the river.

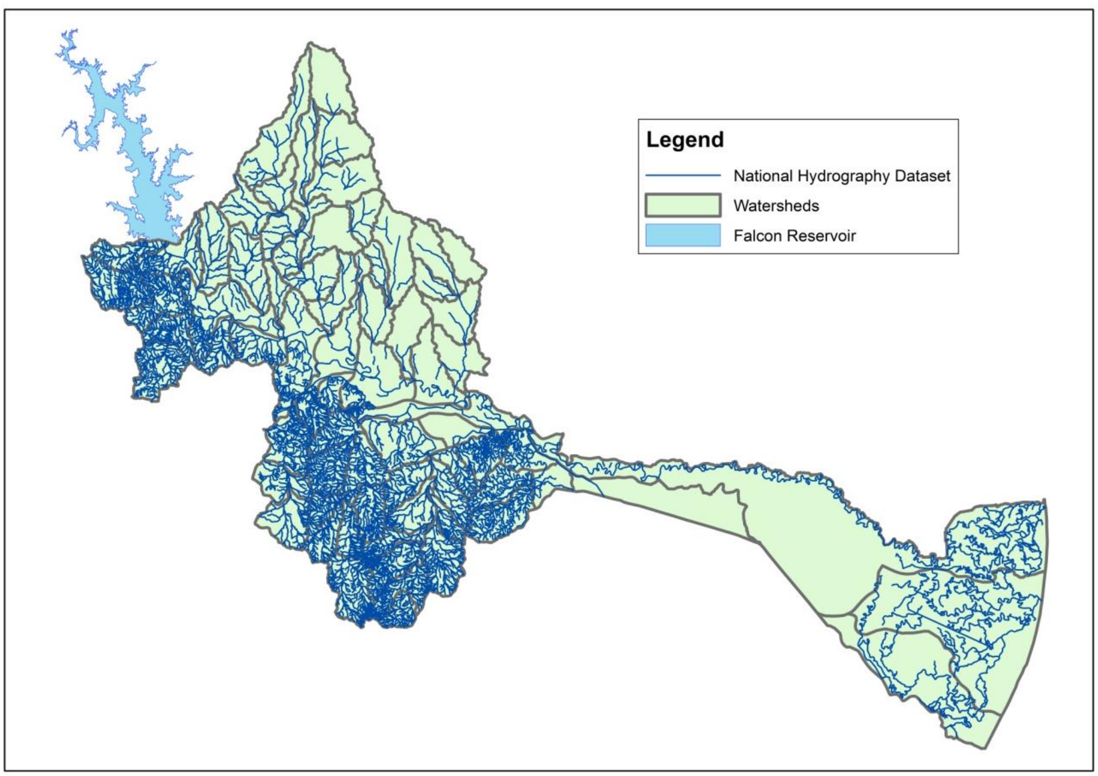
Figure 1: Watersheds of Lower Rio Grande/ Río Bravo



Source: Derived from USGS, "National Hydrography Dataset," The National Map, GIS Shapefile, http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd , INEGI, Unpublished GIS Shapefile, October 13, 2011, Map created by Robin Lynch

The hydrography used in this study is the preliminary NHD file, which is being harmonized by USGS and INEGI for the United States-Mexico Border Geographic System (USMX-GIS).[12] The hydrography is still in development and does not represent the finalized version of the NHD.[13] There currently is no NHDPlus dataset available, which would estimate the stream flow velocity for every stream and river in this dataset. Due to this limitation, this analysis uses rough estimates of the stream velocity. Figure 2 presents the National Hydrography Dataset for this watershed.[14] The National Hydrography Dataset is used as a representation of all the rivers and streams in this study, and it is also used to create riparian corridors in the analysis. Most of the sources that contribute to steady-state pollution occur close to the rivers and streams. As a result, the National Hydrography Dataset is important for defining these riparian corridors surrounding the rivers and streams.

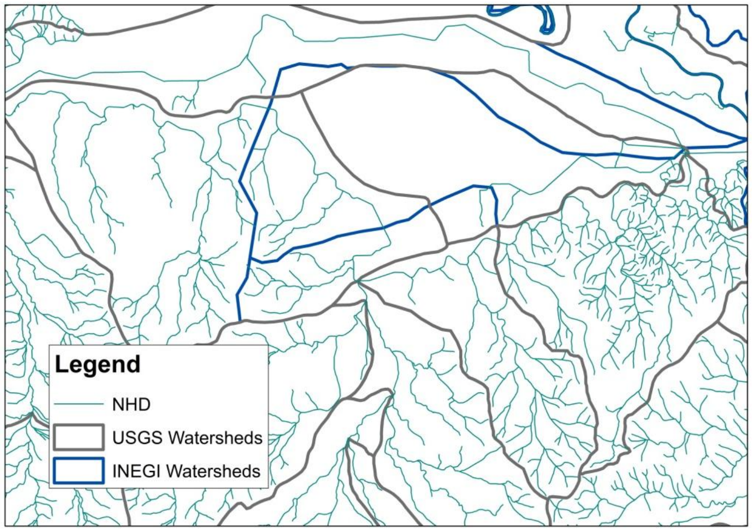
Figure 2: National Hydrography Dataset



Source: Derived from USGS, Unpublished GIS Shapefile, June 2011, Map created by Robin Lynch

For the analysis, a Digital Elevation Model (DEM) was used to determine the flow directions in the watershed. The DEM uses aerial sensing to determine the elevation of the surface. The DEM for this study was taken from the USGS Seamless Server and has a grid size of 30 meters (m) by 30 m.[15] The smaller the grid size, the more accurate the analysis can be. For example, a 30 m x 30 m grid assumes that every grid of that size has the same elevation. A 30 m by 30 m grid size is fairly large, meaning that these data are less accurate than would occur with a smaller grid size. On account of the flat topography of the area in this study, there are many problems resulting from such a large grid size, especially in the agricultural areas. For a more accurate analysis, it would be necessary to start with a more accurate DEM. For example, a Light Detection and Ranging (Lidar) is used in a plane flying over the area which use light reflection to measure accurately the elevation on a very small grid size.[16] Although the IBWC has Lidar data available within 3 miles of the Rio Grande, there is no coherent and compatible small grid representation for the entire watershed of this study.[17] The watersheds of USGS and INEGI do not overlap exactly, meaning that they do not agree completely with each other, as of April 2012, and USGS and INEGI still seek to develop an official harmonized watershed.[18] This report will use the watershed from INEGI for the México side[19] and the watershed from USGS for the U.S. side,[20] when possible. However, there is one area where the watersheds from INEGI do not agree with the NHD hydrography (see Figure 3[21]) and some compromise is necessary. The INEGI watersheds are shown in blue and the USGS watersheds are shown in gray. The NHD used for this study does not match with the watersheds from INEGI, so the watersheds from USGS are used. In future analysis, it is recommended that the harmonized watershed match with the NHD.

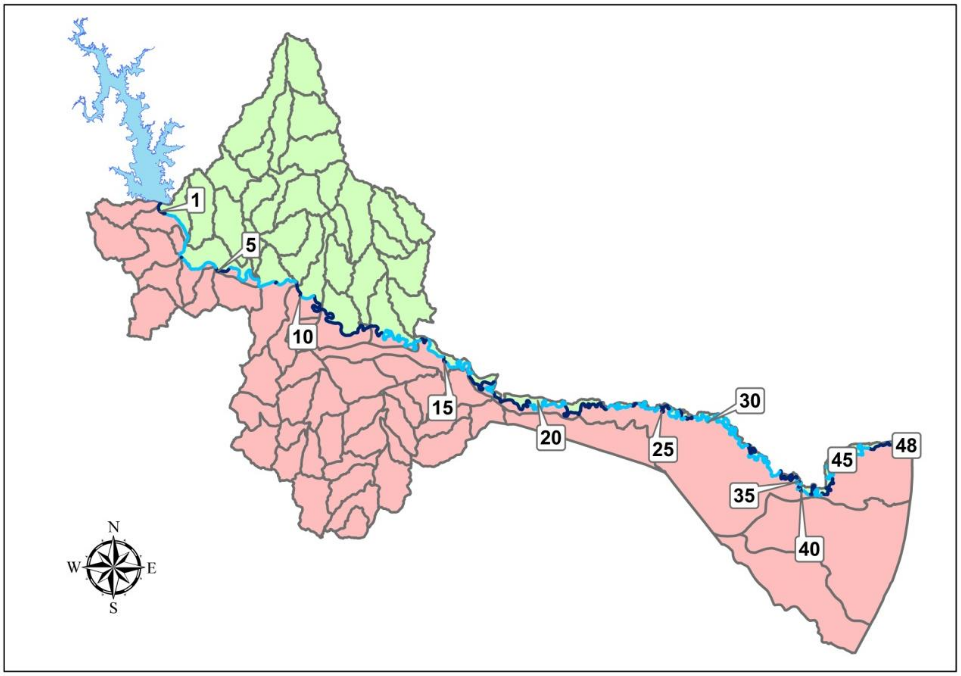
Figure 3: Disagreement of Watersheds from INEGI and USGS just west of Reynosa



Source: Derived from USGS, Unpublished GIS Shapefile, September 15, 2011 & INEGI, Unpublished GIS Shapefile, October 13, 2011, Map Created by Robin Lynch

Non-point source pollution could be released from among 48 different "reaches" or sub-basins along the river. The reaches were digitized from previous TCEQ modeling in QUALTX, based on different hydraulic features of the Rio Grande/ Río Bravo.[22] This analysis uses a pour-point technique, using each reach as a pour-point to determine the pollution that enters that particular section of the river. Figure 4 shows the reaches used in this analysis.[23] They are numbered from 1 to 48, starting at the Falcón Reservoir. In each reach has Figure 4 an alternating color of dark and light blue so as to see the length of each reach. These reaches are used throughout the analysis to divide up the pollution that enters the river into the 48 sections, and the results of the analysis can be used for water quality modeling in a QUALTX or similar style model.

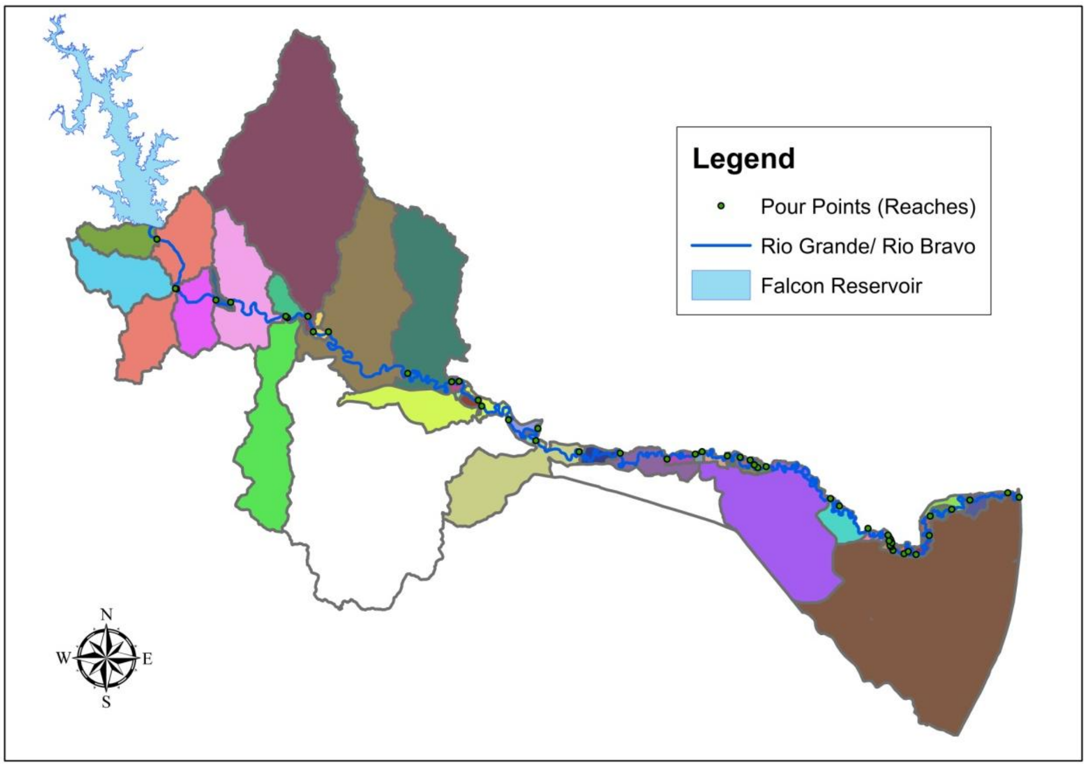
Figure 4: The 48 "Reaches" along the Rio Grande/ Río Bravo



Source: Derived from USGS, "National Hydrography Dataset," The National Map, GIS Shapefile, http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd & INEGI, Unpublished GIS Shapefile, October 31, 2011 & TCEQ, Internal Map, digitized by Robin Lynch, June 03, 2011, Map created by Robin Lynch

The DEM, NHD flowlines, and the watershed delineations were used to create pour-point watersheds for each of the 48 reaches, using ArcHydro. The delineation of these watersheds follows the method of ArcHydro developed by David Maidment, Ph.D. at The University of Texas at Austin and David Tarboton, Ph.D. at Utah State University.[24] The NHD streams were burned into the DEM, which involves decreasing the elevation value along the length of the stream to ensure that the procedure directs the flow in the correct direction.[25] Walls were created around the watersheds to ensure that the procedure does not route water between different watersheds. The sinks were filled, which involves filling any cells that do not have an outlet, as sinks usually are the result of flaws in the DEM.[26] The flow direction grid was created, which defines the direction of flow in each grid cell,[27] and then flow accumulation grid[28] were calculated, which calculates the accumulation grid cells that flow into a particular grid cell. The 48 reaches were used as pour-points for creating watersheds.[29] Figure 5 shows these 48 pour-point watersheds which will form the basis for the analysis.[30] Each of the shapes signifies the entire area that drains into each reach along the Rio Grande/ Río Bravo. This study estimates the amount of pollution entering the river at each of the 48 pour-points on a constant basis. The watersheds shown in white do not actually enter into the Rio Grande/ Río Bravo, but they go to the Gulf of Mexico through the Rodhe Drain. For a complete map of all the individual sub-watersheds used in this study, see Appendix A.[31,32,33]

Figure 5: Pour-Point Watersheds for each of the 48 Reaches



Source: TCEQ, Internal Map, digitized by author, June 03, 2011, Map created by Robin Lynch

Table 3 lists the surface area in square kilometers for each of the 48 reaches.[34] These areas represent the total surface area in the watershed that drains to each of the reaches in the analysis. It is hard to evaluate the accuracy or reliability for the areas for reaches that are downstream of reach 30, because the DEM for these areas is poor and may not accurately represent the actual flow of water.[35]

Table 3: Areas (km^2) for the Watershed of each Reach

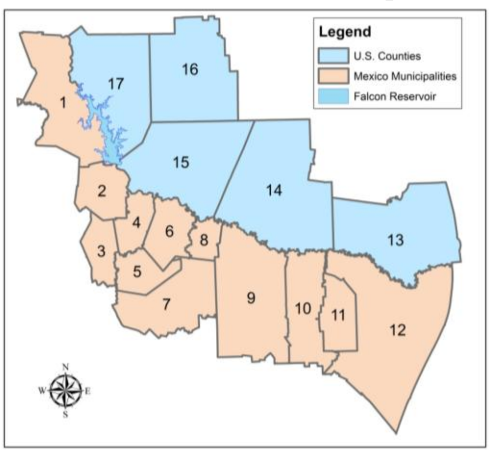
Reach	Area (km^2)	Reach	Area (km^2)	Reach	Area (km^2)	Reach	Area (km^2)
1	113.16	13	8.68	25	6.40	37	0.74
2	424.07	14	7.16	26	8.88	38	3.07
3	230.53	15	11.16	27	1.81	39	1.45
4	157.88	16	200.44	28	6.46	40	3.74
5	19.38	17	20.55	29	5.89	41	4.93
6	343.38	18	7.96	30	634.77	42	4.26
7	426.00	19	302.92	31	3.44	43	12.04
8	54.49	20	30.12	32	63.39	44	13.22
9	1378.14	21	84.27	33	12.02	45	13.80
10	15.71	22	16.73	34	2.59	46	23.14
11	680.06	23	5.36	35	0.36	47	30.99
12	552.80	24	14.19	36	0.59	48	1639.35

Source: TCEQ, Internal Map, digitized by Robin Lynch, June 03, 2011, Map created by Robin Lynch

MUNICIPALITIES AND COUNTIES OF STUDY AREA

Much of the data used for this analysis are available at the county level in the U.S. and at the municipality level in México. Figure 6 displays the counties and municipalities in the study area, labeled from 1 to 17 in counterclockwise order.[36,37] Because the data, such as the agricultural census, are available at the level of the county or municipality, these boundaries are used in the analysis to estimate the bacteria contributions to the river.

Figure 6: U.S. Counties and México Municipalities in Study Area



Source: INEGI, "Áreas Geoestadísticas Municipales," Marco Geoestadístico Municipal 2009 Versión 4.1, GIS Shapefile, http://mapserver.inegi.org.mx/data/mgm/, U.S. Census Bureau, 2010 TIGER/Line® Shapefiles, November 30, 2010, GIS Shapefile, http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html, Map created by Robin Lynch

Table 4 provides the names corresponding to the numbers found in Figure 6 of each of the counties and municipalities, allowing the figure to be less cluttered.[38,39]

Table 4: Numbering of Counties and Municipalities

México

Municipality	State	Number
Guerrero	Tamaulipas	1
Mier	Tamaulipas	2
Los Aldamas	Nuevo León	3
Miguel Alemán	Tamaulipas	4
Doctor Coss	Nuevo León	5
Camargo	Tamaulipas	6
General Bravo	Nuevo León	7
Gustavo Díaz Ordaz	Tamaulipas	8
Reynosa	Tamaulipas	9
Río Bravo	Tamaulipas	10
Valle Hermoso	Tamaulipas	11
Matamoros	Tamaulipas	12

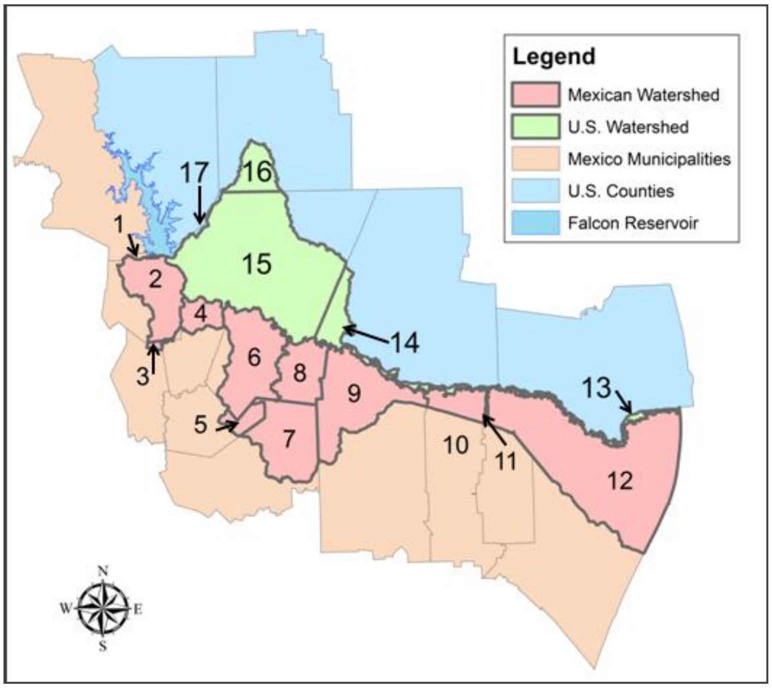
U.S.

County	State	Number
Cameron	Texas	13
Hidalgo	Texas	14
Starr	Texas	15
Jim Hogg	Texas	16
Zapata	Texas	17

Source: INEGI, "Áreas Geoestadísticas Municipales," Marco Geoestadístico Municipal 2009 Versión 4.1, GIS Shapefile, http://mapserver.inegi.org.mx/data/mgm/, U.S. Census Bureau, 2010 TIGER/Line® Shapefiles, November 30, 2010, GIS Shapefile, http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html, Map created by Robin Lynch.

Each municipality and county includes a portion within the watershed boundaries and a portion outside the watershed.[40,41] Figure 7 illustrates how each municipality and county is divided in the watershed.[42,43] As Figure 7 shows, the political boundaries do not line up exactly with the watershed boundaries. Therefore, this study often performs analyses using the proportionality of the area of the watershed located within the municipality or county.

Figure 7: Portions of Municipalities and Counties in Watershed



Source: INEGI, "Áreas Geoestadísticas Municipales," Marco Geoestadístico Municipal 2009 Versión 4.1, GIS Shapefile, http://mapserver.inegi.org.mx/data/mgm/, U.S. Census Bureau, 2010 TIGER/Line® Shapefiles, November 30, 2010, GIS Shapefile, http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html, Map created by Robin Lynch.

Table 5 provides the area within the watershed for each municipality or county, the total area of the municipality or county, and the percentage of the area of each municipality and county in the watershed.[44,45] This percentage can be used for finding the proportionally of the watershed within the municipality or county. The total area of the watershed is 9,682 square kilometers. The México side of the watershed makes up 6,491 square kilometers (67% of the watershed), and the U.S. side of the watershed makes up 3,191 square kilometers (33% of the watershed).

Table 5: Area of each County and Municipality in the Watershed

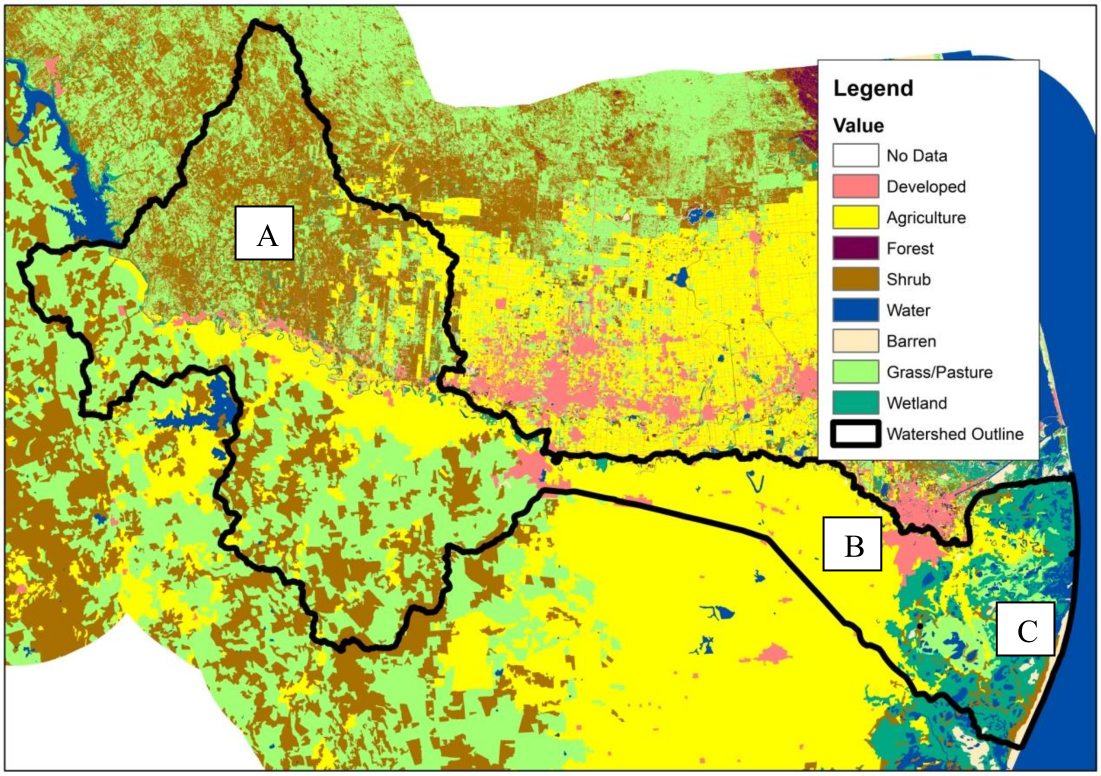
Number	Municipality/County	State	Area in Watershed (km²)	Total Area (km²)	% of Area in Watershed
1	Guerrero	Tamaulipas	3	2,442	0.1%
2	Mier	Tamaulipas	559	923	60.6%
3	Los Aldamas	Nuevo León	16	695	2.2%
4	Miguel Alemán	Tamaulipas	194	639	30.3%
5	Doctor Coss	Nuevo León	125	721	17.4%
6	Camargo	Tamaulipas	790	930	84.9%
7	General Bravo	Nuevo León	704	1,889	37.3%
8	Gustavo Díaz Ordaz	Tamaulipas	432	432	99.9%
9	Reynosa	Tamaulipas	942	3,147	29.9%
10	Río Bravo	Tamaulipas	235	1,584	14.8%
11	Valle Hermoso	Tamaulipas	11	900	1.2%
12	Matamoros	Tamaulipas	2,481	4,633	53.5%
13	Cameron	Texas	105	3,306	3.2%
14	Hidalgo	Texas	352	4,100	8.6%
15	Starr	Texas	2,468	3,183	77.5%
16	Jim Hogg	Texas	264	2,943	9.0%
17	Zapata	Texas	2	2,740	0.1%

Source: INEGI, "Áreas Geoestadísticas Municipales," Marco Geoestadístico Municipal 2009 Versión 4.1, GIS Shapefile, http://mapserver.inegi.org.mx/data/mgm/, U.S. Census Bureau, 2010 TIGER/Line® Shapefiles, November 30, 2010, GIS Shapefile, http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html, Map created by Robin Lynch.

Land Use

This study uses land use and land cover data to estimate the amount of non-point source pollution produced. The land use/land cover data were drawn from the USGS BEHI website and is a combination of USGS's "2001 National Land Cover dataset"[46] for the U.S. side and INEGI's "*Uso de Suelos y Vegetación Series III*."[47] Figure 8 illustrates the Land Use Land Cover data for the watershed.[48] As is presented in Figure 8, the western half of the watershed, labeled A, is mostly shrub and grassland, which is the type of land use more likely to have livestock grazing. The eastern part of the watershed, labeled B, is largely almost completely agricultural, which would not have as much livestock or wildlife. The far eastern part of the watershed, labeled C, is wetland and water, which would result in a large number of migratory waterfowl present.

Figure 8: Land Use Land Cover for Watershed



Source: Land Use/ Land Cover: Binational 2001, U.S.-Mexico Border Envrionmental Health Initiative – Available Data Layers, http://txpub.usgs.gov/BEHI/Data_download/LULC/bin2001f.zip, Raster file, Accessed on July 20, 2011., Map created by Robin Lynch

Table 6 indicates the area in square kilometers of each land use within the watershed.[49] The land use with the largest percentage of area in the watershed is grass or pasture, which covers 30.5 percent of the watershed with 2,948 square kilometers.[50] The second most prominent land use is Shrub, which covers 27.4 percent of the watershed with 2,656.50 square kilometers.[51] These two land uses are mostly in the western part of the watershed, labeled as A in Figure 8. The third most prominent land use is Agriculture, which covers 25.7 percent of the watershed with 2,493.1 square kilometers.[52] Water makes up 2.9 percent of the watershed with 278.91 square kilometers, which accounts for the many rivers and streams throughout the watershed.[53]

Table 6: Type of Land Use in Watershed

Land Use	Km^2	Percentage
Developed	407.88	4.2%
Agriculture	2,493.01	25.7%
Forest	13.39	0.1%
Shrub	2,656.50	27.4%
Water	278.91	2.9%
Barren	79.71	0.8%
Grass/ Pasture	2,948.45	30.5%
Wetland	793.79	8.2%
No Data	10.71	0.1%
Total	9,682.34	100.0%

Source: Land Use/ Land Cover: Binational 2001, U.S.-Mexico Border Envrionmental Health Initiative – Available Data Layers, http://borderhealth.cr.usgs.gov/datalayers.html, Raster file, Accessed on July 20, 2011, Table created by Robin Lynch.

DECAY RATE

A key assumption in any water quality model is the rate at which bacteria will decay over time, the decay rate. The decay rate equation used for this study (see Equation 1), taken from Bowie et al. 1985, calculates the quantity of bacteria that will decay over a period of time.[54] This equation assumes a first order rate of decay for the fecal coliform bacteria. The equation states that the final concentration is equal to the original concentration multiplied by the inverse of the constant e raised to the power of the decay rate (k) multiplied by the time (t):

$$\mathbf{C_t = C_o e^{-kt}} \qquad (1)$$

where C_t is the coliform concentration at time t (MPN or count/100ml), C_o is the initial upstream coliform concentration (MPN or count/100ml), k is the disappearance rate constant (day^{-1}), and t is the exposure time (days).

The data used to calculate the decay rate are taken from International Boundary and Water Commission samples near Brownsville and Matamoros.[55] The data were collected for E. Coli and not fecal coliform.[56] However, Bowie states that "at low decay rates, coliform decay rates were approximately equal to pathogen decay rates."[57] All the data used for calculating decay rates were taken on the same day. The calculation of decay rates used sampling sites adjacent to each other, so the exposure time (t from Equation 1) can be considered the time it takes for water to travel from each upstream sampling site to an adjacent downstream sampling site. The exposure time, or travel time, is calculated by taking the distance traveled and dividing it by the velocity of the river, shown in Equation 2:[58]

$$t = \frac{d}{v} * 3600 * 24 \qquad (2)$$

where t is the exposure time (days), d is the distance between sampling sites (m), and v is the river velocity (m/s).

The velocity of the river was not directly measured, but can be estimated from flow rate measurements using Equation 3, which is taken from earlier TCEQ QUALTX models. Equation 3 relates the velocity of the river to the flow rate using two coefficients, a and b, to account for the hydraulic characteristics of the river.[59] The river characteristics for this stretch of the river are a=0.0758 and b=0.5.[60] The flow of the river on the day the sample was taken was 116 cubic feet per second (cfs), or 4.7 cubic meters per second (m^3/s).[61] The velocity is estimated as the coefficient a multiplied by the flow raised to the power of the coefficient b:[62]

$$v = a * Q^b \qquad (3)$$

where v is the velocity (m/s), a and b are the coefficients, and Q is the flow (m^3/s).

The bacteria decay calculation used data in which the bacteria concentration decreased between the upstream sampling site and the downstream sampling site. Data in which the bacteria increased from upstream to downstream were assumed to have bacteria inputs and therefore not representative of bacteria decay. Three outlier value were not used, because the resulting mean value would be different from typical literature values. Using 11 observations, the mean decay coefficient is k=4.82 day^{-1} and the standard of deviation is 4.40 day^{-1}. Table 7 presents data of the sample sites used to create this decay coefficient.[63]

Table 7: Data Used for Calculating Decay Coefficient

Site 1	Site 2	C1	C2	d (m)	v (m/s)	k (1/days)
20449i	20449h	8.6	6.2	1445	0.164	4.52
20449g	20449f	25.3	12.2	1225	0.164	10.08
20449e	20449d	17.3	6.3	1374	0.164	13.96
20449a	20449	14.8	9.8	1293	0.164	5.70
13178g	13178f	30.7	29.5	1103	0.164	0.55
13178d	13178c	80.9	68.9	851	0.164	2.22
13178c	13178b	68.9	38.9	951	0.164	7.90
13178b	13178a	38.9	34.5	340	0.164	1.66
13177i	13177h	55.6	52	714	0.164	0.93
13177h	13177g	52	51.2	712	0.164	0.21
13177b	13177a	31.3	21.3	809	0.164	5.32

Source: International Boundary and Water Commission, "Bacteria Characterization in Segment 2302_01 of the Rio Grande near Brownsville, Texas: A Texas Clean Rivers Program Special Study," http://www.ibwc.gov/CRP/documents/BrownsvilleBacteriaSpecialStudyFINALSTUDYJune2011.pdf, Accessed on January 12, 2012, 2011, 17

Untreated Wastewater

One of the contributors of bacteria contamination to the Rio Grande/ Río Bravo is untreated sewage entering the river system.[64] This analysis looks at two sources of untreated sewage, that which originates from lack of access to public sewage collection systems and that which originates from leaking septic tanks. The analysis of untreated wastewater is different between the Mexican side and the U.S. side of the river, because each country has different types of data sets for calculating the number of people with septic tanks and sewage connections.

México

The means of disposing of sewage varies between many different forms of disposal, including sewage collection, septic tanks, privies, and deposition on land. The 2010 Population and Household Survey performed by INEGI provides information on the amount of people with different sewage disposal methods in each municipality.[65] The data from INEGI are available at two different levels of aggregation, the municipality and the locality level. The municipality is roughly similar to a county in the U.S. and a locality can be defined as a place, which can range from a population of 1 person to a population of millions of people.[66] This study looks at both levels of data, both municipality and locality, because they both provide different types of data. The municipality level divides the type of sewage between public sewers, septic tanks, and other categories. Therefore, a municipality covers a large area and cannot be divided along the lines of the watershed.[67] On the other hand, the data at the locality level do not provide the level of detail as that at the municipality level, but the localities can be divided into the subwatersheds to which they pertain. Table 8 displays the number of people with and without sewage disposal for each municipality in the watershed.[68] The municipalities that have the most people without sewage disposal were Matamoros, with 43,066 people, and Reynosa, with 28,554 people.[69] These are the two most urban municipalities in the watershed, which also means that they have the largest urban population. The municipalities that have the highest percentage of population without drainage were Río Bravo (15%), Los Aldamas (15%), Valle Hermoso (14%), Gustavo Díaz Ordaz (14%), and General Bravo (13%). The more urban municipalities of Reynosa and Matamoros only had 5 percent and 9 percent of population without drainage, respectively.[70]

Table 8: Population With and Without Sewage on México Side, by Municipality

Number	Municipality	State	With Sewage	No Sewage	Not Specified	Total
1	Guerrero	Tamaulipas	3,712	272	3	3,987
2	Mier	Tamaulipas	4,556	94	78	4,728
3	Los Aldamas	Nuevo León	1,146	190	5	1,341
4	Miguel Alemán	Tamaulipas	25,737	563	137	26,437
5	Doctor Coss	Nuevo León	1,474	189	46	1,709
6	Camargo	Tamaulipas	13,255	1,097	304	14,656
7	General Bravo	Nuevo León	4,760	671	72	5,503
8	Gustavo Díaz Ordaz	Tamaulipas	13,349	2,158	134	15,641
9	Reynosa	Tamaulipas	517,114	28,554	9,587	555,255
10	Río Bravo	Tamaulipas	99,062	17,747	523	117,332
11	Valle Hermoso	Tamaulipas	53,667	8,948	186	62,801
12	Matamoros	Tamaulipas	429,258	43,066	5,419	477,743

Source: INEGI, "Ocupantes de viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo," Censo de Población y Vivienda 2010. Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est.

Of the population that has sewage disposal, INEGI divides this population by the type of drainage they have, such as those with public sewers, septic tanks, piping that goes to a crevice or a cliff, and piping that goes to a river, lake, or sea, as illustrated in Table 9.[71] The difference between population with public sewage and septic tanks clearly distinguishes which municipalities and are urban and rural, with urban being majority public sewage and rural being majority septic tank. Municipalities such as Matamoros, Reynosa, and Río Bravo are more urban, with the majority of the population having public sewage. Municipalities such as Los Aldamas and Gustavo Díaz Ordaz are mare more rural, with the majority of the population having septic tanks.

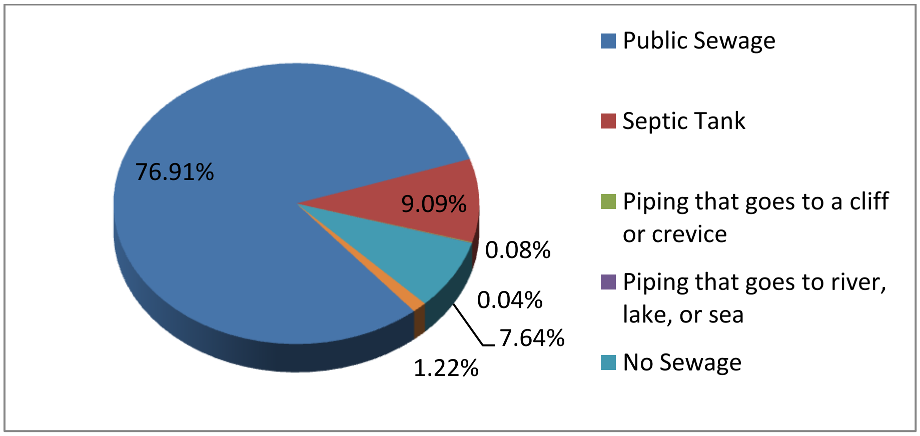
Table 9: Type of Sewage Disposal, for Those Who Have Sewage, by Municipality

Number	Municipality	State	Public Sewage	Septic Tank	Piping that goes to a cliff or crevice	Piping that goes to river, lake, or sea	Subtotal
1	Guerrero	Tamaulipas	3,272	438	2	0	3,712
2	Mier	Tamaulipas	4,455	101	0	0	4,556
3	Los Aldamas	Nuevo León	4	1139	3	0	1,146
4	Miguel Alemán	Tamaulipas	21,781	3,877	28	51	25,737
5	Doctor Coss	Nuevo León	7	1467	0	0	1,474
6	Camargo	Tamaulipas	7,949	5,205	72	29	13,255
7	General Bravo	Nuevo León	914	3846	0	0	4,760
8	Gustavo Díaz Ordaz	Tamaulipas	4,050	9,290	4	5	13,349
9	Reynosa	Tamaulipas	464,858	51,943	144	169	517,114
10	Río Bravo	Tamaulipas	85,886	13,066	92	18	99,062
11	Valle Hermoso	Tamaulipas	50,311	3,004	293	59	53,667
12	Matamoros	Tamaulipas	398,730	29,866	419	243	429,258

Source: INEGI, "Viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo," Censo de Población y Vivienda 2010. Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est

Figure 9 presents the overall percentages of drainage types in the municipalities included in the watershed.[72] Within the 12 municipalities, 81 percent of the population is connected to the public sewage system, 9 percent is connected to a septic tank, 8 percent has no form of drainage, 1.28 percent did not specify, 0.08 percent has piping that goes to a cliff or a crevice, and 0.04 piping had tubing that goes to the river, lake, or sea.

Figure 9: Percentage of Population by Sewage Disposal Type - México Municipalities in Watershed

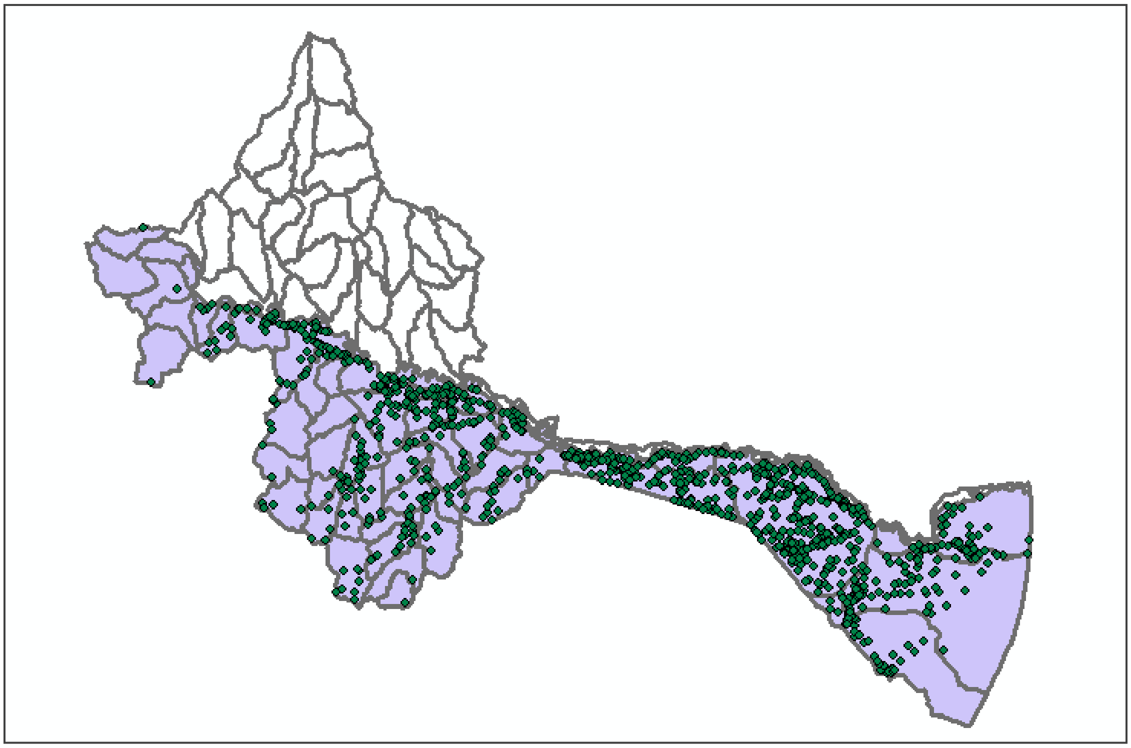


Source: INEGI, "Viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo," Censo de Población y Vivienda 2010. Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est, Chart created by Robin Lynch

The data at the municipal level do not distinguish between the populations within the watershed and the populations outside the watershed. In order to focus the study on only the populations within the watershed, the INEGI data from the Principales Resultados por Localidad (ITER)[73], which provide information at the locality level (*localidad*) in the form of a downloadable database, was merged with the shapefiles of all the localities. Appendix D presents a full list of all the ITER data in the watershed.[74] A quality control check based on total population was made to test how accurate the merged database is compared with the INEGI municipality data. In the municipality level data, the total population in 2010 of the 12 municipalities was 1,355,092, and the total population of the merged database using ITER data was 1,354,576, which resulted in a 0.04 percent difference. With that degree of consistency between the estimated population and the INEGI population totals, it is reasonable to use either dataset for regional comparisons.

Figure 10 illustrates the locations of all the localities.[75] Each locality has information on the number of people with and without sewage treatment. The population without sewage treatment is treated as a direct source of fecal coliform. The amount of fecal coliform that reaches is the Rio Grande/ Río Bravo is calculated by summing up the input over each smaller watershed. In order to account for the decay, the approximate distance from the river is calculated. This calculation sums up the total fecal coliform deposit within each smaller watershed. The centroid is taken of the smaller watershed and the distance of each subwatershed centroid to the reach is calculated. Appendix B shows the travel distances used between sub-watersheds and their corresponding reaches as well as the percent of decay that will occur when bacteria arrives at the reach.[76,77,78]

Figure 10: Localities with Wastewater Data



Source: INEGI. "Principales Resultados por localidad (ITER)." Censo de Población y Vivienda. Aguascalientes, Aguascalientes, 2010. Map created by Robin Lynch

Data are available for the number of households in each locality that has drainage, but information is not available to distinguish whether people are connected to public sewage systems or to septic tanks. Therefore, to distinguish between the number of people connected to public sewage and septic tanks, this study back-calculated from the municipality level data. One assumption this study makes is that rural areas are not connected to public sewers. In other words, all people connected to a public sewer system are attributed to be in an urban city. 'Urban' in this study is defined by the localities included by INEGI in the "Polygons of Urban Localities" shapefile, which are listed in Table 10 along with their population and drainage information. [79] Table 10 presents the number of people with and without drainage in each of these urban areas, but several calculations were necessary to produce this information. For each locality, the data provide the number of households (not population) with or without drainage. Data are not available for the actual number of people. The number of people with and without drainage connections can be estimated by using the average number of people per household in each locality. Equation 4 calculates the number of people in each locality with and without drainage by multiplying the number of households with and without drainage (in each locality) by the average number of people per household in each locality:[80]

$$P = H * PPH \qquad (4)$$

where P is the total population with or without drainage in each locality, H is the number of households with or without drainage in each locality, and PPH is the average number of people per household in each locality.

Table 10: Population and Drainage Information on Mexican Side, by City

City	Municipality	Population	Average People Per Household	Households with Drainage	Households without Drainage	People With Drainage	People Without Drainage
Reynosa	Reynosa	589,466	3.62	139,526	5,237	505,084	18,958
Heroica Matamoros	Matamoros	449,815	3.68	112,307	5,781	413,290	21,274
Ciudad Rio Bravo	Rio Bravo	95,647	3.77	23,478	1,625	88,512	6,126
Ciudad Miguel Aleman	Miguel Aleman	19,997	3.48	5,613	61	19,533	212
Ciudad Gustavo Diaz Ordaz	Gustavo Diaz Ordaz	11,523	3.5	2,984	258	10,444	903
Nuevo Progreso	Rio Bravo	10,178	4.03	1,741	744	7,016	2,998
Ciudad Camargo	Camargo	7,984	3.4	2,184	101	7,426	343
Mier	Mier	4,762	3.3	1,375	33	4,538	109
Los Guerra	Miguel Aleman	4,566	4.02	1,108	11	4,454	44
Nueva Ciudad Guerrero	Guerrero	4,312	3.08	1,182	84	3,641	259
Ramirez	Matamoros	3,743	3.77	705	282	2,658	1,063
El Control	Matamoros	3,136	3.52	781	105	2,749	370
Comales	Camargo	2,429	3.31	694	26	2,297	86

Source: INEGI. "Principales Resultados por localidad (ITER)." Censo de Población y Vivienda. Aguascalientes, Aguascalientes, 2010, INEGI. "Polígonos de Localidades Urbanas Geoestadísticas", INEGI, Aguascalientes, Aguascalientes, 2010. http://mapserver.inegi.org.mx/data/mgm/redirect.cfm?fileX=LOCURBANAS50, Accessed on January 22, 2012.

In order to use the data available at the locality level, it was necessary to create a ratio comparing the number of people with public sewage and the number of people with septic systems. The number of people with drainage in each city in Table 10 was summed for each municipality and compared with the data in Table 8 and Table 9 to find the percentage of people with public sewage compared with septic systems, considering both rural and urban localities. Table 11 presents the division of drainage between public sewage and septic systems.[81,82] The 'other' category refers to waste being discharged into a cliff, crevice, river, lake or sea. It is unclear how to divide the 'other' category between urban and rural, so these numbers were divided proportionally to the urban and rural population of each municipality. Values in Table 11 indicate that the urban areas in the México side of the watershed vary on the percentage of people that have sewage collection and septic tanks. For example, the municipality of Matamoros has 95 percent of the urban population with septic connections and the municipality of Reynosa has 92 percent of the urban population with septic connections. The municipality of Gustavo Díaz Ordaz has 39 percent of the urban population with sewage connections, which shows that the population centers in this municipality have a lower frequency of sewered population than Matamoros or Reynosa.

Table 11: Division of Drainage between Sewage and Septic Systems, by Municipality

			Urban			Rural		
Number	Municipality	State	Sewage	Septic	Other	Sewage	Septic	Other
1	Guerrero	Tamaulipas	90%	10%	0%	0%	100%	0%
2	Mier	Tamaulipas	98%	2%	0%	0%	100%	0%
3	Los Aldamas	Nuevo León	0%	0%	0%	0%	100%	0%
4	Miguel Alemán	Tamaulipas	91%	9%	0%	0%	100%	0%
5	Doctor Coss	Nuevo León	0%	0%	0%	0%	100%	0%
6	Camargo	Tamaulipas	81%	18%	1%	0%	99%	1%
7	General Bravo	Nuevo León	25%	75%	0%	0%	100%	0%
8	Gustavo Díaz Ordaz	Tamaulipas	39%	61%	0%	0%	100%	0%
9	Reynosa	Tamaulipas	92%	8%	0%	0%	100%	0%
10	Río Bravo	Tamaulipas	90%	10%	0%	0%	100%	0%
11	Valle Hermoso	Tamaulipas	98%	1%	1%	0%	98%	2%
12	Matamoros	Tamaulipas	95%	5%	0%	0%	100%	0%

Source: INEGI. "Principales Resultados por localidad (ITER)." Censo de Población y Vivienda. Aguascalientes, Aguascalientes, 2010, INEGI. "Polígonos de Localidades Urbanas Geoestadísticas", INEGI, Aguascalientes, Aguascalientes, 2010. http://mapserver.inegi.org.mx/data/mgm/redirect.cfm?fileX=LOCURBANAS50, Accessed on January 22, 2012. Table created by Robin Lynch.

The analysis for the pollutant load due to human waste is divided into 4 types of waste treatment (sewage, septic, no drainage, and other) and 2 types of communities (rural and urban). A household with access to a public sewer system is assumed to be a household that does not contaminate the rivers or stream. Households with a septic system are assumed to contaminate when the septic system fails. A 2002 report done for the Texas On-Site Wastewater Treatment Research Council found that 4.1 percent of on-site septic systems in the Lower Rio Grande Valley were failing.[83] As both the U.S. and Mexican side have comparable soil conditions, the approach used in this study is to assume the same rate of failure on the Mexican side of the watershed. Only septic systems near to rivers or streams contaminate the surface water, so this study uses a 500 meter riparian corridor around every river or stream.[84] This study assumes that 4 percent of all rural people within this riparian corridor contribute to steady-state pollution of the rivers and streams, and everybody outside of the corridor does not contribute a steady-state bacterial load on the river. The population that has no drainage or other types of drainage are considered to deposit waste directly if they live within the 500 meter riparian corridor. Otherwise, this study assumes that they do not contribute to the river bacterial load. In the urban localities that cross subwatershed lines, the bacteria load will be distributed across the subwatersheds, weighted by the percentage of each community's area within the watershed. Table 12 illustrates the distribution of each urban locality between the subwatersheds that they cross.[85] For example, the city of Heroica Matamoros contains 21 separate subwatersheds, and Reynosa contains 9 subwatersheds.

Table 12: Urban Cities and the Percentage of Area in Each Sub-Watershed

City										
Nuevo Progreso	**Subwatershed**	**88**	**89**							
	Percentage	99.9%	0.1%							
Reynosa	**Subwatershed**	**75**	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**
	Percentage	0.1%	6.7%	6.3%	0.0%	3.2%	34.1%	48.7%	0.9%	0.0%
Los Guerra	**Subwatershed**	**14**								
	Percentage	100.0%								
Ciudad Miguel Aleman	**Subwatershed**	**13**	**14**	**15**	**17**	**20**				
	Percentage	63.0%	33.0%	0.4%	2.1%	1.5%				
Mier	**Subwatershed**	**12**								
	Percentage	100.0%								
Ramírez	**Subwatershed**	**104**								
	Percentage	100.0%								
El Control	**Subwatershed**	**104**								
	Percentage	100.0%								
Heroica Matamoros	**Subwatershed**	**104**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**
	Percentage	3.4%	0.0%	16.4%	0.1%	7.3%	1.8%	0.0%	0.0%	0.1%
	Subwatershed	**116**	**117**	**118**	**119**	**120**	**121**	**122**	**123**	**124**
	Percentage	0.2%	0.0%	0.0%	0.4%	0.0%	2.7%	0.0%	0.5%	0.0%
	Subwatershed	**125**	**142**	**143**						
	Percentage	1.3%	23.9%	41.8%						
Ciudad Gustavo Diaz	**Subwatershed**	**48**	**53**	**58**	**73**					
	Percentage	18.3%	28.3%	42.3%	11.2%					
Nueva Ciudad Guerrero	**Subwatershed**	**3**								
	Percentage	100.0%								
Comales	**Subwatershed**	**25**	**26**							
	Percentage	59.2%	40.8%							
Ciudad Camargo	**Subwatershed**	**25**	**57**							
	Percentage	72.0%	28.0%							

INEGI. "Polígonos de Localidades Urbanas Geoestadísticas", INEGI, Aguascalientes, Aguascalientes, 2010. http://mapserver.inegi.org.mx/data/mgm/redirect.cfm?fileX=LOCURBANAS50,

Equation 5 calculates the amount of wastewater produced per day in each community.[86] This equation multiplies the population of the locality by the average wastewater produced per person per day, using a 15 percent confidence interval to account for the variation:[87]

$$WW_l = POP_l * WWPD_l * CF \pm 15\% \qquad (5)$$

where WW_l is the wastewater produced per second per locality (L/s), POP_l is the population of each locality, $WWPD_l$ is the wastewater produced per person per day (L/day), and CF is a conversion factor of (1/86,400) days/seconds.

The amount of wastewater produced per person per day in Mexico was taken from the Manual of Potable Water, Drainage, and Sanitation: Basic Data, published by the National Commission of Water.[88] Table 13 provides the range of values representative of the amount of wastewater produced per person every five years from the years 1990 to 2010.[89] For this study, the value of 148 liters per person per day (l/p/d) is used, which is the most recent datum found in 2010. Due to the uncertainty with of this number, a margin of error of 15 percent was used.

Table 13: Wastewater Produced per Day per Person

	1990	1995	2000	2005	2010
L/person/day	170	164	159	153	148

Source: Comisión Nacional del Agua. "Manual de Agua Potable, Alcantarillado y Saneamiento: Datos Básicos." Coyoacán, Distrito Federal, 2007.

The average fecal coliform counts produced per person for this study was $1x10^4$ counts/100 ml of septic overcharge, taken from the EPA Bacteria Indicator Tool.[90] The analysis found that the total contribution of rural localities on the Mexican side to the bacteria load was $3.91x10^8$ FC counts/day, and that the decayed bacteria load was $1.72x10^8$ FC counts/day. The bacteria load for the urban localities on the Mexican side was $7.49x10^{11}$ FC counts/day, and the decayed bacteria load was $8.9x10^{10}$ day.

U.S.

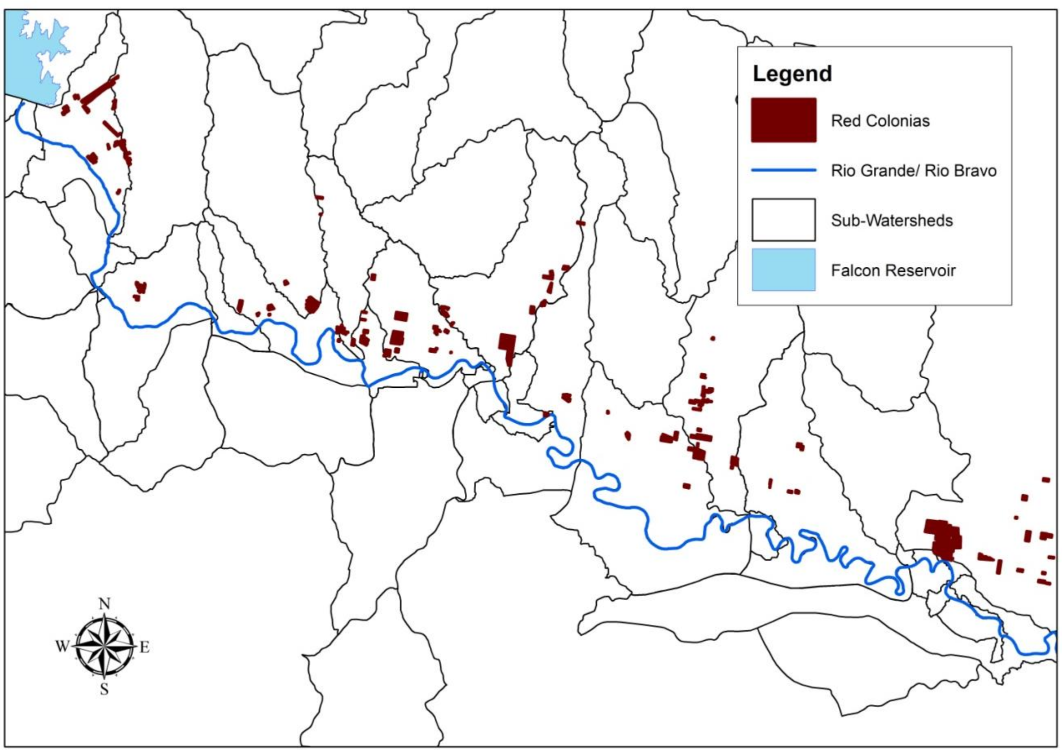
This study divides the analysis of the sewage bacterial load on the U.S. side between two sources, failing septic tanks in general and colonias. The number of septic tanks is found from the United States Census.[91] On the 1990 Census, there were questions on 'what type of sewage treatment' people use, but later census collections (2000 or 2010) do not include this question.[92] The data were available at the census track level, which produced a density of people with septic tanks. Equation 6 calculates the number of people with failing septic tanks in each subwatershed.[93] The equation multiplies the density of septic tanks in the subwatershed by the area of the subwatershed and the failure rate of 4.1 percent:[94]

$$S_i = \rho_i * A_i * FR \qquad (6)$$

where S_i is the number of people with failing septic tanks in each subwatershed, ρ_i is the density of people with septic tanks in each subwatershed (people/km^2), A_i is the area of the riparian corridor in each subwatershed (km^2), and FR is the failure rate of 4.1 percent.

Using Equations 4 and 5, the amount of wastewater produced from leaking septic tanks in the riparian corridor was calculated, assuming a 4.1 percent failure rate in septic tanks.[95] The other source for bacterial load are the colonias, which are the improperly planned developments that lack adequate infrastructure.[96] Each colonia is classified with a color of green, yellow or red, depending on a state-created system on the risk to human health.[97] The colonias labeled as red signify that they lack piped water, adequate wastewater treatment, or platting. This analysis assumes that all the red colored colonias do not have adequate wastewater treatment. Figure 11 illustrates the locations of all the red colored colonias in the watershed on the U.S. side, found from the USGS Border Environmental Health Initiative CHIPS database on the colonias.[98] In the figure, the majority of the colonias without wastewater treatment are found in the area near Rio Grande City.

Figure 11: Red Colonias on the U.S. Side of the Watershed



Source: USGS, "Border Environmental Health Initiative: Colonia CHIPS Database", 2007, http://txpub.usgs.gov/BEHI/Data_download/Places%20Layers/Colonias.zip.

This study chose a riparian corridor of 500 meters as the distance from streams and rivers in which a colonia will discharge sewage into the river system. This study assumes that any colonia within 500 meters of a stream or river will produce a bacterial load into the river. Table 14 presents all the colonias that are within the riparian corridor as well as their estimated population.[99]

Table 14: Red Colonias within Riparian Corridor

Colonia ID	Name	Population	Colonia ID	Name	Population
M2140038	East Alto Bonito	446	M2140050	El Rancho Vela	246
M2140037	E. Lopez	199	M2140003	Ala Blanca	35
M2140228	West Alto Bonito	560	M2140101	La Lomita	110
M2140142	Mike's	538	M2140159	Northridge	107
M2140005	Alto Bonito Heights	281	M2140198	Sandoval	55
M2140174	Ramirez-Perez	47	M2140070	Fronton North	208
M2140229	Zarate	136	M2140110	Las Palmas	60
M2140209	South Refugio	59	M2140097	La Esperanza	102
M2140044	El Castillo	187	M2140193	Sammy Martinez	64
M2140009	Antonio Flores	59	M2140043	El Brazil	43
M2140080	Gutierrez	149	M2140024	Casas	47
M2140007	Amada Acres	27	M2140119	Los Arrieros	149
M2140218	Valle Hermosa	29	M2140191	Salineno South	547
M2140049	El Quiote	229	M2140090	Jardin de San Julian	25
M2140008	Anacua	39	M2140190	Salineno North	250
M2140138	Mi Ranchito Estate	234	M2140100	La Loma de Falcon	136
M2140018	Campo Verde	50	M2140062	Falconaire	119
M2140054	Elodia's	63	M2140087	Indio #2	51
M2140120	Los Barreras North	140	M2140086	Indio #1	42
M2140177	Ranchitos Del Norte	67	M2140061	Falcon Heights	121
M2140126	M. Munoz	199	M2140108	Lago Vista	110

Source: USGS, "Border Environmental Health Initiative: Colonia CHIPS Database", 2007, http://txpub.usgs.gov/BEHI/Data_download/Places%20Layers/Colonias.zip.

Fecal coliform loadings were calculated based upon a septic system fecal coliform density of 10^4 org/100 mL, and a household flow of 210 gal/day (3 persons per household, at 70 gal/capita-day).[100] The analysis calculates the range of wastewater produced by multiplying the population of each colonia by the wastewater produced per person, as shown in Equation 5 from before. Table 15 presents the total wastewater produced per day for each of the subwatersheds.[101,102] The wastewater is divided between that which is from the colonias and that which is not from the colonias. The wastewater from the colonias is more concentrated in a few areas, whereas the non-colonia wastewater has less concentration and is spread out through the whole watershed. The total fecal coliform load on the U.S. side from septic tanks was 6.08×10^9 FC/day, and with decay was 6.94×10^8 FC/day.

Table 15: Wastewater Produced from Failing Septic Tank –U.S.

Subwatershed	Colonia Septic Failure	Non-Colonia Septic Failure (Based on Census)	Subwatershed	Colonia Septic Failure	Non-Colonia Septic Failure (Based on Census)	Subwatershed	Colonia Septic Failure	Non-Colonia Septic Failure (Based on Census)
	WW Produced (L/day)	WW Produced (L/day)		WW Produced (L/day)	WW Produced (L/day)		WW Produced (L/day)	WW Produced (L/day)
1	0	814	**49**	0	9,634	**97**	0	0
2	0	0	**50**	0	8,850	**98**	0	1,102
3	0	0	**51**	528,633	7,185	**99**	0	0
4	386,074	12,847	**52**	18,549	8,875	**100**	0	404
5	24,643	29,389	**53**	0	0	**101**	0	0
6	0	863	**54**	0	12,830	**102**	0	1,140
7	0	0	**55**	160,842	12,320	**103**	0	0
8	0	0	**56**	0	1,022	**104**	0	0
9	0	0	**57**	0	0	**105**	0	12,926
10	0	0	**58**	0	0	**106**	0	0
11	0	0	**59**	0	18,314	**107**	0	2,325
12	0	0	**60**	0	23,492	**108**	0	6,473
13	0	0	**61**	0	15,513	**109**	0	0
14	0	0	**62**	0	7,264	**110**	0	16,106
15	69,689	14,963	**63**	0	59	**111**	0	0
16	0	20,224	**64**	0	9,983	**112**	0	0
17	0	0	**65**	0	3,392	**113**	0	1,558
18	117,386	15,949	**66**	0	0	**114**	0	328
19	28,353	30,011	**67**	0	4,087	**115**	0	0
20	0	0	**68**	0	0	**116**	0	0
21	111,026	5,474	**69**	0	9,444	**117**	0	482
22	0	0	**70**	0	853	**118**	0	449
23	0	0	**71**	0	0	**119**	0	0
24	0	0	**72**	0	0	**120**	0	154
25	0	0	**73**	0	0	**121**	0	0
26	0	0	**74**	0	22,740	**122**	0	737
27	0	0	**75**	0	4,320	**123**	0	0
28	106,786	18,182	**76**	0	0	**124**	0	1,348
29	0	14,696	**77**	0	0	**125**	0	0
30	0	18,124	**78**	0	1,248	**126**	0	0
31	0	6,993	**79**	0	0	**127**	0	2,967
32	0	18,845	**80**	0	0	**128**	0	0
33	0	63	**81**	0	0	**129**	0	1,438
34	0	7,363	**82**	0	0	**130**	0	0
35	0	0	**83**	0	23,238	**131**	0	3,933
36	0	9,721	**84**	0	0	**132**	0	0
37	0	12,401	**85**	0	11,567	**133**	0	8,118
38	0	0	**86**	0	0	**134**	0	0
39	0	9,629	**87**	0	7,795	**135**	0	1,809
40	0	9,890	**88**	0	0	**136**	0	1,385
41	0	6,844	**89**	0	3,046	**137**	0	0
42	118,975	34,312	**90**	0	0	**138**	0	915
43	0	1,221	**91**	0	269	**139**	0	0
44	0	304	**92**	0	3,736	**140**	0	294
45	0	4,196	**93**	0	0	**141**	0	0
46	15,634	527	**94**	0	2,468	**142**	0	0
47	0	0	**95**	0	0	**143**	0	0
48	0	0	**96**	0	4,097	**144**	0	0

Source: U.S. Census Bureau, "1990 Census Data", U.S. Census Bureau. U.S. Geological Survey, "Colonias: Texas Geodatabase", U.S.-Mexico Border Environmental Health Initiative – Available Data Layers, Geodatabase, http://txpub.usgs.gov/BEHI/Data_download/Places%20Layers/Colonias.zip.

ANIMAL GRAZING

There are two ways in which the defecation of livestock animals reaches the streams and rivers. The first is through direct defecation of the animals into the streams and rivers while grazing, and the second is from storm runoff that carries the overland feces to the streams and rivers. Because this study looks at the steady-state bacteria load, it only considers the first kind of contamination in which the livestock directly defecates into the streams and rivers. The TMDL for the Leon River by James Miertschin & Associates, Inc., assumes that cattle and horses spend a "small fraction of their time directly in the stream," whereas other animals such as dairy cows, sheep, goats, and hogs do not spend time in the streams and rivers.[103] The amount of time cattle and horses spend directly in the streams was taken from estimates in the Leon River TMDL (see Table 16).[104] This estimate assumes that the amount of time cattle spend in the stream changes based on the mean water temperature, spending more time in the streams in the summer months and no time in the streams during the winter months.[105]

Table 16: Percent of Time Cattle Spend in Streams

Month	Time Spent in Streams
January	0%
February	0%
March	1.03%
April	1.14%
May	1.26%
June	1.36%
July	1.40%
August	1.40%
September	1.32%
October	1.18%
November	1.00%
December	0%

Source: James Miertschin & Associates, Inc, "Final Modeling Study for Fecal Coliform TMDL (Total Maximum Daily Load) Development for Leon River Below Proctor Lake, Segment 1221: Project Area 2 – Baisn Groups D & E Bacteria Impairments Work Order #5," Prepared for Texas Commission on Environmental Quality, November 2006, 4-10.

Due to the seasonality of the time spent by grazing animals in streams, the pollutant load caused by these animals varies throughout the year. This study chooses a conservative approach estimating the daily bacterial load based on the month in which the animals would have the largest contribution. This approach means that these are the maximum values and are not likely to be exceeded.

Cattle

The number of cattle grazing in the river is calculated using statistics from the Texas Department of Agriculture's 2009 Agricultural Statistics[106] and INEGI's 2007 Agricultural Census.[107] The number of cattle in each county/municipio were divided evenly among land use that supports cattle grazing. Johnson 2009 defines the land uses that support cattle as "deciduous forest, evergreen forest, mixed forest, shrub/scrubland, grassland/herbaceous, and pasture/hay."[108] The LULC for this study is not as detailed as that used in Johnson 2009, so the LULC attributed to cattle are forest, shrub, and grass/pasture. An exception was made for the municipalities of Río Bravo, Valle Hermoso, and Matamoros which are almost entirely agriculture, so the cattle were equally distributed across agriculture as well for these three municipalities. For each, county and municipality, a density of cattle per square kilometer was calculated. Equation 7 calculates the total grazing animals in each sub-watershed by multiplying the area of LULC that pertains to cattle by the density of cattle in that subwatershed:[109]

$$AN_j = AR_j * \rho_i \quad \textbf{(7)}$$

where AN_j is the total animals in each subwatershed j, AR_j is the total area of LULC attributable to the animal (km^2), ρ_i is the density of the animal in each county/municipality i.

In several instances, the sub-watersheds crossed the boundaries of counties or municipalities. In these cases, the sub-watershed was divided at the county or municipality border. The number of cattle in each part was calculated separately, using

Equation 7. Then the cattle in each part were added together to find the total number of cattle in each sub-watershed. The fecal loading rate per cattle was taken as 1.04×10^{11} FC/animal/day, which is the default value from the EPA Bacteria Indicator Tool.[110] Equation 8 calculates the total fecal coliform loading for each subwatershed by multiplying the total number of animals by the fecal coliform loading rate for cattle and the percent of time spent in streams:[111]

$$FC_j = AN_j * LR * P_k \quad \textbf{(8)}$$

where FC_j is the total fecal coliform load per j subwatershed (count/day), AN_j is the total animals in each subwatershed j, LR is the fecal coliform production rate per animal (FC/animal/day), and P_k is the percent of time spent in streams and rivers per k month. For this analysis, the maximum percentage of time spent in streams was chosen in order to create a conservative estimate. The study found that there are a total of 50,126 cattle in the watershed. These cattle produce 7.30x1013 FC/day that reaches the streams, which results in 1.76x1012 FC/day when accounting for the decay.

Horses

The number of horses grazing in the river is calculated using statistics from the USDA 2007 Agricultural Census[112] and INEGI's 2007 Agricultural Census.[113] The number of cattle in each county/municipio were divided evenly among land use that supports cattle grazing. Johnson 2009 assigned all agricultural animals to the same LULC, so this study assigns horses to the same LULC as cattle.[114] The fecal coliform loading for horses was calculated in the same way as with cattle, using Equation 8. A fecal coliform loading rate was used as 4.2×10^{8} count/animal/day for horses, which is the default value used in the EPA Bacteria Indicator Tool.[115]

A computed total of 2,045 horses in the watershed, based on these assumptions, produce a total of 1.2×10^{10} FC/day, which results in 4.14×10^{08} FC/day reaching the Rio Grande/Río Bravo when taking into account decay.

WILDLIFE

The estimates for fecal contamination are based on estimates for the density of each species as well as the LULC each species is expected to be found in. The animals considered by this study include deer, feral hogs, and birds. As with grazing animals, the pollutant load for wildlife varies depending on the time of the year. This study assumes a conservative estimate by choosing the month that would have the highest pollutant load. Therefore, the actual load is likely to be lower than the load presented in this report.

Deer

The bacteria load from deer into the river comes from two sources, one from the direct defecation of deer into rivers and streams and second from the storm runoff carrying the over land defecation into the rivers. This study, as a result of looking at steady state pollution, only looks at the first kind, which is the direct defecation of deer into the rivers and streams. This study defines a 300 foot (91 meter) riparian corridor to account for the animals that are in direct contact with rivers and streams, as used in the TMDL study for Leon River, Segment 1221.[116] Within the 91 meters from each stream, a standard density of deer was assumed on all the LULC types in which deer typically are found. In Johnson 2009, the LULC assigned to deer were "deciduous forest, evergreen forest, mixed forest, shrub/scrubland, grasslands/herbaceous…pasture/hay…cultivated crops, and woody wetlands."[117] The LULC used for this study is less detailed, so deer were assigned to the LULC of forest, shrub, grass/pasture, agriculture, and wetlands. Estimates for the deer population are taken from the Texas Parks and Wildlife Department, as discussed below. Deer are monitored according to Range Management Units, which are units of land in which deer concentrations are kept track of by the Texas Parks and Wildlife Department. The Resource Management Unit Number 8 includes parts of the watershed, particularly in Starr County. Texas Parks and Wildlife Department estimates from surveys that the Resource Management Unit Number 8 in 2010 had a deer density of 13.01 deer per 1000 acres, or 3.21 deer per square kilometer.[118] In order to estimate the total bacteria load for deer, a value of $5x10^8$ FC counts/animal/day was used, which is the default value in the EPA Bacteria Indicator Tool.[119] Equation 9 calculates the total fecal coliform load produced by wildlife.[120] This calculation is performed for each of the 144 subwatersheds. It multiplies the total area of suitable habitat for each animal by the population density, the fecal coliform production rate of each animal and the percent of time assumed to spend in the stream, varying by month:[121]

$$FC_j = HB_j * \rho * LR * P_k \quad (9)$$

where FC_j is the total fecal coliform load per j subwatershed (count/day), HB_j is the suitable habitat per j subwatershed (km^2), ρ is the density (population/km^2), LR is the fecal coliform production rate per animal, and P_k is the percent of time spent in streams and rivers per k month. The amount of time each animal spends in the stream was assumed to be equal to that of cattle, from Table 16. The values number presented in this study represents the maximum fecal coliform load for cattle, which is from the months that have the most percentage of time spent in streams, in order to create a conservative estimate.

This study found that in the entire watershed there is a total of 835.16 km^2 of suitable habitat for deer within the riparian corridors of 91 meters from a river or stream. There is an estimated 2,685 total deer located within the riparian corridors. The estimated total load of fecal coliform deposited by deer into the rivers and streams is $1.88*10^{10}$ counts/day, and the total including decay is $6.14*10^8$ counts/day.

Feral Hogs

Feral hogs typically reside in similar LULC as deer,[122] with forest, shrub, grass/ pasture, agriculture, and wetland considered as their suitable habitat. The Institute of Renewable and Natural Resource at Texas A&M University estimates that the density of feral hogs in Texas range between 1.33-2.45 hogs per square mile, which is equivalent to

0.51-0.95 hogs per square kilometer.[123] This study uses the more conservative estimate of 0.95 hogs per square kilometer. As with deer, this study only looks at the direct defecation of feral hogs into the rivers and streams. A 91 meter (300 feet) riparian corridor from all the streams was used to account for the direct defecation into streams.[124] A value of $1.08*10^{10}$ FC counts/animal/day was used for feral hogs, which is the default value in the EPA Bacteria Indicator Tool.[125]

The total fecal coliform load from feral hogs was calcualed with Equation 9, using the time spent in streams equivalent with the maximum fecal coliform loading, the same as with deer. The total suitable habitat for feral hogs within the 91 meter riparian corridor is 835.16 km^2. There are an estimated 793 feral hogs within the riparian corridor. The total fecal coliform load is $1.20*10^{11}$ counts/day, and the total including decay is $3.92*10^{9}$ counts/day.

Waterfowl

The bacteria load from waterfowl varies throughout the year, depending on the migratory patterns of the waterfowl. The Texas gulf coast is one of the primary locations of seasonal waterfowl in the winter.[126] Many of the waterfowl in the Texas gulf coast stay in the wetlands of the Rio Grande delta, defined in Tunnel and Judd 2002 as the area which divides the Laguna Madre in Texas from the Laguna Madre de Tamaulipas.[127] Table 17 shows the average percentages of migratory waterfowl that were found in the Rio Grande delta, as compared to other locations in the Texas Gulf Coast region. The chart is presented in Smith 2002 and was recorded from aerial surveys between 1970 to 1988.[128] This table shows that the Rio Grande Delta is the favored wintering grounds for all the types of geese in the study, as well as mottled ducks and green-winged teal ducks. Other types of ducks spend more time in the Lower Laguna Madre or Campeche/Yucutan areas, which are outside the watershed of the Rio Grande/ Río Bravo.

Table 17: Percentage of Migratory Waterfowl in Rio Grande

	Rio Grande	Lower Laguna Madre	Tampico/ Tamiahua	Alvarado Lagoons	Tabasco Lagoons	Campeche/ Yucatan
Lesser Canada goose	68.0	27.3	4.7/0.0	0.0	0.0	0.0
White-fronted goose	60.7	28.6	6.6/4.1	0.0	0.0	0.0
Lesser Snow goose	68.4	21.2	0.0/10.4	0.0	0.0	0.0
Whistling ducks	8.7	0.1	20.2/0.4	30.3	40.1	0.1
Mottled duck	64.4	26.7	5.4/0.4	2.6	0.5	0.0
Gadwall	33.4	28.2	15.0/7.8	11.1	3.7	0.8
Northern pintail	18.2	61.1	4.3/3.9	5.0	4.8	2.7
Green-winged teal	56.7	13.4	21.3/4.0	3.7	0.8	0.1
Blue-winged teal	0.6	0.4	2.2/2.2	17.8	47.9	28.9
American wigeon	19.8	42.8	4.0/6.8	11.9	6.8	7.9
Northern shoveler	40.5	9.4	6.1/3.4	8.2	25.0	7.5
Redhead	0.1	97.5	0.0/2.1	0.0	0.0	0.2
Ring-necked duck	1.1	2.9	1.9/0.3	14.4	17.5	62.0
Canvasback	11.4	55.2	7.9/17.7	7.5	0.1	0.2
Scaup	1.1	36.7	6.3/12.7	5.6	5.4	32.2
Ruddy duck	31.8	33.8	14.9/7.2	7.5	4.9	0.0

Source: Elizabeth H. Smith, "*Redheads and Other Wintering Waterfowl*," in *The Laguna Madre of Texas and Tamaulipas*, edited by John W. Tunnell Jr. and Frank W. Judd (College Station: Texas A&M University Press, 2002), 177.

Table 18 uses the percentages of each species in the Rio Grande Delta from Smith (2002) and multiplies it by the waterfowl population in the Lower Texas Coast during the 1980-81 winter season, found from a survey by U.S. Fish and Wildlife Service (1981).[129,130] Table 18 illustrates that the dominant waterfowl in the watershed are the Lesser Snow goose, with 23,461 geese, and the Northern Pintail duck, with 19,474 ducks.

Table 18: Winter Population of Waterfowl in Rio Grande Delta

	Species	% in Rio Grande Delta	Winter Population in Lower Texas Coast	Winter Population in Rio Grande Delta
Geese	Lesser Canadian Goose	68.0	12,100	8,228
	White-fronted goose	60.7	3,900	2,367
	Lesser Snow goose	68.4	34,300	23,461
Ducks	Mottled duck	64.4	2,200	1,417
	Gadwall	33.4	14,900	4,977
	Northern pintail	18.2	107,000	19,474
	Green-winged teal	56.7	4,300	2,438
	Blue-winged teal	0.6	0	0
	American wigeon	19.8	22,800	4,514
	Northern shoveler	40.5	6,700	2,714
	Redhead	0.1	208,000	208
	Ring-necked duck	1.1	100	1
	Canvasback	11.4	700	80
	Scaup	1.1	14,100	155
	Ruddy duck	31.8	3,300	1,049

Source: Smith, "Redheads and Other Wintering Waterfowl," 177. U.S. Fish and Wildlife Service, Wetland Preservation Program, 5.

The land uses attributed to waterfowl in this study are water and wetland. In the riparian corridor of 91 meters, there is a total of 1072 km^2 of suitable habitat for waterfowl. Based on the assumptions above, there are an estimated total 34,057 geese and 37,027 ducks in the watershed. An assumption is made that the waterfowl are spread evenly across their suitable habitat so that there is a density of 31.77 geese/km^2 and 34.54 ducks/km^2 within the suitable habitat. This density was used for the direct Rio Grande Delta, which includes subwatersheds 126 through 144. The density was diminished going upstream from the delta using an inverse distance weighting based on the distance of each subwatershed from the Rio Grande Delta.

This study looks at the maximum fecal coliform load from waterfowl in the peak migratory season in order to create a conservative estimate. The fecal coliform load from waterfowl are taken as 10^7 counts/animal/day for geese and 10^9 counts/animal/day for ducks, taken from Wieskel et al. 1996.[131]

Using Equation 9, the total fecal coliform load from geese is 3.00×10^{11}counts per day and the total fecal coliform load from ducks is $7.91 * 10^{13}$, for a total of 7.97×10^{13} counts per day for all waterfowl. After accounting for decay, the total fecal coliform load for waterfowl is 2.12×10^{12} fecal coliform counts per day.

The pollutant load for grazing animals and wildlife varies seasonally throughout the year. The pollutant load from cattle, horses, deer, and feral hogs will be highest in the summer, when they spend more time in rivers and streams. The pollutant load for waterfowl will be highest in the winter, due to their migratory patterns. The estimate of the pollutant load for each animal in this study is a conservative estimate that chooses the month that will have the highest load for each animal. Therefore, the estimates presented in this report are the maximum value of the pollutant loads, and these estimates are not likely to be exceeded due to the conservative nature of the estimation of the loads.

This chapter has explained the methodology used for this study. Chapter 3 will present the results of this analysis to estimate the fecal coliform bacteria produced from the non-point sources along the Lower Rio Grande/ Río Bravo below Falcón reservoir.

---

[8] U.S. Geological Survey, "National Hydrography Dataset," The National Map, U.S. Geological Survey, GIS Shapefile, http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd, Accessed July 13, 2011.
[9] INEGI and U.S. Geological Survey, e-mail message from Kimberly Jones to author, Unpublished GIS Shapefile, October 31, 2011.
[10] U.S. Geological Survey, "National Hydrography Dataset."
[11] INEGI and U.S. Geological Survey, Unpublished GIS Shapefile, October 31, 2011.
[12] Jean Parcher, "U.S.-Mexico Border Geographic Information System," Fact Sheet 2008-3069, U.S. Geological Survey, October 2008, http://pubs.usgs.gov/fs/2008/3069/.
[13] U.S. Geological Survey, e-mail message from Tony Litschewski to author, Unpublished GIS Shapefile, June 201.1
[14] U.S. Geological Survey, Unpublished GIS Shapefile, June 2011
[15] U.S. Geological Survey, "Seamless Server Viewer", The National Map, DEM Raster file, http://seamless.usgs.gov/website/seamless/viewer.htm.

[16] National Oceanic and Atmospheric Administration Coastal Services Center, *LIDAR 101: An Introduction to LiDAR Technology, Data and Applications* (Charleston, SC: NOAA Coastal Services Center, 2008), 1.
[17] Gilbert Anaya, telephone conversation with author, October 13, 2011.
[18] Kimberly Jones, e-mail message to author, October 31, 2011.
[19] U.S. Geological Survey, "National Hydrography Dataset."
[20] INEGI and U.S. Geological Survey, Unpublished GIS Shapefile, October 31, 2011.
[21] Ibid.
[22] TCEQ, Internal Map, digitized by author, June 03, 2011.
[23] Ibid.
[24] Tarboton, David, "Watershed and Stream Network Delineation: GIS in Water Resources, Fall 2011," Dr. Maidment's Classes, http://www.ce.utexas.edu/prof/Maidment/giswr2011/Ex4/Ex42011.pdf.
[25] Ibid, 9.
[26] Ibid, 14.
[27] Ibid, 15.
[28] Ibid, 16.
[29] Ibid, 21.
[30] TCEQ, Internal Map, digitized by author, June 03, 2011.
[31] U.S. Geological Survey, "National Hydrography Dataset."
[32] INEGI and U.S. Geological Survey, Unpublished GIS Shapefile, October 31, 2011.
[33] TCEQ, Internal Map, digitized by author, June 03, 2011.
[34] Ibid.
[35] U.S. Geological Survey, "Seamless Server Viewer."
[36] INEGI, "Áreas Geoestadísticas Municipales," Marco Geoestadístico Municipal 2009 Versión 4.1, GIS Shapefile, http://mapserver.inegi.org.mx/data/mgm/
[37] U.S. Census Bureau, "2010 TIGER/Line® Shapefiles", GIS Shapefile, http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html, November 30, 2010.
[38] INEGI, "Áreas Geoestadísticas Municipales."
[39] U.S. Census Bureau, "2010 TIGER/Line® Shapefiles," November 30, 2010.
[40] INEGI, "Áreas Geoestadísticas Municipales."
[41] U.S. Census Bureau, "2010 TIGER/Line® Shapefiles," November 30, 2010.
[42] INEGI, "Áreas Geoestadísticas Municipales."
[43] U.S. Census Bureau, "2010 TIGER/Line® Shapefiles," November 30, 2010.
[44] INEGI, "Áreas Geoestadísticas Municipales."
[45] U.S. Census Bureau, "2010 TIGER/Line® Shapefiles," November 30, 2010.
[46] U.S. Geological Survey, "Land Use/ Land Cover: Binational 2001", U.S.-Mexico Border Envrionmental Health Initiative – Available Data Layers, Raster file, http://borderhealth.cr.usgs.gov/datalayers.html.
[47] Ibid.
[48] Ibid.
[49] Ibid.
[50] Ibid.
[51] Ibid.
[52] Ibid.
[53] Ibid.
[54] George L. Bowie and others, *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling*, (Athens, GA: U.S. Environmental Protection Agency, Jun 1985, 2nd ed.), 434.
[55] International Boundary and Water Commission, *Bacteria Characterization in Segment 2302_01 of the Rio Grande near Brownsville, Texas: A Texas Clean Rivers Program Special Study*, (El Paso, TX: International Boundary and Water Commission, 2011), http://www.ibwc.gov/CRP/documents/BrownsvilleBacteriaSpecialStudyFINALREPORTJune2011.pdf, 17.

[56] Ibid.
[57] George L. Bowie and others, *Rates, Constants, and Kinetics Formulations*, 425.
[58] National Council of Examiners for Engineering and Surveying, *Fundamentals of Engineering Supplied-Reference Handbook* (Clemson, SC: National Council of Examiners for Engineering and Surveying, 2005), 29.
[59] TCEQ, Unpublished QUALTX Input File, Data Type 9 (Advective Hydraulic Coefficients), Received by author on June 2011.
[60] Ibid.
[61] International Boundary and Water Commission, *Bacteria Characterization in Segment 2302_01,* 17.
[62] TCEQ, Unpublished QUALTX Input File.
[63] International Boundary and Water Commission, *Bacteria Characterization in Segment 2302_01,* 17.
[64] Texas Comptroller of Public Affairs, *Bordering the Future*: *Challenge and Opportunity in the Texas Border Region* (Austin, Texas: Texas Comptroller of Public Affairs, July 1998), http://www.window.state.tx.us/taxinfo/taxforms/96-599/contents.pdf, 126.
[65] INEGI, "Ocupantes de viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo," Censo de Población y Vivienda 2010, Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est.
[66] INEGI. "Principales Resultados por localidad (ITER)." Censo de Población y Vivienda. Aguascalientes, Aguascalientes, 2010, http://www.inegi.org.mx/sistemas/consulta_resultados/iter2010.aspx?c=27329&s=est.
[67] INEGI, "Viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo," Censo de Población y Vivienda 2010. Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est
[68] Ibid.
[69] Ibid.
[70] Ibid.
[71] INEGI, "Viviendas particulares habitadas por municipio."
[72] Ibid.
[73] INEGI. "Principales Resultados por localidad (ITER)."
[74] Ibid.
[75] Ibid.
[76] U.S. Geological Survey, "National Hydrography Dataset."
[77] INEGI and U.S. Geological Survey, Unpublished GIS Shapefile, October 31, 2011.
[78] TCEQ, Internal Map, digitized by author, June 03, 2011.
[79] INEGI. "Polígonos de Localidades Urbanas Geoestadísticas", INEGI, Aguascalientes, Aguascalientes, 2010. http://mapserver.inegi.org.mx/data/mgm/redirect.cfm?fileX=LOCURBANAS50.
[80] Shuo-Sheng Wu, Le Wang, and Xiaomin Qiu, "Incorporating GIS Building Data and Census Housing Statistics for Sub-Block-Level Population Estimation," *The Professional Geographer* 60, no.1 (2008):121-135, http://www.acsu.buffalo.edu/~lewang/pdf/lewang_sample17.pdf, 123.
[81] INEGI. "Principales Resultados por localidad (ITER)."
[82] INEGI. "Polígonos de Localidades Urbanas Geoestadísticas."
[83] Reed, Stowe & Yanke, LLC, "Study to Conduct Further Research Regarding the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in South Texas," Texas On-Site Wastewater Treatment Research Council, June 20, 2002, 3.
[84] James Miertschin & Associates, Inc, *Final Modeling Report for Fecal Coliform TMDL (Total Maximum Daily Load) Development for Leon River Below Proctor Lake, Segment 1221: Project Area 2 – Baisn Groups D & E Bacteria Impairments Work Order #5*. 4-10.
[85] INEGI. "Polígonos de Localidades Urbanas Geoestadísticas."

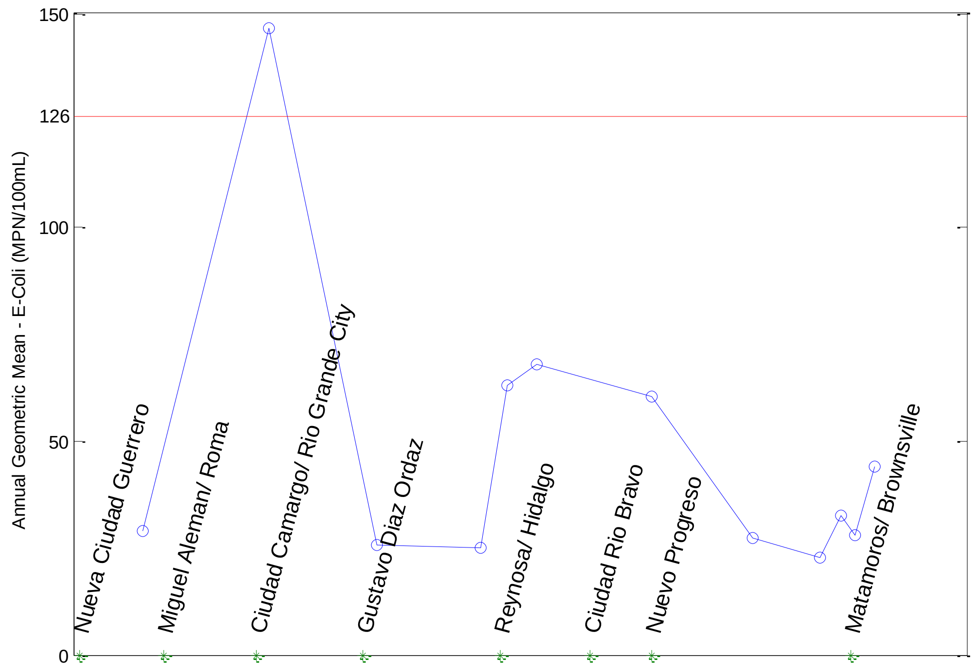
[86] City of Los Angeles Bureau of Engineering, *Part F Sewer Design* (Los Angeles, CA: City of Los Angeles Bureau of Engineering, June 1992), http://eng.lacity.org/techdocs/sewer-ma/f200.pdf, 221.
[87] Ibid.
[88] Comisión Nacional del Agua, *Manual de Agua Potable, Alcantarillado y Saneamiento: Datos Básicos* (Coyocán, D.F.: Comissión Nacional del Agua, December 2007), 73.
[89] Ibid.
[90] Environmental Protection Agency, Bacteria Indictor Tool, Excel Spreadsheet, http://water.epa.gov/scitech/datait/models/basins/bs3tbit.cfm, December 2001, Septics Tab.
[91] U.S. Census Bureau, "1990 Census Data", U.S. Census Bureau.
[92] Ibid.
[93] Stephanie Lynn Johnson, "A General Method for Modeling Coastal Water Pollutant Loadings," 267.
[94] Ibid.
[95] Reed, Stowe & Yanke, LLC, "Study to Conduct Further Research Regarding the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in South Texas," 3.
[96] Texas Secretary of State, Colonia Initiatives Program, Texas Secretary of State, http://www.sos.state.tx.us/border/colonias/what_colonia.shtml, Accessed on March 20, 2012.
[97] U.S. Geological Survey, "Colonias: Texas Geodatabase", U.S.-Mexico Border Environmental Health Initiative – Available Data Layers, Geodatabase, http://txpub.usgs.gov/BEHI/Data_download/Places%20Layers/Colonias.zip.
[98] Ibid.
[99] Ibid.
[100] Environmental Protection Agency, Bacteria Indictor Tool, Septics tab.
[101] U.S. Census Bureau, "1990 Census Data", U.S. Census Bureau.
[102] U.S. Geological Survey, "Colonias: Texas Geodatabase."
[103] James Miertschin & Associates, Inc, *Final Modeling Report,* 4-10.
[104] Ibid.
[105] Ibid.
[106] United States Department of Agriculture National Agricultural Statistics Service, *Texas Agricultural Statistics 2009*, (Austin, TX: United States Department of Agriculture, 2010), http://www.nass.usda.gov/Statistics_by_State/Texas/Publications/Annual_Statistical_Bulletin/bull2009.pdf, 40-41.
[107]INEGI. "Existencias de ganado bovino según rango de edad por entidad y municipio: Ganadero y Forestal 2007: Censo Agrícola," INEGI, Aguascalientes, Aguascalientes, 2007, http://www.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=17177&s=est.
[108] Stephanie Lynn Johnson, "A General Method for Modeling Coastal Water Pollutant Loadings," 230.
[109] Ibid, 231.
[110] Environmental Protection Agency, Bacteria Indictor Tool, References tab.
[111] James Miertschin & Associates, Inc, *Final Modeling Report,* 5-8.
[112] USDA, *2007 Census of Agriculture, Volume 1, Chapter 2: County Level Data*, (Washington DC: USDA, 2008), http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/st48_2_015_015.pdf, 769-771.
[113] INEGI. "Existencias de animales de otras especies por entidad: Ganadero y Forestal 2007: Censo Agrícola," INEGI, Aguascalientes, Aguascalientes, 2007, http://www.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=17177&s=est.
[114] Stephanie Lynn Johnson, "A General Method for Modeling Coastal Water Pollutant Loadings," 231.
[115] Environmental Protection Agency, Bacteria Indictor Tool, References Tab.
[116] Texas A&M Institute of Renewable Natural Resources, "Feral Hog Statewide Population Growth and Density," Texas A&M University Agrilife Research Extension, College Station, TX, 2011, http://feralhogs.tamu.edu/files/2011/05/FeralHogFactSheet.pdf, 2.
[116] James Miertschin & Associates, Inc, *Final Modeling Report,* 4-12.

[117] Stephanie Lynn Johnson, “A General Method for Modeling Coastal Water Pollutant Loadings,” 230.
[118] Texas Parks and Wildlife Department, *2010 Texas Parks and Wildlife Department Big Game Federal Aid Report* (Austin, TX: Texas Parks and Wildlife Department, 2011), 15.
[119] Environmental Protection Agency, Bacteria Indictor Tool, References Tab.
[120] James Miertschin & Associates, Inc, *Final Modeling Report,* 5-8.
[121] Ibid.
[122] Stephanie Lynn Johnson, “A General Method for Modeling Coastal Water Pollutant Loadings,” 231.
[123]Texas A&M Institute of Renewable Natural Resources, “Feral Hog Statewide Population Growth and Density,” 2.
[124] James Miertschin & Associates, Inc, *Final Modeling Report,* 4-12.
[125] Environmental Protection Agency, Bacteria Indictor Tool, References Tab.
[126] U.S. Fish and Wildlife Service, *Wetland Preservation Program Category 8 Texas Gulf Coast* (Albuqurque, NM: U.S. Fish and Wildlife Service, 1981), 5.
[127] John W. Tunnell, Jr., “*Geography, Climate, and Hydrography,”* in *The Laguna Madre of Texas and Tamaulipas*, edited by John W. Tunnell Jr. and Frank W. Judd (College Station: Texas A&M University Press, 2002), 7.
[128] Elizabeth H. Smith, “*Redheads and Other Wintering Waterfowl*,” in *The Laguna Madre of Texas and Tamaulipas*, edited by John W. Tunnell Jr. and Frank W. Judd (College Station: Texas A&M University Press, 2002), 177.
[129] *Ibid.*
[130] U.S. Fish and Wildlife Service, *Wetland Preservation Program: Texas Gulf Coast, category 8* (Albuquerque, NM: USFWS, 1981), 5.
[131] Peter K. Weiskel and others, “Coliform Contamination of a Coastal Embayment: Source and Transport Pathways,” Environmental Science & Technology, 1996, 30 (6), 1872-1881, 1873.

Chapter 3: Results

The steady-state, non-point source bacterial loading of the Rio Grande/ Río Bravo is divided for all the components discussed below: untreated sewage, uncontrolled septic effluents, and the wasteloads associated with cattle, hourses, feral hogs, deer, and birds. The effluents for all sources can be aggregated to compare the watershed of each of the Rio Grande/ Río Bravo 48 reaches, as defined from previous TCEQ water quality models. For an understanding of the how the water quality of the Rio Grande/ Río Bravo changes across the length of this section, Figure 12 illustrates data as sampled by the International Boundary and Water Commission and as available from the Texas Commission on Environmental Quality. Figure 12 illustrates the annual geometric mean of E. Coli in 2010 for several testing stations from upstream to downstream, left to right. The red line indicates an E-Coli concentration of 126 MPN/100mL, which is the maximum allowable annual geometric mean for the ambient concentration of bacteria for recreational contact.[132] The highest bacteria levels are found downstream of Ciudad Miguel Alemán and at the border of Reynosa and Hidalgo.

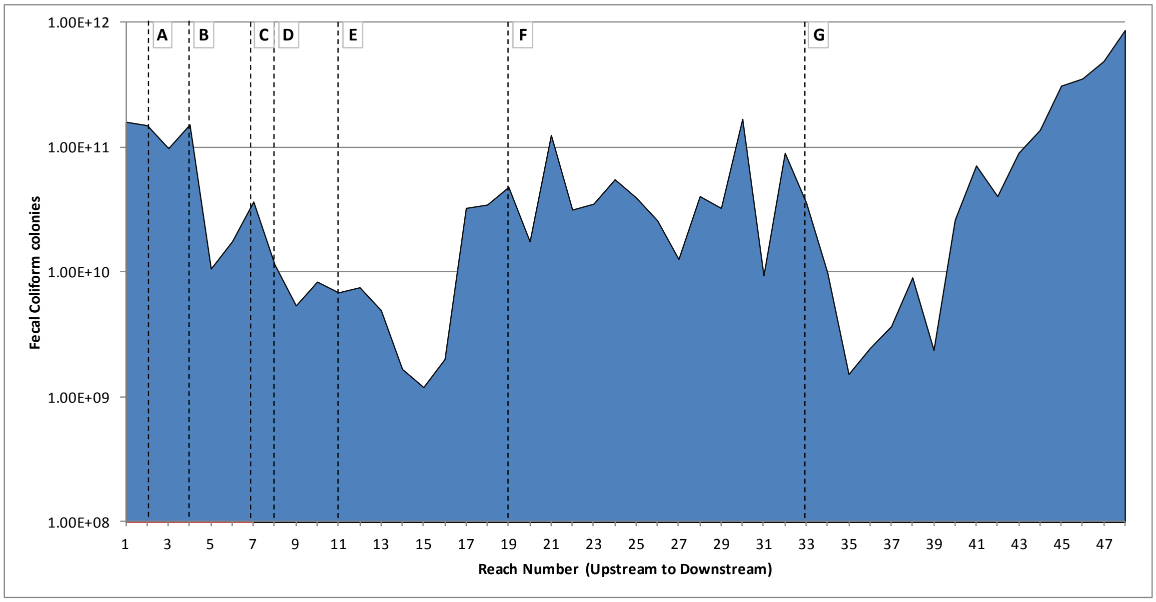
Figure 12: Annual Geometric Mean 2010 E. Coli



Source: Texas Commission on Environmental Quality, Monitoring Station List, http://www8.tceq.state.tx.us/SwqmisWeb/public/index.faces, Accessed on July 12, 2011. Graph created by Robin Lynch

In comparison, the results of this analysis are displayed in Figure 13, which graphs the total non-point source contribution of fecal coliform for each of the 48 reaches.[133] The results are presented in tabular form in Appendix C.[134] The figure uses a logarithmic scale, showing the total fecal coliform colonies that are contributed for each reach. The far left of the figure starts at Falcón dam and it continues to the right until the Gulf of Mexico. The bacteria contribution is high at Ciudad Miguel Alemán (on the order of 10^{11} FC counts/day) and Reynosa/ Hidalgo (on the order of 10^{10} FC counts/day), which conforms with the spike in bacteria concentrations at these locations shown in Figure 12. Bacteria levels also are very high below Matamoros and Brownsville (on the order of 10^{11} FC counts/day). The highest bacteria loading is found close to the Gulf of Mexico, from Reach 44 to 48, almost on the order of 10^{12} FC counts/day. This very large bacteria loading in the tidal region is due to the migratory waterfowl population in the winter, and it would not be present in the summer. The letters A through G represent the major cities and towns along the river. Table 19 provides a key for which letter corresponds with each city, as well as the Reach Number that the city is closest to.[135]

Figure 13: Non Point Source Fecal Coliform Bacteria Loadings, per Reach



Source: Created by Robin Lynch

Table 19: Cities with their Corresponding Reach Number

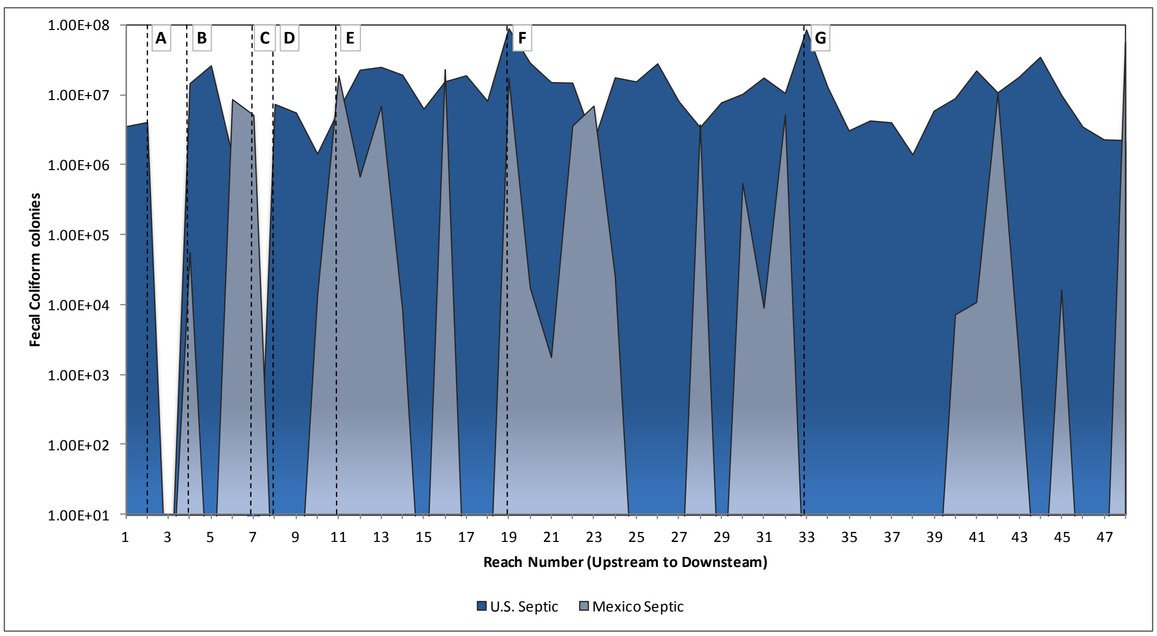
Label	City	Reach Number
A	Mier	2
B	Roma/ Ciudad Miguel Aleman	4
C	Ciudad Camargo	7
D	Rio Grande City	8
E	Gustavo Diaz Ordaz	11
F	Reynosa / Hidalgo	19
G	Matamoros / Brownsville	33

Source: TCEQ, Internal Map, digitized by author, June 03, 2011.

The following figures divide up the various sources that contribute to the total bacteria load. In the first graph, Figure 14 presents the bacteria contributions of septic systems, comparing the U.S. with the Mexican side.[136] From septic tanks, there is generally a larger contribution of bacteria from the U.S. side than from the Mexican side. This can be explained by a larger population in the Mexican watershed living in more concentrated urban areas, whereas the U.S. side of the watershed is mostly rural. According to the

1990 U.S. Census, 65 percent of households on the U.S. side of the watershed use septic tanks while 27 percent are connected to public sewage.[137] The Mexican side of the watershed, on the other hand, has 77 percent of households connected to public sewage and only 9 percent on septic tanks.[138] The U.S. side produces between 0 to 10^8 FC counts/ day in each reach, but remains fairly constant between 10^6 to 10^8 FC counts/day. The U.S. side spikes at the cities of Hidalgo and Brownsville. The Mexican side has produces between 0 to 10^7 FC counts/day, but unlike the U.S. side, only has bacteria contamination in concentrated areas, as shown by spikes in the Figure 14. These spikes represent the urban areas along the border in México. The Mexican side has its largest spikes near the cities of Ciudad Camargo, Gustavo Díaz Ordaz, and Reynosa.

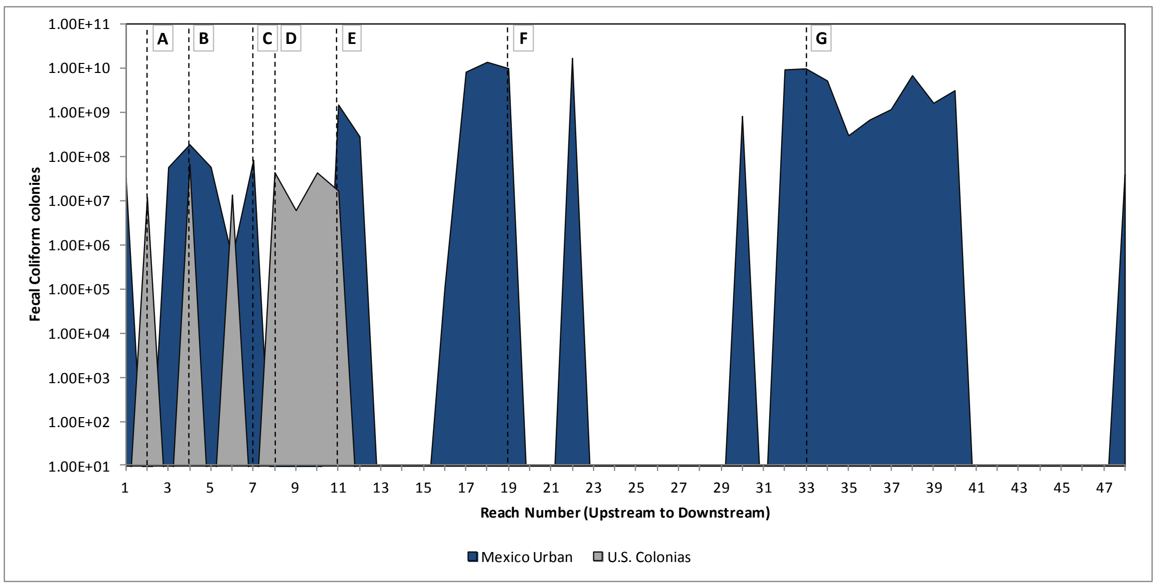
Figure 14: Bacteria Contribution from Septic Systems in the U.S. and Mexico



Source: Created by Robin Lynch

Figure 15 presents the bacteria contributions from colonias on the U.S. side and from urban residents in Mexico.[139] This contamination has peaks in the urban areas with no contamination in other non-urban areas. The bacteria contamination from urban areas in Mexico is larger, reaching 10^{10} FC counts/ day, than the bacteria contamination from U.S. colonias, only reaching 10^8 FC counts/ day. This corresponds to the Mexican side of the watershed being more urban and the U.S. side of the watershed being more rural. The contamination from the U.S. side is all upstream of Hidalgo, because the cities downstream of Hidalgo mostly drain into the Arroyo Colorado instead of the Rio Grande/ Río Bravo. The largest peaks from the Mexican side occur at Reynosa and at Matamoros, reaching 10^{10} FC counts/ day.

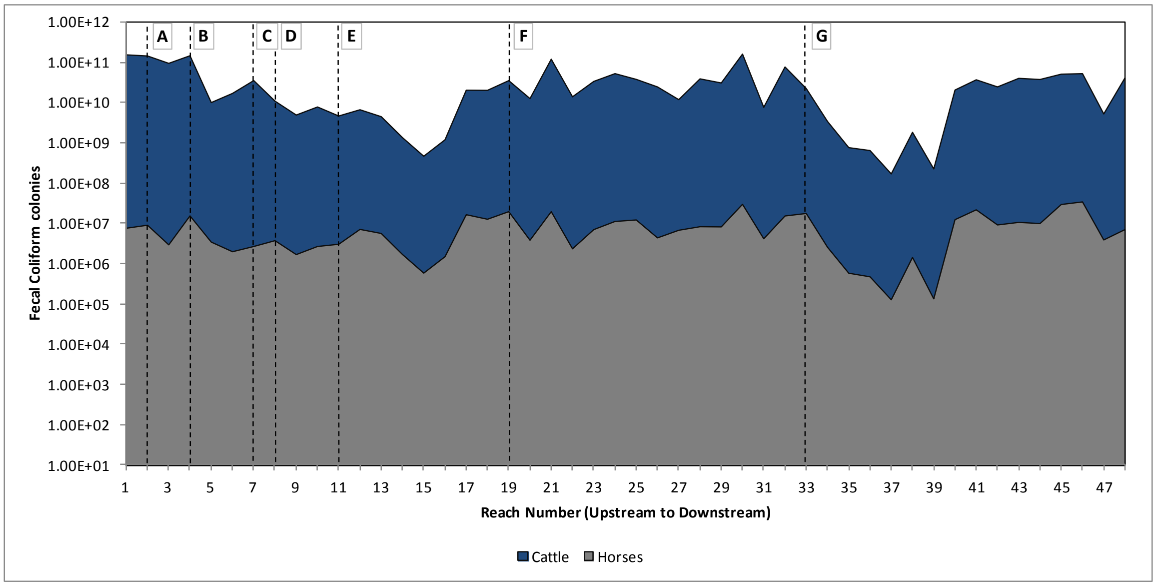
Figure 15: Bacteria Contributions from U.S. Colonias and Mexican Urban Areas



Source: Created by Robin Lynch

Figure 16 presents the bacteria contribution from livestock of cattle and horses.[140] The bacteria from cattle is generally between 3 to 4 orders of magnitude greater than that of horses. The bacteria contribution from cattle ranges from 10^8 to 10^{11} FC counts/ day, whereas the bacteria contribution from horses ranges from 10^5 to 10^7 FC counts/ day. The bacteria from cattle represent one of the largest sources of bacteria in the watershed. The non-point source bacteria contributions for cattle will have a large effect on any water quality model, even though the accuracy of this estimation is largely dependent on estimating how much time cattle spend in streams. A small change in amount of time cattle spend in streams could have a large effect on the water quality model. Therefore, it will be important to develop studies to determine more accurately the percentage of time cattle spend in streams within this watershed.

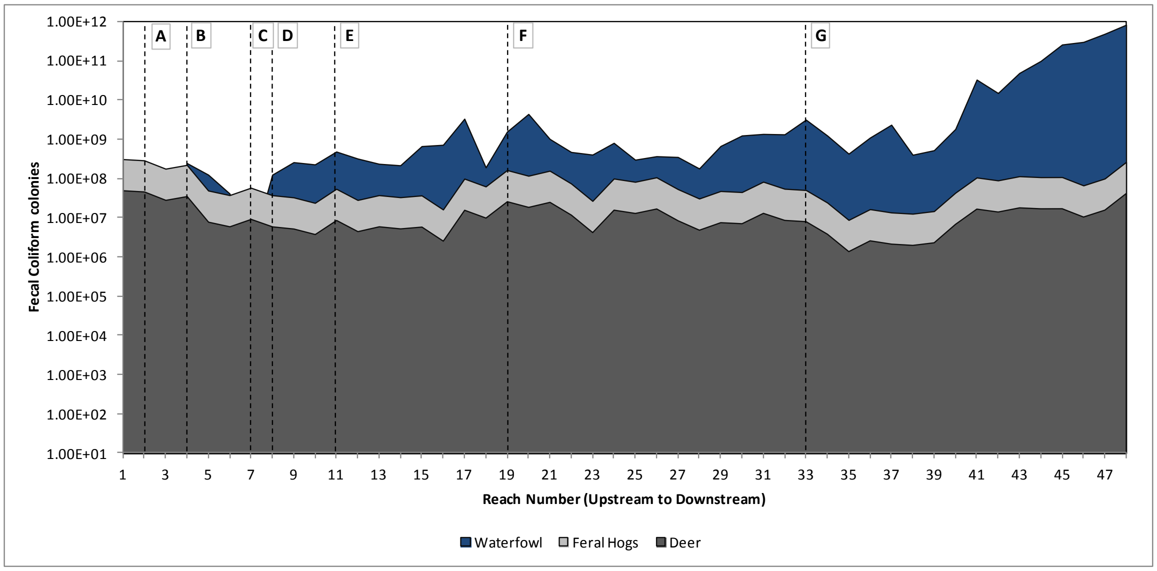
Figure 16: Bacteria Contributions from Livestock (Cattle and Horses)



Source: Created by Robin Lynch

Figure 17 shows the bacteria contributions from wildlife, specifically water fowl, deer, and feral hogs.[141] The bacteria contamination from water fowl is much larger than the contribution from other wildlife, ranging from 10^7 to 10^{12} FC counts/day. The bacteria contribution from deer ranges from 10^6 to 10^7 FC counts/ day and the contribution from feral hogs ranges from 10^6 to 10^8 FC counts/day. The bacteria contribution from waterfowl is from migratory waterfowl that migrate to the Lower Rio Grande in the winter. Thus, the bacteria contamination would vary largely throughout the year. By estimating bird bacterial contributions based on the maximum load, as this study does in the tidal region of the Rio Grande/ Río Bravo, the contamination from waterfowl is the dominant source of bacteria by several factors of magnitude. This estimation was developed from the few waterfowl surveys of the Lower Rio Grande Delta. It is recommended that any further studies and water quality models conduct studies and surveys to more accurately determine the number of waterfowl that are in the watershed, because these numbers would influence the accuracy and reliability of my water quality study.

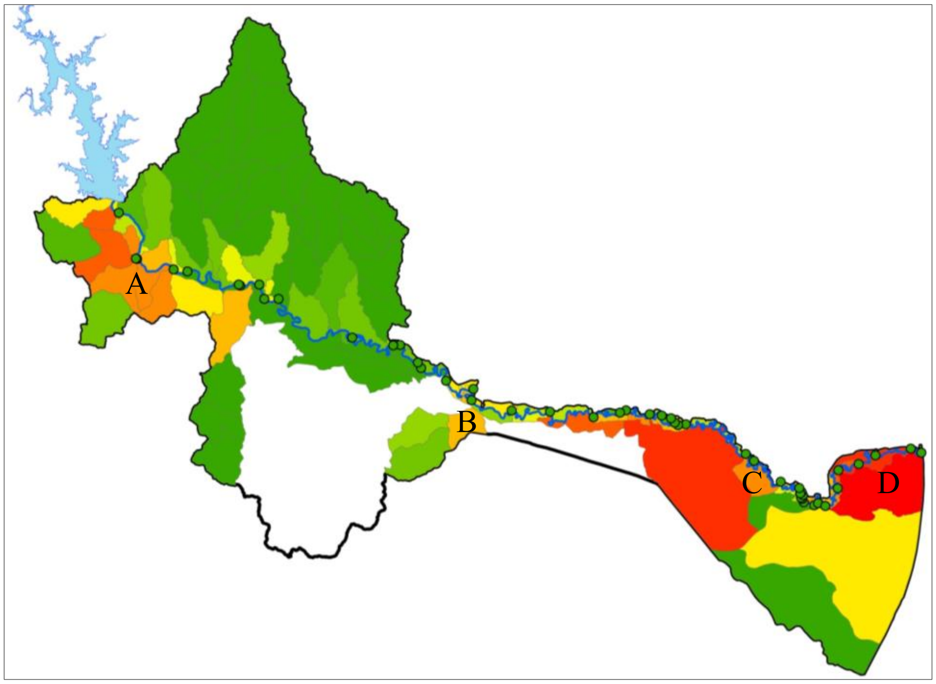
Figure 17: Bacteria Contributions from Wildlife



Source: Created by Robin Lynch

Figure 18 displays a graphical representation of the fecal coliform loading based on each subwatershed.[142,143,144] The scale of colors shows green as the lowest amount of fecal coliform load, up to red which represents the highest fecal coliform load. This figure shows that the subwatersheds closer to the river contribute more to the bacteria loadings to the river. This makes sense, because most of the population in the watershed lives close to the river; bacteria deposited farther away from the Rio Grande/ Río Bravo would decay before reaching the river. In the western part of the watershed, part A, the orange areas largely represent the bacteria from cattle being deposited into rivers and streams. Part B on the map represents the area around Reynosa/Hidalgo, which has many households without sewage collection. Part C on the map represents the area around Matamoros/ Brownsville, which also has many households without sewage connections. Part D represents the Rio Grande Delta, which has a large population of migratory birds.

Figure 18: Geographical Representation of Fecal Coliform Loadings



Source: Derived from USGS, "National Hydrography Dataset," The National Map, GIS Shapefile, http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd & INEGI, Unpublished GIS Shapefile, October 31, 2011 & TCEQ, Internal Map, digitized by Robin Lynch, June 03, 2011, Map created by Robin Lynch

This chapter presented the results of estimating the steady-state non-point source pollution entering into the Rio Grande/ Río Bravo. The last chapter will present recommendations and conclusions for how environmental agencies can use results to improve the water quality models of the river.

---

[132] The State of Texas, *Texas Administrative Code Title 30 Part 1 Chapter 307 Rule §307.7*, (Austin, TX: The State of Texas, 2010), http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=307&rl=7.
[133] TCEQ, Internal Map, digitized by author, June 03, 2011.
[134] Ibid.
[135] Ibid.
[136] Ibid.
[137] U.S. Census Bureau, "1990 Census Data."
[138] INEGI, "Viviendas particulares habitadas por municipio."
[139] TCEQ, Internal Map, digitized by author, June 03, 2011.
[140] Ibid.
[141] Ibid.
[142] U.S. Geological Survey, "National Hydrography Dataset."

[143] INEGI and U.S. Geological Survey, Unpublished GIS Shapefile, October 31, 2011.
[144] TCEQ, Internal Map, digitized by author, June 03, 2011.

Chapter 4: Conclusions and Recommendations

The two challenges for including steady-state, non-point effluent sources is that it is not easy to estimate their actual value and even more difficult to control them. For sources like untreated sewage, several programs have been implemented to provide adequate sewage treatment capacity and connections, such as the Texas Secretary of State's Colonia Initiatives Program[145] and the wastewater control investments of the Border Environment Cooperation Commission.[146] For sources such as migratory waterfowl, it would not be feasible to try to reduce this bacteria contribution, nor would it be preferable to limit the presence of migratory waterfowl in the watershed. This study, as other similar studys of its kind, makes many assumptions, as listed in the Table of Assumptions, and these assumptions should be considered when using this study for future water quality modeling. Much of the data used are taken from a large scale (such as the county or municipality level), and therefore subject to rough estimation. In many areas of this study, the results could be improved and made more accurate through further studies, delineations, surveys, and interviews. This section highlights the areas that could be useful for added investigation. It will be up to the government agencies to determine which areas merit more research to achieve more accurate results.

This study has estimated steady state, non-point source bacteria pollution on the Lower Rio Grande/ Río Bravo between the Falcón Reservoir and the Gulf of Mexico. This study looked at the bacteria contribution from septic tanks, untreated sewage, livestock, and wildlife, comparing the bacteria load from the U.S. and México side of the watershed. The total fecal coliform load of each source is shown in Appendix C and is divided by each subsection, or "reach."

These results are intended for use as an input for creating a steady-state water quality model using QUALTX, or a similar steady-state water quality model. The bacteria contributions in this study were divided in 48 different reaches, as were defined in a previous QUALTX model of the river that was performed by the Texas Commission on Environmental Quality.[147] The information compiled in this study would also be helpful for creating a non-steady state model, but much more information would need to be collected in order to create such a model.

The results indicate that the watershed should continue to improve the wastewater infrastructure and treatment to prevent untreated sewage from reaching the river. The largest contributions of untreated sewage to the river occurred close to the Mexican urban centers as well as the U.S. colonias. Cattle represent another large contributor of bacteria to the watershed, although there is some uncertainty in the estimate of bacteria contributed by cattle due to the assumptions regarding how many, where, and when they have direct access to surface water. This problem could be remedied by enabling cattle to drink water from sources other than rivers, through providing separate watering ponds for cattle to drink from and fences to limit cattle access. Waterfowl have the potential to contribute a very large load of bacteria to the river, especially in the tidal area close to the Rio Grande Delta. The reason that waterfowl and cattle have such a significant contribution to the bacterial load is because these animals produce a very high count of fecal coliform per day (10^{11} and 10^{9} FC counts/ day)[148,149] compared with what humans produce (10^{4} FC counts/ day).[150]

This study has several recommendations for government agencies that will use this study for developing water quality models and policy (see Table 20). Each recommendation will have a different financial cost, so it will be the government agencies' decision on which improvements they choose to invest their resources.

Table 20: Table of Recommendations

Recommendation	Details
1	Research and revise the watershed delineation to accurately represent the movement of water
2	Perform a survey of the percent of septic failure on the Mexican side of the watershed
3	Research the amount of time cattle spend in rivers and streams
4	Perform waterfowl surveys along the river
5	Determine what percentage of collected sewage is untreated
6	For point-source study, determine the degree of treatment at wastewater treatment plants
7	Determine the appropriate riparian corridor to use for septic systems and animals
8	Collect streamflow data for the NHD dataset in order to create an NHD Plus dataset

The first recommendation is that the watershed delineation should be researched and revised to accurately determine what area of land drains into the Rio Grande/ Río Bravo. The watershed delineation as is currently accepted between USGS and INEGI may not accurately represent the true area that drains into the Rio Grande/ Río Bravo. There are many canals built on the Mexican side of the watershed with the purpose of carrying water away from the Rio Grande/ Río Bravo and into the Gulf of Mexico.[151] These canals are not adequately accounted for in the current watershed delineation, which results in a large amount of land that this study includes as draining into the river. In reality some of these areas may not drain into the river. Second, the DEM used for the delineation not only uses a large grid size, meaning less detail, but also it is hard to validate the data in the current DEM. It would be helpful for the analysis to have Lidar data over the entire watershed, and if that is not possible, to at least perform a quality control check on the current DEM data available. Another way to improve the analysis would be to create an NHD file that accurately represents the drainage in the eastern part of the watershed, because many canals and streams are not considered in the current

NHD file that is accepted between USGS and INEGI. The current NHD appears it may be incomplete in the eastern part of the watershed.

Second, government agencies should perform a survey of how well septic systems are functioning in the México side of the watershed. This study used a survey conducted on the U.S. side of the watershed and assumed that the México side would have the same rate of septic tank failure. It is unclear how reliable or valid this assumption may be, so conducting a survey would be helpful.

Third, government agencies should research the amount of time cattle spend in rivers and streams in the watershed. This study used data from previous studies performed in other parts of the state of Texas, because no studies from this watershed were found.[152] The bacteria contribution from cattle to the river is highly dependent on the amount of time they spend in the river, because that is the only way that the bacteria will reach the river in a steady-state model. The accuracy of this model would be greatly improved with a study on the amount of time cattle spend in the rivers and streams, especially since cattle were such a large contributor of bacteria to the river.

Another useful survey would be for waterfowl on the river for various locations along the entire length of the river in the study. There are very few waterfowl surveys performed in this watershed, so this study had to make generalizations based on the few surveys that do exist. A more complete survey of the number of waterfowl in the watershed as well as the amount of time they spend in the watershed would improve the accuracy of this study.

Fifth, government agencies should determine the percentage of collected sewage that enters the Rio Grande/ Río Bravo untreated. This study makes the assumption that all sewage that is collected is properly treated and does not enter into the river. It is likely that a percentage of the sewage collected will enter the river untreated, but no data are currently available to support or reject this idea. A study of the percentage of collected sewage that is not treated should be performed so as to understand the magnitude of this contamination.

Sixth, when government agencies are creating a full water quality model of the river that includes point sources, the study should take into account the fraction of the wastewater actually treated by wastewater treatment facilities. This study only takes into account non-point sources, which does not include wastewater treatment plants. The degree of treatment, whether primary or secondary, ought to affect the bacteria load reaching the river.

Seventh, research should be undertaken to determine what distance of a riparian corridor is appropriate to use in this study. This study used a riparian corridor of 500 meters for septic tanks and 300 meters for wildlife. There is uncertainty as to how representative these riparian corridors are regarding the actual distance from the river one can assume that contamination will reach the river.

Eight, government agencies should collect the stream flow data necessary in order to be able to create an NHD Plus dataset. An NHD Plus dataset does not exist yet for this watershed. The creation of such a dataset would allow better methods for calculating the pollutant load that reaches the river.[153]

This study is meant to be used an input for a full steady-state water quality model for the Lower Rio Grande/ Río Bravo watershed. These recommendations will provide more confidence in the results of the water quality model and provide government agencies with a better knowledge of how policies could reduce bacteria pollution to the river. This steady-state water quality model may be included as part of the Lower Rio Grande/ Río Bravo Watershed Initiative, a bi-national effort to improve the quality of this stretch of the river.

The Appendices provide further documentation of data used and calculated in this study. Appendix A illustrates the 144 subwatersheds used in this study.[154,155] These subwatersheds are labeled with identification numbers for easy reference between other tables. Appendix B provides the information used to calculate decay rates from each of the subwatersheds. Appendix B includes a reference between the subwatershed identification numbers and the reach identification numbers. Each reach is made of several subwatersheds that all drain into the same pour point of the reach. Each subwatershed has a different distance to travel to the reach, and thus has a different amount of decay. The value e^{-kt} represents the fraction of the original bacterial load that will arrive at the reach. Appendix C presents the results of the bacterial load for each reach. These results are in units of total fecal coliforms per day, and they are divided by the different sources. Appendix D provides the INEGI data on the number of households without drainage for each locality.[156] These data were used to calculate the amount of sewage contamination from the Mexican side of the watershed.

---

145 Texas Secretary of State, Colonia Initiatives Program, Texas Secretary of State, http://www.sos.state.tx.us/border/colonias/program.shtml, Accessed on March 10, 2012.

146 Border Environment Cooperation Commission, BECC and NADB: Successful Bi-National Cooperation, Border Environment Cooperation Commission, http://www.becc.org/english/GInformation/Index.html, Accessed on March 10, 2012.

147 TCEQ, Internal Map, digitized by author.

148 Environmental Protection Agency, Bacteria Indictor Tool, References Tab.

149 Peter K. Weiskel and others, “Coliform Contamination of a Coastal Embayment,” 1873.

150 Environmental Protection Agency, Bacteria Indictor Tool, Excel Spreadsheet, http://water.epa.gov/scitech/datait/models/basins/bs3tbit.cfm, Accessed on July 12, 2011, December 2001, Septics Tab.

151 INEGI, Productos y Servicios: Datos vectoriales escala 1:1000000 –descarga, http://mapserver.inegi.org.mx/data/inf_e1m/redirect.cfm?fileX=canal, Accessed March 10, 2012, shapefile

152 James Miertschin & Associates, Inc, “Final Modeling Report for Fecal Coliform TMDL (Total Maximum Daily Load) Development for Leon River Below Proctor Lake, Segment 1221: Project Area 2 – Baisn Groups D & E Bacteria Impairments Work Order #5,” Prepared for Texas Commission on Environmental Quality, November 2006, 4-10.

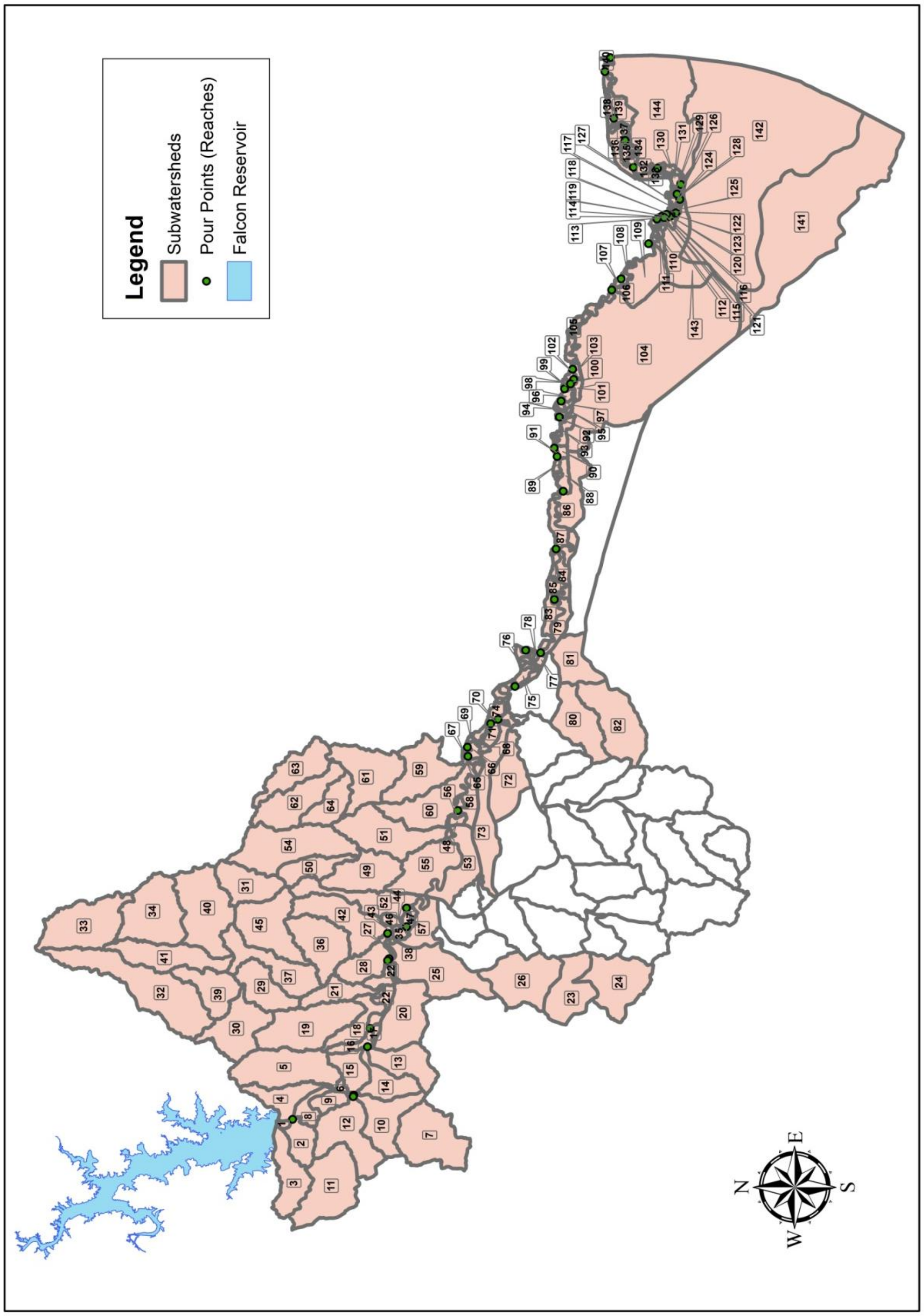
153 Stephanie Lynn Johnson, “A General Method for Modeling Coastal Water Pollutant Loadings,” 136.

154 U.S. Geological Survey, “National Hydrography Dataset.”

155 INEGI and U.S. Geological Survey, Unpublished GIS Shapefile, October 31, 2011.

156 INEGI. "Principales Resultados por localidad (ITER)."

Appendix A: Sub-watersheds for Pour Points



Appendix B: Travel Distances and Decay Rates from Sub-watersheds to Reaches

Subwatershed	Reach	Total (km)	Velocity (m/s)	k (1/days)	t (days)	e^{-kt}	Subwatershed	Reach	Total (km)	Velocity (m/s)	k (1/days)	t (days)	e^{-kt}
1	1	1.87	0.13	4.82	0.17	0.44	73	16	22.40	0.13	4.82	2.04	0.00
2	1	4.65	0.13	4.82	0.42	0.13	74	16	6.10	0.13	4.82	0.55	0.07
3	1	11.04	0.13	4.82	1.00	0.01	75	17	3.23	0.22	4.82	0.17	0.44
4	2	13.31	0.13	4.82	1.21	0.00	76	17	3.77	0.22	4.82	0.20	0.39
5	2	13.98	0.13	4.82	1.27	0.00	77	18	1.43	0.22	4.82	0.07	0.70
6	2	2.35	0.13	4.82	0.21	0.36	78	18	1.63	0.22	4.82	0.09	0.66
7	2	16.90	0.13	4.82	1.54	0.00	79	19	4.76	0.22	4.82	0.25	0.30
8	2	8.77	0.13	4.82	0.80	0.02	80	19	24.33	0.22	4.82	1.27	0.00
9	2	4.69	0.13	4.82	0.43	0.13	81	19	12.48	0.22	4.82	0.65	0.04
10	2	7.84	0.13	4.82	0.71	0.03	82	19	26.22	0.22	4.82	1.37	0.00
11	3	18.05	0.13	4.82	1.64	0.00	83	19	3.76	0.22	4.82	0.20	0.39
12	3	7.71	0.13	4.82	0.70	0.03	84	20	5.35	0.22	4.82	0.28	0.26
13	4	8.07	0.13	4.82	0.73	0.03	85	20	5.49	0.22	4.82	0.29	0.25
14	4	7.82	0.13	4.82	0.71	0.03	86	21	2.72	0.22	4.82	0.14	0.50
15	4	5.28	0.13	4.82	0.48	0.10	87	21	6.49	0.22	4.82	0.34	0.20
16	5	4.63	0.13	4.82	0.42	0.13	88	22	3.93	0.22	4.82	0.20	0.37
17	5	1.40	0.13	4.82	0.13	0.54	89	22	2.81	0.22	4.82	0.15	0.49
18	6	11.46	0.13	4.82	1.04	0.01	90	23	1.63	0.22	4.82	0.08	0.66
19	6	22.18	0.13	4.82	2.02	0.00	91	23	0.89	0.22	4.82	0.05	0.80
20	6	11.51	0.13	4.82	1.05	0.01	92	24	2.67	0.20	4.82	0.15	0.48
21	6	11.97	0.13	4.82	1.09	0.01	93	24	2.92	0.20	4.82	0.17	0.45
22	6	7.55	0.13	4.82	0.69	0.04	94	25	1.65	0.20	4.82	0.09	0.63
23	7	35.22	0.13	4.82	3.20	0.00	95	25	1.72	0.20	4.82	0.10	0.62
24	7	44.29	0.13	4.82	4.03	0.00	96	26	1.32	0.20	4.82	0.08	0.69
25	7	9.73	0.13	4.82	0.88	0.01	97	26	2.07	0.20	4.82	0.12	0.57
26	7	26.08	0.13	4.82	2.37	0.00	98	27	1.08	0.20	4.82	0.06	0.74
27	8	2.85	0.13	4.82	0.26	0.29	99	27	0.90	0.20	4.82	0.05	0.78
28	8	7.29	0.13	4.82	0.66	0.04	100	28	0.55	0.20	4.82	0.03	0.86
29	9	32.99	0.13	4.82	3.00	0.00	101	28	1.81	0.20	4.82	0.10	0.61
30	9	42.16	0.13	4.82	3.83	0.00	102	29	1.36	0.20	4.82	0.08	0.69
31	9	37.75	0.13	4.82	3.43	0.00	103	29	0.99	0.20	4.82	0.06	0.76
32	9	55.45	0.13	4.82	5.04	0.00	104	30	13.41	0.20	4.82	0.77	0.02
33	9	67.98	0.13	4.82	6.18	0.00	105	30	9.14	0.20	4.82	0.52	0.08
34	9	54.79	0.13	4.82	4.98	0.00	106	31	1.84	0.20	4.82	0.11	0.60
35	9	1.76	0.13	4.82	0.16	0.46	107	31	0.97	0.20	4.82	0.06	0.77
36	9	18.42	0.13	4.82	1.67	0.00	108	32	6.53	0.20	4.82	0.37	0.17
37	9	28.41	0.13	4.82	2.58	0.00	109	32	6.50	0.20	4.82	0.37	0.17
38	9	3.61	0.13	4.82	0.33	0.21	110	33	2.26	0.20	4.82	0.13	0.54
39	9	42.87	0.13	4.82	3.90	0.00	111	33	3.44	0.20	4.82	0.20	0.39
40	9	45.07	0.13	4.82	4.10	0.00	112	34	0.67	0.24	4.82	0.03	0.86
41	9	48.35	0.13	4.82	4.39	0.00	113	34	0.76	0.24	4.82	0.04	0.84
42	9	12.06	0.13	4.82	1.10	0.01	114	35	0.23	0.24	4.82	0.01	0.95
43	9	3.74	0.13	4.82	0.34	0.19	115	35	0.27	0.24	4.82	0.01	0.94
44	9	1.66	0.13	4.82	0.15	0.48	116	36	0.44	0.24	4.82	0.02	0.91
45	9	28.57	0.13	4.82	2.60	0.00	117	36	0.48	0.24	4.82	0.02	0.90
46	10	2.94	0.13	4.82	0.27	0.28	118	37	0.43	0.24	4.82	0.02	0.91
47	10	2.17	0.13	4.82	0.20	0.39	119	37	0.45	0.24	4.82	0.02	0.90
48	11	1.82	0.13	4.82	0.17	0.45	120	38	0.37	0.24	4.82	0.02	0.92
49	11	24.23	0.13	4.82	2.20	0.00	121	38	1.32	0.24	4.82	0.06	0.74
50	11	34.54	0.13	4.82	3.14	0.00	122	39	0.92	0.24	4.82	0.04	0.81
51	11	14.45	0.13	4.82	1.31	0.00	123	39	0.49	0.24	4.82	0.02	0.89
52	11	24.61	0.13	4.82	2.24	0.00	124	40	1.75	0.24	4.82	0.08	0.67
53	11	10.81	0.13	4.82	0.98	0.01	125	40	1.67	0.24	4.82	0.08	0.68
54	11	39.34	0.13	4.82	3.57	0.00	126	41	0.54	0.24	4.82	0.03	0.88
55	11	12.31	0.13	4.82	1.12	0.00	127	41	1.23	0.24	4.82	0.06	0.76
56	11	1.44	0.13	4.82	0.13	0.53	128	42	1.16	0.24	4.82	0.05	0.77
57	11	22.87	0.13	4.82	2.08	0.00	129	42	1.21	0.24	4.82	0.06	0.76
58	12	7.45	0.13	4.82	0.68	0.04	130	43	2.79	0.24	4.82	0.13	0.53
59	12	17.88	0.13	4.82	1.63	0.00	131	43	3.37	0.24	4.82	0.16	0.46
60	12	11.50	0.13	4.82	1.04	0.01	132	44	2.28	0.24	4.82	0.11	0.59
61	12	28.08	0.13	4.82	2.55	0.00	133	44	3.55	0.24	4.82	0.17	0.43
62	12	42.61	0.13	4.82	3.87	0.00	134	45	2.74	0.24	4.82	0.13	0.53
63	12	41.44	0.13	4.82	3.77	0.00	135	45	2.50	0.24	4.82	0.12	0.56
64	12	37.14	0.13	4.82	3.38	0.00	136	46	5.82	0.24	4.82	0.28	0.25
65	12	1.05	0.13	4.82	0.10	0.63	137	46	2.37	0.24	4.82	0.12	0.57
66	13	1.44	0.13	4.82	0.13	0.53	138	47	5.84	0.24	4.82	0.28	0.25
67	13	1.10	0.13	4.82	0.10	0.62	139	47	7.28	0.24	4.82	0.35	0.18
68	14	4.60	0.13	4.82	0.42	0.13	140	48	1.10	0.24	4.82	0.05	0.77
69	14	3.59	0.13	4.82	0.33	0.21	141	48	49.16	0.24	4.82	2.40	0.00
70	15	0.66	0.13	4.82	0.06	0.75	142	48	33.30	0.24	4.82	1.62	0.00
71	15	2.84	0.13	4.82	0.26	0.29	143	48	41.59	0.24	4.82	2.03	0.00
72	16	17.99	0.13	4.82	1.64	0.00	144	48	13.30	0.24	4.82	0.65	0.04

Appendix C: Total Fecal Coliforms Per Day Produced, by Reach

Reach	U.S. Colonias	U.S. Septic	Mexico Urban	Mexico Septic	Cattle	Horses	Deer	Feral Hogs	Waterfowl	Total
1	0.00E+00	3.59E+06	3.25E+07	0.00E+00	1.61E+11	7.59E+06	4.91E+07	3.13E+08	2.81E+08	1.61E+11
2	1.19E+07	4.11E+06	0.00E+00	0.00E+00	1.51E+11	9.02E+06	4.57E+07	2.92E+08	2.30E+08	1.51E+11
3	0.00E+00	0.00E+00	5.67E+07	0.00E+00	9.88E+10	2.95E+06	2.80E+07	1.79E+08	6.18E+04	9.91E+10
4	6.90E+07	1.48E+07	1.86E+08	5.65E+04	1.53E+11	1.54E+07	3.49E+07	2.23E+08	2.48E+08	1.54E+11
5	0.00E+00	2.66E+07	5.72E+07	0.00E+00	1.05E+10	3.45E+06	7.77E+06	4.96E+07	1.26E+08	1.07E+10
6	1.36E+07	1.36E+06	5.08E+05	8.83E+06	1.77E+10	1.99E+06	5.93E+06	3.79E+07	4.15E+07	1.78E+10
7	0.00E+00	0.00E+00	8.26E+07	5.24E+06	3.69E+10	2.68E+06	9.15E+06	5.84E+07	1.43E+06	3.70E+10
8	4.38E+07	7.47E+06	0.00E+00	0.00E+00	1.14E+10	3.74E+06	5.91E+06	3.77E+07	1.25E+08	1.16E+10
9	6.05E+06	5.62E+06	0.00E+00	0.00E+00	5.13E+09	1.69E+06	5.20E+06	3.32E+07	2.61E+08	5.44E+09
10	4.32E+07	1.46E+06	0.00E+00	1.40E+04	8.14E+09	2.68E+06	3.77E+06	2.40E+07	2.29E+08	8.44E+09
11	1.67E+07	6.13E+06	1.47E+09	1.93E+07	4.86E+09	3.04E+06	8.60E+06	5.49E+07	4.87E+08	6.92E+09
12	0.00E+00	2.30E+07	2.80E+08	6.85E+05	6.94E+09	7.10E+06	4.46E+06	2.85E+07	3.23E+08	7.61E+09
13	0.00E+00	2.53E+07	0.00E+00	7.02E+06	4.67E+09	5.63E+06	5.93E+06	3.78E+07	2.38E+08	4.99E+09
14	0.00E+00	1.96E+07	0.00E+00	8.45E+03	1.41E+09	1.70E+06	5.25E+06	3.35E+07	2.17E+08	1.68E+09
15	0.00E+00	6.39E+06	0.00E+00	0.00E+00	4.86E+08	5.86E+05	5.83E+06	3.72E+07	6.70E+08	1.21E+09
16	0.00E+00	1.57E+07	1.07E+05	2.37E+07	1.24E+09	1.50E+06	2.56E+06	1.63E+07	7.24E+08	2.03E+09
17	0.00E+00	1.92E+07	8.14E+09	0.00E+00	2.13E+10	1.64E+07	1.56E+07	9.98E+07	3.35E+09	3.29E+10
18	0.00E+00	8.28E+06	1.36E+10	0.00E+00	2.11E+10	1.27E+07	9.89E+06	6.31E+07	1.93E+08	3.50E+10
19	0.00E+00	9.04E+07	9.79E+09	1.78E+07	3.68E+10	1.96E+07	2.58E+07	1.65E+08	1.57E+09	4.84E+10
20	0.00E+00	2.91E+07	0.00E+00	1.79E+04	1.32E+10	3.83E+06	1.85E+07	1.18E+08	4.42E+09	1.78E+10
21	0.00E+00	1.53E+07	0.00E+00	1.79E+03	1.25E+11	1.96E+07	2.49E+07	1.59E+08	1.02E+09	1.27E+11
22	0.00E+00	1.51E+07	1.67E+10	3.69E+06	1.46E+10	2.35E+06	1.18E+07	7.50E+07	4.75E+08	3.19E+10
23	0.00E+00	2.15E+06	0.00E+00	7.11E+06	3.51E+10	7.01E+06	4.23E+06	2.70E+07	4.07E+08	3.56E+10
24	0.00E+00	1.79E+07	0.00E+00	2.56E+04	5.48E+10	1.12E+07	1.57E+07	1.00E+08	8.11E+08	5.58E+10
25	0.00E+00	1.57E+07	0.00E+00	0.00E+00	3.95E+10	1.22E+07	1.30E+07	8.28E+07	3.02E+08	3.99E+10
26	0.00E+00	2.85E+07	0.00E+00	0.00E+00	2.56E+10	4.38E+06	1.69E+07	1.08E+08	3.70E+08	2.62E+10
27	0.00E+00	8.18E+06	0.00E+00	0.00E+00	1.24E+10	6.76E+06	8.45E+06	5.39E+07	3.54E+08	1.28E+10
28	0.00E+00	3.48E+06	0.00E+00	3.84E+06	4.07E+10	8.28E+06	4.86E+06	3.10E+07	1.80E+08	4.09E+10
29	0.00E+00	7.85E+06	0.00E+00	0.00E+00	3.21E+10	8.20E+06	7.54E+06	4.82E+07	6.73E+08	3.29E+10
30	0.00E+00	1.04E+07	8.16E+08	5.54E+05	1.68E+11	2.98E+07	7.10E+06	4.53E+07	1.25E+09	1.70E+11
31	0.00E+00	1.78E+07	0.00E+00	9.15E+03	7.98E+09	4.16E+06	1.30E+07	8.33E+07	1.37E+09	9.47E+09
32	0.00E+00	1.07E+07	9.19E+09	5.29E+06	8.03E+10	1.53E+07	8.63E+06	5.51E+07	1.34E+09	9.09E+10
33	0.00E+00	8.65E+07	9.68E+09	0.00E+00	2.34E+10	1.76E+07	8.00E+06	5.11E+07	3.17E+09	3.64E+10
34	0.00E+00	1.31E+07	5.16E+09	0.00E+00	3.55E+09	2.57E+06	3.83E+06	2.45E+07	1.25E+09	1.00E+10
35	0.00E+00	3.11E+06	2.96E+08	0.00E+00	7.95E+08	5.83E+05	1.38E+06	8.83E+06	4.30E+08	1.54E+09
36	0.00E+00	4.33E+06	6.73E+08	0.00E+00	6.73E+08	4.75E+05	2.60E+06	1.66E+07	1.10E+09	2.47E+09
37	0.00E+00	4.07E+06	1.16E+09	0.00E+00	1.77E+08	1.28E+05	2.15E+06	1.37E+07	2.35E+09	3.70E+09
38	0.00E+00	1.42E+06	6.80E+09	0.00E+00	1.91E+09	1.44E+06	2.00E+06	1.27E+07	4.03E+08	9.13E+09
39	0.00E+00	5.98E+06	1.61E+09	0.00E+00	2.35E+08	1.35E+05	2.32E+06	1.48E+07	5.26E+08	2.40E+09
40	0.00E+00	9.04E+06	3.11E+09	7.32E+03	2.15E+10	1.24E+07	6.84E+06	4.37E+07	1.83E+09	2.65E+10
41	0.00E+00	2.24E+07	0.00E+00	1.10E+04	3.86E+10	2.17E+07	1.67E+07	1.07E+08	3.32E+10	7.20E+10
42	0.00E+00	1.09E+07	0.00E+00	1.07E+07	2.57E+10	9.16E+06	1.41E+07	9.00E+07	1.51E+10	4.09E+10
43	0.00E+00	1.82E+07	0.00E+00	1.83E+03	4.19E+10	1.06E+07	1.80E+07	1.15E+08	4.90E+10	9.11E+10
44	0.00E+00	3.53E+07	0.00E+00	0.00E+00	3.92E+10	9.93E+06	1.70E+07	1.09E+08	9.94E+10	1.39E+11
45	0.00E+00	1.00E+07	0.00E+00	1.65E+04	5.32E+10	2.94E+07	1.71E+07	1.09E+08	2.61E+11	3.14E+11
46	0.00E+00	3.53E+06	0.00E+00	0.00E+00	5.48E+10	3.41E+07	1.05E+07	6.71E+07	3.03E+11	3.58E+11
47	0.00E+00	2.32E+06	0.00E+00	0.00E+00	5.46E+09	3.89E+06	1.58E+07	1.01E+08	4.89E+11	4.95E+11
48	0.00E+00	2.27E+06	4.01E+07	5.85E+07	4.32E+10	7.04E+06	4.17E+07	2.66E+08	8.33E+11	8.76E+11

Appendix D: Household and Sewage Data for Mexican Watershed

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Abel García	28	Tamaulipas	22	Matamoros	1339	974907	260056	10	*	*	*
Agroporcícolas Río Grande	28	Tamaulipas	22	Matamoros	1291	973728	255138	21	4.2	4	1
Agua Dulce (Señor Ovidio)	28	Tamaulipas	32	Reynosa	296	982238	260605	7	1.75	0	4
Alfredo Ávila Cavazos	28	Tamaulipas	33	Río Bravo	1358	980555	260006	4	*	*	*
Alhelíes	28	Tamaulipas	22	Matamoros	1392	974450	255444	2	*	*	*
Altavista	28	Tamaulipas	22	Matamoros	38	972104	254237	7	2.33	1	2
Álvaro García	28	Tamaulipas	22	Matamoros	1081	971934	254844	1	*	*	*
Amador Benítez Guerra	28	Tamaulipas	7	Camargo	289	985618	262120	2	*	*	*
Américo Alanís (El Berrendo)	28	Tamaulipas	32	Reynosa	1055	982712	260744	2	*	*	*
Ampliación Miguel Hidalgo	28	Tamaulipas	32	Reynosa	1039	983125	260726	15	2.14	3	4
Ampliación Miguel Hidalgo	28	Tamaulipas	32	Reynosa	1043	983408	260612	1	*	*	*
npliación Villa de Cortez (Toribio Hernánd	28	Tamaulipas	22	Matamoros	1947	972915	254908	4	*	*	*
Antonio Pérez	28	Tamaulipas	15	Gustavo Díaz Ordaz	336	983611	261131	2	*	*	*
Antonio Silva	28	Tamaulipas	22	Matamoros	761	973846	255148	8	*	*	*
Anzaldúas (Estación Anzaldúas)	28	Tamaulipas	32	Reynosa	494	982219	260906	618	3.66	53	108
Araujo	19	Nuevo León	15	Dr. Coss	7	985551	255756	15	5	2	1
Argüelles	28	Tamaulipas	32	Reynosa	94	982821	261125	504	3.48	118	26
Arroyo de Enmedio (Lozano Salinas)	28	Tamaulipas	22	Matamoros	1209	973024	254443	1	*	*	*
Arroyo de Enmedio (Omar Cárdenas)	28	Tamaulipas	22	Matamoros	47	973136	254413	4	*	*	*
Arroyo del Tigre	28	Tamaulipas	22	Matamoros	1520	973510	254038	33	4.71	0	7
Artemio García	19	Nuevo León	20	Gral. Bravo	398	984051	255638	1	*	*	*
Artemio Garza	28	Tamaulipas	22	Matamoros	1018	974236	254851	2	*	*	*
Arturo Longoria	28	Tamaulipas	7	Camargo	457	984157	261544	5	*	*	*
Asociación Agrícola de Matamoros	28	Tamaulipas	22	Matamoros	1739	974025	255745	2	*	*	*
Aurelio Numillín	28	Tamaulipas	15	Gustavo Díaz Ordaz	373	984155	260749	8	2.67	0	3
Bartolo Falcón	28	Tamaulipas	7	Camargo	188	985530	262125	6	*	*	*
Bartolo Falcón	28	Tamaulipas	7	Camargo	306	985619	262108	5	*	*	*
Bartolo Falcón Garza	28	Tamaulipas	7	Camargo	286	985550	262206	4	1.33	3	0
Basurero Municipal	28	Tamaulipas	7	Camargo	476	985248	261317	9	*	*	*
Belem	28	Tamaulipas	22	Matamoros	459	974537	260116	3	*	*	*
Benavides (Charco Redondo)	28	Tamaulipas	32	Reynosa	719	983304	255441	3	*	*	*
Beto Cantú	28	Tamaulipas	25	Miguel Alemán	164	990402	262347	8	1.6	5	0
Brecha 116 con Vía de FF.CC.	28	Tamaulipas	33	Río Bravo	1038	980230	255920	39	3.55	0	11
Brecha 124 con Vía de FF.CC.	28	Tamaulipas	33	Río Bravo	438	975808	255929	568	5.16	5	62
Buena Vista (Buenavista del Carmen)	28	Tamaulipas	32	Reynosa	283	982834	260206	3	*	*	*
Buenavista	19	Nuevo León	20	Gral. Bravo	9	983840	255129	3	*	*	*
Buenavista	28	Tamaulipas	15	Gustavo Díaz Ordaz	3	983534	260305	105	3.75	3	25
Buenavista (Charco Azul)	28	Tamaulipas	33	Río Bravo	229	975902	255932	312	3.91	25	54
Buenavista del Carmen	28	Tamaulipas	32	Reynosa	1313	982834	260050	4	*	*	*
Buenos Aires	28	Tamaulipas	33	Río Bravo	737	975811	260050	25	3.13	6	2

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Buenos Aires	28	Tamaulipas	22	Matamoros	77	974055	255827	78	3.55	14	8
Buenos Aires	28	Tamaulipas	15	Gustavo Díaz Ordaz	277	984108	261257	5	*	*	*
Bugambilia (Heriberto Menéndez)	28	Tamaulipas	32	Reynosa	865	982615	260817	4	*	*	*
Caballo Blanco (Adolfo de la Garza)	28	Tamaulipas	22	Matamoros	1308	973817	255644	17	5.67	1	2
Cabaña Santo Tomás	28	Tamaulipas	22	Matamoros	1270	973504	255610	4	*	*	*
Cabras Pintas (Celso Cortina)	28	Tamaulipas	22	Matamoros	1710	973306	255131	3	*	*	*
Camargo (Estación Camargo)	28	Tamaulipas	7	Camargo	12	985039	261511	170	3.35	42	5
Camargo (Estradeño Dos)	28	Tamaulipas	7	Camargo	401	984751	261650	99	4.23	13	8
Camargo (Estradeño)	28	Tamaulipas	7	Camargo	11	984902	261713	61	2.76	14	7
Campo de Tiro Club Matamorense	28	Tamaulipas	22	Matamoros	1224	973331	254408	1	*	*	*
Campo Treviño	28	Tamaulipas	33	Río Bravo	233	975726	260056	74	3.22	10	13
Canalero	28	Tamaulipas	7	Camargo	280	985325	262049	3	*	*	*
Capote (Santiago Mendiola)	28	Tamaulipas	22	Matamoros	797	974334	260105	21	2.63	1	7
Capote (Tinajitas)	28	Tamaulipas	22	Matamoros	1331	974413	260005	4	*	*	*
Carmen Aguilar Ortiz	28	Tamaulipas	32	Reynosa	1035	983235	260743	2	*	*	*
Carnestolendas	28	Tamaulipas	22	Matamoros	89	973444	254404	1	*	*	*
Carta Blanca	28	Tamaulipas	33	Río Bravo	238	975945	260311	13	4.33	0	3
Carta Blanca (Rnst Catorce Comesa)	19	Nuevo León	20	Gral. Bravo	12	984032	255608	16	4	3	1
Casa Blanca	28	Tamaulipas	22	Matamoros	1802	973723	254247	1	*	*	*
Casa del Canalero	28	Tamaulipas	32	Reynosa	846	983245	260926	5	*	*	*
CEFERESO Número 3	28	Tamaulipas	22	Matamoros	1890	973800	255050	2082	0	0	0
Centro Cristiano las Palmas	28	Tamaulipas	22	Matamoros	1918	972317	255013	5	*	*	*
Cerralvo	28	Tamaulipas	22	Matamoros	97	973945	260033	12	3	2	1
Chapotal	19	Nuevo León	20	Gral. Bravo	28	984524	260116	6	2	1	2
Charco Azul	28	Tamaulipas	33	Río Bravo	1073	975852	260039	2	*	*	*
Cinco de Febrero	28	Tamaulipas	15	Gustavo Díaz Ordaz	31	983950	261236	2	*	*	*
Cinco de Febrero	28	Tamaulipas	15	Gustavo Díaz Ordaz	4	983940	261209	37	2.64	6	7
Ciudad Camargo	28	Tamaulipas	7	Camargo	1	985000	261856	7984	3.4	2184	101
Ciudad Gustavo Díaz Ordaz	28	Tamaulipas	15	Gustavo Díaz Ordaz	1	983549	261356	11523	3.5	2984	258
Ciudad Miguel Alemán	28	Tamaulipas	25	Miguel Alemán	1	990131	262401	19997	3.48	5613	61
Ciudad Río Bravo	28	Tamaulipas	33	Río Bravo	1	980525	255854	95647	3.77	23478	1625
Club de Tiro, Caza y Pesca del Noreste	28	Tamaulipas	22	Matamoros	1228	973343	254348	3	*	*	*
Club Fronterizo de Tiro, Caza y Pesca	28	Tamaulipas	22	Matamoros	1170	971340	254857	1	*	*	*
Colonia del Bosque	28	Tamaulipas	33	Río Bravo	1382	980810	260058	9	3	0	3
Colonia el Barrileño	28	Tamaulipas	22	Matamoros	1225	973848	255052	32	2.29	1	13
Comales	28	Tamaulipas	7	Camargo	16	985514	261056	2429	3.31	694	26
Congregación Ochoa	28	Tamaulipas	7	Camargo	50	985609	260816	82	2.83	23	5
Control 3 Norte	28	Tamaulipas	22	Matamoros	1943	973119	255310	2	*	*	*
Corrales	28	Tamaulipas	32	Reynosa	306	981338	260304	40	3.08	1	12
Cortez (Jorge Cortez Salazar)	28	Tamaulipas	22	Matamoros	1230	972023	255020	4	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Cuatro Corrales	19	Nuevo León	20	Gral. Bravo	408	984440	254539	6	*	*	*
Cuatro Milpas	28	Tamaulipas	32	Reynosa	125	981216	260341	5	*	*	*
Cuatro Milpas	28	Tamaulipas	22	Matamoros	109	975305	260316	5	*	*	*
De León	28	Tamaulipas	7	Camargo	453	985124	261415	2	*	*	*
Diego Aguirre	28	Tamaulipas	15	Gustavo Díaz Ordaz	413	983830	261324	10	*	*	*
Doctor José Arredondo	28	Tamaulipas	22	Matamoros	1276	973500	255543	5	*	*	*
Don Ramiro	28	Tamaulipas	22	Matamoros	1707	972528	255021	2	*	*	*
Don Tenos (San Román)	28	Tamaulipas	22	Matamoros	1152	973422	254402	5	*	*	*
Dos Hermanos (Doctor Carlos Aguirre)	28	Tamaulipas	22	Matamoros	1233	971858	255042	1	*	*	*
Ebanito Nuevo	28	Tamaulipas	33	Río Bravo	251	975511	255919	242	3.67	18	48
Ébano	28	Tamaulipas	25	Miguel Alemán	162	990433	261851	1	*	*	*
Efraín Sifuentes	28	Tamaulipas	7	Camargo	381	984533	261702	3	*	*	*
El 77	28	Tamaulipas	33	Río Bravo	1377	980615	260129	5	*	*	*
El Álamo	19	Nuevo León	20	Gral. Bravo	2	983752	260053	5	*	*	*
El Alto	28	Tamaulipas	22	Matamoros	40	974234	255128	91	4.55	1	19
El Alto	28	Tamaulipas	15	Gustavo Díaz Ordaz	342	984400	260629	8	*	*	*
El Alto Bonito	28	Tamaulipas	15	Gustavo Díaz Ordaz	27	983809	261244	10	2.5	2	2
El Ausente	28	Tamaulipas	32	Reynosa	973	983041	261238	5	1.67	2	1
El Azúcar	28	Tamaulipas	7	Camargo	6	985104	261428	154	3.02	42	7
El Banco (José Hernández)	28	Tamaulipas	32	Reynosa	1248	981423	260323	108	2.92	1	36
El Banquete	28	Tamaulipas	22	Matamoros	56	975044	260122	8	2	1	3
El Barranco	28	Tamaulipas	32	Reynosa	98	982620	261030	214	4.2	31	19
El Barranco (Adalgisa Farías)	28	Tamaulipas	32	Reynosa	956	982707	261041	1	*	*	*
El Barrote	28	Tamaulipas	15	Gustavo Díaz Ordaz	387	983354	261129	2	*	*	*
El Borbollón (El Llano)	28	Tamaulipas	22	Matamoros	187	973558	254442	5	*	*	*
El Brasil	28	Tamaulipas	22	Matamoros	1911	971720	255252	1	*	*	*
El Campesino	28	Tamaulipas	15	Gustavo Díaz Ordaz	343	983239	261022	9	*	*	*
El Capote	28	Tamaulipas	22	Matamoros	87	974221	260115	407	3.47	34	79
El Caracol	28	Tamaulipas	32	Reynosa	113	982839	260252	3	*	*	*
El Caracol	28	Tamaulipas	22	Matamoros	88	973036	253444	4	*	*	*
El Caracol	28	Tamaulipas	22	Matamoros	882	973051	253532	4	*	*	*
El Caracol	28	Tamaulipas	22	Matamoros	1563	973058	253549	3	*	*	*
El Caracol (Armando Aguilar Cavazos)	28	Tamaulipas	22	Matamoros	937	972949	253418	1	*	*	*
El Carmen	28	Tamaulipas	32	Reynosa	935	980940	260237	12	4	0	3
El Carrizal	28	Tamaulipas	32	Reynosa	117	982917	261157	96	3.56	22	5
El Castillo	19	Nuevo León	20	Gral. Bravo	13	984527	255844	7	*	*	*
El Chaparral	28	Tamaulipas	22	Matamoros	1027	973858	254607	5	*	*	*
El Chaparral (Sergio Segura)	28	Tamaulipas	22	Matamoros	1227	973834	254557	7	*	*	*
El Chapotal	28	Tamaulipas	7	Camargo	487	985424	261340	3	*	*	*
El Chapote	19	Nuevo León	20	Gral. Bravo	29	984717	254640	3	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
El Chino	19	Nuevo León	20	Gral. Bravo	31	984631	254659	1	*	*	*
El Chubasco	28	Tamaulipas	22	Matamoros	1750	971831	255002	1	*	*	*
El Ciprés	28	Tamaulipas	33	Río Bravo	241	975648	260034	7	*	*	*
El Consuelo	28	Tamaulipas	32	Reynosa	1335	982602	260342	2	*	*	*
El Control	28	Tamaulipas	22	Matamoros	104	974848	255741	3136	3.52	781	105
El Coronel	19	Nuevo León	20	Gral. Bravo	167	985036	255337	2	*	*	*
El Deseo	28	Tamaulipas	32	Reynosa	1229	982622	260327	7	*	*	*
El Desmonte	28	Tamaulipas	25	Miguel Alemán	134	990335	261759	1	*	*	*
El Diamante	28	Tamaulipas	33	Río Bravo	1341	980349	260015	2	*	*	*
El Divisadero	28	Tamaulipas	32	Reynosa	323	982432	255909	4	*	*	*
El Dorado	28	Tamaulipas	22	Matamoros	1272	973505	255551	5	*	*	*
El Ebanito	19	Nuevo León	20	Gral. Bravo	356	984258	255827	1	*	*	*
El Ebanito	28	Tamaulipas	22	Matamoros	121	973643	255714	434	3.48	55	68
El Ebanito	28	Tamaulipas	33	Río Bravo	1041	975604	255930	1	*	*	*
El Ebanito	28	Tamaulipas	15	Gustavo Díaz Ordaz	362	983619	261213	1	*	*	*
El Ebanito (Juan Zamarripa)	28	Tamaulipas	22	Matamoros	1309	973727	255621	7	*	*	*
El Ebanito (Mario Hernández)	28	Tamaulipas	22	Matamoros	653	973740	255629	1	*	*	*
El Ebanito Dos	28	Tamaulipas	15	Gustavo Díaz Ordaz	74	983630	261143	1	*	*	*
El Ébano	28	Tamaulipas	32	Reynosa	717	983417	255656	3	*	*	*
El Ébano	28	Tamaulipas	33	Río Bravo	1091	980453	260117	6	*	*	*
El Ébano (Hermelinda Benavides)	28	Tamaulipas	22	Matamoros	1394	974140	255440	6	*	*	*
El Equanil	28	Tamaulipas	22	Matamoros	527	973450	254158	21	5.25	0	4
El Escondido	28	Tamaulipas	22	Matamoros	1435	974749	255307	18	6	1	2
El Espejo	28	Tamaulipas	22	Matamoros	687	973416	255040	7	*	*	*
El Estero (Jesús Canales)	28	Tamaulipas	33	Río Bravo	665	980611	260136	7	2.33	0	3
El Estero (Santos Arreazola)	28	Tamaulipas	33	Río Bravo	1340	980739	260127	14	3.5	0	4
El Estribo	28	Tamaulipas	22	Matamoros	1341	974526	255847	2	*	*	*
El Faro	28	Tamaulipas	32	Reynosa	134	983006	261215	101	3.26	29	2
El Forzado (El Divisadero)	28	Tamaulipas	22	Matamoros	1110	972926	253431	1	*	*	*
El Fresno	28	Tamaulipas	33	Río Bravo	1093	980411	260146	6	*	*	*
El Galaneño	28	Tamaulipas	22	Matamoros	146	973240	254540	1057	3.79	132	139
El Galaneño (Arnulfo Gracia)	28	Tamaulipas	22	Matamoros	1464	973358	254536	1	*	*	*
El Galaneño (Javier Pérez)	28	Tamaulipas	22	Matamoros	1462	973330	254536	6	*	*	*
El Galaneño (La Resaca)	28	Tamaulipas	22	Matamoros	1936	973231	254634	2	*	*	*
El Gomeño Viejo	28	Tamaulipas	22	Matamoros	672	972040	255309	5	*	*	*
El Gonzaleño	28	Tamaulipas	7	Camargo	30	984837	261824	101	3.48	29	0
El Grullo	19	Nuevo León	20	Gral. Bravo	49	983728	255845	2	*	*	*
El Guerreño	28	Tamaulipas	32	Reynosa	1135	981119	260324	13	3.25	1	3
El Guerreño	28	Tamaulipas	32	Reynosa	1136	981145	260304	16	3.2	5	0
El Guerreño	28	Tamaulipas	32	Reynosa	1138	981153	260223	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
El Guerreño	28	Tamaulipas	32	Reynosa	1139	981124	260221	3	*	*	*
El Guerreño	28	Tamaulipas	32	Reynosa	145	981147	260149	471	3.59	67	48
El Guerreño	28	Tamaulipas	32	Reynosa	782	981216	260300	1	*	*	*
El Halcón	28	Tamaulipas	32	Reynosa	756	982301	260152	1	*	*	*
El Herradero	28	Tamaulipas	32	Reynosa	286	983414	255838	2	*	*	*
El Huizachal	28	Tamaulipas	22	Matamoros	165	971731	254926	112	3.39	14	19
El Huizachal (Cornelio Segura)	28	Tamaulipas	22	Matamoros	1501	971450	254804	9	2.25	2	2
El Huizachal (Guadalupe Manrique)	28	Tamaulipas	22	Matamoros	1502	971552	254914	5	*	*	*
El Huizachal (José Luis Hernández)	28	Tamaulipas	22	Matamoros	1499	971631	254858	10	*	*	*
El Jabalí Uno (El Jabalí)	28	Tamaulipas	32	Reynosa	150	983333	255831	5	*	*	*
El Junior (Lorenzo Ramírez)	28	Tamaulipas	7	Camargo	191	984739	261955	7	*	*	*
El Lago	28	Tamaulipas	25	Miguel Alemán	115	985834	262139	2	*	*	*
El Laurel (Abel García)	28	Tamaulipas	22	Matamoros	611	974723	260048	50	3.85	6	7
El León	28	Tamaulipas	33	Río Bravo	667	980523	260101	6	*	*	*
El Lirio	28	Tamaulipas	22	Matamoros	180	974324	260034	9	2.25	3	1
El Longoreño	28	Tamaulipas	22	Matamoros	182	972344	255002	676	3.16	130	78
El Longoreño (El Rincón)	28	Tamaulipas	22	Matamoros	1478	972436	255042	6	*	*	*
El Longoreño (Samuel Alcantar)	28	Tamaulipas	22	Matamoros	1914	972559	254901	3	*	*	*
El Lucero	28	Tamaulipas	32	Reynosa	886	983259	260747	1	*	*	*
El Mape Rojo	28	Tamaulipas	22	Matamoros	1206	973507	254120	5	*	*	*
El Marantes (El Maratis)	28	Tamaulipas	32	Reynosa	345	983416	255325	3	*	*	*
El Mexicano	28	Tamaulipas	33	Río Bravo	281	980043	260257	3	*	*	*
El Mezquite	28	Tamaulipas	22	Matamoros	193	975156	260031	13	3.25	0	4
El Mezquite (Benito Yáñez)	28	Tamaulipas	22	Matamoros	1340	975221	260056	4	*	*	*
El Mezquitito	28	Tamaulipas	22	Matamoros	697	971516	254935	5	*	*	*
El Mezquitito	28	Tamaulipas	25	Miguel Alemán	22	990346	261910	1	*	*	*
El Milagro	28	Tamaulipas	32	Reynosa	796	981948	260112	2	*	*	*
El Milagro	28	Tamaulipas	7	Camargo	113	984800	262002	10	3.33	2	1
El Milagro (Noé Barrera)	28	Tamaulipas	22	Matamoros	1344	974501	255540	3	*	*	*
El Milagro (Retamita)	19	Nuevo León	20	Gral. Bravo	465	984346	260130	3	*	*	*
El Mogote de Santiago	28	Tamaulipas	22	Matamoros	1022	974015	254628	2	*	*	*
El Moquete (Guadalupe García)	28	Tamaulipas	22	Matamoros	1881	973403	253946	3	*	*	*
El Moraleño	28	Tamaulipas	22	Matamoros	1517	973447	254125	5	*	*	*
El Morillo	28	Tamaulipas	32	Reynosa	919	982302	260904	3	*	*	*
El Naranjo	28	Tamaulipas	32	Reynosa	967	982016	260736	3	*	*	*
El Naranjo (Rodolfo Alvarado)	28	Tamaulipas	22	Matamoros	1428	974054	254942	6	*	*	*
El Nogalito	28	Tamaulipas	33	Río Bravo	762	980023	260308	7	*	*	*
El Nuevo Puerto	19	Nuevo León	20	Gral. Bravo	466	984215	255034	2	*	*	*
El Olmito	28	Tamaulipas	33	Río Bravo	526	975648	260053	9	*	*	*
El Olmito	28	Tamaulipas	22	Matamoros	500	973342	254415	22	3.67	2	4

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
El Olmito (Genaro Hernández)	28	Tamaulipas	22	Matamoros	1251	973326	254418	2	*	*	*
El Olmo	28	Tamaulipas	32	Reynosa	728	983054	255840	3	*	*	*
El Oro	19	Nuevo León	20	Gral. Bravo	76	983759	255216	2	*	*	*
El Panalito	28	Tamaulipas	22	Matamoros	230	974317	260052	35	2.92	2	10
El Papalote	19	Nuevo León	20	Gral. Bravo	294	984335	255939	3	*	*	*
El Papalote (Brecha 70 con Dren)	28	Tamaulipas	32	Reynosa	984	983020	261055	3	*	*	*
El Paraíso	28	Tamaulipas	22	Matamoros	231	974608	260055	14	*	*	*
El Paraíso	28	Tamaulipas	22	Matamoros	1749	971927	254633	1	*	*	*
El Paraíso	28	Tamaulipas	33	Río Bravo	1103	980808	255956	4	*	*	*
El Parral	28	Tamaulipas	22	Matamoros	809	971645	254947	5	1.67	0	3
El Paso de la Pita	28	Tamaulipas	22	Matamoros	234	972204	254429	1	*	*	*
El Paso del Tigre	28	Tamaulipas	22	Matamoros	710	973326	254436	7	*	*	*
El Pedernal	28	Tamaulipas	22	Matamoros	236	973818	255925	22	3.14	3	4
El Pénjamo (Faustino Andrade)	28	Tamaulipas	32	Reynosa	791	981354	260324	1	*	*	*
El Pereño	28	Tamaulipas	22	Matamoros	833	973450	254301	8	*	*	*
El Perote	28	Tamaulipas	22	Matamoros	241	974157	255453	61	2.44	6	19
El Perote (Humberto García)	28	Tamaulipas	22	Matamoros	1396	974209	255426	2	*	*	*
El Perote (Rafael García)	28	Tamaulipas	22	Matamoros	1416	974251	255246	1	*	*	*
El Perrito	28	Tamaulipas	22	Matamoros	243	972844	253448	4	*	*	*
El Pilar	28	Tamaulipas	32	Reynosa	189	983020	260856	3	*	*	*
El Pitayos	28	Tamaulipas	33	Río Bravo	1362	975947	260116	2	*	*	*
El Porvenir	19	Nuevo León	20	Gral. Bravo	89	984443	255647	5	*	*	*
El Porvenir	28	Tamaulipas	7	Camargo	59	984337	261620	3	*	*	*
El Potrero	28	Tamaulipas	32	Reynosa	723	982833	255656	2	*	*	*
El Potrero	28	Tamaulipas	22	Matamoros	1017	974240	254910	3	*	*	*
El Profe	19	Nuevo León	20	Gral. Bravo	467	984631	260024	2	*	*	*
El Puerto	19	Nuevo León	20	Gral. Bravo	96	984128	255105	8	*	*	*
El Puerto Dos	28	Tamaulipas	32	Reynosa	200	982447	260825	4	*	*	*
El Queretano	28	Tamaulipas	32	Reynosa	712	982532	255708	3	*	*	*
El Ramireño	28	Tamaulipas	7	Camargo	68	984701	261653	31	3.57	5	1
El Ramireño (Benjamín Barrera)	28	Tamaulipas	22	Matamoros	1771	974600	255734	5	*	*	*
El Ramireño (El Álamo)	28	Tamaulipas	22	Matamoros	1039	974705	255523	22	4.4	1	4
El Ramireño (Ignacio Zúñiga)	28	Tamaulipas	22	Matamoros	1345	974618	255732	4	*	*	*
El Ramireño (Juan González)	28	Tamaulipas	22	Matamoros	1348	974558	255745	12	3	0	2
El Ramireño (María Luisa Limas)	28	Tamaulipas	22	Matamoros	1714	974613	255704	10	*	*	*
El Ranchito	28	Tamaulipas	22	Matamoros	266	972101	255156	75	3.95	1	17
El Ranchito y Refugio (El Refugio)	28	Tamaulipas	22	Matamoros	265	972119	255031	972	3.54	131	141
El Realito	28	Tamaulipas	22	Matamoros	271	973929	255719	217	3.81	21	36
El Realito	28	Tamaulipas	22	Matamoros	1755	974003	255732	1	*	*	*
El Recuerdo	28	Tamaulipas	22	Matamoros	1142	973729	254529	2	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
El Recuerdo	28	Tamaulipas	32	Reynosa	783	981254	260259	2	*	*	*
El Refugio	28	Tamaulipas	32	Reynosa	1144	983133	261015	5	*	*	*
El Refugio	28	Tamaulipas	22	Matamoros	1019	974004	255046	56	2.94	10	8
El Refugio	28	Tamaulipas	22	Matamoros	1007	974225	255124	4	*	*	*
El Retamal	28	Tamaulipas	33	Río Bravo	314	980222	260209	4	*	*	*
El Rincón del Bravo	28	Tamaulipas	32	Reynosa	1234	981109	260329	1	*	*	*
El Río	28	Tamaulipas	22	Matamoros	1320	974007	260113	1	*	*	*
El Rodeo	28	Tamaulipas	33	Río Bravo	779	975805	255817	1	*	*	*
El Rosario	28	Tamaulipas	40	Valle Hermoso	376	975435	260029	1	*	*	*
El Rosario	28	Tamaulipas	33	Río Bravo	316	975520	260310	142	3.84	14	23
El Rosario (Dominga González)	28	Tamaulipas	33	Río Bravo	1116	975521	260008	6	*	*	*
El Rosario (Loma Mogote Largo)	28	Tamaulipas	22	Matamoros	524	971547	254645	1	*	*	*
El Rosario (Rodrigo Sánchez)	28	Tamaulipas	33	Río Bravo	1115	975532	260018	4	*	*	*
El Rucio	19	Nuevo León	15	Dr. Coss	57	985027	255735	4	*	*	*
El Sabinito	28	Tamaulipas	22	Matamoros	623	973546	255658	82	4.1	9	11
El Sabino	28	Tamaulipas	22	Matamoros	285	973549	255642	304	3.71	50	31
El Sabino	28	Tamaulipas	22	Matamoros	751	975212	260314	7	*	*	*
El Sabino (Napoleón Benavides)	28	Tamaulipas	22	Matamoros	1301	973556	255653	85	4.25	2	17
El Saucito	28	Tamaulipas	22	Matamoros	839	973435	254244	15	3.75	0	4
El Saucito	28	Tamaulipas	22	Matamoros	705	973546	254404	3	*	*	*
El Saucito (Javier García)	28	Tamaulipas	22	Matamoros	419	974026	255027	11	3.67	3	0
El Sauz	19	Nuevo León	20	Gral. Bravo	127	984616	254914	4	*	*	*
El Sauz	28	Tamaulipas	22	Matamoros	1567	973356	254130	1	*	*	*
El Sauz	28	Tamaulipas	7	Camargo	233	985119	262036	1	*	*	*
El Sauz (El Paraíso)	28	Tamaulipas	33	Río Bravo	533	980610	260239	6	*	*	*
El Siete A (La Presita)	19	Nuevo León	20	Gral. Bravo	190	984407	254755	9	*	*	*
El Silencio (Manuel Campos)	28	Tamaulipas	22	Matamoros	1397	974131	255340	2	*	*	*
El Socorro	28	Tamaulipas	22	Matamoros	376	973731	254344	5	*	*	*
El Sol	28	Tamaulipas	22	Matamoros	1891	973816	254708	1	*	*	*
El Solecito	28	Tamaulipas	22	Matamoros	922	974129	255808	2	*	*	*
El Soliseño (José Serrata)	28	Tamaulipas	22	Matamoros	1335	974712	260005	7	2.33	0	3
El Soliseño Sur (Santa Fe)	28	Tamaulipas	22	Matamoros	1762	974728	260047	7	2.33	1	2
El Solito	28	Tamaulipas	22	Matamoros	1193	975124	255924	7	*	*	*
El Tahuachal	28	Tamaulipas	22	Matamoros	381	973711	255809	216	3.66	12	47
El Tahuachal (Encarnación Puentes)	28	Tamaulipas	22	Matamoros	1303	973749	255903	15	3.75	4	0
El Tahuachal (Juan Antonio Duque)	28	Tamaulipas	22	Matamoros	1754	973822	255645	19	6.33	2	1
El Tahuachal (Los Guerra)	28	Tamaulipas	22	Matamoros	774	973728	255842	12	*	*	*
El Tamaulipeco (Ramiro de la Garza)	28	Tamaulipas	32	Reynosa	1090	982854	260406	1	*	*	*
El Tecolote	28	Tamaulipas	22	Matamoros	383	972457	254738	168	3.73	6	39
El Tecolote	28	Tamaulipas	22	Matamoros	1485	972500	254953	68	3.78	11	7

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
El Tecolote (Alfredo Ramírez)	28	Tamaulipas	22	Matamoros	654	972448	254837	2	*	*	*
El Tecolote (Carlos Longoria)	28	Tamaulipas	22	Matamoros	768	972436	254928	47	4.27	11	0
El Tecolote (Joaquín Renteral)	28	Tamaulipas	22	Matamoros	763	972434	254909	4	*	*	*
El Tecolote (Martín García Ramírez)	28	Tamaulipas	22	Matamoros	1484	972446	254815	2	*	*	*
El Tesoro	28	Tamaulipas	33	Río Bravo	1376	975810	255915	2	*	*	*
El Testerazo (Francisco Salazar)	28	Tamaulipas	22	Matamoros	930	971732	254934	8	*	*	*
El Texano	28	Tamaulipas	22	Matamoros	816	971931	255036	3	*	*	*
El Tigre	28	Tamaulipas	22	Matamoros	386	973452	254103	11	2.75	0	4
El Tigre (Javier López)	28	Tamaulipas	25	Miguel Alemán	137	990456	261730	1	*	*	*
El Tobi (Señor Tobías de la Fuente)	28	Tamaulipas	22	Matamoros	1154	973348	254953	3	*	*	*
El Torito	28	Tamaulipas	32	Reynosa	968	982137	260748	3	*	*	*
El Trabuco	28	Tamaulipas	22	Matamoros	380	972634	253747	4	*	*	*
El Trece	28	Tamaulipas	32	Reynosa	991	982616	260225	5	*	*	*
El Triunfo	28	Tamaulipas	33	Río Bravo	354	980633	260118	22	3.14	0	7
El Triunfo	28	Tamaulipas	33	Río Bravo	355	980719	260110	7	*	*	*
El Triunfo	28	Tamaulipas	33	Río Bravo	1342	980747	260145	40	4.44	2	7
El Triunfo	28	Tamaulipas	33	Río Bravo	591	980736	260238	20	4	0	5
El Triunfo	28	Tamaulipas	33	Río Bravo	592	980708	260232	2	*	*	*
El Triunfo	28	Tamaulipas	33	Río Bravo	593	980551	260055	1	*	*	*
El Triunfo	28	Tamaulipas	33	Río Bravo	1078	980913	260241	7	*	*	*
El Triunfo	28	Tamaulipas	33	Río Bravo	1096	980551	260039	50	4.55	1	10
El Triunfo (Braulio Pérez)	28	Tamaulipas	33	Río Bravo	1086	980731	260207	4	*	*	*
El Triunfo (Guadalupe Mata)	28	Tamaulipas	33	Río Bravo	1079	980736	260253	3	*	*	*
El Tule	28	Tamaulipas	22	Matamoros	390	972028	255415	9	*	*	*
El Veintidós	28	Tamaulipas	22	Matamoros	532	973441	254131	2	*	*	*
El Venadito	28	Tamaulipas	22	Matamoros	1436	974723	255234	4	*	*	*
El Vergel	28	Tamaulipas	33	Río Bravo	929	980107	260027	3	*	*	*
El Zapoteco	28	Tamaulipas	33	Río Bravo	598	980831	260238	30	5	1	5
El Zorro	28	Tamaulipas	33	Río Bravo	1068	980705	260306	6	*	*	*
Eleuterio López	28	Tamaulipas	15	Gustavo Díaz Ordaz	390	983811	261244	1	*	*	*
Eliseo Tavares	28	Tamaulipas	33	Río Bravo	662	980420	260022	1	*	*	*
Empalme	28	Tamaulipas	40	Valle Hermoso	53	974826	255356	778	3.48	176	43
Enrique Sáenz	28	Tamaulipas	7	Camargo	276	985155	262052	1	*	*	*
Ensenada (Juan García)	28	Tamaulipas	22	Matamoros	1354	975037	255830	6	*	*	*
Escobedo (Guadalupe Escobedo)	28	Tamaulipas	22	Matamoros	421	974023	254903	1	*	*	*
Esperanza (Campestre Camargo)	28	Tamaulipas	7	Camargo	111	985037	261903	5	*	*	*
Esquina del Potrero	19	Nuevo León	20	Gral. Bravo	410	984846	255312	26	3.25	5	3
Estación Canales	28	Tamaulipas	33	Río Bravo	234	975716	255929	112	4	1	27
Estación Ochoa	28	Tamaulipas	7	Camargo	51	985559	260729	1	*	*	*
Estación Rosita	28	Tamaulipas	22	Matamoros	1929	973633	255124	22	3.67	2	4

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Estación Sandoval	28	Tamaulipas	22	Matamoros	297	973950	255409	1146	3.45	97	217
Estero Verde	28	Tamaulipas	22	Matamoros	137	971707	255014	5	*	*	*
Eugenio Hérnandez Flores	28	Tamaulipas	22	Matamoros	1899	972851	254821	1	*	*	*
Eva García	28	Tamaulipas	7	Camargo	370	984635	261731	3	*	*	*
Everardo Sandoval Buenrostro	28	Tamaulipas	22	Matamoros	1895	974232	255838	37	4.5	0	2
Ezequiel Alcocer	28	Tamaulipas	22	Matamoros	1236	973511	255604	3	*	*	*
Feliciano (Gustavo Villarreal)	28	Tamaulipas	22	Matamoros	1237	973808	254722	1	*	*	*
Feliciano (Miguel Villarreal Garza)	28	Tamaulipas	22	Matamoros	674	973802	254731	7	2.33	0	3
Fermín	28	Tamaulipas	32	Reynosa	1024	983005	261055	1	*	*	*
Flor de Mayo	28	Tamaulipas	22	Matamoros	1317	973951	255637	1	*	*	*
Florentino Espinoza	28	Tamaulipas	32	Reynosa	918	982436	260938	13	*	*	*
Francisco Álvarez	28	Tamaulipas	32	Reynosa	847	983217	261222	7	*	*	*
Francisco Barrientos (Tres Hermanos)	28	Tamaulipas	32	Reynosa	902	982119	260708	1	*	*	*
Francisco Dávila	28	Tamaulipas	32	Reynosa	1314	980914	260009	5	*	*	*
Francisco Gracia	28	Tamaulipas	22	Matamoros	1239	971833	254957	2	*	*	*
Francisco Martínez	28	Tamaulipas	32	Reynosa	1305	983135	261137	1	*	*	*
Fructuoso Díaz	28	Tamaulipas	7	Camargo	391	984449	261626	3	*	*	*
Gerardo Gutiérrez	28	Tamaulipas	33	Río Bravo	1081	980636	260247	3	*	*	*
Gilberto Ciro Barrera	28	Tamaulipas	32	Reynosa	842	983211	260831	1	*	*	*
Gina Olivares	28	Tamaulipas	7	Camargo	414	985009	261630	2	*	*	*
Gomeño Nuevo (El Gomeño)	28	Tamaulipas	22	Matamoros	153	972113	255259	52	2.89	18	0
Graneros, Semillas y Forrajes S.A.	28	Tamaulipas	22	Matamoros	1168	973820	255106	6	2	1	2
Granja Cristal	28	Tamaulipas	32	Reynosa	1345	981024	260317	5	*	*	*
Granja Guadalupe	28	Tamaulipas	22	Matamoros	1268	973509	255609	2	*	*	*
Granja San Epitacio	28	Tamaulipas	22	Matamoros	1933	973134	255341	7	*	*	*
Granjenitos	28	Tamaulipas	22	Matamoros	155	972344	254202	11	*	*	*
Guadalupe	19	Nuevo León	20	Gral. Bravo	51	983615	255407	3	*	*	*
Guadalupe	28	Tamaulipas	22	Matamoros	158	973458	255536	742	3.66	117	83
Guadalupe	28	Tamaulipas	22	Matamoros	159	973935	255054	43	3.58	10	2
Guadalupe	28	Tamaulipas	22	Matamoros	1752	973515	255550	3	*	*	*
Guadalupe	28	Tamaulipas	33	Río Bravo	263	975813	260244	16	3.2	1	4
Guadalupe	28	Tamaulipas	33	Río Bravo	486	975546	255930	5	*	*	*
Guadalupe (Juan Degollado)	28	Tamaulipas	22	Matamoros	1269	973445	255630	5	*	*	*
Guadalupe Barrientos	28	Tamaulipas	7	Camargo	400	984724	261733	3	*	*	*
Guadalupe Guerrero Hinojosa	28	Tamaulipas	7	Camargo	284	985510	262159	2	*	*	*
Guardado de Abajo (Guardados de Abajo)	28	Tamaulipas	7	Camargo	32	985609	262158	326	3.54	74	17
Guardados de Arriba	28	Tamaulipas	25	Miguel Alemán	14	985751	262253	462	3.65	100	25
Hda. de las Rusias (El Lago de las Rusias)	28	Tamaulipas	22	Matamoros	1706	973306	255453	4	*	*	*
Heliodoro Rodríguez C.	28	Tamaulipas	22	Matamoros	1243	973324	254502	1	*	*	*
Heriberto Bravo	28	Tamaulipas	7	Camargo	333	984911	261822	3	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Heroica Matamoros	28	Tamaulipas	22	Matamoros	1	973015	255247	449815	3.68	112307	5781
Horacio Hernández	28	Tamaulipas	15	Gustavo Díaz Ordaz	363	983323	261148	4	*	*	*
Horacio Hernández (La Casa de Piedra)	28	Tamaulipas	32	Reynosa	1304	983056	261147	14	2.8	5	0
Huizachal	28	Tamaulipas	22	Matamoros	1492	971713	254844	12	*	*	*
Huizachitos	19	Nuevo León	20	Gral. Bravo	54	984200	255942	4	*	*	*
Huizachitos Sección Dos	19	Nuevo León	20	Gral. Bravo	442	984339	260049	7	*	*	*
Ideal del Campesino	28	Tamaulipas	15	Gustavo Díaz Ordaz	215	983252	260854	7	*	*	*
Ideal del Campesino	28	Tamaulipas	15	Gustavo Díaz Ordaz	6	983400	260924	41	3.15	8	4
Idelfonso García	28	Tamaulipas	15	Gustavo Díaz Ordaz	328	984105	260826	8	2	1	3
Ignacio Zaragoza	28	Tamaulipas	22	Matamoros	167	973707	255156	314	3.53	59	30
Isabel Meraz	28	Tamaulipas	32	Reynosa	1033	983207	260753	3	*	*	*
Isidoro García	28	Tamaulipas	22	Matamoros	1546	972306	254145	10	*	*	*
Isidro Pérez	28	Tamaulipas	7	Camargo	294	985630	262004	1	*	*	*
J.G.B.	28	Tamaulipas	25	Miguel Alemán	123	990253	262031	1	*	*	*
Jabalí Dos (El Jabalí)	28	Tamaulipas	32	Reynosa	308	983259	255901	7	*	*	*
Jaime Carranza	28	Tamaulipas	32	Reynosa	907	982457	260537	2	*	*	*
Javier Jiménez	28	Tamaulipas	15	Gustavo Díaz Ordaz	388	983522	261136	2	*	*	*
Jesús Canales (Granja Porcina la Soledad)	28	Tamaulipas	33	Río Bravo	807	975547	255623	8	2.67	0	3
Jesús Olivares	28	Tamaulipas	7	Camargo	281	985437	262110	1	*	*	*
Jesús Ortiz	28	Tamaulipas	15	Gustavo Díaz Ordaz	392	983611	260319	3	*	*	*
Jesús Ruvalcaba	28	Tamaulipas	32	Reynosa	1269	982456	260556	3	*	*	*
Jesús Vega Sánchez	28	Tamaulipas	15	Gustavo Díaz Ordaz	419	983703	261338	81	4.26	12	7
Jorge Alberto Lira Castillo	28	Tamaulipas	7	Camargo	328	984944	261935	10	3.33	3	0
Jorge Galaviz	28	Tamaulipas	15	Gustavo Díaz Ordaz	421	983619	261145	1	*	*	*
José Luis Flores Villegas	28	Tamaulipas	25	Miguel Alemán	173	990011	262309	3	*	*	*
José Luis Martínez	28	Tamaulipas	15	Gustavo Díaz Ordaz	174	983812	261313	1	*	*	*
José Luis Vázquez	28	Tamaulipas	33	Río Bravo	1084	980535	260149	2	*	*	*
José Luis Villarreal García	28	Tamaulipas	22	Matamoros	430	971824	254436	1	*	*	*
José María Morelos	28	Tamaulipas	22	Matamoros	171	974615	255304	78	2.89	15	12
José María Morelos (Rafael Pérez)	28	Tamaulipas	22	Matamoros	1389	974542	255327	2	*	*	*
José Villarreal Alanís	28	Tamaulipas	22	Matamoros	1920	971833	255001	3	*	*	*
Juan Garza	28	Tamaulipas	25	Miguel Alemán	110	985658	262045	2	*	*	*
Juan Gutiérrez	28	Tamaulipas	15	Gustavo Díaz Ordaz	76	984330	260258	5	*	*	*
Juan José Andrade (Santa Adelaida)	28	Tamaulipas	22	Matamoros	1252	973841	255100	1	*	*	*
Juan Pablo Ramírez	28	Tamaulipas	7	Camargo	340	984757	261804	7	*	*	*
Juan Pérez	28	Tamaulipas	15	Gustavo Díaz Ordaz	352	983813	260904	1	*	*	*
Juanillo	28	Tamaulipas	22	Matamoros	172	973416	255539	186	3.8	27	22
Juanillo (Benjamín Vela)	28	Tamaulipas	22	Matamoros	1294	973459	255224	13	*	*	*
Julián Vélez	28	Tamaulipas	32	Reynosa	1056	982852	260747	2	*	*	*
La Adarga	28	Tamaulipas	22	Matamoros	1174	973412	254431	25	4.17	1	5

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
La Alberca	19	Nuevo León	15	Dr. Coss	4	985158	255721	6	*	*	*
La Altamira	28	Tamaulipas	22	Matamoros	488	974144	260047	2	*	*	*
La Amistad	28	Tamaulipas	22	Matamoros	42	972443	254621	9	3	0	3
La Arena	28	Tamaulipas	15	Gustavo Díaz Ordaz	68	983838	261210	3	*	*	*
La Atravesada	28	Tamaulipas	22	Matamoros	1513	973445	254358	12	4	1	2
La Atravesada	28	Tamaulipas	22	Matamoros	813	973506	254326	4	*	*	*
La Bandera	19	Nuevo León	15	Dr. Coss	8	985722	255809	10	1.67	6	0
La Barranca	28	Tamaulipas	22	Matamoros	58	974416	260050	271	3.2	20	60
La Barranca (Ángel González García)	28	Tamaulipas	22	Matamoros	1759	974350	260023	5	*	*	*
La Barranca (Curva Texas)	28	Tamaulipas	22	Matamoros	606	974458	255924	17	5.67	2	1
La Barranca (Curva Texas)	28	Tamaulipas	22	Matamoros	1760	974436	255938	20	4	3	2
La Barranca (El Porvenir)	28	Tamaulipas	22	Matamoros	1197	974547	260013	19	4.75	0	4
La Bartolina	28	Tamaulipas	22	Matamoros	57	971606	255132	337	3.52	69	25
La Bocatoma	28	Tamaulipas	32	Reynosa	859	982022	260826	307	3.7	61	22
La Bolsa (Pedro Cantú García)	28	Tamaulipas	22	Matamoros	1222	975210	260317	5	*	*	*
La Brigada	28	Tamaulipas	22	Matamoros	71	973900	255959	295	3.24	11	79
La Brisa	28	Tamaulipas	22	Matamoros	632	974302	255141	5	*	*	*
La Brisa	28	Tamaulipas	32	Reynosa	284	982914	260211	1	*	*	*
La Burrita	28	Tamaulipas	22	Matamoros	80	971548	255631	9	1.8	3	1
La Cabaña	28	Tamaulipas	22	Matamoros	1955	972525	255020	2	*	*	*
La Canela	19	Nuevo León	15	Dr. Coss	13	985719	255729	30	3.75	7	1
La Carrera	28	Tamaulipas	22	Matamoros	91	972115	255348	3	*	*	*
La Cieneguita (Las Flores)	28	Tamaulipas	33	Río Bravo	1124	975747	260117	4	*	*	*
La Colmena	28	Tamaulipas	33	Río Bravo	792	975646	255714	2	*	*	*
La Colmena	28	Tamaulipas	7	Camargo	273	985134	262019	2	*	*	*
La Coma	28	Tamaulipas	25	Miguel Alemán	48	990122	262041	4	*	*	*
La Coma (Rafael Ramírez)	28	Tamaulipas	25	Miguel Alemán	126	990213	262056	6	*	*	*
La Concepción	28	Tamaulipas	22	Matamoros	799	975035	260049	17	3.4	1	4
La Cuchilla (Los Miranda)	28	Tamaulipas	15	Gustavo Díaz Ordaz	142	983943	261341	4	1	0	4
La Cueva	19	Nuevo León	20	Gral. Bravo	197	983645	255543	3	*	*	*
La Delicia	28	Tamaulipas	25	Miguel Alemán	49	990126	261941	1	*	*	*
La Dieta	28	Tamaulipas	22	Matamoros	1894	973349	254628	3	*	*	*
La División	28	Tamaulipas	32	Reynosa	835	983228	261049	4	*	*	*
La Engorda (Los Balderas)	28	Tamaulipas	25	Miguel Alemán	53	990435	261859	1	*	*	*
La Ermita	28	Tamaulipas	22	Matamoros	125	973412	254420	4	*	*	*
La Escondida	28	Tamaulipas	32	Reynosa	1236	981233	260321	6	*	*	*
La Escuadra	28	Tamaulipas	22	Matamoros	516	974129	255056	8	*	*	*
La Escuadra (Los Palomo)	28	Tamaulipas	22	Matamoros	1012	974144	255103	20	5	0	4
La Escuadra (Rómulo Zermeño)	28	Tamaulipas	22	Matamoros	734	974120	255113	7	*	*	*
La Esmeralda	28	Tamaulipas	22	Matamoros	1547	972922	254412	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
La Esperanza	28	Tamaulipas	22	Matamoros	1495	971719	255138	16	3.2	4	1
La Esperanza	28	Tamaulipas	32	Reynosa	731	982410	255632	15	4	3	0
La Fe	28	Tamaulipas	32	Reynosa	856	983021	260927	6	*	*	*
La Florida	28	Tamaulipas	32	Reynosa	136	982908	255850	3	*	*	*
La Fortuna	19	Nuevo León	20	Gral. Bravo	387	983657	255508	5	*	*	*
La Gloria	28	Tamaulipas	22	Matamoros	150	973714	255223	713	3.38	95	109
La Gloria	28	Tamaulipas	33	Río Bravo	393	975803	260005	5	*	*	*
La Gloria	28	Tamaulipas	22	Matamoros	802	971917	255055	2	*	*	*
La Gloria (El Llano)	28	Tamaulipas	22	Matamoros	1286	973634	255428	6	*	*	*
La Herradura (Genaro Cantú)	28	Tamaulipas	32	Reynosa	1079	982013	260637	2	*	*	*
La Higuera	28	Tamaulipas	22	Matamoros	1919	971704	255123	7	*	*	*
La Ilusión	28	Tamaulipas	33	Río Bravo	1373	980400	260149	1	*	*	*
La Laguna	28	Tamaulipas	22	Matamoros	173	974349	255252	77	2.96	6	19
La Leona	19	Nuevo León	20	Gral. Bravo	207	983739	254502	3	*	*	*
La Leona	28	Tamaulipas	22	Matamoros	556	972429	253814	4	*	*	*
La Lomita	28	Tamaulipas	22	Matamoros	685	971821	255507	1	*	*	*
La Luz (Gregorio Elizondo)	28	Tamaulipas	22	Matamoros	1452	973238	254726	3	*	*	*
La Luz (Hacienda de la Flor)	28	Tamaulipas	22	Matamoros	1458	973201	254730	1	*	*	*
La Luz (Las Margaritas)	28	Tamaulipas	22	Matamoros	1460	973242	254810	1	*	*	*
La Magnolia	19	Nuevo León	20	Gral. Bravo	469	983637	255608	4	*	*	*
La Majada	19	Nuevo León	20	Gral. Bravo	346	984614	260133	6	*	*	*
La Mesa	19	Nuevo León	20	Gral. Bravo	258	984214	255611	2	*	*	*
La Mesa	28	Tamaulipas	33	Río Bravo	280	975648	255958	7	*	*	*
La Milagrosa	28	Tamaulipas	32	Reynosa	1095	982519	260447	2	*	*	*
La Misión	28	Tamaulipas	7	Camargo	269	985045	261933	31	3.1	9	1
La Morita	28	Tamaulipas	32	Reynosa	852	983018	261030	16	3.2	5	0
La Morita Dos	28	Tamaulipas	32	Reynosa	1023	983023	261111	16	5.33	3	0
La Nacahuita	28	Tamaulipas	32	Reynosa	1328	982502	260540	3	*	*	*
La Nueva Victoria	28	Tamaulipas	22	Matamoros	999	974438	255456	6	*	*	*
La Palangana	28	Tamaulipas	22	Matamoros	219	974554	260133	102	3.78	2	25
La Palangana (Ramiro Martínez)	28	Tamaulipas	22	Matamoros	854	972644	254706	4	*	*	*
La Palma	28	Tamaulipas	32	Reynosa	1302	981857	260134	4	*	*	*
La Palma	28	Tamaulipas	22	Matamoros	220	975032	260246	8	2	2	2
La Palma	28	Tamaulipas	7	Camargo	52	985606	260131	25	4	0	4
La Palmita	28	Tamaulipas	22	Matamoros	223	975126	260257	2	*	*	*
La Paloma	28	Tamaulipas	22	Matamoros	1386	974214	255027	29	3.22	6	3
La Piedra	28	Tamaulipas	22	Matamoros	244	971347	254907	15	3	4	1
La Posta	28	Tamaulipas	33	Río Bravo	302	975830	260029	412	3.71	64	47
La Providencia	28	Tamaulipas	22	Matamoros	562	972543	253651	1	*	*	*
La Puerta	28	Tamaulipas	22	Matamoros	259	974029	260002	96	3.31	2	27

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
La Puerta (Hilario Valdez)	28	Tamaulipas	22	Matamoros	1324	974055	255836	3	*	*	*
La Puerta (Zoilo Torres)	28	Tamaulipas	22	Matamoros	1323	974009	255734	8	*	*	*
La Quinta Bugambilia	28	Tamaulipas	32	Reynosa	978	982715	260753	2	*	*	*
La Reforma	28	Tamaulipas	22	Matamoros	1906	974005	255416	28	3.5	2	6
La Reforma	28	Tamaulipas	22	Matamoros	272	974134	255626	93	3.1	6	23
La Reforma	28	Tamaulipas	33	Río Bravo	313	980519	260228	115	3.83	3	27
La Reforma	28	Tamaulipas	15	Gustavo Díaz Ordaz	82	983556	260153	6	*	*	*
La Roca	28	Tamaulipas	22	Matamoros	1138	974035	255405	4	*	*	*
La Roca (Ignacio Vázquez)	28	Tamaulipas	22	Matamoros	1400	974139	255259	4	*	*	*
La Rosa	28	Tamaulipas	32	Reynosa	289	983406	260201	2	*	*	*
La Rosita	28	Tamaulipas	32	Reynosa	288	983359	260103	3	*	*	*
La Rosita	28	Tamaulipas	22	Matamoros	747	974132	260039	78	3.12	12	13
La Rosita	28	Tamaulipas	32	Reynosa	287	983447	260040	2	*	*	*
La Rosita	28	Tamaulipas	32	Reynosa	1225	982044	260729	24	5.25	4	0
La Rosita (Federico García)	28	Tamaulipas	22	Matamoros	1293	973717	255128	23	4.6	2	3
La Sierrita	19	Nuevo León	20	Gral. Bravo	166	984552	255500	1	*	*	*
La Sierrita	28	Tamaulipas	22	Matamoros	372	975320	255925	395	3.56	52	59
La Sierrita (Enriqueta Echavarría)	28	Tamaulipas	22	Matamoros	1353	975320	255613	7	*	*	*
La Sierrita (Juan José Cabada)	28	Tamaulipas	22	Matamoros	1350	975313	255956	10	2.5	2	2
La Soledad	28	Tamaulipas	40	Valle Hermoso	378	975501	255604	146	3.4	22	21
La Soledad (Asunción Álvarez)	28	Tamaulipas	22	Matamoros	1768	975456	255604	8	*	*	*
La Tijerita	28	Tamaulipas	22	Matamoros	775	973242	254446	301	3.96	29	47
La Tijerita	28	Tamaulipas	22	Matamoros	776	973247	254419	33	3.67	3	6
La Tijerita	28	Tamaulipas	22	Matamoros	387	973416	254402	9	*	*	*
La Tijerita	28	Tamaulipas	22	Matamoros	1470	973252	254252	16	3.2	0	5
La Tijerita	28	Tamaulipas	22	Matamoros	992	973352	254350	2	*	*	*
La Tijerita	28	Tamaulipas	22	Matamoros	1868	973407	254412	124	4.32	8	20
La Tijerita (Potrero Nuevo)	28	Tamaulipas	22	Matamoros	1471	973300	254515	124	3.18	18	21
La Tijerita (Rubén Garza)	28	Tamaulipas	22	Matamoros	1238	973339	254351	2	*	*	*
La Toma Sur	28	Tamaulipas	7	Camargo	255	985538	261127	1	*	*	*
La Toquilla	19	Nuevo León	20	Gral. Bravo	407	984444	254628	10	*	*	*
La Trinidad	28	Tamaulipas	15	Gustavo Díaz Ordaz	45	984316	260403	6	*	*	*
La Unión	28	Tamaulipas	33	Río Bravo	791	975637	255729	4	*	*	*
La Vaina (Santa Ana)	28	Tamaulipas	32	Reynosa	901	982309	260708	3	*	*	*
La Vanguardia	28	Tamaulipas	22	Matamoros	393	974223	255026	377	4.44	33	52
La Vanguardia (Claudio Zúñiga)	28	Tamaulipas	22	Matamoros	1421	974301	255015	33	4.71	4	3
La Vanguardia (Joel Santos)	28	Tamaulipas	22	Matamoros	1423	974153	255027	35	3.89	8	1
La Vanguardia (Mariano Aguirre)	28	Tamaulipas	22	Matamoros	1422	974220	254932	20	4	3	2
La Vanguardia (Mario García)	28	Tamaulipas	22	Matamoros	1424	974133	255055	44	4.4	6	4
La Vaquita	19	Nuevo León	20	Gral. Bravo	308	984215	255537	9	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
La Venada	28	Tamaulipas	22	Matamoros	397	973527	254721	606	3.31	58	114
La Venada (Francisco Cabello)	28	Tamaulipas	22	Matamoros	1447	973744	254800	3	*	*	*
La Venada (Gabriel Hernández)	28	Tamaulipas	22	Matamoros	1444	973654	254853	6	*	*	*
La Venada (José Guadalupe Cabello)	28	Tamaulipas	22	Matamoros	1446	973734	254815	10	3.33	0	3
La Venada (José Marcelino Ramos)	28	Tamaulipas	22	Matamoros	876	973435	254849	11	*	*	*
La Venada (Merced Casas)	28	Tamaulipas	22	Matamoros	1449	973709	254803	2	*	*	*
La Venada (Rafael Ramos)	28	Tamaulipas	22	Matamoros	1445	973711	254856	5	*	*	*
La Ventana	28	Tamaulipas	22	Matamoros	399	973613	255312	75	3.56	10	8
La Ventana (Hilario Ceballos)	28	Tamaulipas	22	Matamoros	1288	973557	255301	4	*	*	*
La Ventana (José Ortiz)	28	Tamaulipas	22	Matamoros	1289	973546	255259	3	*	*	*
La Virgen	19	Nuevo León	20	Gral. Bravo	141	983753	255324	3	*	*	*
La Virgen	28	Tamaulipas	15	Gustavo Díaz Ordaz	406	984355	260212	4	*	*	*
La Yerbajosa	28	Tamaulipas	22	Matamoros	793	972252	254651	2	*	*	*
Laguna Redonda (Florencio Raya)	28	Tamaulipas	22	Matamoros	982	973353	254729	3	*	*	*
Laguna Redonda (Francisco Aguilar)	28	Tamaulipas	22	Matamoros	1925	973340	255225	1	*	*	*
Laguna Redonda (Juana Raya)	28	Tamaulipas	22	Matamoros	689	973358	254858	3	*	*	*
aguna Redonda Km. 7 (José Reyna Quinter	28	Tamaulipas	22	Matamoros	1930	973536	255135	5	*	*	*
Laguna Seca	28	Tamaulipas	33	Río Bravo	270	975731	255839	64	4	4	12
Lagunitas Uno	28	Tamaulipas	32	Reynosa	312	983426	255741	12	3	4	0
Las Alamedas	28	Tamaulipas	22	Matamoros	1399	974044	255236	15	3.75	3	1
Las Bayitas	28	Tamaulipas	22	Matamoros	61	974940	260241	5	*	*	*
Las Blancas	28	Tamaulipas	22	Matamoros	65	973800	254550	3	*	*	*
Las Carolinas	28	Tamaulipas	22	Matamoros	936	973001	253519	2	*	*	*
Las Ciénegas (Las Ciénegas de Flores)	28	Tamaulipas	15	Gustavo Díaz Ordaz	128	983914	261208	11	3.67	2	1
Las Comas	28	Tamaulipas	22	Matamoros	101	972113	255356	1	*	*	*
Las Comas	28	Tamaulipas	15	Gustavo Díaz Ordaz	240	983246	261128	12	*	*	*
Las Cruces	19	Nuevo León	20	Gral. Bravo	352	984613	255944	2	*	*	*
Las Cuatrocientas (Julián Cabrera)	19	Nuevo León	20	Gral. Bravo	444	984317	260120	2	*	*	*
Las Delicias	19	Nuevo León	20	Gral. Bravo	32	983718	255447	5	*	*	*
Las Delicias	28	Tamaulipas	22	Matamoros	791	974306	255801	12	4	1	2
Las Dos Palmas	28	Tamaulipas	32	Reynosa	843	983242	260950	2	*	*	*
Las Esquinas	28	Tamaulipas	22	Matamoros	494	973742	255114	32	3.56	4	5
Las Flores	19	Nuevo León	20	Gral. Bravo	279	984609	260120	6	*	*	*
Las Glorias	28	Tamaulipas	22	Matamoros	953	972738	253554	1	*	*	*
Las Lomas	28	Tamaulipas	22	Matamoros	1909	972209	254832	2	*	*	*
Las Margaritas	28	Tamaulipas	32	Reynosa	995	983102	255736	3	*	*	*
Las Margaritas	28	Tamaulipas	22	Matamoros	1926	973506	255159	2	*	*	*
Las Mariposas	28	Tamaulipas	15	Gustavo Díaz Ordaz	341	984019	261236	7	*	*	*
Las Mercedes	28	Tamaulipas	32	Reynosa	711	982533	255625	5	*	*	*
Las Minitas	28	Tamaulipas	32	Reynosa	792	981327	260355	7	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Las Moras	28	Tamaulipas	15	Gustavo Díaz Ordaz	132	984034	261230	2	*	*	*
Las Norias	19	Nuevo León	20	Gral. Bravo	73	983726	255338	9	1.8	4	1
Las Nubes	28	Tamaulipas	32	Reynosa	953	980948	260244	1	*	*	*
Las Once Palmas (Las Dos Palmas)	28	Tamaulipas	15	Gustavo Díaz Ordaz	130	984009	261313	6	*	*	*
Las Palmas	28	Tamaulipas	25	Miguel Alemán	116	990027	262311	3	*	*	*
Las Palmas del Caracol	28	Tamaulipas	22	Matamoros	1611	972841	253632	5	*	*	*
Las Pencas	28	Tamaulipas	22	Matamoros	904	973438	254215	1	*	*	*
Las Peñitas	19	Nuevo León	20	Gral. Bravo	193	984229	255504	1	*	*	*
Las Potrancas	28	Tamaulipas	22	Matamoros	1369	973054	254609	1	*	*	*
Las Rusias (Alfredo Báez)	28	Tamaulipas	22	Matamoros	1282	973259	255531	7	*	*	*
Las Rusias (Aurora Coronado)	28	Tamaulipas	22	Matamoros	1281	973348	255531	21	3.5	3	3
Las Rusias (Cristóbal Lozano)	28	Tamaulipas	22	Matamoros	1267	973349	255444	4	*	*	*
Las Rusias (El Ranchito)	28	Tamaulipas	22	Matamoros	1932	973158	255347	2	*	*	*
Las Rusias (Francisco Arredondo González)	28	Tamaulipas	22	Matamoros	1923	973310	255337	1	*	*	*
Las Rusias (Manuel Castillo)	28	Tamaulipas	22	Matamoros	1285	973226	255458	1	*	*	*
Las Rusias (Pedro Báez)	28	Tamaulipas	22	Matamoros	1280	973331	255527	17	*	*	*
Las Tres	28	Tamaulipas	22	Matamoros	840	971241	254859	3	*	*	*
Las Tres Esquinas	28	Tamaulipas	22	Matamoros	1555	972637	254538	6	*	*	*
Las Yesquitas	28	Tamaulipas	22	Matamoros	408	972940	254237	8	2	0	4
Lázaro Garza (La Reforma)	28	Tamaulipas	7	Camargo	277	985255	262056	1	*	*	*
Leonel Barrera	28	Tamaulipas	15	Gustavo Díaz Ordaz	136	983912	261336	6	*	*	*
Librando Falcón Garza	28	Tamaulipas	7	Camargo	285	985515	262230	3	*	*	*
Localidad sin Nombre	19	Nuevo León	3	Los Aldamas	60	991302	261356	7	*	*	*
Localidad sin Nombre	28	Tamaulipas	22	Matamoros	1466	974522	255148	4	*	*	*
Localidad sin Nombre	28	Tamaulipas	32	Reynosa	1064	982517	261004	1	*	*	*
Localidad sin Nombre	28	Tamaulipas	32	Reynosa	1069	982135	260906	2	*	*	*
Localidad sin Nombre	28	Tamaulipas	22	Matamoros	1928	973547	255142	2	*	*	*
Localidad sin Nombre	28	Tamaulipas	15	Gustavo Díaz Ordaz	429	983809	260537	2	*	*	*
Localidad sin Nombre	28	Tamaulipas	15	Gustavo Díaz Ordaz	206	983522	260950	1	*	*	*
Localidad sin Nombre	28	Tamaulipas	15	Gustavo Díaz Ordaz	408	984415	260320	1	*	*	*
Localidad sin Nombre	28	Tamaulipas	15	Gustavo Díaz Ordaz	411	983937	261342	2	*	*	*
Localidad sin Nombre	28	Tamaulipas	15	Gustavo Díaz Ordaz	422	983901	260918	3	*	*	*
Loma Linda (La Polvareda)	28	Tamaulipas	32	Reynosa	195	982103	260034	3	*	*	*
Loma Vista	28	Tamaulipas	7	Camargo	265	985441	261346	3	*	*	*
López y Nuevo Cadillo	28	Tamaulipas	7	Camargo	48	984557	261700	319	3.3	82	2
Los Alacranes	28	Tamaulipas	33	Río Bravo	3	980827	260311	10	3.33	3	0
Los Altos	28	Tamaulipas	32	Reynosa	90	983056	261231	99	2.63	18	5
Los Altos (El Alto)	28	Tamaulipas	32	Reynosa	89	983022	261131	353	3.43	88	11
Los Álvarez	28	Tamaulipas	15	Gustavo Díaz Ordaz	131	984213	261135	4	*	*	*
Los Amaro	28	Tamaulipas	22	Matamoros	831	973417	254331	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Los Ángeles	28	Tamaulipas	22	Matamoros	1614	972906	253416	1	*	*	*
Los Ángeles	28	Tamaulipas	25	Miguel Alemán	4	985907	262304	834	4.12	185	12
Los Arados (Joaquín Luitón)	28	Tamaulipas	22	Matamoros	1711	973413	255206	8	*	*	*
Los Arados (Juan José Sauceda)	28	Tamaulipas	22	Matamoros	1775	973326	255019	1	*	*	*
Los Borregos	28	Tamaulipas	22	Matamoros	1796	972216	254719	2	*	*	*
Los Canchola	28	Tamaulipas	33	Río Bravo	337	980755	260332	1	*	*	*
Los Cantú y los García	28	Tamaulipas	32	Reynosa	1289	981429	260326	25	3.13	3	5
Los Cavazos	28	Tamaulipas	32	Reynosa	120	982053	260845	2187	3.79	459	107
Los Chiapas	28	Tamaulipas	32	Reynosa	920	983349	255133	3	*	*	*
Los Cinco Hermanos (Los dos Estados)	19	Nuevo León	20	Gral. Bravo	161	983507	255824	7	*	*	*
Los Compadres	28	Tamaulipas	22	Matamoros	1468	973441	255551	29	3.63	0	8
Los Cuates	28	Tamaulipas	22	Matamoros	106	974115	255745	26	3.71	4	3
Los Cuervos (Basilio Reyes)	28	Tamaulipas	22	Matamoros	1789	972611	254425	1	*	*	*
Los Cuervos (José Villafranca H.)	28	Tamaulipas	22	Matamoros	1556	972644	254534	2	*	*	*
Los Díaz	28	Tamaulipas	15	Gustavo Díaz Ordaz	99	984055	260932	7	*	*	*
Los Divisaderos	19	Nuevo León	20	Gral. Bravo	33	984354	254920	3	*	*	*
Los Divisaderos	19	Nuevo León	20	Gral. Bravo	275	984409	254934	4	*	*	*
Los Dos Ébanos	28	Tamaulipas	22	Matamoros	819	972353	254442	2	*	*	*
Los Dos Estados	28	Tamaulipas	32	Reynosa	1165	983503	255814	1	*	*	*
Los Ébanos	28	Tamaulipas	32	Reynosa	309	983417	255827	4	*	*	*
Los Ébanos	28	Tamaulipas	22	Matamoros	614	971738	254938	2	*	*	*
Los Federales	28	Tamaulipas	22	Matamoros	625	972643	254758	2	*	*	*
Los Fresnos	28	Tamaulipas	32	Reynosa	137	982445	261005	5	*	*	*
Los Fresnos	28	Tamaulipas	7	Camargo	26	985109	262056	131	3.54	28	9
Los García	28	Tamaulipas	32	Reynosa	1122	982438	255942	3	*	*	*
Los García	28	Tamaulipas	7	Camargo	182	984941	262057	5	*	*	*
Los Garza	28	Tamaulipas	15	Gustavo Díaz Ordaz	344	983531	261047	1	*	*	*
Los Guayabos	28	Tamaulipas	22	Matamoros	1862	972327	254248	1	*	*	*
Los Guerra	28	Tamaulipas	25	Miguel Alemán	15	990451	262342	4566	4.02	1108	11
Los Gutiérrez	19	Nuevo León	20	Gral. Bravo	52	984444	255945	10	2.5	0	4
Los Indios	28	Tamaulipas	22	Matamoros	289	974338	255907	1	*	*	*
Los Laureles	28	Tamaulipas	22	Matamoros	835	973445	254216	1	*	*	*
Los Laureles	28	Tamaulipas	22	Matamoros	1511	973725	254250	1	*	*	*
Los Laureles	28	Tamaulipas	15	Gustavo Díaz Ordaz	9	984323	260508	16	4	3	1
Los Limones	28	Tamaulipas	22	Matamoros	498	974220	255835	18	3	6	0
Los Llanos (Juan N. Guerra)	28	Tamaulipas	22	Matamoros	804	972727	254837	10	*	*	*
Los Mares (Gregorio Mares)	28	Tamaulipas	32	Reynosa	1276	981801	260036	7	2.33	3	0
Los Martínez	28	Tamaulipas	32	Reynosa	310	983447	255817	1	*	*	*
Los Martínez	28	Tamaulipas	15	Gustavo Díaz Ordaz	155	983803	261208	19	1.75	0	1
Los Martínez	28	Tamaulipas	15	Gustavo Díaz Ordaz	309	984024	260732	2	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Los Martínez (Trinidad Solís)	28	Tamaulipas	15	Gustavo Díaz Ordaz	157	983912	261220	5	*	*	*
Los Mezquites (Joel Tovar)	28	Tamaulipas	22	Matamoros	1384	973929	255435	1	*	*	*
Los Monteros	28	Tamaulipas	33	Río Bravo	726	975911	255717	5	*	*	*
Los Moreno	28	Tamaulipas	7	Camargo	230	985627	262141	4	*	*	*
Los Naranjos	28	Tamaulipas	33	Río Bravo	1053	975806	255833	5	*	*	*
Los Naranjos	28	Tamaulipas	15	Gustavo Díaz Ordaz	2	983544	261131	2	*	*	*
Los Nogales	28	Tamaulipas	22	Matamoros	210	971853	255011	4	*	*	*
Los Nogales	28	Tamaulipas	22	Matamoros	209	973437	254209	2	*	*	*
Los Nogales	28	Tamaulipas	7	Camargo	477	985537	261123	1	*	*	*
Los Nogales	28	Tamaulipas	15	Gustavo Díaz Ordaz	64	983542	261119	7	*	*	*
Los Olmos	28	Tamaulipas	22	Matamoros	217	974324	255726	62	3.65	17	0
Los Olmos (Arturo Cárdenas)	28	Tamaulipas	22	Matamoros	1333	974306	255742	1	*	*	*
Los Ortiz	28	Tamaulipas	15	Gustavo Díaz Ordaz	327	983656	260451	1	*	*	*
Los Pinos	19	Nuevo León	20	Gral. Bravo	328	983726	255418	1	*	*	*
Los Plebes	28	Tamaulipas	33	Río Bravo	1343	975806	255814	4	*	*	*
Los Ramírez	19	Nuevo León	20	Gral. Bravo	98	983609	255343	1	*	*	*
Los Ramírez	28	Tamaulipas	22	Matamoros	826	973210	253834	8	*	*	*
Los Ramírez	28	Tamaulipas	15	Gustavo Díaz Ordaz	286	983612	261011	2	*	*	*
Los Ranchitos (Arturo García)	28	Tamaulipas	22	Matamoros	267	974139	254922	46	3.07	12	3
Los Ranchitos (Clemente Arizpe)	28	Tamaulipas	22	Matamoros	1419	974201	255000	9	1.8	4	1
Los Ranchitos (El Crucero)	28	Tamaulipas	22	Matamoros	1420	974103	255041	22	3.14	4	3
Los Ranchitos (Porfirio Méndez)	28	Tamaulipas	22	Matamoros	731	974111	255016	220	3.56	23	38
Los Ranchitos (Santana Garza)	28	Tamaulipas	22	Matamoros	1417	974154	254857	42	3.5	6	6
Los Sáenz	28	Tamaulipas	32	Reynosa	282	982846	260354	3	*	*	*
Los San Pedros	28	Tamaulipas	22	Matamoros	329	973524	254050	7	*	*	*
Los Sauces	28	Tamaulipas	15	Gustavo Díaz Ordaz	43	984304	260541	4	*	*	*
Los Sauces (Julio Leyva)	28	Tamaulipas	22	Matamoros	1455	973548	254555	1	*	*	*
Los Soto	28	Tamaulipas	15	Gustavo Díaz Ordaz	414	983725	261310	4	*	*	*
Los Taralles	28	Tamaulipas	22	Matamoros	382	973345	254113	4	*	*	*
Los Timones	28	Tamaulipas	22	Matamoros	388	974056	255643	174	3.23	26	27
Los Timones (Reynaldo Garza)	28	Tamaulipas	22	Matamoros	1757	974044	255715	3	*	*	*
Los Tres Potrillos	28	Tamaulipas	32	Reynosa	1228	982440	260439	4	*	*	*
Los Venados	28	Tamaulipas	32	Reynosa	839	983227	261122	1	*	*	*
Los Villarreal	28	Tamaulipas	15	Gustavo Díaz Ordaz	250	983511	260926	3	*	*	*
Los Villarreales	28	Tamaulipas	15	Gustavo Díaz Ordaz	19	983824	261352	193	2.92	55	11
Lucas Sáenz (El Barrote)	28	Tamaulipas	32	Reynosa	1025	983021	261031	1	*	*	*
Luciano Ramírez	28	Tamaulipas	22	Matamoros	1044	971758	254950	4	*	*	*
Lucio Blanco	28	Tamaulipas	15	Gustavo Díaz Ordaz	5	984051	260619	418	3.03	46	89
Luis Echeverría Álvarez	28	Tamaulipas	15	Gustavo Díaz Ordaz	196	983530	260935	164	4.03	22	18
Luz Gómez	28	Tamaulipas	7	Camargo	272	985227	262037	2	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Magdaleno Cortés	28	Tamaulipas	15	Gustavo Díaz Ordaz	347	983915	261401	2	*	*	*
Manuel Delgado	28	Tamaulipas	22	Matamoros	1433	974815	255346	38	3.45	3	8
Manuel Galaviz	28	Tamaulipas	15	Gustavo Díaz Ordaz	168	983925	261135	4	*	*	*
Manuel Huitrón	28	Tamaulipas	7	Camargo	372	984618	261724	3	*	*	*
Maravatío	28	Tamaulipas	33	Río Bravo	794	975705	255654	3	*	*	*
Maravillas	28	Tamaulipas	22	Matamoros	1016	974219	255024	9	3	3	0
María Isabel	28	Tamaulipas	22	Matamoros	792	973311	254444	5	*	*	*
María Natividad Villalobos	28	Tamaulipas	7	Camargo	368	984458	261655	1	*	*	*
María Rosa (Elena de Flores)	28	Tamaulipas	22	Matamoros	1131	972551	254555	1	*	*	*
María Teresa	28	Tamaulipas	22	Matamoros	1864	973431	254142	6	*	*	*
María Teresa	28	Tamaulipas	32	Reynosa	245	983006	260925	3	*	*	*
María Teresa Dos	28	Tamaulipas	32	Reynosa	1028	983016	260911	3	*	*	*
Maribel	28	Tamaulipas	22	Matamoros	536	973616	254218	10	3.33	0	3
Marte R. Gómez	28	Tamaulipas	15	Gustavo Díaz Ordaz	351	983751	261003	85	3.54	17	7
Marte R. Gómez	28	Tamaulipas	15	Gustavo Díaz Ordaz	10	983648	261047	15	3.75	2	2
Martina Garza	28	Tamaulipas	15	Gustavo Díaz Ordaz	21	984023	261256	4	*	*	*
Matías Pérez Villarreal	28	Tamaulipas	22	Matamoros	260	974019	260048	1	*	*	*
Medrano	28	Tamaulipas	22	Matamoros	1150	973627	254900	3	*	*	*
Mi Magdalena	28	Tamaulipas	32	Reynosa	1344	981013	260323	2	*	*	*
Mi Paraíso	28	Tamaulipas	22	Matamoros	1630	971926	255025	3	*	*	*
Mier	28	Tamaulipas	24	Mier	1	990855	262550	4762	3.3	1375	33
Miguel A. García	28	Tamaulipas	15	Gustavo Díaz Ordaz	376	983534	260538	10	3.33	1	2
Miguel García	28	Tamaulipas	15	Gustavo Díaz Ordaz	106	984043	260644	2	*	*	*
Miguel Hidalgo	28	Tamaulipas	32	Reynosa	1036	983301	260720	33	3	9	1
Miguel Hidalgo	28	Tamaulipas	15	Gustavo Díaz Ordaz	274	983306	260728	64	3.56	18	0
Miramar del Caracol	28	Tamaulipas	22	Matamoros	1619	973014	253517	3	*	*	*
Mogote de Santiago	28	Tamaulipas	22	Matamoros	200	973737	254820	157	3.74	4	38
Morteritos	28	Tamaulipas	25	Miguel Alemán	72	990044	262231	4	*	*	*
Muñoz Garza	28	Tamaulipas	15	Gustavo Díaz Ordaz	287	983356	261138	2	*	*	*
Nicanor González (El Mono)	28	Tamaulipas	32	Reynosa	1306	983122	261200	9	*	*	*
Nicolás Gutiérrez	28	Tamaulipas	15	Gustavo Díaz Ordaz	139	983812	261317	8	*	*	*
Nueva Ciudad Guerrero	28	Tamaulipas	14	Guerrero	1	991338	263358	4312	3.08	1182	84
Nuevo Cadillo	28	Tamaulipas	7	Camargo	194	984514	261555	3	*	*	*
Nuevo Camargo	28	Tamaulipas	7	Camargo	472	984917	262035	907	3.75	234	0
Nuevo Camargo (Villanueva)	28	Tamaulipas	7	Camargo	49	985040	261730	420	3.93	78	0
Nuevo México	28	Tamaulipas	32	Reynosa	1283	982336	260115	1731	3.75	325	0
Nuevo México (ITAVU)	28	Tamaulipas	32	Reynosa	1339	982344	260022	692	4.13	76	74
Nuevo Progreso	28	Tamaulipas	33	Río Bravo	291	975708	260322	10178	4.03	1741	744
Nuevo Santana	28	Tamaulipas	32	Reynosa	177	981018	260215	299	3.48	66	20
Octavio García	28	Tamaulipas	7	Camargo	231	985601	262117	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Pájaros Azules	28	Tamaulipas	22	Matamoros	805	971903	255039	11	*	*	*
Palo Blanco	28	Tamaulipas	22	Matamoros	226	974151	255551	244	3.29	12	53
Palo Blanco	28	Tamaulipas	22	Matamoros	227	972553	254628	4	*	*	*
Palo Blanco	28	Tamaulipas	22	Matamoros	1360	975420	255554	12	3	2	2
Palo Blanco	28	Tamaulipas	22	Matamoros	1558	974236	255434	63	2.86	7	15
Palomares (Santa Anita)	28	Tamaulipas	32	Reynosa	228	981946	260136	1	*	*	*
Pamoranas	19	Nuevo León	15	Dr. Coss	191	984803	255859	1	*	*	*
Paraíso (José Fallet)	28	Tamaulipas	22	Matamoros	1245	971813	254950	5	*	*	*
Paso Matamoros	28	Tamaulipas	22	Matamoros	1038	971803	254957	8	*	*	*
Pedro Guzmán (El Rodeo)	28	Tamaulipas	33	Río Bravo	734	975811	255826	22	7.33	0	3
Pedro Villalobos	28	Tamaulipas	22	Matamoros	1035	975129	255503	2	*	*	*
Pekaly	28	Tamaulipas	22	Matamoros	806	971758	254937	1	*	*	*
Petra Garza	28	Tamaulipas	33	Río Bravo	802	975655	255638	2	*	*	*
Petra Luna Delgado	28	Tamaulipas	7	Camargo	350	984721	261752	1	*	*	*
Petroquímica Reynosa	28	Tamaulipas	32	Reynosa	570	982033	260813	129	3.58	10	26
Piedras	28	Tamaulipas	15	Gustavo Díaz Ordaz	12	984332	260236	32	3.2	8	1
Porcina Blanquis	28	Tamaulipas	22	Matamoros	818	973455	254316	4	*	*	*
Porcina Modelo	28	Tamaulipas	32	Reynosa	828	981048	260054	8	*	*	*
Pozo Noria	19	Nuevo León	20	Gral. Bravo	91	983628	255705	5	*	*	*
Predio el Moquete (Javier Aguirre)	28	Tamaulipas	22	Matamoros	541	973354	253934	31	4.43	1	6
Presidente Cárdenas (Misael García)	28	Tamaulipas	22	Matamoros	1380	974720	255451	2	*	*	*
Presidente Cárdenas (Villa Cárdenas)	28	Tamaulipas	22	Matamoros	253	974758	255419	553	3.69	85	65
Primer Campo Pesquero	28	Tamaulipas	22	Matamoros	1506	970912	254904	493	2.85	1	169
Prisciliano Delgado	28	Tamaulipas	22	Matamoros	256	975426	255617	210	3.56	38	21
Prisciliano Delgado (Antonio Reyna)	28	Tamaulipas	22	Matamoros	1358	975309	255553	5	*	*	*
Prisciliano Delgado (Enrique Manzano)	28	Tamaulipas	33	Río Bravo	1243	975539	255630	4	*	*	*
Prisciliano Delgado (Francisco Rodríguez)	28	Tamaulipas	22	Matamoros	1368	975458	255612	8	2	1	3
Prisciliano Delgado (Gilberto Alonso)	28	Tamaulipas	22	Matamoros	1364	975423	255708	13	3.25	3	1
Prisciliano Delgado (Moisés Azuara)	28	Tamaulipas	22	Matamoros	1359	975345	255543	6	*	*	*
Progreso Agrario (Familia Peña Quintero)	28	Tamaulipas	22	Matamoros	1334	974516	255842	23	4.6	3	2
Progreso Agrario (Santa Librada)	28	Tamaulipas	22	Matamoros	258	974533	255803	469	3.42	63	74
Progreso Agrario (Santa Librada)	28	Tamaulipas	22	Matamoros	721	974512	255723	5	1.67	1	2
Providencia (Los Llanitos)	19	Nuevo León	20	Gral. Bravo	94	984803	255713	1	*	*	*
Puertas Verdes	28	Tamaulipas	33	Río Bravo	307	980105	260303	1	*	*	*
Puertecitos	28	Tamaulipas	7	Camargo	197	984318	261607	50	2.94	11	6
Puertecitos	28	Tamaulipas	7	Camargo	65	984437	261604	143	3.25	37	6
Purilimpia	28	Tamaulipas	15	Gustavo Díaz Ordaz	66	984323	260323	2	*	*	*
Quinta Campestre Miraflores	28	Tamaulipas	22	Matamoros	1922	973217	255426	2	*	*	*
Quinta la Cáscara Amarga	28	Tamaulipas	32	Reynosa	1077	982149	260826	5	*	*	*
Quinta Quezada	28	Tamaulipas	22	Matamoros	1249	973329	254450	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Quinta Victoria	28	Tamaulipas	32	Reynosa	1326	982019	260744	2	*	*	*
R.R. (Roberto Rodríguez)	28	Tamaulipas	22	Matamoros	1256	972822	254431	2	*	*	*
Ramírez	28	Tamaulipas	22	Matamoros	264	974713	255656	3743	3.77	705	282
Ramón Longoria	28	Tamaulipas	7	Camargo	199	984919	262051	15	5	3	0
Ramón Longoria	28	Tamaulipas	7	Camargo	320	984913	262106	1	*	*	*
Rancherías	28	Tamaulipas	32	Reynosa	203	982233	260125	3	*	*	*
Rancherías	28	Tamaulipas	7	Camargo	70	985356	262049	404	3.43	77	38
Rancherías (Catalina López)	28	Tamaulipas	7	Camargo	278	985324	262056	1	*	*	*
Rancho Blanco (Los Suárez)	28	Tamaulipas	15	Gustavo Díaz Ordaz	335	983448	261210	6	*	*	*
Rancho Canales	28	Tamaulipas	25	Miguel Alemán	170	990545	262321	2	*	*	*
Rancho de León	28	Tamaulipas	22	Matamoros	1037	971900	255047	2	*	*	*
Rancho de los Suárez	28	Tamaulipas	22	Matamoros	732	974610	260011	21	4.2	0	5
Rancho Grande (Potreritos)	28	Tamaulipas	32	Reynosa	1082	982043	260703	2	*	*	*
Rancho Nuevo	28	Tamaulipas	32	Reynosa	314	983237	255405	3	*	*	*
Rancho Nuevo (Esther Gaytán)	28	Tamaulipas	22	Matamoros	1497	971449	255225	9	*	*	*
Rancho Nuevo los Cavazos	28	Tamaulipas	22	Matamoros	844	975120	255800	9	3	1	2
Rancho Viejo	28	Tamaulipas	22	Matamoros	270	974616	260133	160	3.56	9	36
Rancho Viejo (Benito González)	28	Tamaulipas	22	Matamoros	1336	974721	255948	14	3.5	4	0
Rancho Viejo (Israel Carbajal)	28	Tamaulipas	22	Matamoros	1075	974650	260028	4	*	*	*
Raúl Sáenz	28	Tamaulipas	7	Camargo	331	984907	261840	3	*	*	*
Reforma (La Reforma)	28	Tamaulipas	7	Camargo	110	985232	262100	12	4	2	1
Reforma Sur (La Roca)	28	Tamaulipas	22	Matamoros	1385	974032	255409	5	1.67	3	0
Retamitas	19	Nuevo León	20	Gral. Bravo	104	984326	260156	2	*	*	*
Revolución	28	Tamaulipas	22	Matamoros	276	974419	255211	297	3.79	36	40
Revolución (Benigno Criado)	28	Tamaulipas	22	Matamoros	1004	974314	255018	6	*	*	*
Revolución (Braulio Longoria)	28	Tamaulipas	22	Matamoros	1002	974425	255057	8	2.67	0	3
Revolución (El Alto)	28	Tamaulipas	22	Matamoros	1772	974237	255125	84	4.5	5	13
Revolución (Modesto Cerda)	28	Tamaulipas	22	Matamoros	741	974510	255232	2	*	*	*
Revolución (Roberto Contreras)	28	Tamaulipas	22	Matamoros	743	974307	255131	8	*	*	*
Revolución (San Isidro)	28	Tamaulipas	22	Matamoros	1015	974338	255007	23	3.83	0	6
Revolución (Sergio Martínez)	28	Tamaulipas	22	Matamoros	1887	974531	255311	3	*	*	*
Revolución (Vicente Rodríguez)	28	Tamaulipas	22	Matamoros	1003	974315	255114	2	*	*	*
Reyes Alaffa	28	Tamaulipas	15	Gustavo Díaz Ordaz	127	984048	261249	6	*	*	*
Reynosa	28	Tamaulipas	32	Reynosa	1	981640	260532	589466	3.62	139526	5237
Reynosa Díaz	28	Tamaulipas	32	Reynosa	209	982721	261213	437	4.05	68	40
Reynosa Díaz	28	Tamaulipas	32	Reynosa	210	982738	260928	30	3.38	6	2
Reynosa Díaz	28	Tamaulipas	32	Reynosa	1050	982751	261031	300	3.72	71	8
Reynosa Díaz (Matiana Capetillo)	28	Tamaulipas	32	Reynosa	1054	982824	261003	1	*	*	*
Ricardo Chapa	28	Tamaulipas	22	Matamoros	1033	975122	255550	4	*	*	*
Rigo Garza	28	Tamaulipas	32	Reynosa	975	982644	261205	5	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Río Bravo	28	Tamaulipas	33	Río Bravo	562	980431	260044	8	*	*	*
Río Bravo	28	Tamaulipas	33	Río Bravo	1094	980424	260019	3	*	*	*
Río Bravo	28	Tamaulipas	33	Río Bravo	1097	980524	260003	9	*	*	*
Río Hondo (Los Lugo)	28	Tamaulipas	22	Matamoros	1073	974710	260105	1	*	*	*
Río Rico	28	Tamaulipas	22	Matamoros	278	975324	260325	267	3.99	24	43
Roberto F. García	28	Tamaulipas	22	Matamoros	1255	971851	255043	8	2.67	1	2
Roberto F. García (Guadalupe Rincón)	28	Tamaulipas	22	Matamoros	1490	971725	255039	4	*	*	*
Román Vázquez Nuncio	28	Tamaulipas	7	Camargo	336	984831	261804	3	*	*	*
Rubén Álvarez	28	Tamaulipas	7	Camargo	252	984932	262014	8	*	*	*
Rumualdo Barrera Silva	28	Tamaulipas	33	Río Bravo	1367	980707	255939	1	*	*	*
Sabino Cerda	28	Tamaulipas	15	Gustavo Díaz Ordaz	116	983543	260529	1	*	*	*
Sacramento	28	Tamaulipas	22	Matamoros	1562	973117	253630	1	*	*	*
Sainogasim (Rancho del General)	28	Tamaulipas	22	Matamoros	1258	973319	254502	4	*	*	*
San Agustín (Los Coyotes)	28	Tamaulipas	22	Matamoros	1162	972816	254536	6	*	*	*
San Alejandro	19	Nuevo León	20	Gral. Bravo	157	984511	260039	4	*	*	*
San Ambrosio	28	Tamaulipas	32	Reynosa	553	981011	260241	2	*	*	*
San Andrés	28	Tamaulipas	22	Matamoros	288	974421	255704	269	3.64	9	65
San Andrés	28	Tamaulipas	32	Reynosa	962	982953	261046	6	*	*	*
San Antonio	28	Tamaulipas	22	Matamoros	1195	975142	255923	7	*	*	*
San Antonio	28	Tamaulipas	32	Reynosa	722	982613	255544	6	*	*	*
San Antonio	28	Tamaulipas	33	Río Bravo	736	975714	260219	14	3.5	2	2
San Antonio	28	Tamaulipas	22	Matamoros	508	973411	254336	7	*	*	*
San Antonio	28	Tamaulipas	32	Reynosa	899	982032	260632	8	*	*	*
San Antonio (Cristo Jesús Rodríguez)	28	Tamaulipas	22	Matamoros	486	971749	254909	13	4.33	0	3
San Antonio (San Antonio de los Olmos)	28	Tamaulipas	33	Río Bravo	318	975733	260227	6	*	*	*
San Carlos	28	Tamaulipas	32	Reynosa	311	983451	255814	1	*	*	*
San Cosme (Santa Cecilia)	28	Tamaulipas	32	Reynosa	229	983019	255943	3	*	*	*
San Felipe	28	Tamaulipas	32	Reynosa	781	981210	260259	6	*	*	*
San Francisco	28	Tamaulipas	33	Río Bravo	322	975553	260250	32	3.2	2	8
San Francisco	28	Tamaulipas	22	Matamoros	730	972250	255013	1	*	*	*
San Francisco	28	Tamaulipas	22	Matamoros	301	972726	254423	1	*	*	*
San Francisco	28	Tamaulipas	33	Río Bravo	1107	980232	260158	10	*	*	*
San Francisco	28	Tamaulipas	7	Camargo	75	984218	261555	384	3.39	92	17
San Francisco	28	Tamaulipas	15	Gustavo Díaz Ordaz	426	983625	260534	2	*	*	*
San Francisco (Francisco Treviño)	28	Tamaulipas	22	Matamoros	1766	974729	255808	3	*	*	*
San Fructuoso (Erasmo García)	28	Tamaulipas	22	Matamoros	920	974123	255811	4	*	*	*
San Gerardo	28	Tamaulipas	22	Matamoros	1431	974121	254837	3	*	*	*
San Isidro	28	Tamaulipas	32	Reynosa	220	983022	260836	5	*	*	*
San Isidro	28	Tamaulipas	22	Matamoros	828	973420	254326	1	*	*	*
San Isidro	28	Tamaulipas	32	Reynosa	957	982759	260759	5	1.67	3	0

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
San Isidro	28	Tamaulipas	15	Gustavo Díaz Ordaz	400	984327	260433	3	*	*	*
San Isidro (La Bodega Blanca)	28	Tamaulipas	32	Reynosa	963	983022	260950	2	*	*	*
San Jacinto	28	Tamaulipas	32	Reynosa	285	983338	260055	6	*	*	*
San Jacinto Dos (San Jacinto)	28	Tamaulipas	32	Reynosa	486	983256	255910	3	*	*	*
San Joaquín (José Matilde Luna)	28	Tamaulipas	22	Matamoros	1761	974439	260046	2	*	*	*
San José	28	Tamaulipas	22	Matamoros	310	972133	253706	3	*	*	*
San José	28	Tamaulipas	7	Camargo	94	985338	261328	3	*	*	*
San José	28	Tamaulipas	15	Gustavo Díaz Ordaz	13	984246	260301	24	2.18	3	7
San José (Clemente Zúñiga)	28	Tamaulipas	33	Río Bravo	730	975733	255652	4	*	*	*
San José (Los Treviño)	28	Tamaulipas	33	Río Bravo	1063	980036	260318	1	*	*	*
San José (Luis Cárdenas Cavazos)	28	Tamaulipas	22	Matamoros	1260	973325	255021	3	*	*	*
San José de los Martínez	19	Nuevo León	20	Gral. Bravo	112	983659	255634	3	*	*	*
San José del Caracol	28	Tamaulipas	22	Matamoros	1617	972857	253456	5	*	*	*
San Juan	28	Tamaulipas	22	Matamoros	312	972255	254949	53	4.42	7	5
San Juan	28	Tamaulipas	22	Matamoros	1062	974528	260117	1	*	*	*
San Juan	28	Tamaulipas	32	Reynosa	724	983108	255932	3	*	*	*
San Juan	28	Tamaulipas	22	Matamoros	511	973903	254454	3	*	*	*
San Juan de los Lagos	28	Tamaulipas	22	Matamoros	1036	975231	255520	1	*	*	*
San Juan del Río	28	Tamaulipas	33	Río Bravo	1080	980643	260252	2	*	*	*
San Juan del Sauz	28	Tamaulipas	22	Matamoros	316	972340	254415	1	*	*	*
San Juanito	28	Tamaulipas	22	Matamoros	95	973429	254348	3	*	*	*
San Juanito	28	Tamaulipas	33	Río Bravo	328	975906	260302	11	2.2	3	2
San Lorenzo	28	Tamaulipas	22	Matamoros	318	973404	253904	174	3.75	9	35
San Lorenzo (Francisca Arriaga Ruvalcaba)	28	Tamaulipas	22	Matamoros	1564	973321	253916	1	*	*	*
San Luisito	28	Tamaulipas	33	Río Bravo	1072	980030	255901	6	*	*	*
San Luisito	28	Tamaulipas	22	Matamoros	320	973932	260007	266	3.55	16	58
San Luisito (Hermenegildo Sáenz)	28	Tamaulipas	22	Matamoros	1319	974038	255817	1	*	*	*
San Manuel	19	Nuevo León	20	Gral. Bravo	164	984610	255629	3	*	*	*
San Manuel	28	Tamaulipas	32	Reynosa	805	981103	260308	1	*	*	*
San Manuel	28	Tamaulipas	7	Camargo	117	985139	261630	5	*	*	*
San Marcos	28	Tamaulipas	22	Matamoros	321	974213	255118	7	*	*	*
San Martín	28	Tamaulipas	32	Reynosa	276	982117	260658	7	*	*	*
San Martín	28	Tamaulipas	7	Camargo	170	984837	262009	7	*	*	*
San Matías	28	Tamaulipas	22	Matamoros	451	974412	255742	2	*	*	*
San Matías	28	Tamaulipas	15	Gustavo Díaz Ordaz	48	984106	260341	1	*	*	*
San Nicolás	28	Tamaulipas	22	Matamoros	1274	973509	255546	1	*	*	*
San Pablo	28	Tamaulipas	32	Reynosa	1098	982541	260510	1	*	*	*
San Pedro	28	Tamaulipas	22	Matamoros	1067	974448	255901	6	*	*	*
San Pedro	28	Tamaulipas	22	Matamoros	879	973321	254444	6	*	*	*
San Pedro (Sección Catorce)	28	Tamaulipas	22	Matamoros	328	972730	254553	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
San Rafael	28	Tamaulipas	22	Matamoros	331	973250	253820	5	*	*	*
San Rafael	28	Tamaulipas	40	Valle Hermoso	377	975425	260316	9	*	*	*
San Rafael de Buenos Aires	28	Tamaulipas	22	Matamoros	78	974114	255805	2	*	*	*
San Ramón (Mario Salinas)	28	Tamaulipas	32	Reynosa	1053	982837	261108	3	*	*	*
San Vicente	28	Tamaulipas	22	Matamoros	526	971703	254917	13	*	*	*
San Vicente	28	Tamaulipas	22	Matamoros	752	975319	255717	2	*	*	*
San Vicente	28	Tamaulipas	22	Matamoros	759	971639	254844	3	*	*	*
San Vicente (Álvaro Cárdenas)	28	Tamaulipas	22	Matamoros	1467	974450	255046	2	*	*	*
San Vicente (Sergio Larrasquitu)	28	Tamaulipas	22	Matamoros	1794	971727	254941	2	*	*	*
an Vicente del Potrero (Bertha Dávila Lópe	28	Tamaulipas	15	Gustavo Díaz Ordaz	415	983704	261305	4	1.33	2	1
Sandoval (Daniel Pizaña)	28	Tamaulipas	22	Matamoros	1406	973820	255247	14	2.8	1	4
Sandoval (Ernesto Gutiérrez)	28	Tamaulipas	22	Matamoros	1774	973905	255137	8	*	*	*
Sandoval (Gumaro Sánchez)	28	Tamaulipas	22	Matamoros	1405	973839	255309	4	*	*	*
Sandoval (Juan Antonio Banda)	28	Tamaulipas	22	Matamoros	760	973952	255229	1	*	*	*
Sandoval (Los Soto)	28	Tamaulipas	22	Matamoros	1888	973941	255309	5	*	*	*
Santa Adelaida	28	Tamaulipas	22	Matamoros	337	973905	255119	1754	3.66	244	173
Santa Adelaida (Guadalupe Olivares)	28	Tamaulipas	22	Matamoros	1407	973800	255118	23	4.6	3	2
Santa Adelaida (Hermenegildo de la Cruz)	28	Tamaulipas	22	Matamoros	1414	973936	255112	11	3.67	3	0
Santa Adelaida (Las Esquinas)	28	Tamaulipas	22	Matamoros	338	973740	255119	42	3.23	7	6
Santa Amalia	28	Tamaulipas	15	Gustavo Díaz Ordaz	334	983652	261017	7	*	*	*
Santa Ana	28	Tamaulipas	33	Río Bravo	336	980914	260236	35	3.89	5	4
Santa Ana (El Gato)	19	Nuevo León	20	Gral. Bravo	120	983636	255239	11	1.83	1	5
Santa Ana (Petroleros)	28	Tamaulipas	32	Reynosa	554	981005	260324	4	*	*	*
Santa Anita	28	Tamaulipas	32	Reynosa	807	981056	260232	6	*	*	*
Santa Anita (Elba Herrera)	28	Tamaulipas	32	Reynosa	1257	981948	260131	9	*	*	*
Santa Bárbara	28	Tamaulipas	32	Reynosa	725	982504	255520	3	*	*	*
Santa Cecilia	28	Tamaulipas	22	Matamoros	422	974347	255005	9	*	*	*
Santa Cruz	28	Tamaulipas	7	Camargo	80	984902	262039	7	2.33	3	0
Santa Eduviges	28	Tamaulipas	22	Matamoros	1536	974155	254751	3	*	*	*
Santa Elena	28	Tamaulipas	22	Matamoros	341	974546	255958	4	*	*	*
Santa Fe	28	Tamaulipas	22	Matamoros	412	971924	255516	6	*	*	*
Santa Fe	28	Tamaulipas	32	Reynosa	1338	982326	260125	476	3.48	130	0
Santa Gertrudis	28	Tamaulipas	22	Matamoros	1535	974041	254628	3	*	*	*
Santa Gertrudis	28	Tamaulipas	7	Camargo	469	984414	260838	54	2.43	12	9
Santa Herminia	28	Tamaulipas	32	Reynosa	1044	983048	260737	14	4.67	0	3
Santa Herminia	28	Tamaulipas	32	Reynosa	235	983024	260741	36	4	9	0
Santa Irene	28	Tamaulipas	22	Matamoros	347	973825	255311	142	3.16	7	37
Santa Irene (José Ángel Zamorano)	28	Tamaulipas	22	Matamoros	1290	973738	255225	10	*	*	*
Santa Irene (Leónides Zamorano)	28	Tamaulipas	22	Matamoros	765	973820	255206	3	*	*	*
Santa Juana	28	Tamaulipas	22	Matamoros	350	973346	254514	1	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Santa Librada	19	Nuevo León	20	Gral. Bravo	210	983630	254751	1	*	*	*
Santa Lucía	28	Tamaulipas	32	Reynosa	588	983331	260447	2	*	*	*
Santa Lucía	28	Tamaulipas	22	Matamoros	1123	973336	254400	5	*	*	*
Santa Luisa	28	Tamaulipas	22	Matamoros	958	972840	253442	1	*	*	*
Santa María (Gilberto Garza)	28	Tamaulipas	33	Río Bravo	1069	980754	260139	3	*	*	*
Santa Maty (Fructuoso García Longoria)	28	Tamaulipas	22	Matamoros	1065	974204	255946	6	*	*	*
Santa Mónica	28	Tamaulipas	22	Matamoros	823	973438	254219	5	*	*	*
Santa Rita	19	Nuevo León	20	Gral. Bravo	348	983621	255448	3	*	*	*
Santa Rita	28	Tamaulipas	22	Matamoros	437	973358	254033	5	*	*	*
Santa Rita de la Noria	28	Tamaulipas	32	Reynosa	996	982507	255857	3	*	*	*
Santa Rosa	28	Tamaulipas	22	Matamoros	360	975056	255742	12	2.4	5	0
Santa Rosa	28	Tamaulipas	22	Matamoros	769	972208	255008	11	3.67	2	1
Santa Rosa	28	Tamaulipas	32	Reynosa	242	982943	260024	44	3.67	6	6
Santa Rosa	28	Tamaulipas	25	Miguel Alemán	168	990523	262303	4	*	*	*
Santa Rosalía	28	Tamaulipas	7	Camargo	82	985716	260539	229	3.1	62	9
Santa Silvia	28	Tamaulipas	22	Matamoros	1437	974732	255246	4	*	*	*
Santa Silvia	28	Tamaulipas	32	Reynosa	1346	981040	260243	1	*	*	*
Santa Teresa	28	Tamaulipas	32	Reynosa	1293	980918	260052	1	*	*	*
Santa Teresa de Jesús (El Amole)	19	Nuevo León	20	Gral. Bravo	126	984603	260037	8	2.67	0	3
Santo Domingo	28	Tamaulipas	22	Matamoros	365	971945	255424	6	*	*	*
Santo Domingo	28	Tamaulipas	33	Río Bravo	347	980149	260238	145	3.92	24	13
Santo Domingo (La Loma)	28	Tamaulipas	7	Camargo	198	985227	262029	6	*	*	*
Santo Domingo (Rancho de Chema)	28	Tamaulipas	33	Río Bravo	1339	980123	260257	2	*	*	*
Santo Niño	28	Tamaulipas	32	Reynosa	247	983022	260736	449	3.74	97	22
Santo Niño (David Ramírez Arredondo)	28	Tamaulipas	32	Reynosa	1307	982925	260723	6	*	*	*
Seis de Enero	28	Tamaulipas	33	Río Bravo	349	980153	255942	404	3.51	68	46
Sergio Saldaña	19	Nuevo León	20	Gral. Bravo	403	984804	255443	5	*	*	*
Siete Hermanos	28	Tamaulipas	32	Reynosa	1040	983207	260617	1	*	*	*
Soledad	28	Tamaulipas	22	Matamoros	772	973647	255722	31	5.17	1	5
Soliseño	28	Tamaulipas	22	Matamoros	377	974829	260124	279	3.33	51	32
Tacuba	28	Tamaulipas	32	Reynosa	252	982449	255737	3	*	*	*
Tanque Alegre (Isabel Treviño)	28	Tamaulipas	22	Matamoros	1178	974236	255118	1	*	*	*
Tenacitas (Familia Ramírez Cavazos)	28	Tamaulipas	33	Río Bravo	1071	980130	255943	6	*	*	*
Tepehuaje	28	Tamaulipas	22	Matamoros	1790	972022	255522	3	*	*	*
Tepehuaje	28	Tamaulipas	7	Camargo	84	984153	261508	129	3.67	26	6
Tepehuaje	28	Tamaulipas	15	Gustavo Díaz Ordaz	179	983811	261019	47	3.92	10	2
Tepehuaje	28	Tamaulipas	15	Gustavo Díaz Ordaz	15	983852	261027	19	3.17	3	3
Teresa de Mier	19	Nuevo León	20	Gral. Bravo	153	984721	260209	11	1.83	1	4
Timones (Elva Bazaldúas)	28	Tamaulipas	22	Matamoros	777	974118	255619	1	*	*	*
Timones (Los Ángeles)	28	Tamaulipas	22	Matamoros	1885	974102	255705	22	*	*	*

*Latitude and Longitude in North_America_Lambert_Conformal_Conic - Datum ITRF_1992

Name of Locality	State Code	State	Mun. Code	Mun.	Loc. Code	Long.	Lat.	Pop.	Average Residents per Household	Households with Drainage	Households Without Drainage
Todos Santos	28	Tamaulipas	15	Gustavo Díaz Ordaz	46	984227	260347	14	2.8	0	5
Tres Hermanos	28	Tamaulipas	33	Río Bravo	1364	975651	260231	5	*	*	*
Tres Hermanos	28	Tamaulipas	22	Matamoros	956	972847	253427	1	*	*	*
Tres Palmas	28	Tamaulipas	33	Río Bravo	590	980011	260106	1	*	*	*
Treviño	28	Tamaulipas	7	Camargo	290	985637	262117	7	*	*	*
Trinidad Alonso	28	Tamaulipas	33	Río Bravo	738	975806	255657	4	*	*	*
Unidad Habitacional 23 de Noviembre	28	Tamaulipas	22	Matamoros	645	973320	254427	362	3.89	86	0
Úrsulo Galván (Salvador Reyes)	28	Tamaulipas	22	Matamoros	1438	974649	255155	3	*	*	*
Valadeces	28	Tamaulipas	15	Gustavo Díaz Ordaz	353	984029	261019	107	3.15	22	10
Valadeces	28	Tamaulipas	15	Gustavo Díaz Ordaz	16	984023	261401	2009	3.33	499	93
Valadeces	28	Tamaulipas	15	Gustavo Díaz Ordaz	17	983925	261041	2	*	*	*
Veintiuno de Marzo (Las Cuatrocientas)	28	Tamaulipas	22	Matamoros	426	973941	254807	33	3.3	0	10
Venecia	28	Tamaulipas	32	Reynosa	1045	983216	261226	20	4	4	1
Venecia	28	Tamaulipas	15	Gustavo Díaz Ordaz	18	983305	261221	477	3.46	68	70
Veracruz y Progreso	28	Tamaulipas	33	Río Bravo	361	975840	260215	281	4.32	14	50
Villa Hermosa	28	Tamaulipas	22	Matamoros	460	974301	255851	22	3.67	5	1
Villanueva	28	Tamaulipas	22	Matamoros	401	974118	260033	104	3.47	13	17
Villaverde	28	Tamaulipas	22	Matamoros	403	972221	254505	4	*	*	*
Villaverde	28	Tamaulipas	22	Matamoros	402	973701	255739	186	4.07	11	34
Virgen de Guadalupe	28	Tamaulipas	32	Reynosa	1021	982518	260510	4	*	*	*
Virgilio Torres	28	Tamaulipas	22	Matamoros	1886	974824	255506	5	*	*	*
Virginia	28	Tamaulipas	33	Río Bravo	725	975827	255703	6	*	*	*
Vista Hermosa (Paulino Sánchez)	28	Tamaulipas	22	Matamoros	1379	975055	255451	1	*	*	*
Xochipilli	28	Tamaulipas	32	Reynosa	1324	982132	260909	5	*	*	*
Zaragoza	28	Tamaulipas	15	Gustavo Díaz Ordaz	56	983519	260838	10	*	*	*
Zona Residencial	28	Tamaulipas	22	Matamoros	1504	970902	255043	66	3	2	20

Glossary

ArcHydro: An add-in for ArcGIS that is specifically designed for graphical analysis of water data

ArcGIS: a software that allows for analysis with GIS data

Colonia: a housing development on the U.S. border that lacks adequate infrastructure, not to be confused with the Spanish word *colonia*, which means “neighborhood”

Digital Elevation Model: a dataset collected from satellites that measures the elevation across the globe

E-coli: a bacteria that is generally association with a fecal source, either from human or animal defecation

Fecal coliform: a bacteria that is generally associated with an a fecal source, either from human or animal defecation

Fecal coliform colonies: a way of measuring the quantity of fecal coliform

First Order Decay rate: the rate at which bacteria decays, assuming that the decay occurs at an exponential rate

Geometric mean: a mean taken by multiplying a series of n numbers by each other than then taking the n^{th} root of the product

GIS: geographic information system

Low-flow conditions: the conditions in a river in which it has the lowest volume of water flowing through it

LULC: land use/ land cover, a map that categorizes the type of use or vegetation each parcel of land has

Non-point source pollution: the pollution that cannot be attributed to a single source, but is the collection of many smaller sources that are not easily traceable

QUAL-TX: a steady-state water quality model developed for the Texas Commission on Environmental Quality

Reach: a term in a QUAL-TX water quality model that signifies a small stretch of the river that shares similar hydraulic characteristics

Steady-state model: a water quality model that only considers the inputs that enter the river on a constant basis, not considering storm-water runoff

Total Maximum Daily Load: an analysis of the total pollutant load entering into a river that is required by the Clean Water Act

Watershed: the entire area of land in which water drains to a certain point

Bibliography

Anaya, Gilbert, telephone conversation with the author, October 13, 2011.

Border Environment Cooperation Commission. “BECC and NADB: Successful Bi-National Cooperation, Border Environment Cooperation Commission.” http://www.becc.org/english/GInformation/Index.html.

Bowie, George L., William B. Mils, Donald B. Porcella, Carrie L. Campbell, James R. Pagenkopf, Gretchen L. Rupp, Kay M. Johnson, Peter W.H. Chan, and Steven A. Gherini. *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling, 2nd ed*. Athens, GA: U.S. Environmental Protection Agency, 1985.

Chief Engineer’s Office, Water Programs, TMDL Section. *One Total Maximum Daily Load for Bacteria in the Guadalupe River Above Canyon Lake*. Austin, TX: Texas Commission on Environmental Quality, 2007.

City of Los Angeles Bureau of Engineering. *Part F Sewer Design*. Los Angeles, CA: City of Los Angeles Bureau of Engineering, 1992. http://eng.lacity.org/techdocs/sewer-ma/f200.pdf.

Comisión Nacional del Agua. *Manual de Agua Potable, Alcantarillado y Saneamiento: Datos Básicos*. Coyocán, D.F.: Comissión Nacional del Agua, 2007.

Instituto Nacional de Estadística y Geografía and United States Geological Survey, e-mail message from Kimberly Jones to author, unpublished GIS Shapfile, October 31, 2011.

Instituto Nacional de Estadística y Geografía, “Áreas Geoestadísticas Municipales,” Marco Geoestadístico Municipal 2009 Versión 4.1,” GIS Shapefile, http://mapserver.inegi.org.mx/data/mgm/.

Instituto Nacional de Estadística y Geografía, “Existencias de animales de otras especies por entidad: Ganadero y Forestal 2007: Censo Agrícola,” Aguascalientes, Aguascalientes, 2007, Excel Spreadsheet, http://www.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=17177&s=est.

Instituto Nacional de Estadística y Geografía, “Existencias de ganado bovino según rango de edad por entidad y municipio: Ganadero y Forestal 2007: Censo Agrícola,” Aguascalientes, Aguascalientes, 2007, http://www.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=17177&s=est.

Instituto Nacional de Estadística y Geografía, “Ocupantes de viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo, Censo de Población y Vivienda

2010," Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est.

Instituto Nacional de Estadística y Geografía, "Principales Resultados por localidad (ITER): Censo de Población y Vivienda," Aguascalientes, Aguascalientes, 2010, Excel Spreasheet, http://www.inegi.org.mx/sistemas/consulta_resultados/iter2010.aspx?c=27329&s=est.

Instituto Nacional de Estadística y Geografía, "Productos y Servicios: Datos vectoriales escala 1:1000000 –descarga," Shapefile, http://mapserver.inegi.org.mx/data/inf_e1m/redirect.cfm?fileX=canal.

Instituto Nacional de Estadística y Geografía, "Viviendas particulares habitadas por municipio, disponibilidad de energía eléctrica y agua según disponibilidad de drenaje y lugar de desalojo, Censo de Población y Vivienda 2010." Aguascalientes, Aguascalientes, 2010, Excel Spreadsheet, http://www3.inegi.org.mx/sistemas/TabuladosBasicos/Default.aspx?c=27302&s=est.

Instituto Nacional de Estadística y Geografía, Polígonos de Localidades Urbanas Geoestadísticas", INEGI, Aguascalientes, Aguascalientes, 2010, GIS Shapefile http://mapserver.inegi.org.mx/data/mgm/redirect.cfm?fileX=LOCURBANAS50.

International Boundary and Water Commission. *Bacteria Characterization in Segment 2302_01 of the Rio Grande near Brownsville, Texas: A Texas Clean Rivers Program Special Study*. El Paso, TX: International Boundary and Water Commission, 2011. *http://www.ibwc.gov/CRP/documents/BrownsvilleBacteriaSpecialStudyFINALREPORTJune2011.pdf.*

James Miertschin & Associates, Inc. *Final Modeling Report for Fecal Coliform TMDL (Total Maximum Daily Load) Development for Leon River Below Proctor Lake, Segment 1221: Project Area 2 – Baisn Groups D & E Bacteria Impairments Work Order #5*. Austin, TX: Texas Commission on Environmental Quality, 2006.

Johnson, Stephanie Lynn. "A General Method for Modeling Coastal Water Pollutant Loadings," PhD diss., The University of Texas at Austin, 2009.

Jones, Kimberly, e-mail message to author, October 31, 2011.

National Agricultural Statistics Service. *Texas Agricultural Statistics 2009*. Austin, TX: United States Department of Agriculture, 2010. http://www.nass.usda.gov/Statistics_by_State/Texas/Publications/Annual_Statistical_Bulletin/bull2009.pdf.

National Council of Examiners for Engineering and Surveying, *Fundamentals of Engineering Supplied-Reference Handbook*. Clemson, SC: Council of Examiners for Engineering and Surveying, 2005.

National Oceanic and Atmospheric Administration Coastal Services Center. *LIDAR 101: An Introduction to LiDAR Technology, Data and Applications*. Charleston, SC: NOAA Coastal Services Center, 2008.

Parcher, Jean. "U.S.-Mexico Border Geographic Information System: Fact Sheet 2008-3069." United States Geological Survey. 2008. http://pubs.usgs.gov/fs/2008/3069/.

Reed, Stowe & Yanke, LLC. "Study to Conduct Further Research Regarding the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in South Texas." Austin, TX: Texas On-Site Wastewater Treatment Research Council, 2002.

Smith, Elizabeth H. "*Redheads and Other Wintering Waterfowl*," in *The Laguna Madre of Texas and Tamaulipas*, edited by John W. Tunnell Jr. and Frank W. Judd, 169-181. College Station, TX: Texas A&M University Press, 2002.

State of Texas. *Administrative Code Title 30 Part 1 Chapter 307 Rule §307.7*. Austin, TX: State of Texas, 2010. http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=307&rl=7.

Tarboton, David. "Watershed and Stream Network Delineation: GIS in Water Resources, Fall 2011: Dr. Maidment's Classes." http://www.ce.utexas.edu/prof/Maidment/giswr2011/Ex4/Ex42011.pdf.

Texas A&M Institute of Renewable Natural Resources. *Feral Hog Statewide Population Growth and Density*. College Station, TX: Texas A&M University Agrilife Research Extension, 2011. http://feralhogs.tamu.edu/files/2011/05/FeralHogFactSheet.pdf,

Texas Commission on Environmental Quality, internal map, digitized by the author, June 03, 2011.

Texas Commission on Environmental Quality, Unpublished QUALTX Input File, Data Type 9 (Advective Hydraulic Coefficients), Received by author, June 2011.

Texas Comptroller of Public Affairs. *Bordering the Future*: *Challenge and Opportunity in the Texas Border Region*. Austin, TX: Texas Comptroller of Public Affairs. 1998. http://www.window.state.tx.us/taxinfo/taxforms/96-599/contents.pdf.

Texas Parks and Wildlife Department. 2010 Texas Parks and Wildlife Department Big Game Federal Aid Report. Austin, TX: Texas Parks and Wildlife Department, 2011, e-mail message from Eric Garza to author, November 16, 2011.

Texas Secretary of State. “Colonia Initiatives Program.” http://www.sos.state.tx.us/border/colonias/what_colonia.shtml.

Tunnell, Jown W., Jr, “Geography, Climate, and Hydrography*,”* in *The Laguna Madre of Texas and Tamaulipas*, edited by John W. Tunnell Jr. and Frank W. Judd, 7-27. College Station, TX: Texas A&M University Press, 2002.

United State Geological Survey, “Land Use/ Land Cover: Binational 2001: U.S.-Mexico Border Environmental Health Initiative – Available Data Layers,” Raster file, http://borderhealth.cr.usgs.gov/datalayers.html.

United States Census Bureau,“2010 TIGER/Line® Shapefiles,” GIS Shapefile, http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html

United States Department of Agriculture. *of Agriculture, Volume 1, Chapter 2: County Level Data*. Washington, DC: United States Department of Agriculture, 2008. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/st48_2_015_015.pdf.

United States Environmental Protection Agency, “Bacteria Indicator Tool,” 2001, Excel Spreadsheet. http://water.epa.gov/scitech/datait/models/basins/bs3tbit.cfm.

United States Environmental Protection Agency. Impaired Waters and Total Maximum Daily Loads. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/.

United States Fish and Wildlife Service. *Wetland Preservation Program Category 8 Texas Gulf Coast*. Albuqurque, NM: United States Fish and Wildlife Service, 1981.

United States Geological Survey, “Seamless Server Viewer: The National Map.” DEM raster file. http://seamless.usgs.gov/website/seamless/viewer.htm.

United States Geological Survey, e-mail message from Tony Litschewski to author, Unpublished GIS Shapefile, June 2011.

United States Geological Survey. , “Colonias: Texas Geodatabase, U.S.-Mexico Border Environmental Health Initiative – Available Data Layers,” Geodatabase, http://txpub.usgs.gov/BEHI/Data_download/Places%20Layers/Colonias.zip.

United States Geological Survey. “National Hydrography Dataset: The National Map.” Shapefile. http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd.

United States Government Printing Office, *Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande: Treaty Between the United States of America and Mexico*. Washington D.C.: GPO, 1946.

Ward, George H., Jr. and Benaman, Jennifer. *Models for TMDL Application in Texas Watercourses*. Austin, TX: Texas Natural Resource Conservation Commission, 1999. http://www.crwr.utexas.edu/reports/pdf/1999/rpt99-7.pdf.

Weiskel, Peter K., Brian L. Howes, and George R. Heufelder. “Coliform Contamination of a Coastal Embayment: Source and Transport Pathways,” Environmental Science & Technology, 1996, 30 (6), 1872-1881.

Wu, Shuo-Sheng, Wang, Le, and Qiu, Xiaomin. “Incorporating GIS Building Data and Census Housing Statistics for Sub-Block-Level Population Estimation.” *The Professional Geographer* 60, no.1 (2008):121-135. http://www.acsu.buffalo.edu/~lewang/pdf/lewang_sample17.pdf.