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Data Collection for Cooperative Water Resources Modeling in the Lower Rio Grande Basin, Fort Quitman to the Gulf of Mexico

Howard Passell, Vincent C. Tidwell, Jim Brainard, Martha Ennis, Javier Aparicio, Alberto Guitron, Rene Lovato, Juan Valdes, Aleix Serrat-Capdevila, Ari M. Michelsen, Zhuping Sheng, Wendy Morrison, Thomas Gerik, Giovanni Piccinni, Joshua Villalobos, Gretchen Newman, Kiran Pallachula, Jim Emery

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Abstract

Water resource scarcity around the world is driving the need for the development of simulation models that can assist in water resources management. Transboundary water resources are receiving special attention because of the potential for conflict over scarce shared water resources. The Rio Grande/Rio Bravo along the U.S./Mexican border is an example of a scarce, transboundary water resource over which conflict has already begun. The data collection and modeling effort described in this report aims at developoing methods for international collaboration, data collection, data integration and modeling for simulating geographically large and diverse international watersheds, with a special focus on the Rio Grande/Rio Bravo. This report describes the basin, and the data collected. This data collection effort was spatially aggregated across five reaches consisting of Fort Quitman to Presidio, the Rio Conchos, Presidio to Amistad Dam, Amistad Dam to Falcon Dam, and Falcon Dam to the Gulf of Mexico. This report represents a nine-month effort made in FY04, during which time the model was not completed.

Key words: modeling, Lower Rio Grande River, Rio Bravo

Acknowledgements

The authors gratefully acknowledge and thank the many contributors to this project. In addition to data and information provided by the many partners, other data and information were provided by or obtained from the Texas Commission for Environmental Quality (TCEQ), International Boundary Water Commission (IBWC), Texas Parks and Wildlife Department (TPWD), National Agricultural Statistics Service (NASS), Texas A&M University (TAMU), Texas Rio Grande Watermaster Office, the Texas Dept. of Commerce, and United States Geological Survey (USGS), all in the U.S.A. In the United States of Mexico, data were obtained from the Secretaria de Economia, the Secretaria de Industria y Comercio, and the Instituto Nacional de Estadistica Geographia y Informatica (INEGI).

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Acronym List

af	acre-feet
°C	degrees Celsius
CILA	Comision Internacional de Limites y Aguas
CMT	cooperative modeling team
EDAC	Earth Data Analysis Center (EDAC)
ET	evapotranspiration
in	inches
MRGCD	Middle Rio Grande Conservancy District
m	meter
mg	milligrams
MJ/m^2da	millijouls per meter squared per day
ppm	parts per million
RGC	Rio Grande Compact
sec	second
SNL	Sandia National Laboratories
TDS	total dissolved solids
USBR	U.S. Bureau of Reclamation
USGS	U. S. Geological Survey
yr	year

1.0 Introduction

Water resource scarcity around the world is driving the need for the development of simulation models that can assist in water resources management. Transboundary water resources are receiving special attention because of the potential for conflict over scarce shared water resources. The Rio Grande/Rio Bravo along the U.S./Mexican border is an example of an increasingly scarce, transboundary water resource over which conflict has already begun. The data collection effort described in this report is an effort to develop methods for international collaboration, data collection, data integration and modeling for simulating geographically large and diverse international watersheds, with a special focus on the Rio Grande/Rio Bravo. The effort described here is somewhat unique on account of the international transboundary collaboration that engages partners from both sides of the border.

The project described here represents a collaboration between Sandia National Laboratories, the Instituto Mexicano de Tecnologia del Agua, the University of Arizona, and Texas A&M University. This report describes an unfinished effort to collect data and model the lower Rio Grande/Rio Bravo.

The Rio Grande River, or Rio Bravo as it is called in Mexico, is the 24th longest river in the world. Its drainage basin is the 6th largest in the US, an area of about 335,000 square miles, or approximately 11% of the continental United States. It is also one of the most important international waterways in the US, forming the whole of the international border between Texas and Mexico. The river is almost 1900 mi. long from its headwaters in southern Colorado, in the San Juan Mountains, to its mouth in the Gulf of Mexico (Patrick 2003).

The drainage basin dates from the Late Cretaceous Period. A number of geological events and processes – earthquakes, mountain building, volcanoes, sedimentation, and erosion – have given it the form it has today. The climate of the watershed is temperate in the high mountain ranges near the headwaters of the river, semi-arid from northern New Mexico to Belen, in the center of the state, and arid through the rest of the drainage basin. In the high mountain areas, annual precipitation may average as much as 25 in., although it ranges from 7 in. to 15 in. for most of the rest of the basin.

From 30-75% of the annual precipitation in the northern parts of the drainage basin comes from snowfall, but it comprises less than 25% in other areas. Summer monsoon precipitation, in the form of convective storms, provides over 50% of annual precipitation in these lower regions of the basin, and is a significant factor throughout (2). Natural inflow to the river and its tributaries comes from snowmelt in the higher elevations and from springs, monsoonal and seasonal rains, and tropical storms throughout the reach of the watershed.

The area of interest for this model is defined as the Lower Rio Grande and is the stretch of river bordering Texas from Fort Quitman, which is approximately 80 miles southeast of El Paso extending to the Gulf of Mexico near Brownsville, Texas and Matamoros, Mexico. Four states of Mexico from west to east that border this region are Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas (Figure 1).

There are two large dams within the study area of the Lower Rio Grande. Just north of Del Rio, Texas, is the Amistad Dam (completed 1969), and below Laredo and Zapata is the Falcon Dam (completed 1954).

Figure 1. Mexican states bordering the Rio Grande River. (modified from http://mrgbi.fws.gov/Resources/Dams/).

Near the mouth of the Rio Grande is the irrigation-dependent citrus-fruit and truck-farm region commonly called the Rio Grande Valley and developed principally in the 1920s.

This project has divided the Lower Rio Grande River into four reaches for modeling purposes (Figure 2). Below is a description of the four reaches:

- Reach 1 begins at Fort Quitman and ends just past the town of Presidio, Texas/Ojinaga, Mexico. There is one major tributary, the Rio Conchos, entering from Mexico which provides approximately 69-85% of the water in the Rio Grande from Presidio to the Gulf of Mexico (http://www.nps.gov/bibe/riogrand.html). Reach 1 is sparsely populated. The 2000 population of Presidio, Texas was 4167 and the 2000 population of Ojinaga, Mexico was 24,875.

- Reach 2 runs from just past Presidio to the Amistad Dam near Del Rio, Texas. Although Del Rio is just downstream of the dam, it is included in Reach 2 calculations. Inflows from the Amistad Dam just above Del Rio are included, but not outflows. The Pecos River and the Devil's River are the main tributaries in this Reach, both entering the Rio Grande from Texas. It is the most sparsely habited of the four reaches.

- Reach 3 begins at Amistad Dam and extends to Falcon Dam. River flows include outflows from the Amistad Dam and inflows up to the Falcon Reservoir. Reach 3 has the second highest population of the four reaches, behind reach 4.

- Reach 4 begins just past the Falcon Dam and ends at the mouth of the Rio Grande River at the Gulf of Mexico, at Brownsville, Texas/Matamoros, Mexico. Flows in this reach of the river include outflows from the Falcon Dam. This is the most heavily populated reach.

This project was funded by SNL Laboratory Directed Research and Development Program for FY 04. Data collection and basic modeling were completed in FY04, but Version 1 of the model was not completed. Tasks remaining include calibration of the model and development of an interface.

Figure 2. The Lower Rio Grande River with study Reaches 1, 2, 3 and 4.

Control of Water

Beginning in June 1971 the Texas Water Rights Commission, later called the Texas Natural Resource Conservation Commission (TNRCC) in 2001 and then the Texas Commission of Environmental Quality (TCEQ) in 2004, assumed control of the US portion of the water in Falcon Reservoir and in the Rio Grande below Falcon Dam. The disposition of waters are made by the Rio Grande Watermaster. Between that time and 1956, such waters had been under the jurisdiction of the 93rd District Court of Texas administered by its Special Watermaster.

2.0 Methods

2.1 Collaborative Transboundary Project Development

Engaging experts from both sides of the Rio Grande was a critical component in the project. A collaboration evolved between the Instituto Mexicano de Tecnologia del Agua (the technical water agency of the Mexican federal government), the University of Arizona, Texas A&M University, and Sandia National Labs. The Universidad Autonoma de Ciudad Juarez has also been peripherally involved and may increase its involvement in the future. Meetings between the partner institutions named above took place to help identify the spatial and temporal scales most appropriate for the modeling effort.

2.2 Model Architecture

The Lower Rio Grande (LRG) model is being built in Studio Expert 2001, an application produced by Powersim, Inc. Accompanying the model is a user interface which uses virtual slider bars and buttons for prescribing model input and viewing simulation results. The slider bars and buttons allow easily simulate various combinations of hydrological, economic, or demographic conditions, and then run the model and view output immediately. This allows users in private or public settings to experiment with competing management strategies and evaluate the comparative strengths and weaknesses of each. The interface includes specific explanations of the issues and attributes of each of the topic areas as well as definitions as to what each user-defined slider bar does.

2.3 Data Sharing Website

The AguaNet website (http://philostrate.unm.edu/cgi-bin/AguaNet/aguanet_homepage.php) was created in a collaborative effort between the partner institutions as a virtual clearinghouse for hydrological, climatological, economic and population data being used in the modeling effort. This website was developed under funding from the DOE National Border Technology Partnership Program. The AguaNet site is currently in operation and makes available to other workers and to the public data on the Rio Grande/Rio Bravo basin from institutions on both sides of the border. This continued effort will continue to support follow-on LRG modeling efforts and it will support other water-related research and projects going on in the basin.

3.0 Conceptual Model

The LRG model includes the border region from Ft Quitman to the Gulf of Mexico (Figure 1). The model simulates the water balance over four reaches: Ft. Quitman (near El Paso, Texas) to Presidio/Ojinaga; Presidio/Ojinaga to Amistad Reservoir; Amistad Reservoir to Falcon Reservoir; and Falcon Reservoir to the mouth at the Gulf of Mexico. Each reach represents a single spatially aggregated component in the model, such that at each timestep all inflows (precipitation, tributary flows, etc.) to the reach are summed, and all outflows (evaporation, evapotranspiration, river seepage) are summed at each timestep. The model operates on an annual timestep from 1950 to 2050. Data for the years 1950 to 2001 come from the historical record. Gaps in the historical record are filled using probabilistic approaches described in Appendix A. Data for the years 2002-2050 come from published projections, or are generated within the model through a variety of probabilistic means.

3.1 Inflows

Surface Water: Surface water inflows accounted for in the model include the main stem of the Rio Grande as it flows past Ft. Quitman; the Conchos River in Mexico entering at Presidio; the Pecos and Devils Rivers entering into the Amistad Reservoir from the United States; and the Rio Salado and Rio San Juan entering the Rio Grande from Mexico.

3.2 Outflows

Consumptive outflows can be distributed into four broad classes: open-water evaporation, riparian transpiration, agricultural evapotranspiration, and municipal consumption.

Open-Water Evaporation: Open-water evaporation is calculated for the main stem of the Rio Grande and for both Amistad and Falcon Reservoirs. Because tributaries are gaged at their discharge to the Rio Grande, tributary evaporation does not need to be considered.

To estimate the evaporative losses we begin by calculating the reference evapotranspiration (ET) rate, ET_r. Reference ET rates are calculated using a modified form of the Penman-Monteith equation (Shuttleworth, 1993):

$$ET_r = \frac{\Delta}{\Delta + \gamma^*}(SR) + \left(\frac{\gamma}{\gamma^* + \Delta}\right)\frac{900 * U}{T + 275} D \qquad \text{Equation 2}$$

ET_r = reference evapotranspiration rate
Δ = vapor pressure/temperature gradient
λ = psychrometric constant
SR = net solar radiation
γ^* = scaled psychrometric
U = wind speed
T = temperature
D = vapor pressure deficit

In this way, ET_r accounts for the effects of climatic variability on evaporative losses. To determine the ET rate specific to an open-water body, ET_r is multiplied by an evaporation coefficient. Here we adopt the same open-water evaporation coefficient value as used in the ET Toolbox (USBR, 2002).

The Penman model calculates monthly open water evaporation based in part upon monthly open water acreage. Data for open water acreage was unavailable. We constructed an open water acreage data set based upon the assumption that the river in all reaches is 60 feet wide in the months August through February, 80 feet wide in the months March and July, 100 feet wide in April, and 120 feet wide in the months of May and June. Better data on river open water acreage relative to discharge are needed to improve the model.

Evaporative losses from large bodies of water, like reservoirs, must be handled in a slightly different manner. Lake evaporation, evaporative losses (ET_L) is calculated according to the following relation given by Shuttleworth (1993):

$$ET_L = \left(2.909 * D * U * A^{-0.05}\right) * A * \Delta t \qquad \text{Equation 3}$$

where

ET_L = evaporative losses
D = vapor pressure deficit
U = wind speed
A = reservoir surface area
Δt = number of evaporation days (i.e., number of days in the year).

Surface areas are computed from volume-surface area relationships specific to each lake (Mark Yuska, personal communication, 2002), while the open water evaporation coefficients were determined through calibration with available historic data (USACE, 2002).

Transpiration rates are adjusted annually for precipitation. An effective precipitation multiplier, M_p, is calculated as the ratio between the yearly rainfall and the 50-year average precipitation (8.7 in), P_a:

$$M_p = \frac{P + ET_a}{P_a + ET_a} \qquad \text{Equation 4}$$

M_p = effective precipitation multiplier
P = yearly rainfall
ET_a = average evaporation rate
P_a: = 50-year average precipitation

where ET_a is the average evaporation rate. Precipitation for years 1950-2001 is modeled from historical data, while future precipitation is projected for years 2002-2050 by simply repeating the data from 1952-1950.

Irrigated Agriculture:

To maintain consistency, reference evaporation rates for the irrigated crops are calculated according to the Penman-Monteith equation. Evaporative losses specific to each crop are estimated by multiplying ET_r by the evaporation coefficient, growing days, and acreage particular to each crop. These crop specific data are consistent with the ET Toolbox (USBR, 2002). As irrigated crops generally grow under some degree of water stress, the calculated ET rates must be adjusted for actual growing conditions. This involves reducing the calculated ET rates by a stress factor.

The total water diverted from the Rio Grande for irrigated agriculture is simply calculated by summing the individual losses. Specifically, the total diversion equals the sum of evapotranspiration from the crops, evaporative losses from the conveyance system, conveyance system leakage, irrigation seepage, and ditch bank evapotranspiration.

Municipal Demand: Most municipal demand in the LRG is met with diversions from the Rio Grande. Municipal demand in the model is simulated using historic or projected population data multiplied by a per capita consumptive use term. The per capita consumptive use term for U.S. consumption was calculated by subtracting IBWC return data from IBWC diversion data for each municipality for which those records are kept, and then dividing the result by the number of people reported for each municipality. Mexican per capita consumption, for which very few data were available, will be modeled as a percentage of U.S. per capita consumption. Historic population data and population projections come from a variety of sources (see Appendix B).

4.0 Data Collection Process and Discussion

The data collected for the Lower Rio Grande Model came from various sources including partners listed above, internet sites, libraries, phone calls to various agencies and city officials, electronic mail requests and maps. A discussion of each model data parameter and its source(s) is discussed in parameter sections below. The discussion below is incomplete.

A minimum of 50 years of data collection was used to represent past historical hydrological events. Data collection period from 1950 to present was used based on a decision made by Mexico where possible, data from 1950 through 2003 was collected. When data was lacking, correlated data was entered to fill the missing periods. Various methods of correlation were used. Discussions of how data was correlated is presented in parameter sections below.

The majority of the data was collected from IBWC and NOAA websites, or was provided by Mexican partners. Weather data came primarily from NOAA websites and digital sources. Hydrologic data was found in the IBWC Water Bulletins Numbers 20 through 71. This covered years 1950 through 2001. Data included the flow values found digitally on the IBWC website, outfalls from wells and sewers, municipal water use, evaporation from the Rio Grande Basin, temperature, humidity and wind and various other parameters not used in this model. Data in the water bulletins from 1950 through 1989 were in English units (acre-feet, inches, fahrenheit) while data from 1990 through present year were in metric units (cubic meters, millimeters, and centigrade). All English units were converted to metrics prior to model input.

4.1 Hydrologic Data

Three major tributaries entering the Rio Grande from Mexico and United States were included in the model. The Rio Conchos enters Presidio/Ojinaga from the Mexican side, and the Pecos and Devils rivers enter Amistad Reservoir from the United States. Hydrologic data collected consisted of surface water flow data, outfalls from sewers and municipal and industrial use diversions. Data was collected from International Boundary Water Commission (IBWC), United States Geological Survery (USGS) and from the Instituto Mexicano de Tecnologia del Agua.

4.1.1 Surface Flow Data

Defining which source of data to use for hydrologic surface flow was researched in the beginning months of the project. Four sources of flow data were defined on the Web that included USGS flow data, USGS Water Quality Data, IBWC, and the National Weather Service West Gulf River Forecast Center (NWSWGRFC). The data ranging from the early 1900's to present was analyzed for duration of collection, site location, and consistency of data. It was determined that IBWC best met our needs for several reasons. IBWC offered more operational gaging sites than USGS with longer periods of record with some gaging sites record beginning in the early 1900's. In addition, IBWC often times included USGS gaging sites in their reports. The USGS water quality data listed some flows but not at all sampling locations. The NWSWGRFC used many of the same IBWC site names when defining the weather data. This was of particular interest for leaning more towards using IBWC data because the model would later need weather data associated with each reach. Therefore it was determined to use IBWC since the site best met our needs with records of 68 gaging sites with good periods of record through present. In addition, the lower agricultural portion of Texas (downstream of Falcon Dam) was very well represented in the IBWC records.

All of the flow data was easily retrieved from the IBWC website http://www.ibwc.state.gov. Figure 3 shows IBWC monitoring stations currently in use.

Hydrographs were produced for quick comparison and decision making on which gauge stations would be used to best represent the Lower Rio Grande. Eleven flow gauge sites were chosen along the U.S. Mexican border to represent four segments of the lower Rio Grande between Ft. Quitman and the Gulf of Mexico (Figure 4). These segments were chosen to define the reaches along the Rio Grande where changes in major surface flow occur such as large tributaries entering the river, and reservoirs causing fluctuations in flow.

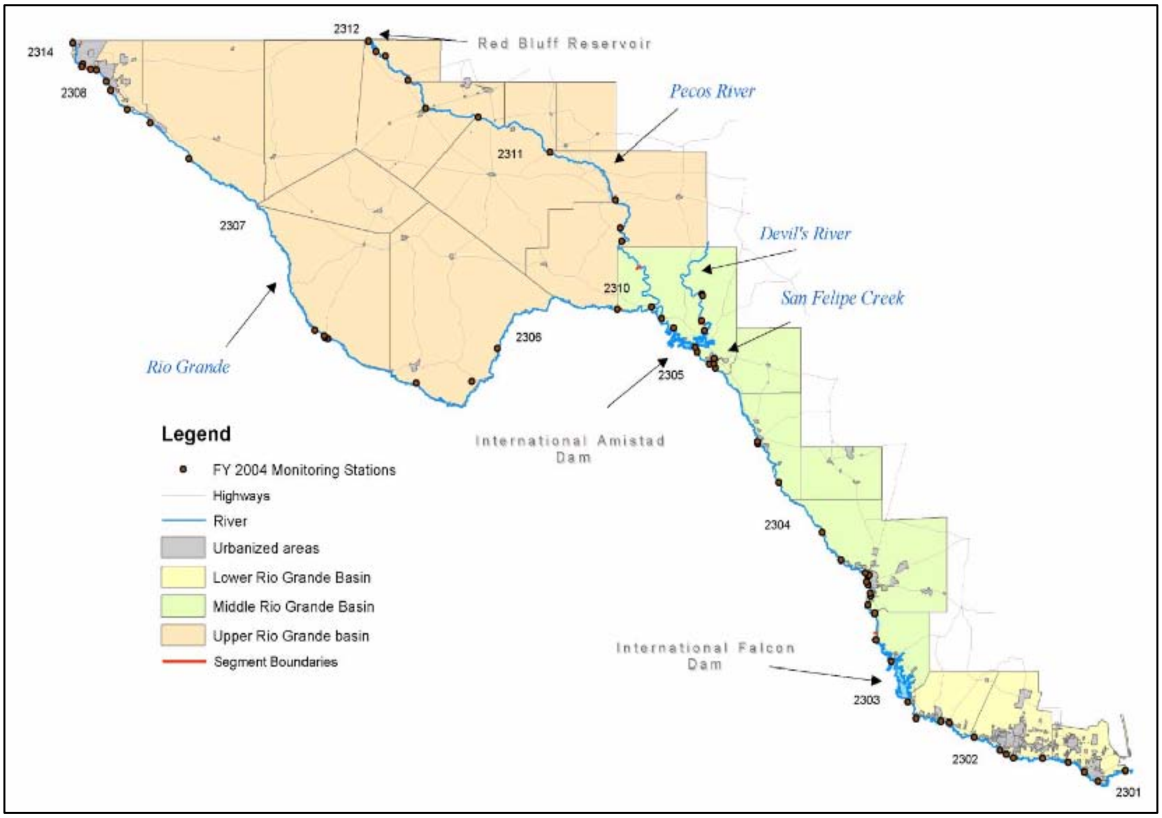


Figure 3. IBWC gaging site locations.

The eleven points defined as surface flow along the Rio Grande consisted of flow gauges at Fort Quitman, above the Conchos River (near Presidio), Conchos River at Rio Grande River, Rio Grande below the confluence of the Conchos River, Rio Grande above Amistad Reservoir near Langtry, Pecos River at Langtry, Rio Grande below Amistad Dam near Del Rio, Rio Grande above Falcon Reservoir near Laredo, Rio Grande below Falcon near Falcon, and Rio Grande at Brownsville, Texas.

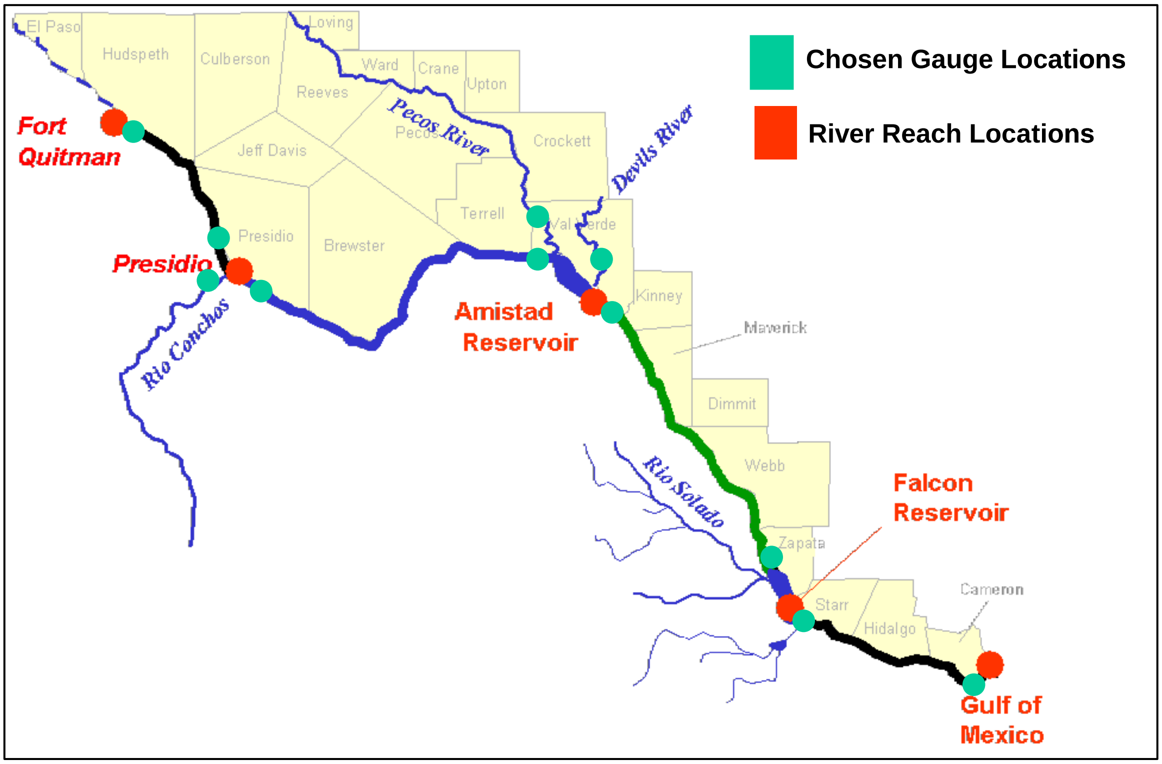


Figure 4. Green dots represent IBWC flow gage sites chosen for model.

A list of tributaries entering the Lower Rio Grande include:

United States	Mexico
Alamito Creek near Presidio, Texas	Rio Alamo at Cd. Mier, Tamaulipas
Cienegas Creek near Del Rio, Texas	Rio Conchos near Ojinaga, Chih.
Eight Mile Creek near Del Rio, Texas	Rio Escondido at Villa De Fuente, Coahuila
Pinto Creek near Del Rio, Texas	Rio Salado near Las Tortillas, Tamaulipas
San Felipe Creek near Del Rio, Texas	Rio San Diego near Jimenez, Coahuila
Terlingua Creek near Terlingua, Texas	Rio San Juan at Camargo, Tamaulipas
Devils River near Comstock, Texas	Rio San Rodrigo at El Moral, Coahuila
Pecos River near Langtry, Texas	

Hydrographs and pie charts were used in deciding which tributaries to include in the model. The rivers with the largest flow entering the Lower Rio Grande were analyzed. Figure 5 shows a pie chart plotting the larger tributary inflows to the Lower Rio Grande. Because Terlingua was such a small contributor it was not included as a main tributary contributor for the model. Rivers chosen for the model included Devils River and Pecos River in the United States, and the Rio Conchos from Mexico.

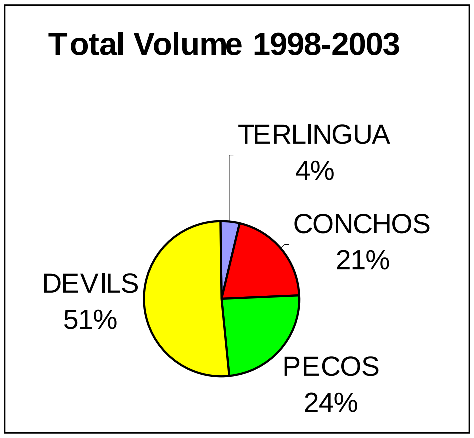


Figure 5. Major tributaries entering Lower Rio Grande River.

IBWC was the preferred website used for gaging station flow data selected for flow analysis on the Rio Grande. However in cases where IBWC data did not exist, USGS gaging sites were used to create simulated data. A discussion of how data was simulated for the missing time periods in Pecos_Langtry and Devils_Pafford follows found in Appendix A.

4.1.2 Outfalls from Sewers Into River

Data for sewer outfalls to the Rio Grande was obtained from IBWC and consisted of return flows to the river from municipalities. Cities along the border that had measured sewer outfalls to the river are shown in Figure 5 and are represented by their years the data has been recorded. The US had five sites Eagle Pass, Laredo, Roma, Rio Grande City, and Brownsville and Mexico had one site, Nuevo Laredo. Laredo had the longest period of record beginning in 1950 followed by Brownsville, which began recordings in 1957. Eagle Pass records began in 1962. Records for Nuevo Laredo began in 1957-1987 and then picked up again along with Roma and Rio Grande City beginning in 1999 though present time.

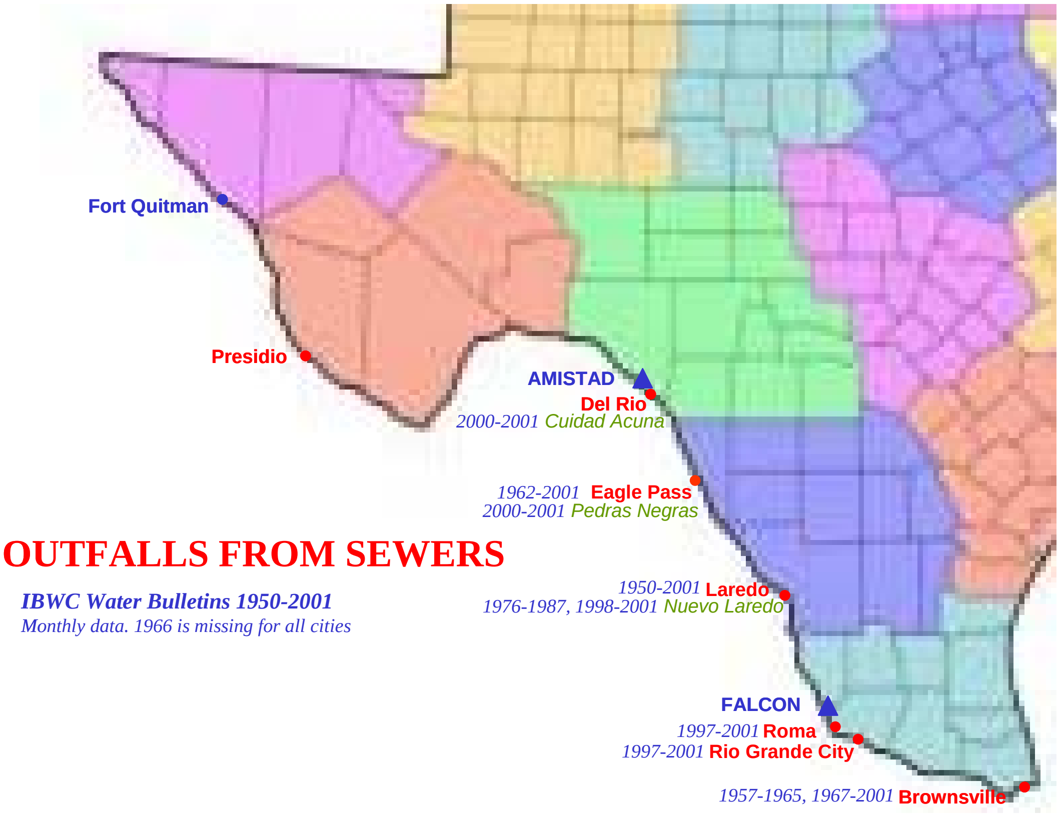


Figure 5. Locations of outfalls from sewers to the Rio Grande River.

4.1.3 Urban and Municipal Use

Urban and Municipal use data was derived directly from tables found within IBWC Water Bulletins. The tables were generated digitally from data obtained from UNM and NMSU library. Years 1950-1986 was obtained from UNM library while years 1987-1999 was obtained from NMSU library. Both sources were hand entered and checked into the digital file used for the model. Years 2000 and 2001 were obtained from IBWC Water Bulletin Site and entered (http://www.ibwc.state.gov/html/water_accounting.html). Year 2002-2004 has not been published as of August 2004.

The urban and municipal values represent monthly and yearly diversions of water pumped from the Rio Grande surface water directly into municipal distribution systems of cities along the border. Eleven cities and 1 power station from the United States and 12 cities from Mexico were included.

All IBWC data was entered from the Water Bulletins in the format it was published. Years 1950-1989 data was reported in English system (acre-feet, inches, and fahrenheit)., and data for years 1990 to present was presented and entered as metric system (1000's of cubic meters, mm, centigrade). All data was converted to both metric and English on separate spreadsheets for easy importation into the model.

In addition, telephone conversations conducted in July 2004 with Ken Rakestraw (IBWC senior hydrologist) and Maria Romo (Texas Rio Grande Watermaster Eagle Creek Office) stated the following. Eagle Pass, Laredo, San Ygnacio and Zapata water works get their municipal water from Rio Grande surface water, Del Rio receives its water from San Felipe Springs, and Presidio, Ojinaga, Peidras Negras, Cuidad Acuna, depend primarily on groundwater and very little surface water. Ciudad Acuna, Coahuila, whose municipal diversion from the Rio Grande started in 1971, often uses an alternate source of water from Arroyo Las Vacas, which was its previous source of supply.

4.2 Weather Data

Weather data for the Lower Rio Grande Model was obtained from many different sources. Weather data consisting of temperature, precipitation, evaporation, relative humidity, windspeed, radiation, and dewpoint were collected. Parameters and their sources are described below.

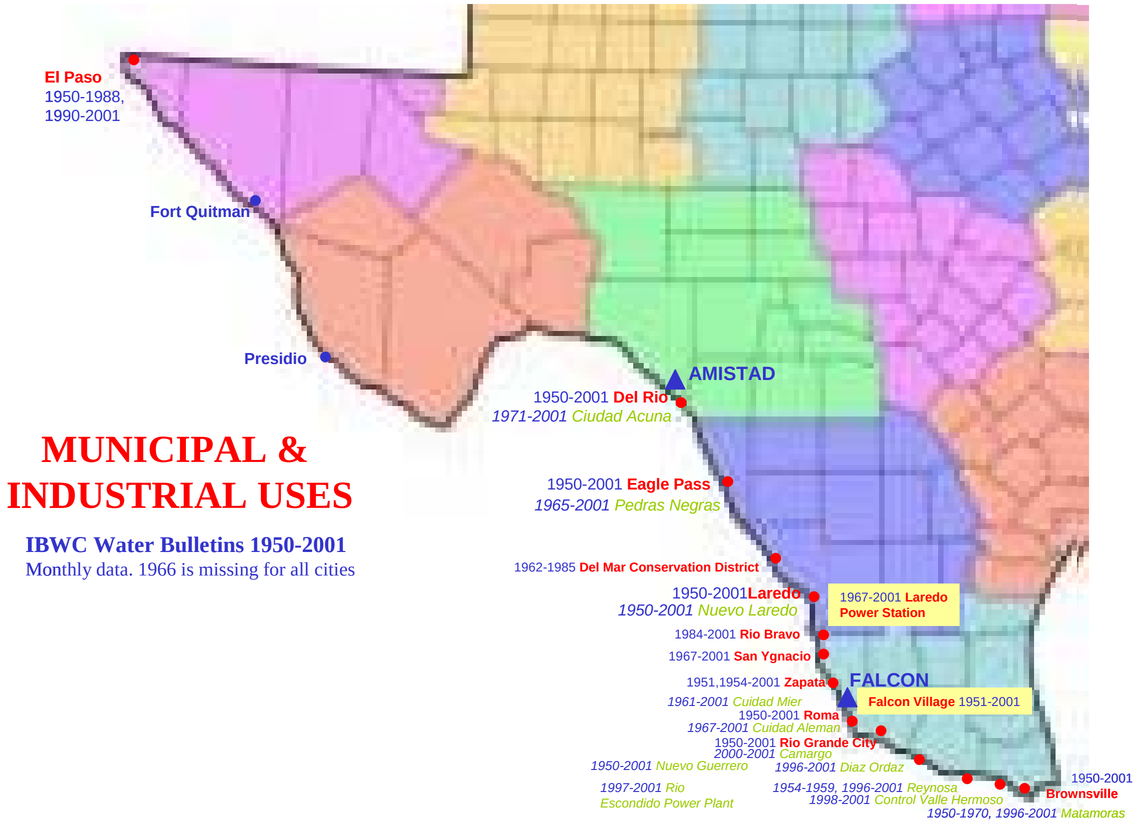


Figure 6. IBWC municipal and industrial use along the Lower Rio Grande River.

4.2.1 Temperature and Precipitation

Temperature data was downloaded from the NOAA site at a price of $280.00. NOAA refers these sites as “Mom and Pop” type stations where individuals in the different cities read their gauges on their home properties and report the data to NOAA. Twenty-seven Texan cities located close to the Rio Grande River were chosen for download. Maximum, minimum and average temperature data as well as precipitation data was received. Monthly averaged years 1950-2003 data was taken from the original file.

The original data can be found in “TEXAS precip and temp data.xls” in worksheet labeled “All Data – Original Format”. This data needed to be reformatted for model input. A macro in Excel was written to parse and transpose the data. The directions for the macro can be found in the worksheet labeled “Macro Here” within the same excel file. Once the macro was run on each city’s data, many cities had missing periods of data. These missing periods were entered as blank cells and highlighted in gray to show the missing data.

The missing data was then filled with other data using the following procedure. If Jan 1951- Oct 1951 was missing, the following years data Jan 1952-Oct 1952 was copied and placed into this space. If 2 years of data several years of data were missing, the next 2 years containing the same months of missing data were copied and placed into the missing years.

Lastly the data was converted for units. In the case of NOAA temperature data, the data was converted from 10’s degrees Fahrenheit to Centigrade for model input.

After downloading and formatting all the cities’ data, the periods of record for each city and their locations within the reaches was analyzed. The cities and their time periods of precipitation and temperature record, as well as the source of the data was placed on a PowerPoint slide for easy reference (“Texas Bordering County & City Maps 100104.ppt”). Several cities’ data was averaged for several of the reaches depending on their location on the map and their period of record (Figures 7 and 8).

Precipitation and temperature data was averaged for the 4 reaches. Reach 1 included averages of El Paso and Presidio precipitation and temperature data, Reach 2 consisted of averages between Presidio and Del Rio data, Reach 3 consisted of Eagle Pass data, and Reach 4 consisted of Rio Grande City data.

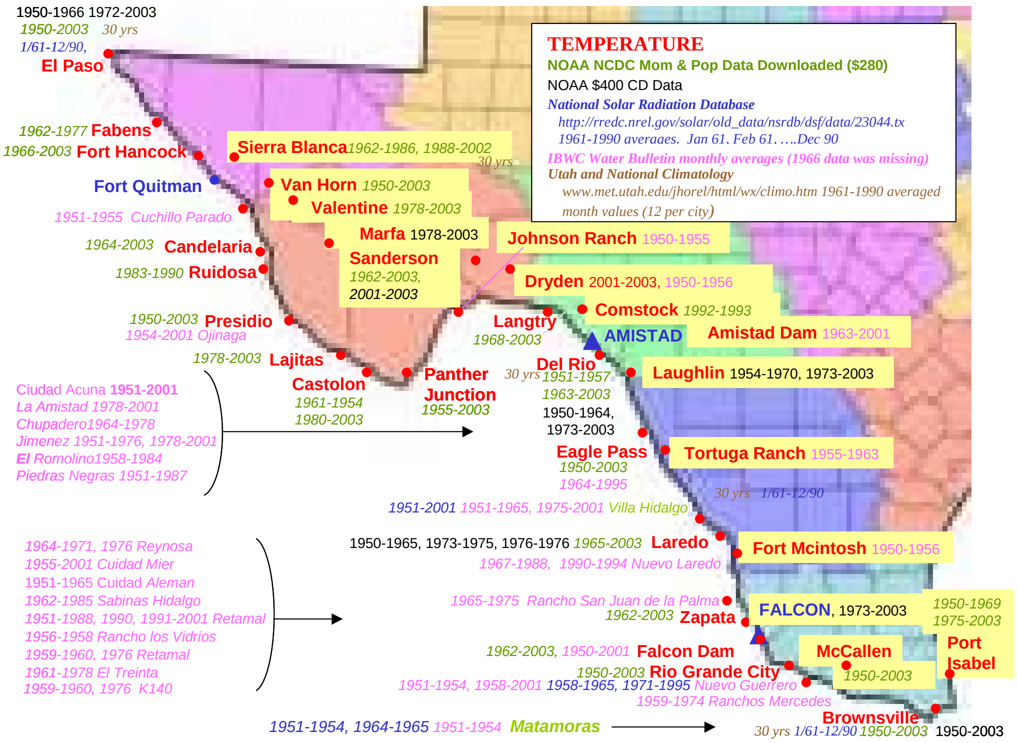


Figure 7. Precipitation data collected for Lower Rio Grande River.

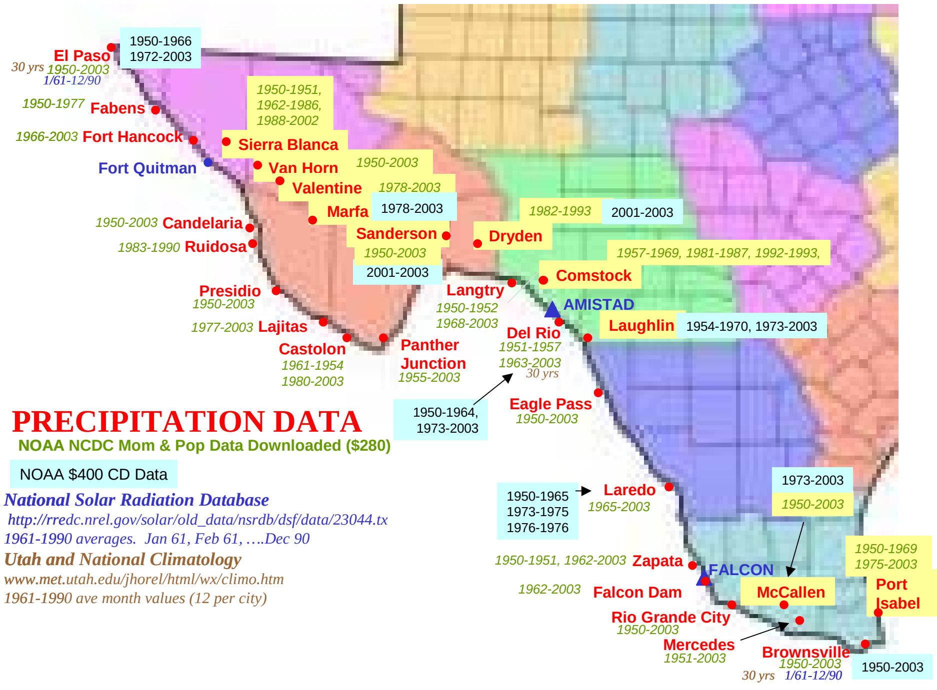
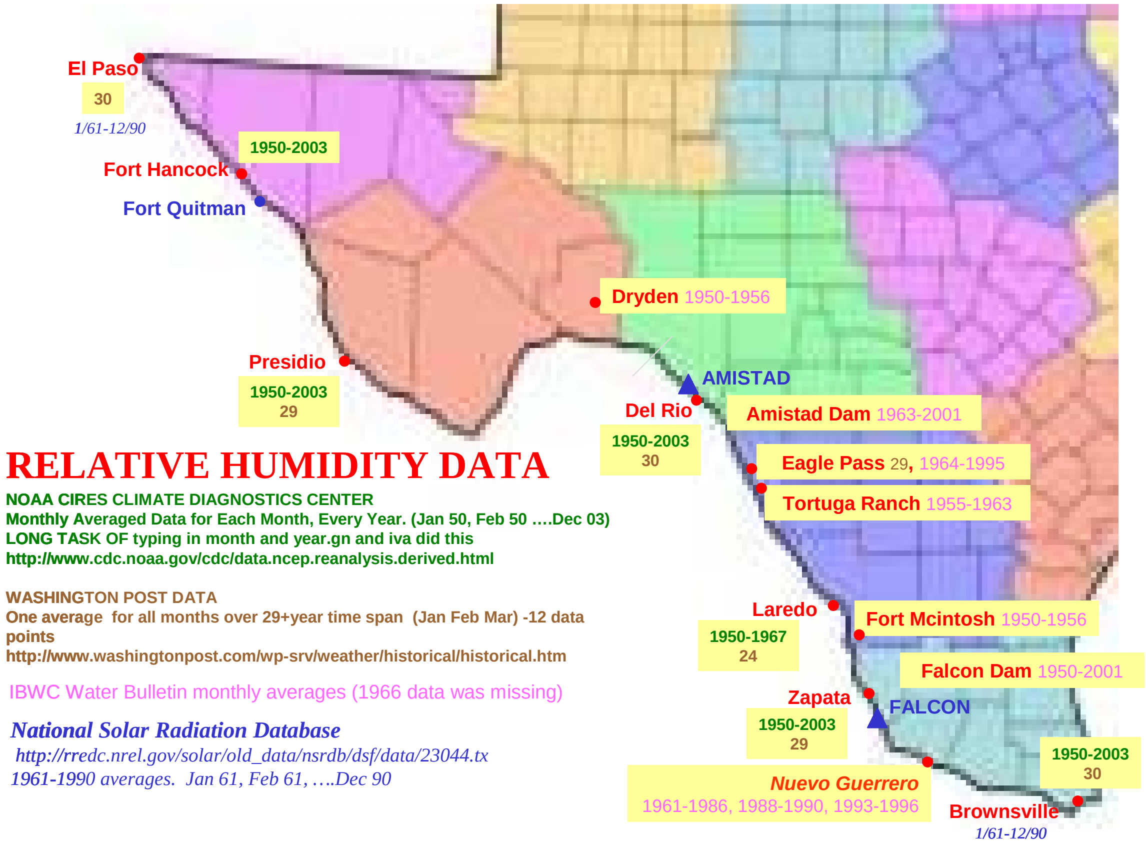


Figure 8. Temperature data collected for Lower Rio Grande River.

4.2.2 Relative Humidity

Obtaining 1950-2003 monthly averaged data for relative humidity was difficult. Several major cities had one value listed for all January's, February's, March's etc. averaged over the last 40 years (12 values total) however, the model needed averaged monthly values (i.e., Jan 50, Feb 50, Mar 50…Dec 2003) for each year. All relative humidity data obtained was entered onto an Excel spreadsheet "Relative Humidity.xls". The same information (city and period of record) was placed on a slide in PowerPoint representing the mapped city points ("Texas Bordering County & City Maps 051804.ppt"). Figure 9 shows a copy of the relative humidity data.



RELATIVE HUMIDITY DATA

NOAA CIRES CLIMATE DIAGNOSTICS CENTER
Monthly Averaged Data for Each Month, Every Year. (Jan 50, Feb 50 ….Dec 03)
LONG TASK OF typing in month and year.gn and iva did this
http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.html

WASHINGTON POST DATA
One average for all months over 29+year time span (Jan Feb Mar) -12 data points
http://www.washingtonpost.com/wp-srv/weather/historical/historical.htm

IBWC Water Bulletin monthly averages (1966 data was missing)

National Solar Radiation Database
http://rredc.nrel.gov/solar/old_data/nsrdb/dsf/data/23044.tx
1961-1990 averages. Jan 61, Feb 61, ….Dec 90

Figure 9. Relative humidity data collected for Lower Rio Grande River.

After plotting these on the map it was realized what little relative humidity data was available for the model. We learned of a website from Enrique Vivoni (professor at NM University) that had weather data ranging from 1948-2003. The site was called: NOAA CIRES CDC (Climate Diagnostics Center) located at URL: *http://www.cdc.noaa.gov/cdc/data.Ncepreanalysis .derived.html.*

The site lists many weather parameters. We chose cities Ft. Hancock, Presidio, Del Rio, Zapata and Brownsville for gathering relative humidity and radiation data for the model's reaches. The site states that with proper software (i.e. MatLab) the files can be downloaded easily in one file. After many attempts to download the correct files and software it was decided to hand enter the longitude and latitudes of each city and enter the time period for each one-month average and get single values. These values were then entered into the spreadsheet called "Relative Humidity.xls". Longitude and latitude coordinate information for the 5 cities was obtained from U.S. Census Bureau - U.S. Gazetteer located at URL *http://www.census.gov/cgi-bin/gazetteer*

Each Reach consisted of the averages of 2 cities - one at the west end of the reach and one at the east end of the reach. Reach One consisted of Fort Hancock and Presidio. Reach Two consists of Presidio and Del Rio, Reach Three consists of Del Rio and Zapata, and Reach Four consists of Zapata and Brownsville.

There were no maximum, minimum values available from this website. Therefore since the model required maximum and minimum relative humidity values the following procedure was used for each of the reaches.

Maximum RH was calculated by adding 1/2 the difference of the yearly 30-year RH min max average using three cities; El Paso, Del Rio, and Brownsville. This RH data is available from "Free NOAA RH data" worksheet *(http://www.ncdc.noaa.gov/oa/climate/onlline/ccd/avgrh .html)*. For example if the average RH value for Reach One was determined to be 53.0 from the average of two cities Fort Hancock and Presidio data from NOAA CIRES CDC, and the "Free NOAA RH Data" value for El Paso has an average temperature throughout the year of 24.5, then ½ of 24.5 is 12.25. 12.25 was then added to 53.0 for the maximum value (53.0+12.25=67.25), and subtracted from 53.0 (53.0-12.25=38.75) for the minimum value for that particular averaged month

Reach One is defined by the river area between Fort Quitman and Presidio. Because no relative humidity data existed for Fort Quitman, Fort Hancock's data was used because it was the closest city to Fort Quitman. Fort Hancock represented the western extent of Reach One with Presidio being the eastern extent. These two individual monthly averaged values were averaged together to gain one monthly average for Reach One. The minimum and maximum values for Reach One were based on yearly averaged data values from 42 years of averaged El Paso's data from Free NOAA RH Data *(http://www.ncdc.noaa.gov/oa/climate /onlline/ccd/avgrh.html).* Value 28.50 is the averaged 42-year value, therefore 14.25 (half of 28.50) was added to the average for maximum monthly value, and 14.25 was subtracted from the average for the minimum monthly value.

Reach Two average RH value was obtained from an average of NOAA CIRES Presidio and Del Rio values. The minimum and maximum was calculated using an average of Del Rio and El Paso data from "Free NOAA RH Data" *(http://www.ncdc.noaa.gov/oa/ climate/onlline/ccd/avgrh.html).* Del Rio contained averages for 23 years of data. The monthly average was 16.50 (8.25 + or -). El Paso contained averages for 42 years of data. The monthly average was 28.50 (14.25 + or -).

Averaged together, Del Rio and El Paso had a joint value of 11.25. This 11.25 was added and subtracted to the averaged NOAA CIRES Presidio/Del Rio monthly averaged values to obtain maximum and minimum values respectively.

Reach Three averaged RH values obtained from averages of NOAA CIRES Del Rio and Zapata monthly values. The maximum and minimum RH values were determined using Del Rio's 23 years of averaged data from Free NOAA RH Data *(http://www.ncdc.noaa. gov/oa/climate/onlline/ccd/avgrh.html).* A value of plus or minus 8.25 was used to determine the maximum and minimum RH values.

Reach Four consisted of an average of NOAA CIRES Zapata and Brownsville data. The maximum and minimum RH values were determined using Brownsville's 26 years of averaged data from Free NOAA RH Data *(http://www.ncdc.noaa.gov/oa/climate/ onlline/ccd/avgrh.html)*. A value of plus or minus 12.25 was used to determine the maximum and minimum RH values.

4.2.3 Windspeed

Three different sources of wind speed data were collected. NOAA $800 CD contained monthly averaged data from 1950-2003 (Jan 50, Feb 50….Nov 03, Dec 03) for El Paso, Del Rio, Laredo, and Brownsville. Unfortunately some of the city's data had periods of missing data. Data was filled in for these missing periods using the previous or next years group of data available. For example if monthly averages for Jan 1955, Feb 1955 and Mar 1955 had no values associated, the next year's averaged values Jan 1956, Feb 1956 and Mar 1956 were copied and placed into the missing 1955 data values. In the case were 3 years of data was missing, the same procedure was used only instead of using just the next 1 years worth of data, the next 3 years data was used beginning with the month the data was missing from. For example, if June 1965-July 1968 were missing, June 1969-July 1972 would be copied and placed into the missing period of June 1965-July 1968. Excel File "Solar Radiation &Wind Texas and National Databases 023504g.xls" contains the backup information used to fill the model. The actual model's information for wind is found on "Model Wind" workbook within the excel file. Lastly, a conversion factor of 1.609344 was used to convert mph to km/hr for final format to the model. Figure 10 shows data collected for wind speed along with some temperature readings.

4.2.4 Solar Radiation

Data for solar radiation in the Lower Rio Grande was sparse. Averaged 30-year monthly values existed for several cities however the model required monthly averaged values from 1950-2003 for 4 reaches. Solar radiation data was obtained from the NOAA-CIRES Climate Diagnostics Center using longitude and latitude coordinates for each of the reach's east and western cities *(http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.html).* Longitude and latitudes were entered for 5 cites (Ft. Hancock, Presidio, Del Rio, Zapata, and Brownsville).

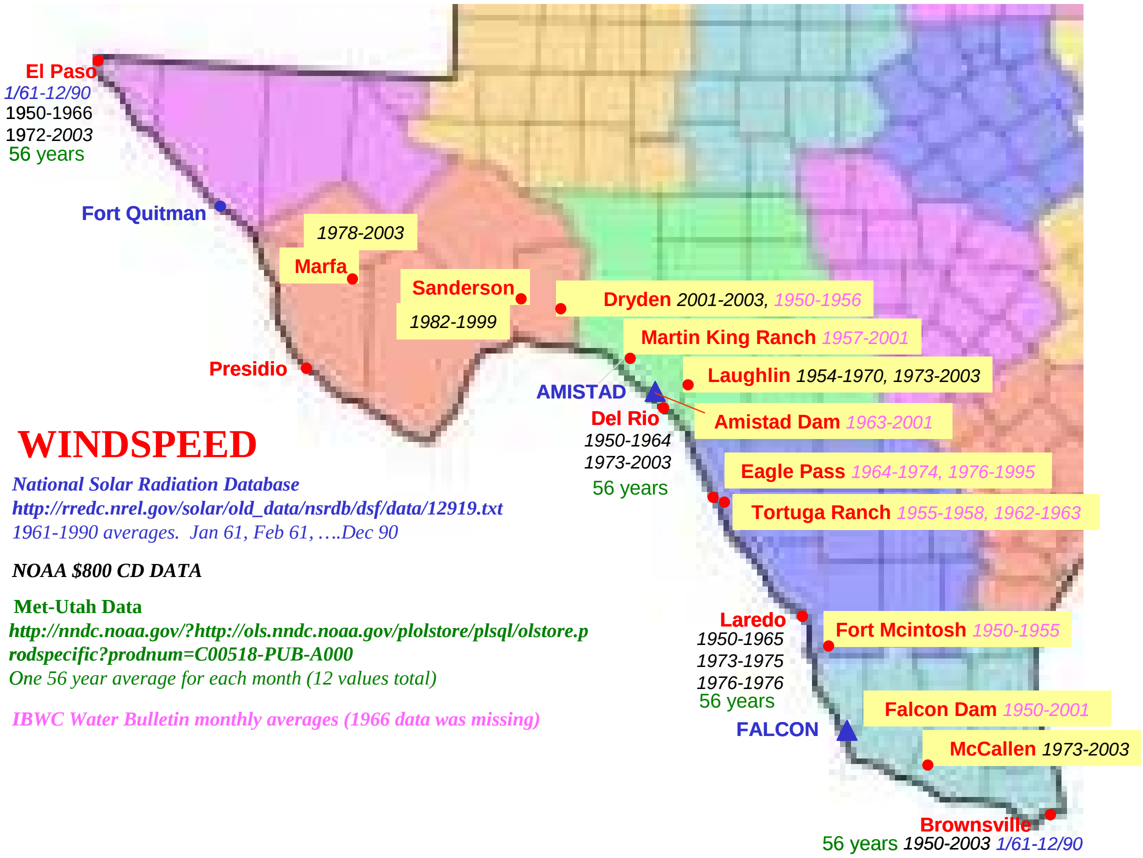


Figure 10. Windspeed data collected for the Lower Rio Grande River.

Longitude and latitude values for each city were obtained from U.S. Census Bureau - U.S. Gazetteer located at URL *www.census.gov/cgi-bin/gazetteer*. Averaged monthly data was requested between January 1950 through December 2003 for each city, for every month between 1950 and 2003. These values were hand entered into a spreadsheet. The units of the data were in W/m2. An assumption was made that the units were W/m2/day. They were then converted to MJ/m2/day using a conversion rate of 1 W/m2 = 0.0864 MJ/m2/day.

Note: All values from original data have been replaced with blank cells. All blank cells were copied and replaced with the next year's info beginning with the month of data that was missing. If April 1950 was missing, April 1951 data was used to fill the blank cell. These cells are highlighted in blue.

Each consisted of the averages of 2 cities - one at the west end of the reach and one at the east end of the reach. Reach 1 consists of an average of monthly data from Fort Hancock and Presidio. Reach 2 consists of an average from Presidio and Del Rio, Reach 3 consisted of an average of Del Rio and Zapata data, and Reach 4 consists of Zapata and Brownsville averaged data. Figure 11 is a compilation of solar radiation data received for various cities.

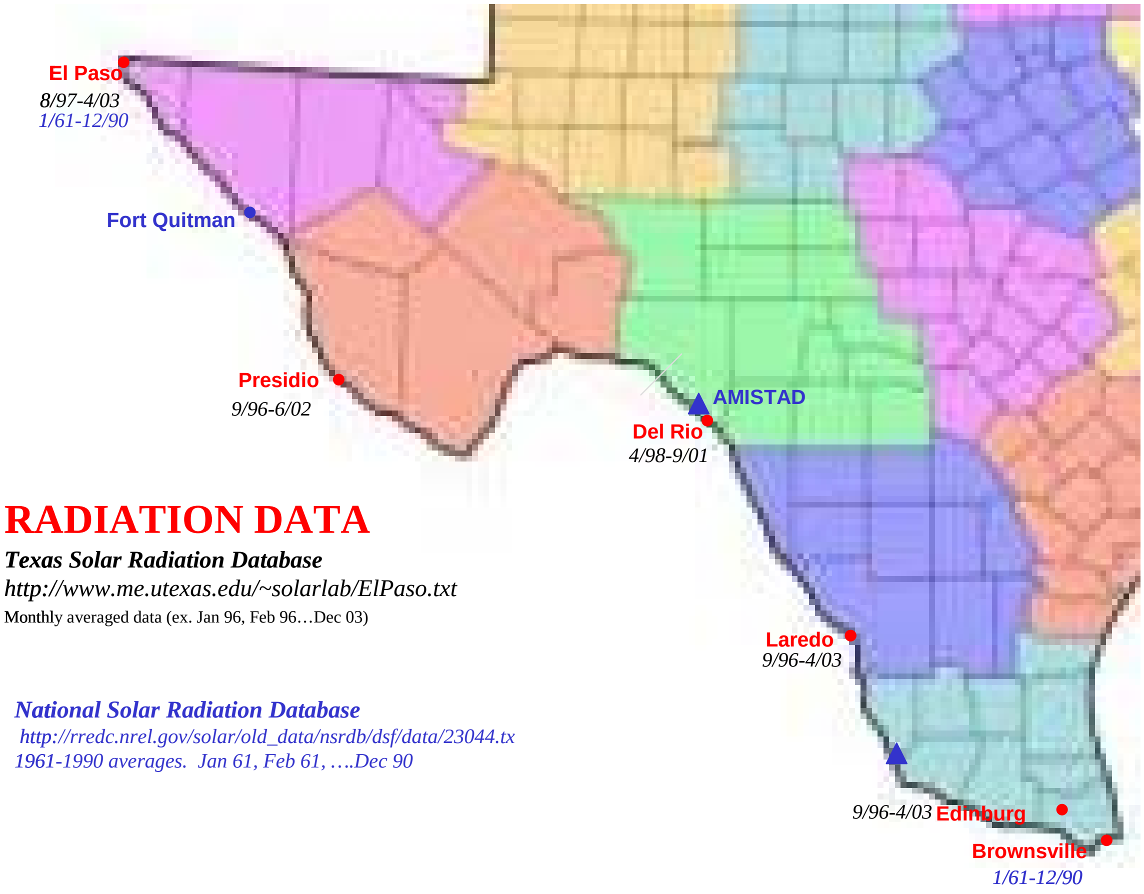


Figure 11. Solar radiation data collected for the Lower Rio Grande River.

4.2.5 Evaporation

Evaporation data was collected from the Texas Water Development Board's website: http://hyper20.twdb.state.tx.us/evaporation/evap.html. Lake evaporation and precipitation rates are provided at this site for each one-degree quadrangle in Texas. The quadrangle data were determined from all available data collection sites operated by the National Weather Service and the Texas Water Development Board. Monthly and annual gross lake surface evaporation data are available from 1954 through 2002, and precipitation data were available from 1940 through 2002.

Evaporation rates were downloaded for each of the quadrangles bordering Texas and Mexico from Fort Quitman to the Gulf of Mexico. The quadrangles were then divided into their respective reaches for the model and averaged to get a single value for a particular year for a particular reach. Figure 12 shows the quadrangles highlighted in blue that were used for the model.

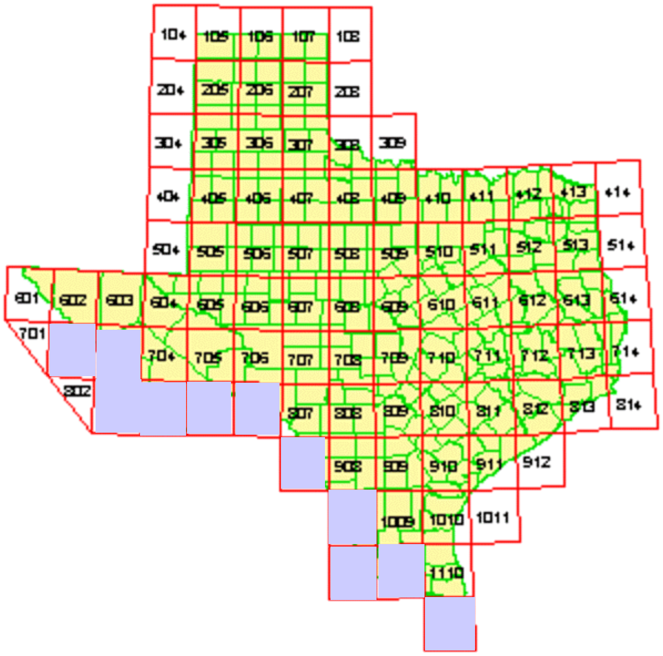


Figure 12. TWDB quads used to select evaporation rates or each reach.

Reach 1 averaged evaporation rates given for quadrangles 702, 803, and 804, and Reach 2 was an average of quadrangles 805, 806 and 807. Reach 3 consisted of an average of quadrangles 807, 907 and 1108 evaporation rates and Reach 4 consisted of an average of quadrangles 1109, 1110, and 1210. These were compiled on a spreadsheet ("Evap Rates for Reaches 072304.xls") and used as input for the model.

4.3 Border Population

Several sources of population data were used including IBWC water bulletins, census data, Handbook of Texas (from internet searches on "cityname, state and population") and miscellaneous other internet searches. Figure 13 shows cities with populations from various sources. The file containing this slide is "Texas Bordering County & City Maps 100104.ppt".

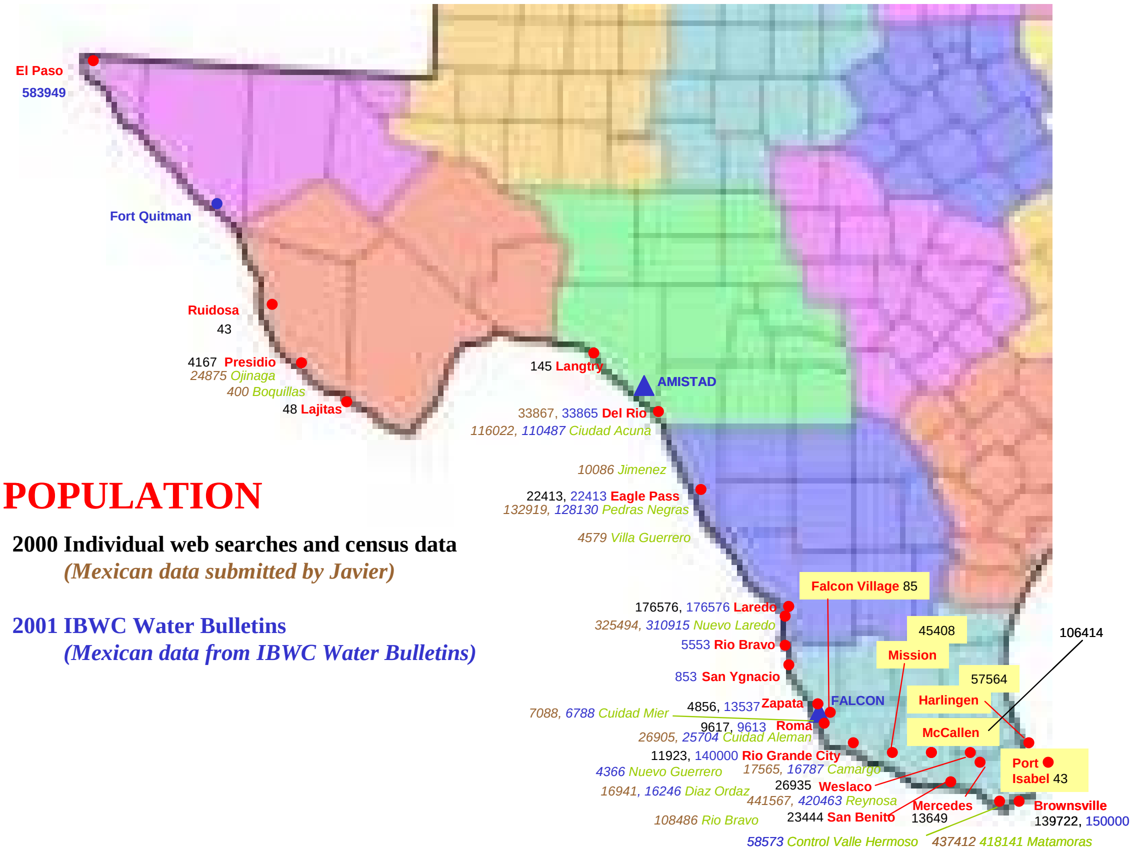


Figure 13. Population data collected for Lower Rio Grande River.

Annual city population data from yearly reported IBWC Water Bulletins in the Lower Rio Grande from Fort Quitman to the Gulf was provided in the Municipal and Industrial Use tables. He IBWC received the data published in each of the Water Bulletins by the Chamber of Commerce for each city in the United States unless otherwise indicated. For example, Falcon Village population was estimated by the International Boundary and Water Commission; Del Rio was estimated by the Middle Rio Grande Development Council; Laredo, by the Laredo Development Foundation; and Rio Bravo and San Ygnacio were based on utilities connections.

Another source of population data came from work using a map (Map of Mexico, scale 1:2,600,000, Hallwag AG, Bern, 2000-2001) to identify cities and towns along both sides of the border of the Rio Grande River. Initially data was downloaded from U.S Census reports however when data was unavailable the Google search engine was used to locate various cities and their population data. When no data was found for past years between 1950-2003 a general technique for interpolating or extrapolating values was used.

Given a pair of non-contiguous population values, the standard growth formula
$N_i = N_0 e^{ir}$ was used to calculate intervening values. The annual growth factor r was found and then the formula was used to calculate each year in the interval, using the 0^{th} value and r.

4.3.1 United States Population

Single population values were found on the world wide web for small towns with populations of less than 200. The towns of Ruidosa, Lajitas, Langtry, and Amistad, were not located in census data therefore the search engine Google was used with keywords ‘population, *cityname,* Texas’. This value was input for all years between 1950-2050 because no other data was located.

Actual values for the town of Presidio came from several sources. The values for 1960, 1990, and 2000 came from the US Census Data. The value for 1988 came from the Google search engine typing in ‘population of Presidio Texas’ as keywords. The decadal values of projected future population for years 2010, 2020, 2030, 2040, and 2050 came from the Texas 2006 Regional Water Plan. Intervening values were calculated from the 2 nearest known values and the growth formula discussed above.

For Zapata, the value for 1950 came from the Census, as did the values for1960 and 2000. 1990 data came from the Zapata city website. Values for the decadal years 2010, 2020, 2030, 2040, and 2050 came from the Regional Water Plan. Intervening values were calculated from the 2 nearest known values and the growth formula discussed above.

Del Rio, Eagle Pass, Laredo, Roma, Rio Grande City, Mission, McAllen, Weslaco, Mercedes, Harlingen, and Benito, and Brownsville data were all determined in the same way. Values for the decadal years 2010, 2020, 2030, 2040, and 2050 came from the Regional Water Plan. Intervening values were calculated from the 2 nearest known values and the growth formula discussed above.

4.3.2 Mexico Population

For Boquillas, a single value was found searching the city name and population keywords using Google. This value of 400 was used throughout the range of 1950-2050.

For Ojinaga, (Chihuahua), Acuna, Jimenez, Piedra Negras (all Coahuila), Nuevo Laredo, Guerrero, Mier, Camargo, Reynosa, and Matamoros (all Tamaulipas) came from the Mexican Census for 1950(8), 1960(9), 1970(10), 1980(11), 1990(12), 1995(13). The growth formula described above was used to interpolate between actual data. Values for the years 2000-2030 inclusive came from IMTA. Microsoft Excel used the results of a trendline plotted from the years 2020-2030 inclusive to determine the population for the years 2031 through 2050.

The city of Miguel Alemán had data for all the years as in the previous discussion except for 1950. The growth formula for the interval 1960-1970 was used to extrapolate the population back to 1950. All other data ranges (between 1960 and 2050) were treated the same as in the previous discussion.

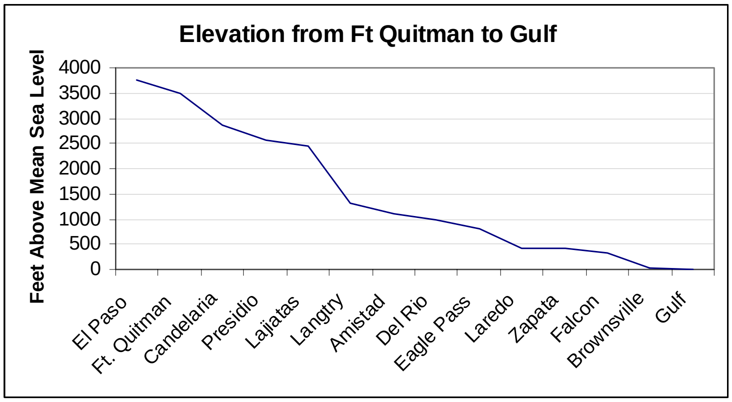
Cities Gustavo Diaz Ordaz and Rio Bravo lacked values for 1950 and 1960. This data was obtained by extrapolating from the relevant growth formula for 1970 to 1980. All other data was found from the sources listed above. And all other data ranges (between 1960 and 2050) were treated the same as in the previous discussion.

4.5 Elevation

Elevations were taken from various websites by using search words "cityname", Texas, and elevation or the word altitude. City elevations were collected for Ft. Quitman, Candelaria, Presidio, Lajitas, Langtry, Amistad, Del Rio, Eagle Pass, Laredo, Zapata, Falcon, Brownsville and Gulf of Mexico (0). Elevation averages of each city at the extent of the reaches were then used to estimate the one value needed for each reach elevation. For example, Fort Quitman and Presidio were the extents of Reach One and therefore their elevations were averaged to determine the elevation for Reach One ((3480+2581)/2 = 3035 feet above mean sea level (famsl). Presidio and Amistad were averaged together for Reach Two ((2581+1117)/2 = 1849 famsl), elevations for Amistad and Falcon were used for Reach Three ((1117+325)/2 = 721 famsl) and Falcon and Sea Level were used to determine the elevation for Reach Four ((325+0)/2).

Table 1. Represents elevations of major cities along the Lower Rio Grande Border.

City	Elevation (FAMSL)
El Paso	3762
Ft. Quitman	3480
Candelaria	2875
Presidio	2581
Lajitas	2440
Langtry	1315
Amistad	1117
Del Rio	999
Eagle Pass	797
Laredo	414
Zapata	404
Falcon	325
Brownsville	33
Gulf	0



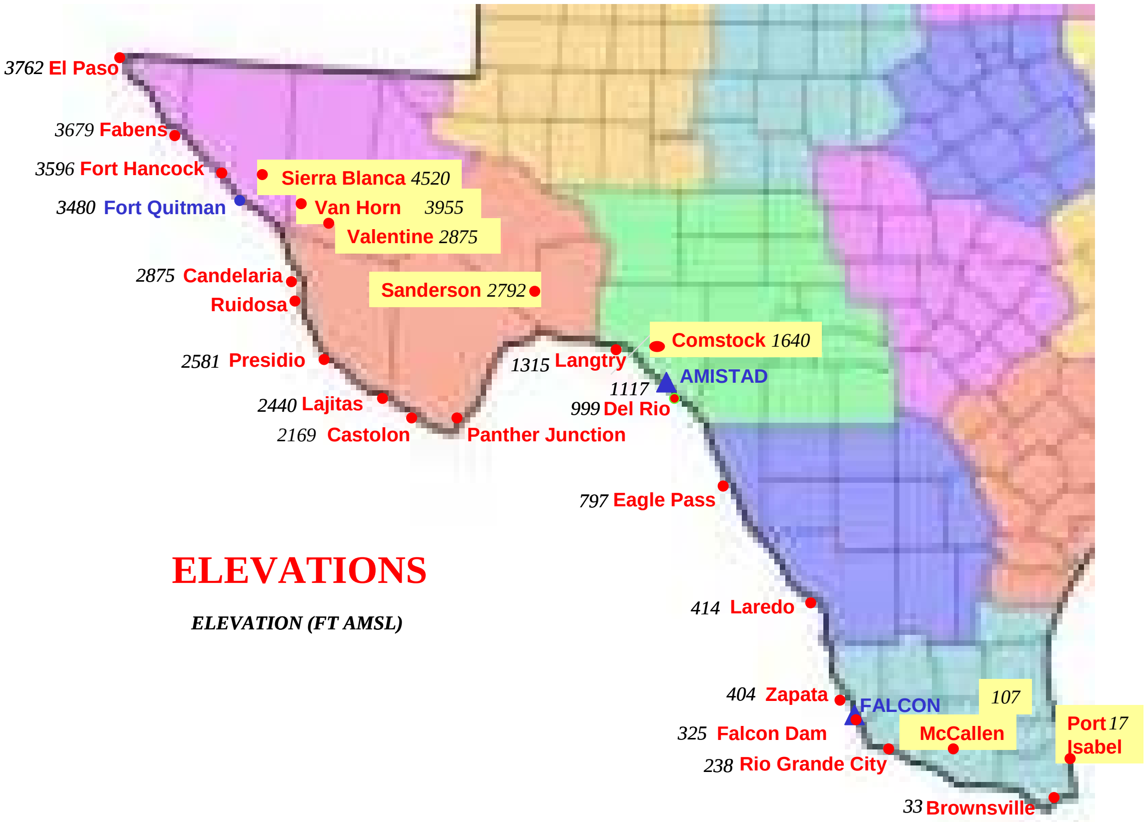


Figure 14. Elevation data for major cities along the Lower Rio Grande River.

4.4 Vegetation

Various vegetation parameters along the Rio Grande River were needed for the model. They included riparian acreage amounts, irrigated crop types, crop acreages, and their associated growing degree day (GDD) regression parameters. GDD parameters included crop start and stop months (planting and harvesting), and the monthly crop coefficients. Several unsuccessful efforts were used to obtain this data including web and library searches. Sections 4.4.1 describes the first approach used to obtain the vegetation and riparian data and the results from the search. Texas Agricultural Experiment Station at Texas A&M University (TAMU) System was hired to define the vegetation including riparian acreages, open water acreages and irrigated crops and their acreages. TAMU's findings and description of their riparian and open water acreage work can be found in Section 4.4.2. TAMU's work on irrigated crops were sent in one data filled spreadsheet and will not be discussed in this report.

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4.4.1 Riparian and Crop Data from Web and Library Searches.

Riparian acreages has been well defined in Reach 4 (Falcon Dam to the Gulf of Mexico) however no values were found for the upper reaches of the model using web and library searches. The riparian zone of the Lower Rio Grande Valley was classified using Landsat TM imagery acquired in 1996 and was estimated to be 17484 acres in 1996 for a 149 mile stretch of the river (1996 Riparian Classification Results http://www.csr.utexas.edu/projects/ rs/riparian.html).

Riparian regression and crop GDD regression parameter data was obtained from a Middle Rio Grande (MRG) project which used the URGWM ET Toolbox. Therefore its accuracy for use on the Lower Rio Grande project is questionable. The data was selected from the farthest point down river on the Middle Rio Grande Project near Elephant Butte as the data resembled the environment most closely related to the Lower Rio Grande portion of the river from Fort Quitman to the Gulf.

All of the start and stop month parameters for the crops were taken from the ET toolbox located in the Middle Rio Grande project (http://www.usbr.gov/pmts/rivers/awards/ /ettoolbox.pdf). The start and stop month parameter for soybeans, however, was generated by taking the starting planting date and the ending harvesting date from the ET Toolbox. The monthly crop coefficients were given by growing degree day (GDD), so to get monthly coefficients the beginning GDD and ending GDD and used them for the start and stop months. All of the other months were obtained by averaging the likely GDD based crop coefficients for that month together. Under Crop Parameters – Equations heading are equations using GDD as the independent variable to create a Crop Coefficient form the ET toolbox website.

The different types of crops and the crop acreage were obtained from the National Agriculture Statistics Service (NASS). The types of crops for each reach was separated by county and then by reach within the digital file. The data from Mexico was received from IMTA and translated from Spanish to English by Paul van Bloemen Waanders. Mexican data was originally given in hectares and they were converted to acres using the 2.471 acres per hectare conversion (Google: keyword, hectares to acres) using Excel. The U.S. crop acreage data was received from the NASS by county. The data was sorted by county, crop type and acreage of crop irrigated. The Lower Rio Grande was separated into four reaches for this project. Reach 1 was from Fort Quitman to the city of Presidio and consisted of the Texas counties of Hudspeth, Culberson, Jeff Davis, and Presidio. Reach 2 was from the city of Presidio to Amistad and consisted of the Texas counties of Brewster, Terrell, and Val Verde. Reach 3 boundaries existed between Amistad and Falcon Reservoirs and consisted of the Texas counties of Kinney, Maverick, Dimmit, Webb, and Zapata. Reach 4 was from Falcon Reservoir to the Gulf of Mexico and consisted of the Texas counties Starr, Hidalgo, and Cameron. All county crop acreages were totaled by reach and summed using Excel utilities and can be found in the digital tables for this project. Table 2 defines the results of the crops grown in counties within the reaches.

4.4.2 Riparian and Open Water Acreages

An estimation of riparian acreage coverage and open water acreage along the four reaches of the Lower Rio Grande was conducted by Dr.’s Zhuping Sheng and Joshua Villalobos of TAMU.

Spectral identification of riparian environment was used to estimate acreages of riparian and open water area (the river, reservoirs and canals) for four geographic reaches along the Rio Grande utilizing several data sources integrated within a GIS system. To accomplish the identification of riparian environment, remote sensing and associated data was acquired and verified for each reach. Sources of data included Texas View Remote Sensing Consortium for Texas (Texasview, 2004), University of Texas at El Paso, and U.S. EPA. Riparian area acreage was identified by measuring land with riparian vegetation, and open water area was identified by measuring the coverage of surface water in the river channel. Estimates of seasonal riparian and open water acreage in the U.S. by reach for the year 1992 are provided. The total open water area (river, reservoir and canals) for the four reaches is estimated to be 19,530 acres. The total area of riparian coverage amounts to 68,370 acres. Shrub and grass are dominant species, accounting for 86% of total riparian coverage.

Table 2. Crops grown within each reach and country.

	U.S. Reaches				**Mexico Reaches**			
Crop Type	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Alfalfa					X	X	X	
Barley	X	X	X					
Beans					X	X		
Chile					X	X		
Citrus								X
Corn	X	X	X		X	X	X	X
Cotton Amer. Pima	X				X			
Cotton Upland	X		X	X	X	X		X
Forage						X		
Fruit Trees							X	
Grass							X	X
Hay-All	X	X	X	X				
Melon						X		
Oats	X	X	X	X	X	X	X	
Okra								X
Onions					X			
Other					X	X	X	X
Peanuts				X	X	X		
Pistachio						X		
Prairie					X	X		
Rye Grass						X		
Sorghum	X	X	X	X	X		X	X
Soy Beans			X	X	X			
Sugarcane				X				
Sunflower seeds	X			X				
Vegetables							X	X
Vine					X			
Walnut					X	X		
Wheat	X	X	X	X	X	X	X	

Data Sources and Processing

Several sources of data were used to estimate and verify land use types. A combination of several GIS shape files was used to delineate and define the geographic reaches and several (26 total) Landsat 7 ETM+ satellite images were used for verification. Sources of information include images and data from Texas View Remote Sensing Consortium for Texas (Texasview, 2004), University of Texas at El Paso (2004), and U.S. EPA (2004). Due to the large extent of the area (over 830 miles in length), computer processing capacity, budget and time constraints, selected types of identification techniques were applied to most efficiently identify riparian environments. Riparian land use was defined as vegetation associated with wetlands*, where saturation with water is the dominant factor determining soil development and the types of plant and animal communities living in the soil and on its surface (wetlands is described below in the footnote).

In this study, the following vegetative types were included: deciduous forest, evergreen forest, mixed forest, shrubland, grass1ands & herbaceous, woody wetlands and emergent herbaceous wetlands. Multiple 1992 MRLC/NLCD’s (Multi-Resolution Land Characteristics/ National Land Coverage Dataset) images (tiff format) were used (Figure 15) to identify riparian vegetation and land coverage.

The open water defined in the MRLC/NLCD’s consists of rivers, lakes and canals. The 1992 MRLC/NLCD’s images utilized 1991 Landsat 5 images (30 m resolution) to spectrally identify, utilizing a variety of spectral analysis methods, and various land types throughout the contiguous U.S.

Wetlands: The lands where saturation with water is the dominant factor determining soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al. 1979). A characteristic feature shared by all wetlands is soil or substrate that is at least periodically saturated with or covered by water. The upland limit of wetlands is designated as (1) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover; (2) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or (3) in the case of wetlands without vegetation or soil, the boundary between land that is flooded or saturated at some time during the growing season each year and land that is not (Cowardin et al. 1979)."

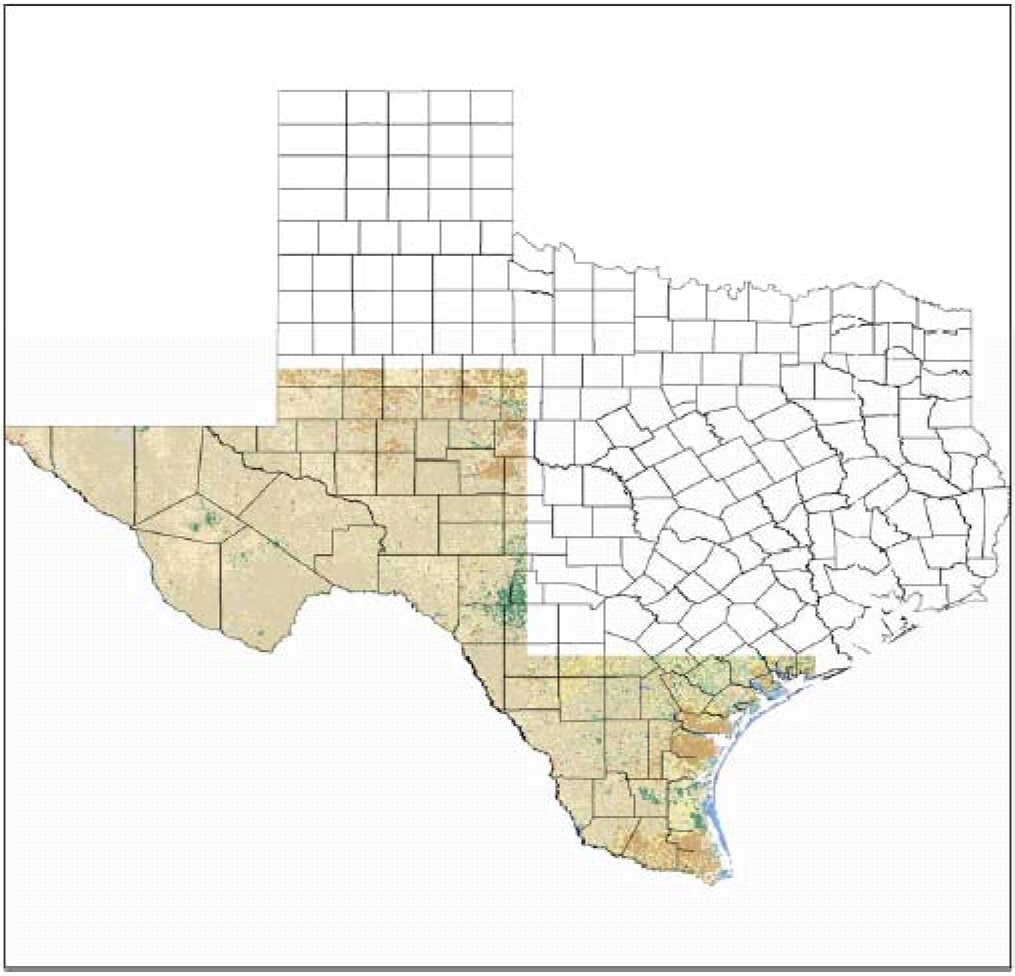


Figure 15. NLCD/MRLC's used for riparian assessment.

With the definition of riparian in mind, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), was used for visual comparison because of its wider spectral range (8 bands total) and additional panchromatic band with a ground resolution of 15 m for enhanced resolution and detection ability. In this study 13 Landsat 7 images (1999 and 2002/2003) were selected along the Rio Grande in Texas for the comparison with 1992 MRLC/NLCD's.

These were comprised of a 1999 set with months ranging from April to November and a 2003 set with months ranging from March to December. The data sets available represent images that were collected on days with highest reflectance and the least amount of cloud coverage. This posed a potential problem in the identification of riparian plants outside of their peak reflectance period or growing seasons. In comparison the MRLC/NLCD images used a variety of dates of satellite image in order to obtain an areas highest reflectance (e.g. peak growth in vegetation, highest level of water) for each class. The acquired Landsat 7 ETM+ images were used minimally to do a gross visual comparison to verify any dramatic land use or land type changes. Therefore, the riparian coverage estimates represent a combination of peak seasonal plant growth.

GIS Analysis

The original MRLC/NLCD images were first reformatted from .tif files into grid files using ArcInfo. This allowed for the clipping of the specific region within each MRLC/NLCD image, which separates a selected area from the whole image and only keeps the data within the selected area. A study area boundary was first identified along the Rio Grande with a GIS shape file for each individual reach (Figure 16). The boundary (or shape) of the shape file was specified by creating a region along the Rio Grande by manually tracing a buffer around the Rio Grande.

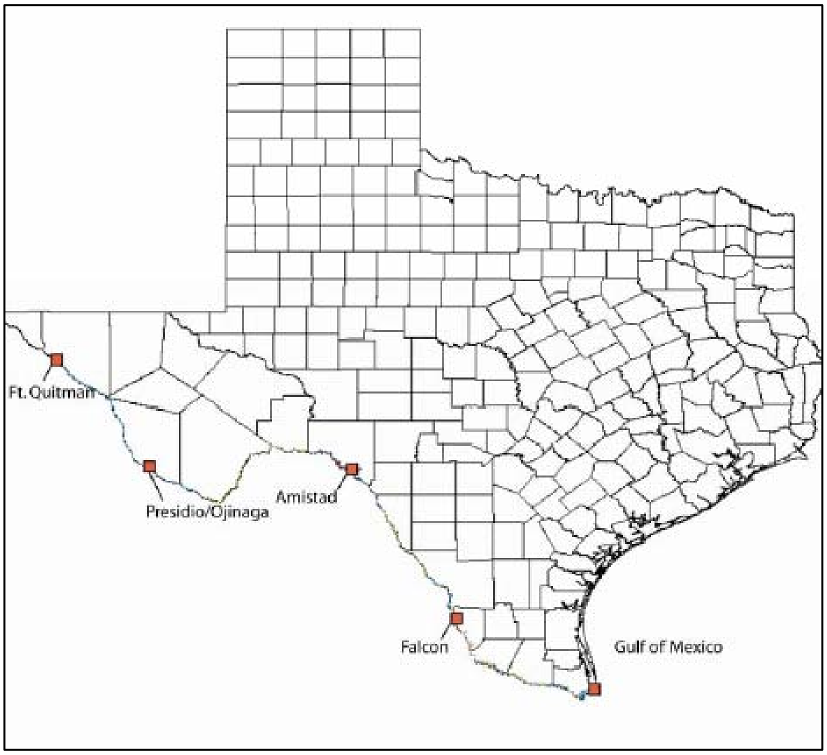


Figure 16. Delineation of the riparian zones for all four reaches.

A manual tracing method was used in lieu of a computer generated buffer because large variation of topography along the Rio Grande makes it difficulty for the computerized buffer to represent regions more accurately. The manual method allowed for the encompassing of pixels that represent either open water of riparian flora that would otherwise not be included if a buffer function was used. Once the regions were identified, a clipping method was used to remove all data outside of the reaches to decrease the overall size of the data and processing time (Figure 17). After the clipping was performed the identification of the pixel ID's that would be used in the identification of riparian environments was done. Pixel ID's were chosen based on either or both their MRLC code's* ability to fit the predefined definition of a wetland and their proximity to open water or to the Rio Grande. After the clipping the pixel, information within each reach's clip was exported and calculated for total area and acreage for each land type.

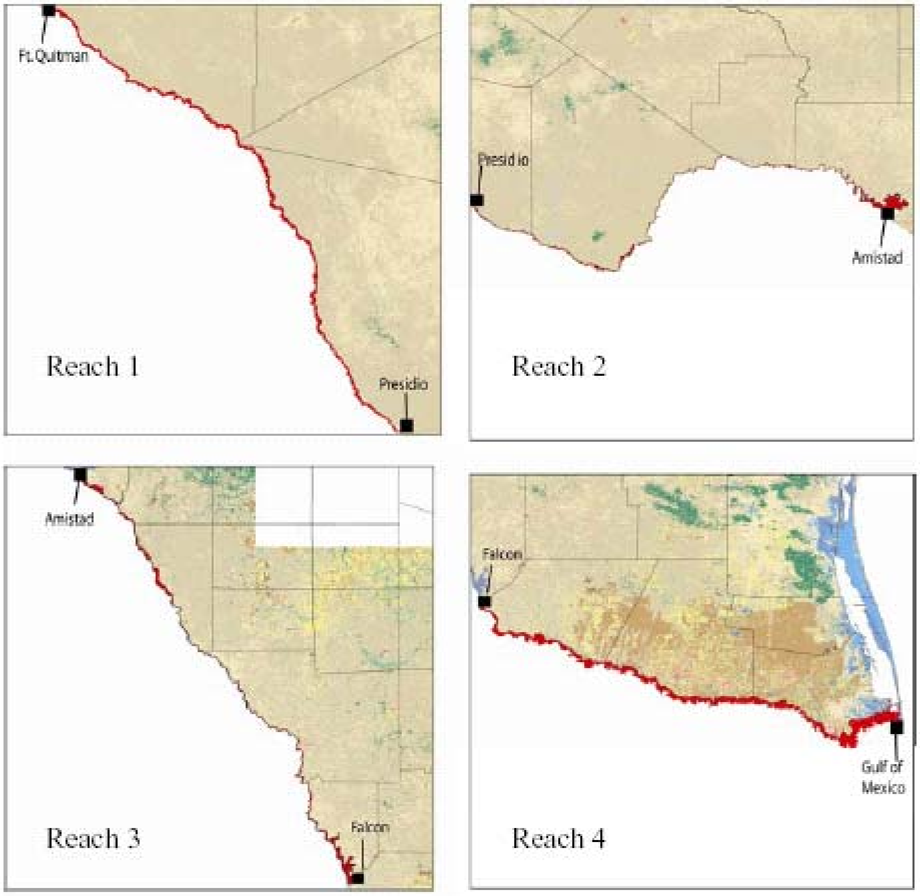
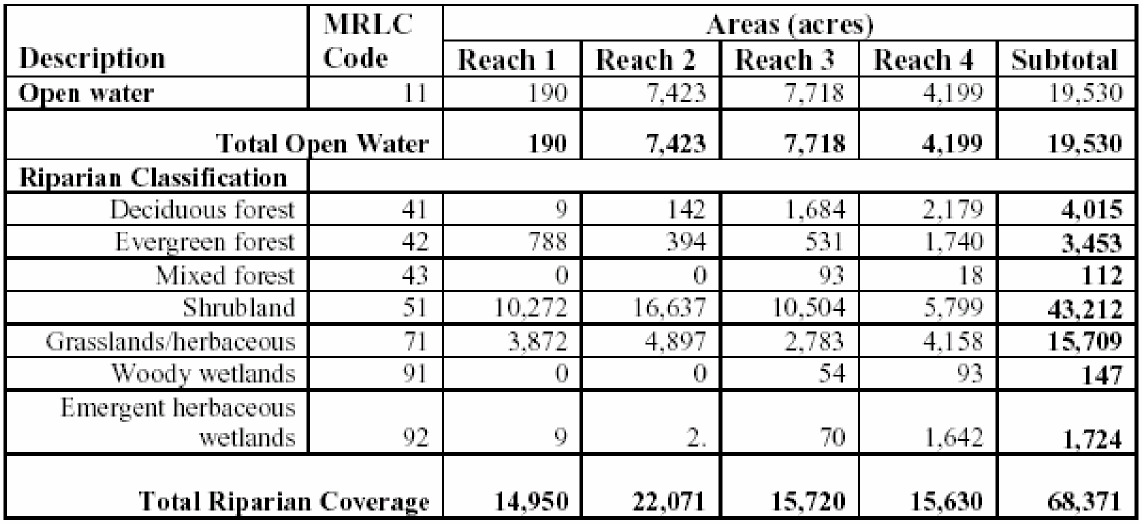


Figure 17. Clipped riparian zones for each reach along the Rio Grande.

The total riparian vegetative area for the four reaches is estimated to be 68,370 acres. This includes the following vegetative types associated with riparian zones: deciduous forest, evergreen forest, mixed forest, shrubland, grass1ands & herbaceous, woody wetlands and emergent herbaceous wetlands. Shrub and grass are dominant types of coverage, accounting for 86% of total riparian coverage (Figure 18). The total open water area (river, reservoir and canals) for the four reaches is estimated to be 19,530 acres. Riparian vegetation cover and open water acreages by river reach are reported in Table 3.

Table 3. Estimate of open water and riparian zones for four reaches along the Rio Grande River.



Description	MRLC Code	Areas (acres)				
		Reach 1	Reach 2	Reach 3	Reach 4	Subtotal
Open water	11	190	7,423	7,718	4,199	19,530
Total Open Water		**190**	**7,423**	**7,718**	**4,199**	**19,530**
Riparian Classification						
Deciduous forest	41	9	142	1,684	2,179	**4,015**
Evergreen forest	42	788	394	531	1,740	**3,453**
Mixed forest	43	0	0	93	18	**112**
Shrubland	51	10,272	16,637	10,504	5,799	**43,212**
Grasslands/herbaceous	71	3,872	4,897	2,783	4,158	**15,709**
Woody wetlands	91	0	0	54	93	**147**
Emergent herbaceous wetlands	92	9	2.	70	1,642	**1,724**
Total Riparian Coverage		**14,950**	**22,071**	**15,720**	**15,630**	**68,371**

Reach 1 estimated total area of open water is 190 acres. The riparian coverage for Reach 1 is estimated to be 14,950 acres. No mixed forest and woody wetlands were identified in this reach. Reach 2 estimated total area of open water is 7,423 acres including Amistad Reservoir. The riparian coverage for Reach 2 is estimated to be 22,071 acres. No mixed forest and woody wetlands were identified in this reach. Reach 3 estimated total area of open water is 7,718 acres including Falcon Reservoir. The riparian coverage is estimated to be 15,720 acres. Reach 4 estimated total area of open water is 4,199 acres with the riparian coverage estimated to be 15,630 acres.

The overall accuracy of this data on the Anderson Level I classification (Anderson et al. 1976) (for this study: open water) is ~85% for the year 1992. For Anderson Level II classification (for this study: deciduous forest, evergreen forest, mixed forest, shrubland, grasslands/herbaceous, woody wetlands, and emergent herbaceous wetlands) the overall accuracy of the 1992 MRLC/NLCD is ~ 60%. A method of evaluating and comparing current land types to the 1992 data set is needed since the 2001 MRLC/NLCD images are not yet available for the state of Texas. The following recommendations are made for future studies to gain a better understanding of riparian vegetative cover and their spatial and temporal variation. A more detailed analysis of each reach by identifying major riparian flora in each reach is recommended. Due to elevation and soil type variations in different reaches, dramatic changes were observed in flora types and water availability. As a result, each reach is biologically different and therefore has a unique spectral reflectance. A closer look at the individual reaches and their main riparian flora types will yield a more detailed analysis of riparian environments for each reach.

The Landsat 7ETM+ images are recommended to be used for a more detailed verification of land types and temporal variation of land uses. By merging of Landsat 7 panchromatic band with 3 (7-4-2) bands it is expected to yield an image with a spectral resolution of 15 meters, instead of the 30 meter resolution of the 1992 MRLC/NLCD, which will help improve accuracy of land use identification.

4.5 Consumption Per Capita

The water consumption per capita was computed by taking IBWC's yearly municipal water use and subtracting the yearly sewage return flow, and dividing by the population provided by IBWC Water Bulletins for each city. A per capita consumptive use was then converted to gallons per day a single person used. Cities Eagle Pass, Laredo, Rio Grande City, Roma and Brownsville had data for the United States side of the border with Laredo having the most complete data form 1950-2002 with the exception of year 1966 which is missing throughout all of IBWC's records. Nuevo Laredo, was the only Mexican city IBWC recorded for outfalls to the river. Unfortunately data for this city is limited 1976-1984, and 1999-2001. Figure 19 shows the years of consumptive rate per capita data recorded by IBWC for each of the cities.

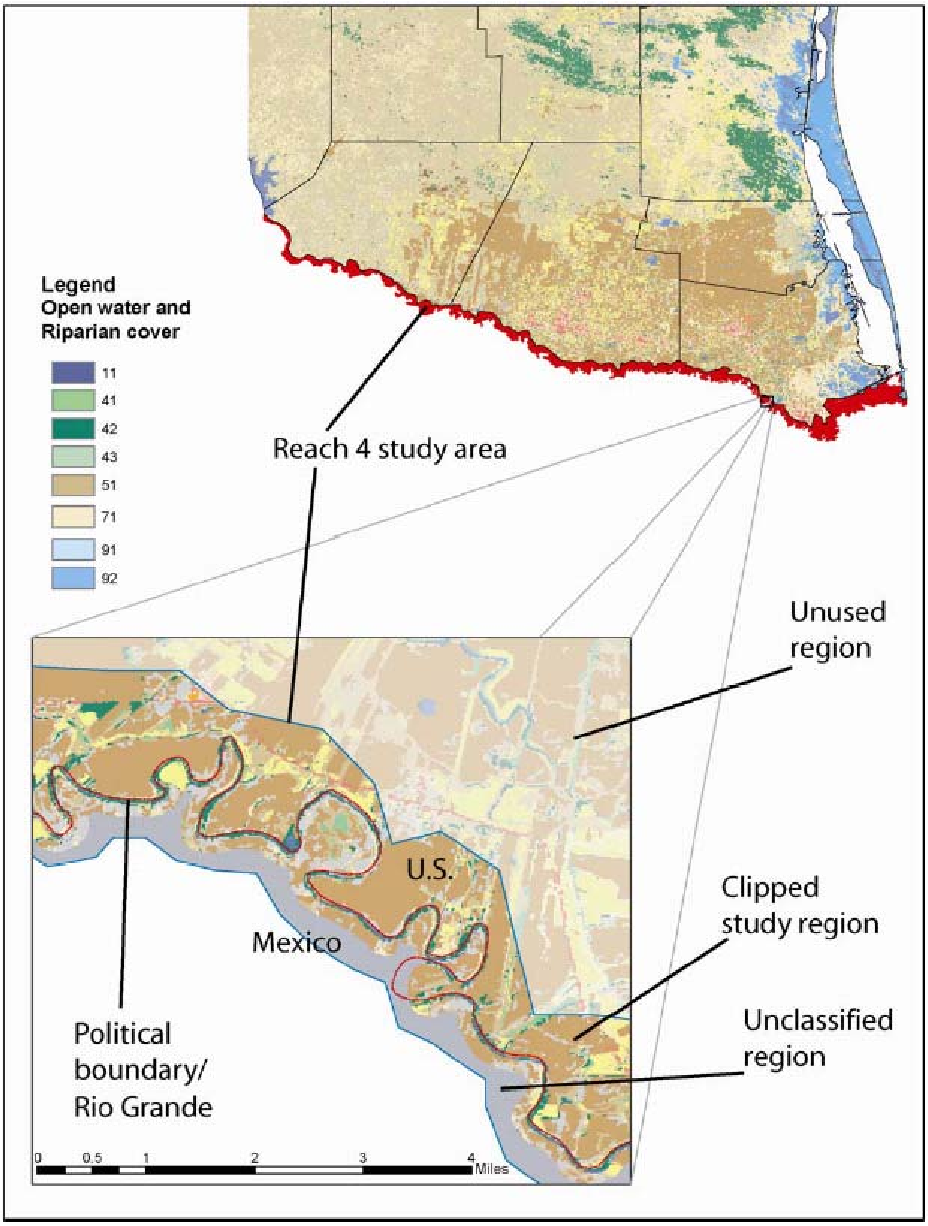


Figure 18. Examples of riparian cover and open water for Reach 4.

A computed water consumption per capita value using IBWC results was obtained for each reach using the following method. Cities that fell within each reach were averaged. Reach 1 and 2 had no data associated with these reaches therefore an adjustment using Reach 3 and 4 data was used.

Because no data existed for cities within Reach 1, 2, or 3 for the years 1950-1959, the same Laredo (Reach 3) value was used for these reaches. Years 1960-2001 had data for Reaches 3 and 4 but again do data for Reaches 1 and 2. The average of Reach 3 and Reach 4 data was used to fill in years 1960-2001 for Reaches 1 and 2.

The model uses the computed reach consumptive use per capita values, and total population for each Reach to compute total consumptive use per reach in gallons per day. Populations for all bordering cities is discussed in the Population Section above. Figure 19 shows cities of IBWC consumptive use per capita values that were used to define all cities along the border.

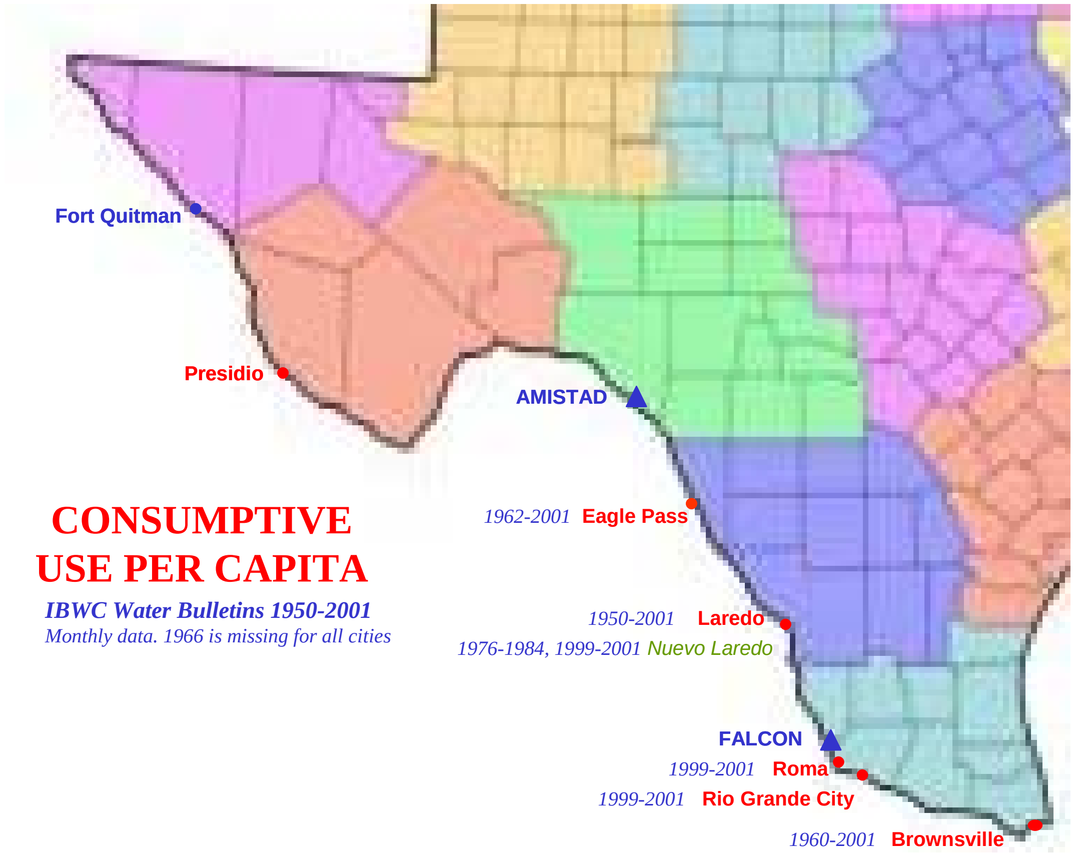


Figure 19. Consumptive use values calculated using IBWC data for bordering cities.

4.6 Geology

The lower Rio Grande River's geology discussion was prepared using a 1999 Land Resource Map of Texas provided by the Bureau of Economic Geology at the University of Texas at Austin. Figure 20 shows a depiction of the various rock types for the Lower Rio Grande River.

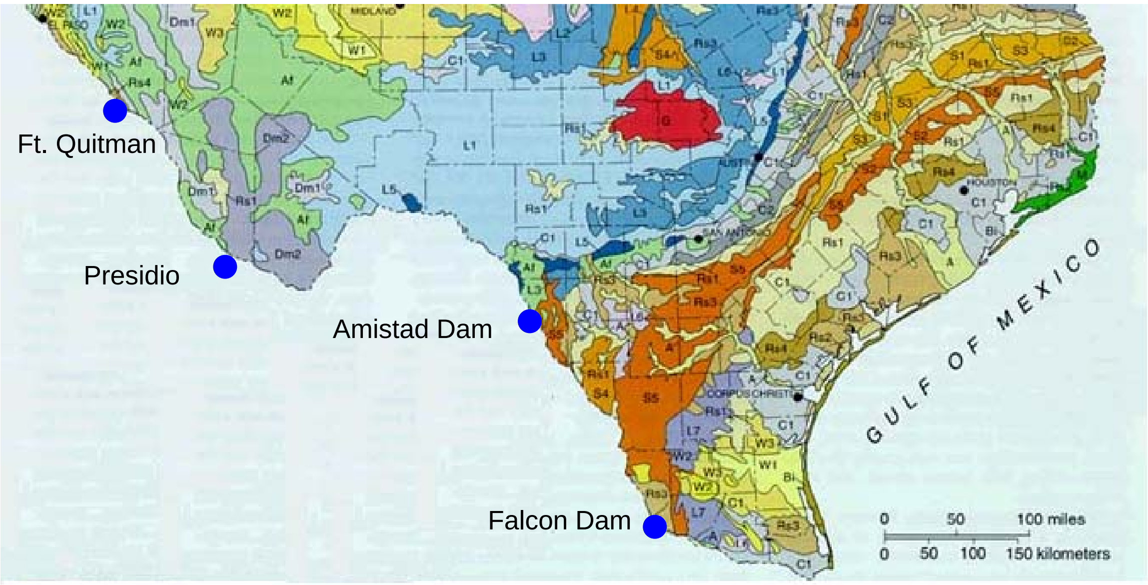


Figure 20. Depiction of rock types for the lower Rio Grande River. (http://www.lib.utexas.edu/geo/landresj3.jpg).

The percentages of land resources for the four major reaches of this model are estimated from the Land Resources Map of Texas. The first reach between Fort Quitman and Presidio contains about 55% alluvial tar, 40% desert mountain terrain, and 5% aquifer recharge zone. The second reach between Presidio and Amistad Dam contains 40%, desert mountain and canyon land (volcanic rock), 55% massive limestone, and 5% chalk. Land along the Rio Grande River between Amistad and Falcon Dams making up the third reach contains 50% sand and mud (undifferentiated), 10% chalk, 10% sandstone and shale, 5% major recharge sand, 10% alluvial tar, and 15% secondary aquifer recharge. Lastly, the fourth reach from Falcon Dam to the Gulf of Mexico contains 70% expansive clay and mud, 16% flood-prone valley and terrace, 7% sand and mud (undifferentiated), and 7% secondary aquifer recharge.

Table 4 shows a relationship table of rock types and reaches and Table 5 contains a description of each of the rock types (1999 Map of Texas, Bureau of Economic Geology at UT at Austin).

Table 4. Comparison of rock types percentages of the reaches within the model.

Rock Type	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**
Major recharge sand			5	
Secondary aquifer recharge			15	7
Aquifer recharge zone	5			
Sandstone and shale			10	
Sand and mud (undifferentiated)			50	7
Expansive clay and mud				70
Massive limestone		55		
Chalk		5	10	
Desert mountain terrain (sedimentary rock)	40			
Desert mountain and canyon land (volcanic rock)		40		
Alluvial tar	55		10	
Flood prone valley and terrace				16
Total: Percent	*100*	*100*	*100*	*100*

Table 5. Rock descriptions and definitions.

Rock Type	Description
Major recharge sand	Some gravel; high permeability, stable, vegetated slopes in rolling hills to flats.
Secondary aquifer recharge	Sand with mud; moderate permeability, relict barrier strand plain
Aquifer recharge zone	Mix of mainly coarse and lesser fine sand systems; low-relief, sandy loam soil.
Sandstone and shale	Locally thin coal and limestone; poor soil; subdued stair step topography.
Sand and mud (undifferentiated)	Cuesta - swale topography; colluvial, Deep sand and clay loam
Expansive clay and mud	Locally silty, locally calcareous flat to low, hilly prairie; commonly tilled.
Massive limestone	Building stone, thin soil; flat with locally deep dissection; karst topography
Chalk	Potential cement material; high slope stability; black, expansive soils; rolling prairie.
Desert mountain terrain (sedimentary rock)	Steep, variable rock types; loose surface rock.
Desert mountain and canyon land (volcanic rock)	Rugged; many box canyons; lava and explosive debris.
Flood prone valley and terrace	Alluvium of sand and mud; sparse gravel stream channels flats and coastal marshes.
Alluvial tar	Trans Pecos; active cover; Rio Grande; relict chert gravel; balcones escarpment; calcareous detritus.

4.7 Soils

Figure 21 presents a graphic showing the major types of soils in the lower Rio Grande (from *"Land Resource Regions and Major Land Resource Areas of the United States". United States Department of Agriculture Soil Conservation Service Handbook 296. Dec. 1981. pages 58-59.*) Each reach of the model has a different soil type with Reachs 2 and 3 being the most similar. A description of each reach and their soils and vegetation is discussed.

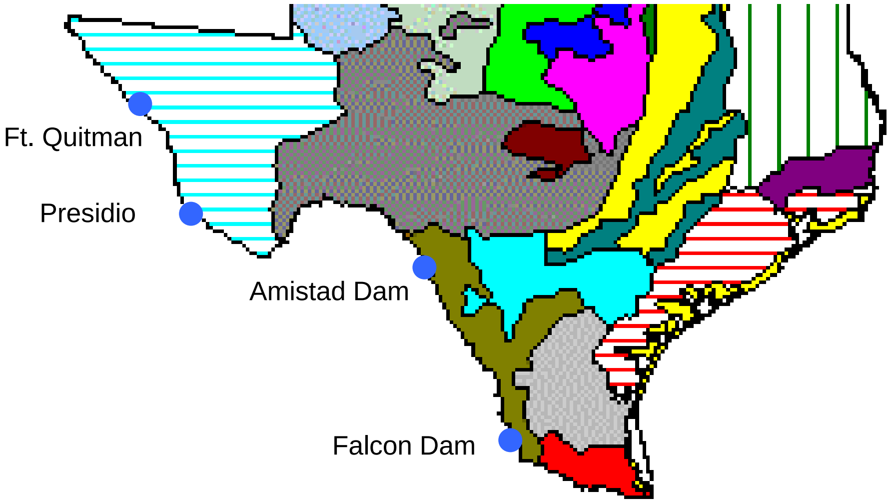


Figure 21. Soil types of Lower Rio Grande border region.
(modified from http://soilphysics.okstate.edu/S257/south/mlra/ 42.htm)

Reach 1 soils are Argids and Orthids. They are well drained and medium textured and have a thermic temperature regime, an aridic moisture regime, and mixed or carbonatic mineralogy. Deep and moderately deep Haplargids, Paleargids, and Calciorthids are on uplands, piedmont plains, and dissected terraces. Shallow Haplargids, shallow Calciorthids, Ustolls, and Torriorthents are on bedrock-controlled uplands. Shallow Paleorthids are on mesas, uplands, and terraces. Deep and moderately deep Gypsiorthids are in closed basins. Camborthids, Natrargids, and Torrerts are on basin floors. Torrifluvents are on the flood plains. Torripsamments are on hummocky sandy uplands.

Natural vegetation for Reach 1 includes desert grass-shrub vegetation. Giant dropseed and mesa dropseed, along with scattered shrubs such as sand sagebrush and yuccas, grow on the sandier soils. Creosotebush, tarbush, catclaw, and javalinabush are on gravelly, calcareous foot slopes. Giant sacaton, vine-mesquite, desert willow, brickellbush, and mesquite grow in drainage ways and depressions. Juniper, pinyon, scattered ponderosa pine, and Douglas-fir are on upper mountain slopes.

wells and ponds provide water for livestock, domestic use, and irrigation. Most of the soils are Usterts and Torrerts. They are deep, fine textured saline soils that have montmorillonitic mineralogy. Also extensive are Ustolls and Orthids that have been mixed mineralogy. These soils have a hyperthermic temperature regime and an ustic or aridic moisture regime. Nearly level to gently sloping Pellusterts are on plains over clayey marine sediments. Gently undulating Torrerts are on plains in the southwestern part of the area. Nearly level Haplustolls and Calciustolls are on broad plains in the northern part. Shallow and gravelly Calciustolls are on ridges and small hills. Nearly level to gently undulating Calciorthids are on plains over marine sediments. (Modified from http://soilphysics.okstate.edu/S257/south/mlra/83b.htm

Reaches 2 and 3 support open grassland with scattered shrubs. Mid grasses such as alkali sacaton, twoflower trichloris, pink pappusgrass, white tridens, whiplash pappusgrass, and vine-mesquite are dominant on deep, clayey soils. Guayacan, spiny hackberry, desert yaupon, and fourwing saltbush are the principal shrubs. Bundleflower, bush sunflower, Texas varilla, and other forbs make up a minor but significant part of the plant communities. The more gravelly soils support semi-open grassland vegetation of mid grasses interspersed with low-growing shrubs. Guajillo, blackbrush, and kidneywood are the principal shrubs. Arizona cottontop, sideoats grama, pink pappusgrass, pinhole bluestem, green sprangletop, and tanglehead are the dominant grasses. Several species of forbs grow on these soils, mainly bush sunflower, orange zexmania, snoutbeans, daleas, and gauras. From *"Land Resource Regions and Major Land Resource Areas of the United States". United States Department of Agriculture Soil Conservation Service Handbook 296. Dec. 1981. pages 57 - 58.*)

Rainfall is adequate for the growth of range grasses and is characterized by high temperatures and high evaporation and transpiration rates. The Rio Grande, the only perennial stream, provides water for irrigation. Locally, deep wells and ponds provide water for live- stock, domestic use, and irrigation.

Most of the soils in Reach 4 are Ustalfs. They are deep, moderately fine textured and fine textured soils that formed in alluvial sediments. They have a hyperthermic temperature regime, an ustic moisture regime, and mixed mineralogy. Ustolls having mixed mineralogy are also extensive. Nearly level to gently sloping Paleustalfs are on plains in the northeast. Nearly level to gently undulating Haplustalfs are on plains in the west. Nearly level to gently sloping Calciustolls are on plains in the central and eastern parts of the area. Nearly level Ustifluvents are on flood plains along the Rio Grande.

Reach 4 is characterized by open mid grass prairie vegetation with scattered woody plants and some perennial forbs and legumes on upland soils. Twoflower and fourflower trichloris, plains bristlegrass, and lovegrass tridens are among the dominant grasses. Desert yaupon, spiny hackberry, and blackbrush are major woody plants. Tall and mid grasses such as switchgrass, giant sacaton, fourflower trichloris, big sandbur, little bluestem, and southwestern bristlegrass are dominant on the savanna plant communities on bottom lands. Hackberry and elms are major woody plants. Forbs are important but minor components of the plant communities.(Modified from http://soilphysics.okstate.edu/S257/south/mlra/83d.htm.

5.0 Results

The model is incomplete. No results are available.

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X Censo General de Poblacion. 1980. The data was by state, which are described below.
Coahuila t.5 V. 1. Table 1 – Poblacion total por municipio y edad según sexo.
Chihuahua t. 8 V. 1 Table 1 – Poblacion total por municipio y edad según sexo.
Tamaulipas t. 28 V. 1 Table 1 – Poblacion total por municipio y edad según sexo.

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Appendix A

Simulating Data for Missing Time Periods in the Pecos and Devils Rivers

This document presents the method used to simulate data for the Pecos and Devils Rivers from the time period of January 1950 through December 2003. IBWC was the preferred website used for gaging station flow data selected for flow analysis on the Rio Grande. However in cases where IBWC data did not exist, USGS gaging sites were used to create simulated data.

Pecos River

The primary site chosen for Pecos River outflow to the Rio Grande River was IBWC site Pecos_Langtry which is the closest Pecos River gaging station to the Rio Grande River as shown in the map below.

PECOS RIVER

Nine other gaging station sites were considered for defining the outflow of the Pecos River into the Rio Grande. These included USGS gaging sites Orla, Mentone, Barstow, Pecos at Pecos, Pecos River below Grandfalls, Pecos County WID No. 2 Canal near Imperial, Pecos County WID No. 3 Canal near Imperial, Pecos near Sheffield, and Girvin.

The IBWC Langtry station contains data for the period Jul 67 through Oct 03, while the USGS Girvin station has data for the period Sep 39 through Sep 02, and the USGS Orla station has data for the period Jun 37 through Sep 93. All other gaging stations were missing the period of record between 1950 through 1967 and were therefore not used in further analyses. As the Lower Rio Grande project requires data for the period from Jan 50 to Dec 03 it was decided to simulate data for the Langtry station for the period from Jan 50 through Jun 67 using both Girvin and Orla Gaging station data.

Examination of the graph in Figure 1 indicates that the Girvin and Orla stations are the only stations that have data for the missing period Jan 50 through Jun 67, and as these stations are both upstream from Langtry, the data sets will be correlated. The objective is to use this upstream data to identify a seventeen-year period in the existing Langtry data that most closely mimics the behavior of either the Girvin or Orla stations for the period from Jan 50 through Jun 67. This was accomplished by calculating a sequence of correlation coefficients between the Jan 50 through Jun 67 period of the Girvin and Orla data with a moving seventeen-year period starting from Jun 67 of the Langtry data. Specifically, the first correlation value is between the period (1/1/50 – 6/30/67) for Girvin or Orla stations and the period (7/1/67 – 12/28/84) for the Langtry station. The next correlation value will be between the same period for Girvin and Orla while the Langtry period moves ahead one day (7/2/67 – 12/29/84). This pattern continues until the last seventeen-year period of the Langtry data (7/3/86 – 12/31/03). The time period corresponding to the largest positive correlation coefficient will be the period that most closely matches the data for the Jan 50 through Jun 67 period and is the best fit for the time period of missing data for the IBWC Langtry station (01/01/50 – 07/01/67).

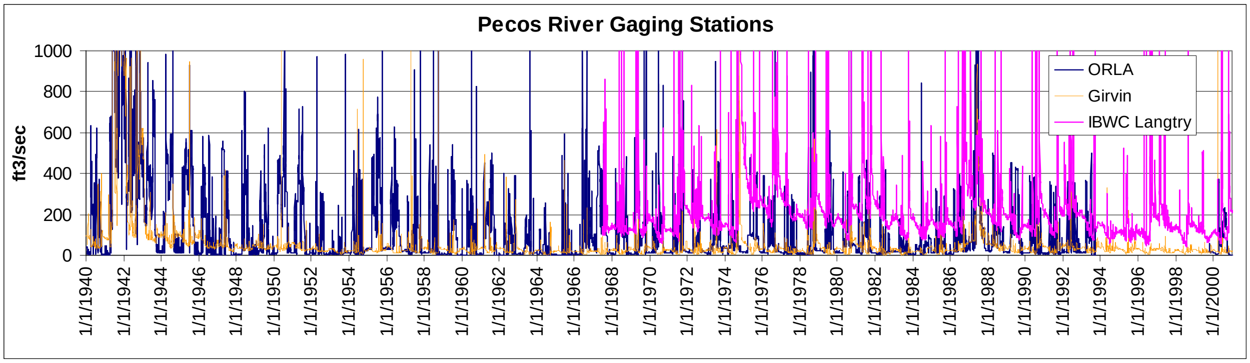


Figure 1 – Plot of the data from the Langtry, Girvin, and Orla gaging stations.

This method was employed for both the Orla and Girvin data sets with the Orla data analysis resulting in the largest positive correlation coefficient (0.288). The time period corresponding to this value was 12/20/68 through 6/19/86 of the Langtry station data. Therefore this period is the best match for the missing time period Jan 50 through Jun 67 and is copied and pasted into the period from Jan 50 through June 67 for Langtry. This result is shown in Figure 2 in red.

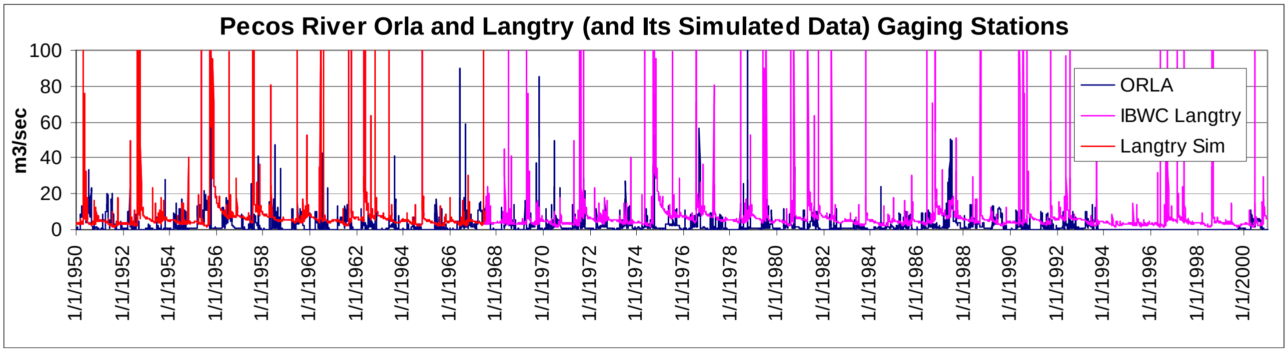
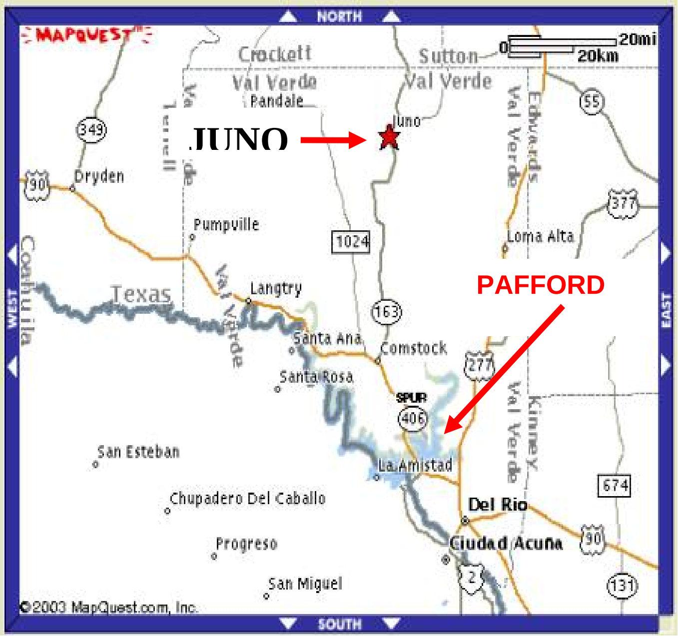


Figure 2 – Plot of the data from the Langtry and Girvin gaging stations, including the simulated data.

Devils River

Two stations, Devils_Pafford and Devils_Juno, were used to define the outflow of the Devils River to the Rio Grande. The approximate location of the stations is shown in the map below. The IBWC Devils_Pafford site was the gaging station closest to the Rio Grande and contained data for the periods Jun 25 through Sep 49 and Jan 60 through Dec 03. USGS Devils_Juno contained data from Oct 63 through Sep 73. As with the Pecos River, the project requires data for the period from Jan 50 to the present. Therefore it was necessary to simulate data for the Pafford station for the period Jan 50 through Dec 59.



DEVILS RIVER

With the Pecos River it was possible to use the data from a gaging station upstream of the site to simulate data for Langtry, the site closest to the Rio Grande River. For the Devils River this was not possible as there is no actual data available from the Juno station for the period Jan 50 through Dec 59. Therefore it was necessary to consider an alternative solution. Since actual data exists on the Pecos River for the period of interest it was decided to consider this for the simulation employing the correlation methodology presented earlier.

The procedure used to simulate the missing Devils_Pafford data was identical to that used to simulate the Pecos Langtry data. Only the period of missing time has changed to the ten years from Jan 50 through Dec 60. The correlation was performed for both the Pecos Girvin data versus the Devils Pafford data and for the Pecos Orla data versus the Devils Pafford data. The highest positive correlation values were 0.277 for the Orla data and 0.579 for the Girvin data. As the Girvin correlation was higher the period corresponding to this value was used, namely Nov 28, 1989 through Nov 27, 1999. Figure 3 shows a line graph of Juno, Orla, Girvin, and Pafford with Pafford simulated data for comparison. The data corresponding to this period from the Devils_Pafford station was used to simulate the missing Devils_Pafford data from Jan 50 through Dec 60. The results are presented in Figures 4 and 5 in bolded red.

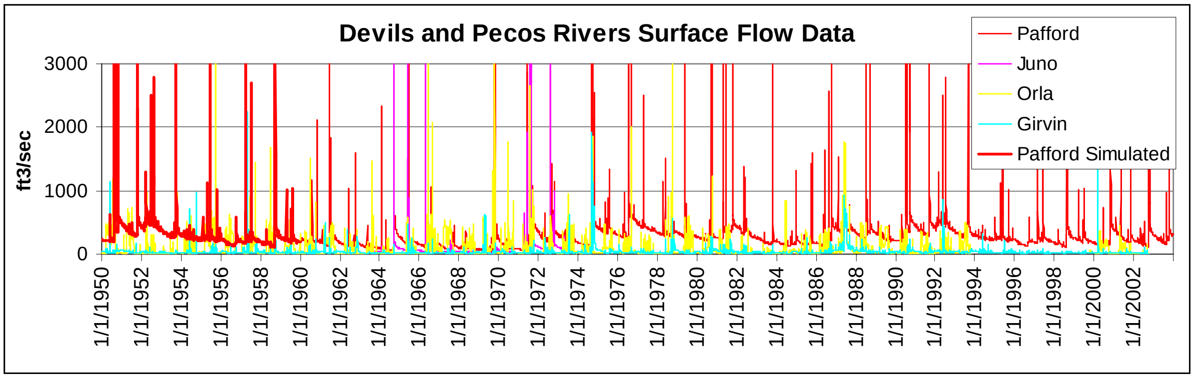


Figure 3 - Devils and Pecos Rivers surface flow data with Pafford Crossing simulated data.

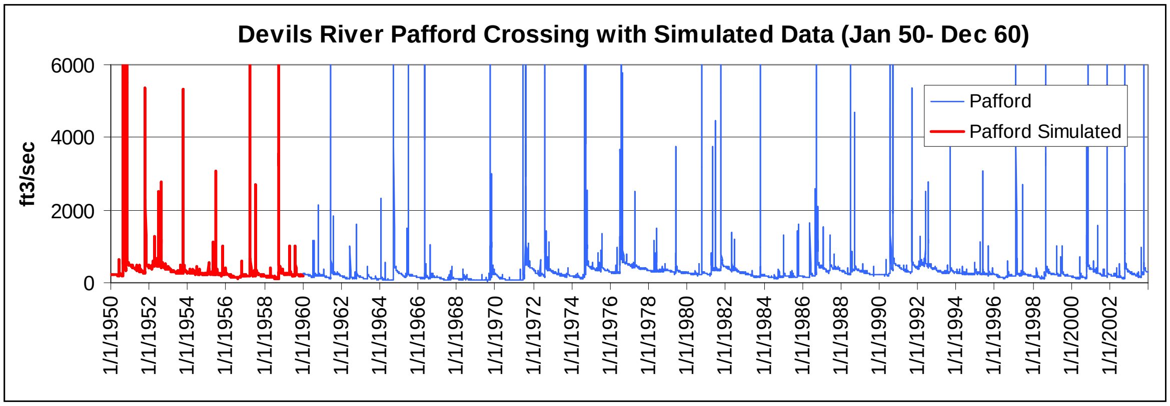


Figure 4 - Plot of the Devils River Pafford Crossing with simulated data.

Rio Grande

There are a total of nine stations along the Rio Grande that supply flow data; Rio Grande at Fort Quitman, Rio Grande above Conchos, Rio Grande at Conchos, Rio Grande below Conchos, Rio Grande above Amistad Reservoir at Langtry, Rio Grande below Amistad Reservoir near Del Rio, Rio Grande above Falcon Reservoir at Laredo, Rio Grande below Falcon Reservoir near Falcon, and Rio Grande at Brownsville. Of these nine, four stations do not have data for the entire period of interest and required simulation. These are Rio Grande at Conchos, Rio Grande above Amistad Reservoir at Langtry, Rio Grande below Amistad Reservoir near Del Rio, and Rio Grande below Falcon Reservoir near Falcon.

For the Rio Grande at Conchos station, data is lacking for the period from Jan 50 through Mar 54. The neighboring station Rio Grande above Conchos contains data for this period so the moving correlation method was employed where the Jan 50 through Mar 54 period of flow data from the Rio Grande above Conchos station was correlated with a moving four-year period from the Rio Grande at Conchos flow data. The results indicate that the highest positive correlation is 0.673 corresponding to the time period Mar 68 through May 72 of the Rio Grande at Conchos data. Therefore the data from this period was substituted for the missing Jan 50 through Mar 54 data. This result is shown in Figure 5.

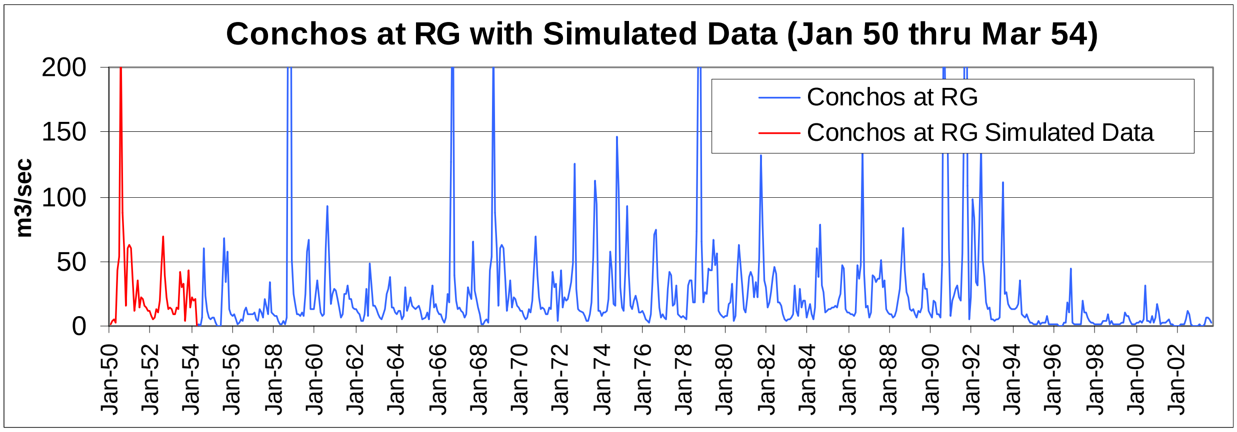


Figure 5 - Plot of the Rio Grande at Conchos, including the simulated data.

Data is lacking for the period from Jan 50 through Aug 61 for the Rio Grande above Amistad Reservoir at Langtry station. The neighboring station Rio Grande below Conchos contains data for this period so the moving correlation method was employed where the Jan 50 through Aug 61 period of flow data from the Rio Grande above Amistad Reservoir at Langtry station was correlated with a moving eleven-year period from the Rio Grande below Conchos flow data. The results indicate that the highest positive correlation is 0.625, corresponding to the time period Jan 70 through Aug 81 of the Rio Grande above Amistad Reservoir at Langtry data. Therefore the data from this period was substituted for the missing Jan 50 through Aug 61 data. This result is shown in Figure 6.

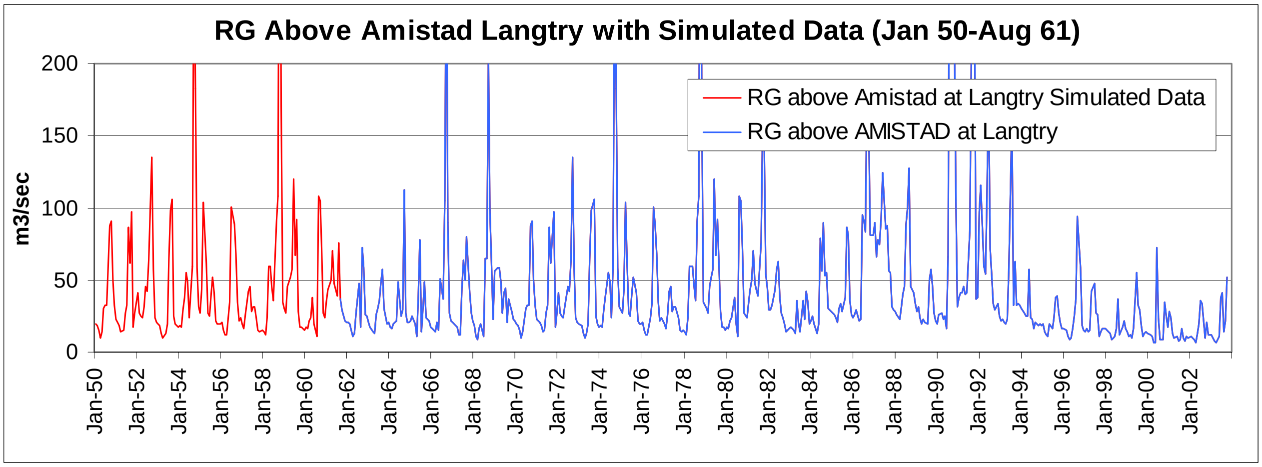


Figure 6 - Plot of the Rio Grande above Amistad Reservoir at Langtry, including the simulated data.

Data is lacking for the period from Jan 50 through Aug 54 for the Rio Grande below Amistad Reservoir near Del Rio station. The neighboring stations Rio Grande below Conchos and Rio Grande above Falcon Reservoir at Laredo each contain data for this period so the moving correlation method was employed where the Jan 50 through Aug 54 period of flow data from the Rio Grande below Conchos and the Rio Grande above Falcon Reservoir at Laredo stations was correlated with a moving four-year period from the Rio Grande below Amistad Reservoir near Del Rio. The results indicate that the highest positive correlation is 0.861 with the Rio Grande above Falcon Reservoir at Laredo data, corresponding to the time period Apr 60 through Nov 64 of the Rio Grande below Amistad Reservoir near Del Rio data. Therefore the data from this period was substituted for the missing Jan 50 through Aug 54 data. This result is shown in Figure 7.

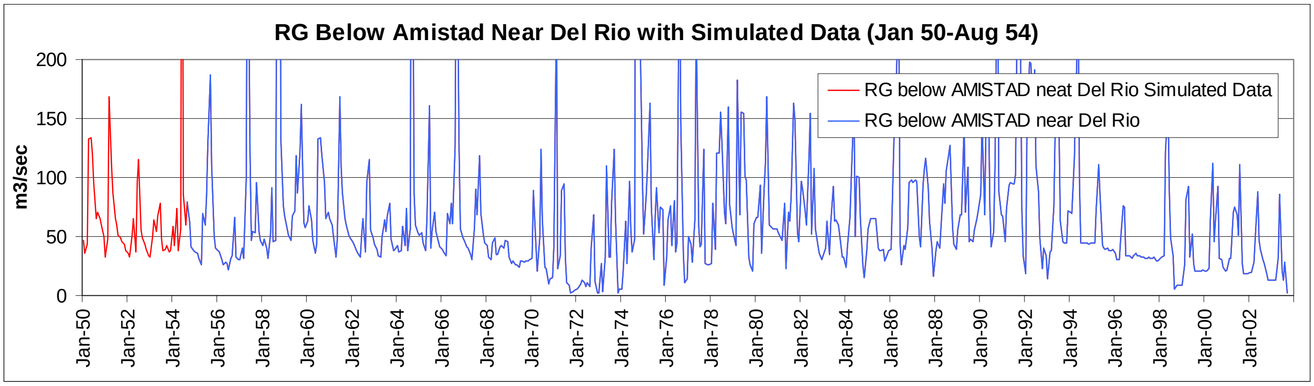


Figure 7 - Plot of the Rio Grande below Amistad Reservoir near Del Rio, including the simulated data.

Data is lacking for the period from Jan 50 through Dec 57 for the Rio Grande below Falcon Reservoir near Falcon station. The neighboring stations, Rio Grande above Falcon Reservoir at Laredo and Rio Grande Brownsville, each contain data for this period so the moving correlation method was employed where the Jan 50 through Dec 57 period of flow data from the Rio Grande above Falcon Reservoir at Laredo and the Rio Grande Brownsville stations was correlated with a moving seven-year period from the Rio Grande below Falcon Reservoir near Falcon. The results indicate that the highest positive correlation is 0.611 with the Rio Grande Brownsville data, corresponding to the time period Apr 94 through Jul 02 of the Rio Grande below Falcon Reservoir near Falcon data. Therefore the data from this period was substituted for the missing Jan 50 through Dec 57 data. This result is shown in Figure 8.

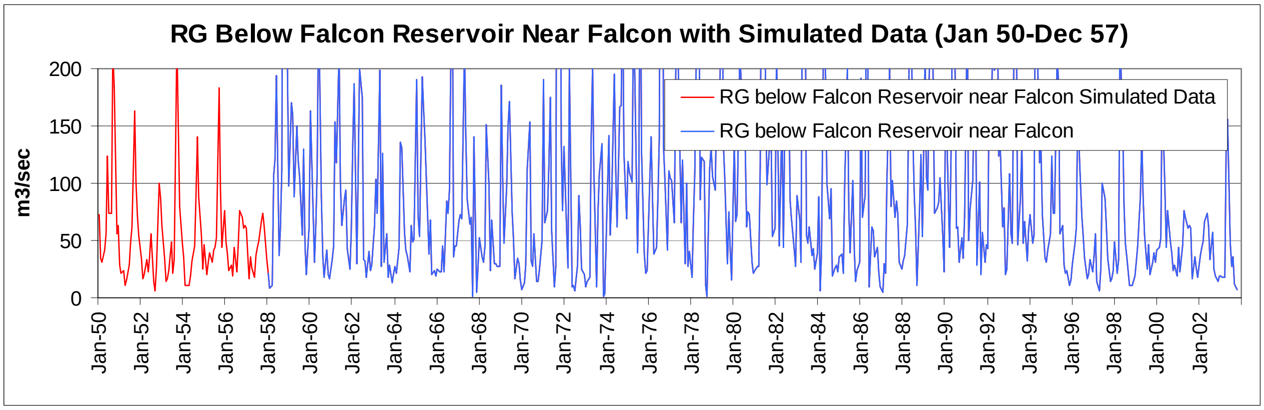


Figure 8 - Plot of the Rio Grande below Falcon Reservoir near Falcon, including the simulated data.

<u>All data files pertaining these plots are:</u>
Correlated Devils 061504.xls
Correlated Pecos 061503.xls
Correlated LRG Stations m3 per sec 061504.xls
Pecos and Devils Gaging Sites.ppt
Correlated LRG Pecos Devils Discussion 061504.doc (this file)

APPENDIX B

Data files collected for the Lower Rio Grande Model are summarized on the following pages.

File Type		US/MEX	Source(s)	Filename	Notes
xls	Flow (Surface)	U	http://water.usgs.gov/data.html	USGS Historic to Present STREAMFLOW DATA.xls	Has all the USGS sites along Lower Rio Grande by County. Contains a readme spreasheet. Lists all historic to present surface flow data available from USGS.
doc	Agriculture links in Texas	U	n/a	Texas Ag Useful Links.doc	File contains hyperlinks to various agriculture centers for data and information.
doc	Riparian Vegetation	U-M	http://www.csr.utexas.edu/projects/rs/riparian.html	1996 Riparian Vegetation Estimate.doc	This is a short clipping of the article that gives an estimate of the riparian acreage from Falcon to the Gulf. See the original source for the entire document.
doc	Texas Watermaster Duties	U	http://www.tnrcc.state.tx.us/enforcement/fod/wmaster/wmaster1.html#rgofc	What the Watermaster Does.doc, Watermaster OFFICE Names and Numbers.doc	This is taken from the Texas Watermaster site. Describes what the watermaster does, how to get in contact with him, and has a nice graphic showing the area of Texas that he is responsible for. The second file lists only phone numbers in the Watermaster office and the graphic.
pdf	Economy	U-M	Taken from “The Border Economy" Federal Reserve Bank of Dallas June 2001 http://www.dallasfed.org/research/border/	Border Economy june01.pdf	This is a good article about border economy. Has a good photograph of the larger bordering cities and Mexican states.
xls	Agriculture	U	http://www.nass.usda.gov/census/census97/highlights/tx/tx.htm	1997 census ag data.xls	Lists all the bordering counties 1992 and 1997 highlights of agriculture. Most of this data has not been formatted.
xls	Agriculture	U	http://agcensus.mannlib.cornell.edu/show2.php	Census AG 87 92 97.xls	Contains agriculture census data for 1987, 1992, 1997
xls	Consumptive Use	U	Texas Water Development Board (http://www.twdb.state.tx.us/data/popwaterdemand/2003Projections/HistoricalWaterUse/2002WaterUse/HTML/2002city.htm)	Consumptive per capita 2002.xls	2002 Water Use Survey with estimates by city
xls	Dewpoint	U	NOAA$400 Cd Data	NOAA$400 *.xls, * is El Paso, Marfa, Sanderson, Dryden, Laughlin, Del Rio Laredo, McCallen and Brownsville.	Data is in 9 individual city files associated with NOAA$400 CD directory. Data period of record varied for each city. Brownsville was the only city with complete data (1950-2003) .

xls	Elevation	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Elevations were listed on Municipal and Industrial Use tables from the Water Bulletins 1950-2001.
xls	Evaporation	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Evaporation Tables are found in most Water Bulletins. The digital file lists these values.
xls	Evaporation	M	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Evaporation Tables are found in most Water Bulletins. The digital file lists these values.
xls	Municipal per capita use	U	Phone calls by Marty.	Marty phone calls on Municipal per capita data 090904.xls	Gretchen put together a sheet with all major cities and researched phone numbers to call agencies about per capita use. This is a summary of those phone calls.
xls	Population	U	http://txsdc.tamu.edu/download/pdf/estimates/2001_txpopest_place.pdf and 'http://txsdc.tamu.edu/tpepp/2001_txpopprj_cntytotnum.php	2000 census Pop with 2040 projection.xls	Census county and city populations in Texas for 2000 and projected for 2040.
xls	Precipitation	U	Utah and National Climatology www.met.utah.edu/jhorel/html/wx/climo.htm	Met-utah data-NOT USED.xls	1961-1990 averaged month values, 12 values for cities El Paso, Del Rio, and Brownsville
xls	Precipitation	U	National Solar Radiation Database http://rredc.nrel.gov/solar/old_data/nsrdb/dsf/data/12919.txt	Solar Radiation & WIND texas and National Databases 092904 MODEL.xls	Only 2 cities El Paso and Brownsville listed that had data for 1961-1990 therefore not used.
xls	Relative Humidity	U	Utah and National Climatology www.met.utah.edu/jhorel/html/wx/climo.htm	Met-utah data-NOT USED.xls	Through 1993 averaged month values, 12 values for cities El Paso (33 yr ave, Del Rio (16 yr ave), and Brownsville (27 yr ave).
xls	Relative Humidity	U	Washington Post Data www.washingtonpost.com/wp-srv/weather/historical/historical.htm	Relative Humidity 100104 MODEL.xls	One average for all months over 29+year time sapn (Jan Feb Mar - a total of 12 values for each city
xls	Relative Humidity	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Only Falcon Dam has a record for 1950-2001. The rest are broken years and couldn't be used (Dryden, Eagle Pass, Tortuga Ranch, Ft. Mcintosh, and Nuevo Guerrero).

xls	Relative Humidity	U	National Solar Radiation Database (http://rredc.nrel.gov/solar/old_data/nsrdb/dsf/data/12919.txt	"Solar Radiation & WIND Texas and National Databases 052504.xls".	1961-1990 averages Jan 61, Feb 61…Dec 90 for cities El Paso and Brownsville only
xls	Relative Humidity	U	Free NOAA Data (www.ncdc.noaa.gov/oa/climate/onlline/ccd/avgrh.html)	Relative Humidity MODEL 100104.xls	El Paso, Del Rio ad Brownsville were listed with averages for all Jan, Feb, Mar etc for 31, 14 and 18 year respectively for each city.
xls	Temperature	U	Utah and National Climatology www.met.utah.edu/jhorel/html/wx/climo.htm	Met-utah data-NOT USED.xls	1961-1990 averaged month values, 12 values for cities El Paso, Del Rio, and Brownsville
xls	Texas Water Use Survey	U	http://www.twdb.state.tx.us/RWPG/main-docs/regional-plans-index.htm and http://www.twdb.state.tx.us/data/popwaterdemand/2003Projections/HistoricalWaterUse/2001WaterUse/HTML/2001County.htm	2001 Texas region_twdb_state_US.xls, 2001-2002 TWDB Consumption Rates for LRG Cities.xls, 2001 Texas County.xls	2001 Water Use Survey Summary Estimates in acft for Region and State Total. Lists municipal, manufacturing, mining, steam electric, irrigation, and livestock values. Second file has summary estimates by city. Third file is a formated file of the county data.
xls	Water Right Diversions from RG	U	Krila@TNRCC.state.tx.us TNRCC is now Texas Commission on Environmental Quality (TCEQ).	Kelly DIVERSION 072304g.xls	Summary of Surface Water Rights diverted from RG (Ft. Quitman to Gulf). 072104. This file was created from Kellye Rila, Water Rights Permitting (512) 239-4612, krila@tnrcc.state.tx.us.G16
xls	Water Right Usage	U	Legal and Institutional Framework for Resotring Instream Flows in the Rio Grande: Fort Quitman to Amistad March 16, 2001 TCPS Authors: Laura Brock, Mary Kelly, Karen Chapman	Ac-ft Water Right Use Ft Quitman to Amistad 1991-2000.xls	Summary of total water right usage in ac-ft for years 1991 to 2000.
xls	Windspeed	U	Utah and National Climatology www.met.utah.edu/jhorel	Met-utah data-NOT USED.xls	Through 1993 averaged month values, 12 values for cities El Paso (51 yr ave), Del Rio (16 yr ave), and Brownsville (51 yr ave)

			/html/wx/climo.htm 1961-1990 averaged month values (12 per city		
xls	Windspeed	U	National Climatic Data Center (http://nndc.noaa.gov/?http://ols.nndc.noaa.gov/plolstore/plsql/olstore.prodspecific?prodnum=C00518-PUB-A0001) and (http://www.ncdc.noaa.gov/oa/climate/online/ccd/avgwind.html)	NOAA Free Windspeed.xls	El Paso, Del Rio, Laredo and Brownsville had 36 years of data averaged for each month (a total of 12 values per city) on spreadsheet.
xls	Windspeed	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	This data was found long after model input for the wind variable. Only 2 cities (Martin King Ranch,and Falcon Dam)of the 7 cities listed would have been worthy data because of their time period of record
xls	Windspeed	U	MET Utah Data	Analyzed in "Solar Radiation & WIND texas and National Databases 052504.xls". Original MET Utah Data is called "Met-Utah Data.xls"	One 56 year average for each month (12 values total)
xls		U-M	http://www.tpwd.state.tx.us/gis/vegetation_types/pdf/veg_34.pdf	Estimate for Riparian Acres - do not use.xls	Decided not to use this file for riparian acreage. A description within the spreadsheet says how it was done.
xls	Water Use	U	http://www.twdb.state.tx.us/data/popwaterdemand/2003Projections/HistoricalWaterUse/2001WaterUseSurvey.asp	2001 Water Use Texas County.xls	Contains all the counties in Texas along the border. Has data by county and type of water use categories.
xls	Precipitation	U	NOAA $400 CD we bought	See Directory of files under Weather/$400 CD	Texas Bordering County & City Maps 092404.xls has summary of data visually
bmp	Map of Dams and Border Crossings	U-M	http://mrgbi.fws.gov/Resources/Dams/, www.window.state.tx.us/specialrpt/border/sfatb1.html	DAMS along RG 100104.ppt, texas border crossing map.bmp	Contains several maps of Texas/Mexico with the dams and their dates of completion. This file also contains a good map of the border crossings along Texas border with the cities and sister cities named.
bmp	Map of Texas border crossings.	U-M	www.window.state.tx.us/specialrpt/border/sfatb1.	Texas border crossing map.bmp	Map containing the border crossing cities along Texas border along Rio Grande.

			html		
doc	Allocating Water in LRG	U	Allocating Water on the Rio Grande vhttp://www.tnrcc.state.tx.us/admin/topdoc/pd/020/00-10/riogrande.html, October 2000	Allocating RG Water.doc	Two page article on allocating water in the Lower RG. Contains information about the Watermasters role.
doc	Amistad and Falcon Dam Information	U-M	International Amistad Reservoir (http://www.bartleby.com/69/45/I01445.html), International Falcon Reservoir (http://www.bartleby.com/69/46/I01446.html), http://www.ibwc.state.gov/wad/storage.html	Basic Dam Info.doc	Basic information on Amistad and Falcon Dams
doc	Population	U	http://txsdc.tamu.edu/cgi-bin/prj2001totnum.cgi and http://txsdc.tamu.edu/tpepp/2001_txpopprj_cntytotnum.php	TAMU Pop projections for TX border Counties 2001-2004.doc	Paper written by TAMU entitled "Projections of the Population of Texas and Counties in Texas by Age, Sex and Race/Ethnicity for 2000-2040". Written in 2001.
doc	Relative Humidity	U	NOAA CIRES Climate Daiagnostics Center (www.cdc. noaa.gov/cdc/data.ncep. reanalysis .derived.html)	Solar Radiation & WIND texas and National Databases 092904 MODEL.xls, LONG LAT Gazeteer info.doc	Long-Lat data was hand entered for each city month and year from 1950-2003. Cities included Ft. Hancock, Presidio, Del Rio, Zapata, and Brownsville. Average of data values for Ft. Hancock and Presidio was used for Reach 1, ave of Presidio and Del Rio for Reach 2, ave of Del Rio and Zapata used for Reach 3 , and ave of Zapata and Brownsville were used for Reach 4. File "LONG LAT Gazeteer info.doc" contains the long lats for each city used. Website to obtain this info was taken from US Census Bureau U.S. Gazetteer. (http://www.census.gov/cgi-bin/gazetteer?city=presidio&state=tx&zip)

doc	RG Water Right Allocation	U-M	Rio Rio Grande Technical Summary for the House Water & Power Committee May 3, 2002, http://www.house.gov/resources/107cong/water/2002may03/rubenstein.htl	RG Allocation of Water Rubinstein.doc	Carlos Rubinstein, Rio Grande Watermaster wrote this about article. Talks about water rights and distribution of water and priority of water rights.
doc	Rio Grande Aquifer	U-M	http://www.ibwc.state.gov/html/body_body_binational_waters.html	Transboundary Aquifers.doc	Contains information on the Rio Grande Aquifer and basin. Name of the paper is Transboundary Aquifers and Binational Ground-Water Database, City of El Paso/Cuidad Juarez Area.
doc	Rio Grande Aquifer System	U-M	"RIO GRANDE AQUIFER SYSTEM" from GROUND WATER ATLAS of the UNITED STATES Oklahoma, Texas - HA 730-E http://capp.water.usgs.gov/gwa/ch_e/E-text2.html	RG Aquifer System by USGS.doc	Good writeup on the Rio Grande Aquifer by USGS. Defines the aquifers in Texas that support the RG. Contains nice graphics.
doc	Rio Grande Basin and Drainage Network	U	© Encyclopaedia Britannica Inc., All Rights Reserved, 1996 http://www.utexas.edu/courses/h2o/encyclop.html	RG Basins and Drainage Network.doc	"Sustainable Water Management for the Paso del Norte Border Region" describes in a few paragraphs the basin of the Rio Grande. This is a general overview of the basin.
doc	Rio Grande River	U-M	National Park Service Website for Big Bend National Park, http://www.nps.gov/bibe/riogrand.html	RG NPS Desert Life Blood.doc	Article on Lower Rio Grande River that has a general overview of the River and its water quality.
doc		U	http://www.ibwc.state.gov/CRP/Stdyarea.html	IBWC Texas Clean Rivers Program.doc	Simple writeup on the "Texas Clean Rivers Program within the Rio Grande Basin Study Area". Contains a few paragraphs and a graphic of the IBWC study area with the gage sites.
doc		U		ARI README 092804.doc	Contains email correspondence between Howard Passell

					and Ari Michelson.
doc	1944 Treaty	U-M	http://www.ibwc.state.gov/html/water_resources.html	1944 RG Treaty.doc	Treaty Between the United States of America and Mexico. Signed at Washington February 3, 1944 and Protocol Signed at Washington November 14, 1944. This is a copy of the treaty.
doc	IBWC Monitoring Sites	U-M	http://www.ibwc.state.gov/CRP/monstats.htm	IBWC Monitoring Sites.doc	File contains hyperlinks to the IBWC gaging sites and contains a graphic of the IBWC study area with the gage sites.
doc	Longitude Latitudes of Texas Cities	U	US Census Bureau U.S. Gazetteer http://www.census.gov/cgi-bin/gazetteer?city=presidio&state=tx&zip=	Long-Lat Gazeteer info.doc	Contains longitude and latitude information for Texas border cities of concern.
pdf	Surface Water Rights	U	www.tnrcc.state.tx.us/name_change.html	Rights to Surface Water in Texas.pdf	Rights to Surface Water in Texas, TNRCC GI228, PDF version (revised 5/02). Great writeup, easy to read on who has surface water rights in Texas. Talks about prior appropriations, who owns the water, what kinds of water right exist.
pdf		U	http://www.texascenter.org/publications/instreamflow.pdf	Legal and Institutional Framework.pdf	Legal and Institutional Framework for Restoring Instream Flows in the Rio Grande: Fort Quitman to Amistad March 16, 2001 TCPS Authors: Laura Brock, Mary Kelly, Karen Chapman. Talks about geography, land use water quality, planning efforts, water rights etc.
pdf		U-M	http://www.environmentaldefense.org/documents/2874_RioGrande_waterdispute.pdf	Dispute over shared waters RG.pdf	"Dispute Over Shared Waters Rio Grande/Rio Bravo, A Primer" was written in July 2002 by TCPS. Great pictures, good ariticle on drought, treaties etc on the river.
pdf	Surface water	M	http://www.texascenter.org/publications/rioconchos.pdf	Rio Conchos Overview.pdf	"Rio Conchos: A Preliminary Overview" Prepared by: Mary E. Kelly, Director Jan 2001 TCPS. 28 page report on the Rio Conchos.
pdf	Riparian Vegetation	U-M		ARI Sandia Riparian Evaluation Project 2004-draft-version2.pdf	"Estimation Estimation of Riparian Acreage Coverage Along Four Reaches of the Lower Rio Grande" by Dr. Zhuping Sheng and Joshua Villalobos, Agriculture Research and Extension Center at El Paso, Texas Agricultural Experiment Station, The Texas A&M University System

pdf		U		ARI Sandia-Final Report Letter.pdf	Letter from Ari Michelson to Howard Passell describing the work he performed including: 1) Crop ET - Rio Grande Reaches 1, 2 and 3 (Piccinni), 2) Lower Rio Grande Valley Crop Water Use and Precipitation, Reach 4 (Gerik), 3) US Surface Water Irrigated Acreage and Crop Mix by Reach, TWDB (Michelsen and Morrison). 4) US and MX IBWC Reported Irrigated Acreage by Reach, 1950-2001 (Michelsen and Morrison), 5) Riparian and Open Water Acreage, Lower Rio Grande by Reach (Sheng and Villalobos)
ppt	IBWC gage site map and modifications by Newman	U-M	http://www.ibwc.state.gov/CRP/Stdyarea.html	RG Border modified IBWC gage map with cities.ppt	IBWC surface water gaging station map that has various stages of modification for other uses in the model. Most modifications were used for presentation purposes.
ppt	Lower Rio Grande maps.	U-M	Gretchen created this	Texas Bordering County & City Maps 100104.ppt	This has a host of graphics that shows counties, cities, cities and counties, data collected for the RG with years of data for each city indicated on maps. Much of this was put into SAND doc.
ppt	NWSWGFC NOAA weather gage map	U	National Weather Service West Gulf River Forecast Center http://www.srh.noaa.gov/wgrfc/map/lower_rio_grande_river.htm	NWSWGFC NOAA Gage Locations.ppt	Graphic of National Weather Service West Gulf Forcast Center. Shows site locations of weather stations. Many are tied into IBWC gaging station locations.
ppt	Presentation 091003 by Newman	U-M		Presentation 091003 What Data Do We Use gn.ppt.	Presentation given by Gnewman on 091003 on data found for surface water flow. Presented in Mexico.
ppt	Presentation Draft for Howard 092003	U-M		Presentaton 090203 Howard g.ppt	Presentation draft 090203 for Howard.
ppt	Texas geology, land resource, basin map	U	http://tx.usgs.gov/basins.html	Texas maps.ppt	Land Resource Map of Texas, Geology map of Texas, Water Basin map of Texas. These were copied from various sites on the internet.
ppt	map	U		Texas Clean Rivers Waterqual ids.ppt	Graphic of Texas Clean Rivers water quality sites along RG.
ppt	map	U		modified RG Drainage Network.ppt	Rio Grande Drainage Network original map and modifications to it by Gnewman for presentations.
ppt	map	U-M		misc RG Basin maps.ppt	Misc RG basin maps that were collected from various sources as well as modified for presentation purposes.

ppt	map	U-M	www.mapquest.com search google "mapquest Mexico" enter city Nuevo Laredo and mouse along the border.	Map mapquest ftquit-gulf.ppt	This was compiled by using Mapquest and taking screen shots of the entire reach and pasting them together digitally. It is the entire border area with all cities. It would be great to plot on a big plotter. To see this you'll need to view 400% on Powerpoint.
ppt	map	U	http://riogrande.tamu.edu/	LRG Irrigation Map.ppt	Lower Rio Grande from Falcon to Gulf irrigation area map.
ppt	map	U	http://www.tpwd.state.tx.us/gis/vegetation_types/	Blowup map of RG vegetation.ppt	Blowup map and description of RG border region vegetation. 1994 map provided by GIS Lab of Texas Parks and Wildlife.
xls	Consumption per capita/per reach/	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092804.xls, Marty Population 100104.xls	Per capita per person was computed using IBWC Water Bulletin Tables "Municipal & Industrial Use", subtracting "Outfalls from Sewers to RG" and dividing by the population listed on the "Municipal & Industrial Use" tables for those cities which have all 3 values. These cities were Del Rio, Eagle Pass, Laredo, Nuevo Laredo (Mexico), Roma, Rio Grande City and Brownsville. This value was then used with populations defined for each reach defined in file "Marty Population 100104.xls"
xls	Elevation	U	Used Handbook of Texas On-Line, and from searching city, elevation on the internet. Other city elevations not found using Handbook of Texas On-Line were searched by city and elevation.	Elevations 092204.xls	Consists of elevations for main US cities along reaches and the elevations chosen for each reach for the model. An average of each east and west city of each reach was used to get one value for the reach.
xls	Flow (Surface)	M	Javier	Mexican files were compiled into one file Mexico **Flow Data 042204.xls.** There were many original files	Original files were:Proyecciones de la pblacion de los municipios edad y sexo1.xls, Proyecciones de la poblacion total de las localidades 2000-2030.xls

xls	Flow (Surface)	U	IBWC Water Bulletins (Years 1900-2004), flow data was mostly taken from internet site IBWC Historical Rio Grande Surface Water Data http://www.ibwc.state.gov/wad/histflo1.html) August 15, 2003, gnewman	1900-2003 MODEL day ave mo yr IBWC historic 032604.xls	This file is the core file of all downloaded IBWC files. All of Newmans created flow data files originated from this file which originally came from downloading data directly from the IBWC Historical Rio Grande River Basin Data site. This file cosists of the original daily files. Conversions to monthly averages are done in this spreadsheet, as well as some yearly averages.There are also some hydrographs that were created to see which tribuataries contributed the most. This file was used to determine our models reaches, tributaries of interest and identify good periods of record for various gages. The readme file has all of the gages available and has hilites on those gages chosen for the model at the onset of the project. These gage choices may have changed slightly over the past year.
xls	Flow (Surface)	U	IBWC = International Boundary Water Commission (www.ibwc.state.gov) USGS = United States Geological Survey (www.water.usgs.gov), WGRFC =National Weather Service West Gulf River Forecast Center (www.srh.noaa.gov/wgrfc)	ALL GAGE NAMES usgs ibwc wgrfc.xls	This is a file that compares names of gages from International Boundary Water Commission (IBWC), United States Geological Survey (USGS), and National Weather Service - West Gulf River Forecast Center (WGRFC). RED text in file represents gages used in model.
xls	Flow (Surface)	U	Original data source was IBWC Water Bulletins (1950-2001). Correlated values were created by Jim Emery. This spreadsheet has VALUES only (no calculations). Used for direct input into Model. (http://www.ibwc.state.gov/wad/histflo1.htm)	MODEL 1950-2003 MONTH FLOW m3 per sec correl.xls	This file has only the gages chosen for the model. Data that was missing for periods was correlated. This file has only the original values in black and correlated values in red. This was the file used for model input. There are no calculations in this file.

xls	Flow (Surface)	U	Original data source was IBWC Water Bulletins (1950-2001), and USGS flow files for Pecos River and Devils River. This file is a precurser to 1950-2003 MONTH FLOW m3 per sec correl.xls. (http://www.ibwc.state.gov/wad/histflo1.htm)	1920-2003 SHORT LIST IBWC HISTORICAL flow conditions.xls	Original data source was IBWC Water Bulletins (1950-2001). This file is a precurser to 1950-2003 MONTH FLOW m3per sec correl.xls. There are no correlations in this. The original USGS gaging station data for Pecos River Near Langtry Texas, and Devis River at Pafford Comstock Texas are included in this file. The USGS data and IBWC data for this file are compared and data is converted to m3/sec versus original USGS format of ft3/sec. This data was later used in establishing the Pecos and Devils river data.
xls	Flow (Surface)	U	IBWC Water Bulletins (Years 1950-2004), flow data was mostly taken from internet site IBWC Historical Rio Grande Surface Water Data is http://www.ibwc.state.gov/ wad/histflo1.html) August 15, 2003, gnewman	Flow 1950-2003 Terlingua creek only.xls	This file was created 092804 for Jim Brainard from file 1900-2003 MODEL day ave mo yr IBWC historic 032604.xls. It was decided to add Terlingua flow data to the model. Units are averaged monthly values m3/sec (ie. Jan 50, Feb 50, Mar 50….Dec 03).
xls	Municipal and Industrial Uses	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Many cities listed. Each city has a dffrerent range of data between 1950-2003. Some have only a few years of data, others more.
xls	Municipal and Industrial Uses	M	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Many cities listed. Each city has a dffrerent range of data between 1950-2003. Some have only a few years of data, others more.
xls	Outfalls from Sewers into RG	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Outfall data from IBWC includes cities: Eagle Pass, Laredo, Roma, Rio Grande City, Brownsville, Nuevo Laredo, Cuidad Acuna, Cuidad Piedras Negras
xls	Outfalls from Sewers into RG	M	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Outfall data from IBWC includes Mexican cities: Cuidad Acuna, Pedras Negras, and Nuevo Laredo
xls	Population	M	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Approximately 16 cities are listed for Mexico for the year 2000.
xls	Population	U	Individual web searches and census data, Handbook of Texas on Line	Marty Population 092204.xls	Various sources were used to define populations along lower Rio Grande border.
xls	Population	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	Approximately 20 cities are listed for U.S for the year 2000.

xls	Population	M	Javier	Original files from Javier were inserted into file "**Marty Population 092204.xls**"	Original files were:Proyecciones de la pblacion de los municipios edad y sexo1.xls, Proyecciones de la poblacion total de las localidades 2000-2030.xls
xls	Population	U	Texas Environmental Profiles (http://www.texasep.org/html/cnty/county_main.html)	Texas RG Border counties data.xls	County populations
xls	Precipitation	U	NOAA Mom & Pop data downloaded	Texas Precip and Temp MODEL 100104.xls	
xls	Radiation	U	NOAA-CIRES Climate Diagnostics Center (http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.derived.html)	Solar Radiation & WIND texas and National Databases 092904 MODEL.xls	Information was taken from NOAA-CIRES Climate Diagnostics Center. Longitude/Latitudes were entered for 5 cites (Ft. Hancock, Presidio, Del Rio, Zapata, and Brownsville). Averaged monthly data was requested between Jan 1950-Dec 2003 for each city, each month and hand entered into this spreadsheet.
xls	Sewer Outfalls to Rio Grande	U	IBWC Water Bulletins (Years 1950-2004)	IBWC Water Bulletins_with Conversions 092404.xls	
xls	Temperature	U	NOAA Mom & Pop data downloaded	Texas Precip and Temp MODEL 100104.xls	Contains temperature and precip data used for the model.
xls	Windspeed	U	National Solar Radiation Database (http://rredc.nrel.gov/solar/old_data/nsrdb/dsf/data/12919.txt	Solar Radiation & WIND texas and National Databases 092904 MODEL.xls	Used a combination of $400 NOAA Data for El Paso, Del Rio, and Brownsville to define reaches. When data did not exist on the $400 NOAA Data, we used National Solar Radiation Database Website: http://rredc.nrel.gov/solar/old_data/nsrdb/dsf/data/23044.txt Data from 1961-1990 for the same cities to fill the gap.
xls	Windspeed	U	NOAA $400 CD Data	Solar Radiation & WIND texas and National Databases 092904 MODEL.xls	Used a combination of $400 NOAA Data for El Paso, Del Rio, and Brownsville to define reaches. When data did not exist on the $400 NOAA Data, we used National Solar Radiation Database Website: http://rredc.nrel.gov/solar/old_data/nsrdb/dsf/data/23044.txt Data from 1961-1990 for the same cities to fill the gap.
xls	Counties	U	Taken from a Texas Map.	Texas RG Border County ALPA ORDER.xls	This file has the Texas Rio Grande border counties that can be sorted in alphabetical order or west to east order.
xls	Report Files			Where did the data come from 100104.xls	THIS FILE. Contains a listing of most files used and saved for this modeling project.

xls	Citys	U-M		RG cities and pops 100104.xls	This spreadsheet shows all the bordering towns, cities and their populations along with their corresponding reaches. They can be sorted west to east order, or alphabetical listing order, or by reach. This was used quite a bit for the model.
xls	ET	U-M	Taken from Texas Water Development Board's website: http://hyper20.twdb.state.tx.us/Evaporation/evap.html.	ET RATES FOR REACHES 072304.XLS	This defines the ET for each reach. Some of the cells had no data. Marty Lennis updated these cells with a description of how she did it within the file.
xls	Crop	U		ARI Crop ET-TAMU-TAES-RG REach1 2 3-Piccinni-v2 g100104.xls	Contains Jan-Dec crop ET values in inches for 7 crops to be used in model
xls	Water Acreage	U		ARI IBWC data sent to Sandia.xls	Contains surface water acreages of RG tributaries, and RG river for both Mexico and US for the 4 reaches.
xls	Crop	U-M		ARI Sandia lRGV Reach 4 crop water use and precip-Gerik-1 g100104.xls	Contains Reach 4 crop water usage estimates.
xls	Crop	U-M		ARI TWDB Crop Data RG Reaches-Final g092204.xls	Contains crop acreage estimates for Reaches 1,3 and 4. This is a listing of various crops by County and summarized by Reach.
xls	Irrigated Agriculture	U	TAMU - Wendy Morrison	Rio Grande Irr Ag from MORRISON 071704.xls	Agriculture Irrigation data from TAMU Wendy Morrison. Has values for each reach starting from 1950-2002. Has both Mexico and US data.
xls	Municipal and Irrigation Diversion	U	Lupe Luna from Watermaster Office at Harlingen Texas sent this info	Luna MUNICIPAL & IRRIGATION DIVERSIONS for US 072204.xls	Rio Grande 11 Year Diversion History. File received from Lupe Luna at Watermaster Office in Harlingen Texas. Only Reach 3 had values. The rest were generated from other data.
xls	Climate	U-M	Taken from various climate data files.	BRAINARD CLIMATE 100804	This has the temp, RH, windspeed, solar radiation, and precipitaiton values for the model in model format.
xls	Misc	U-M	Taken from various crop, consumption, population files etc.	BRAINARD Stuff STILL neeeded for MODEL 080504.xls	This file was used as a working file for the modeler to pull data from. There are notes within this file that may be useful to define parameters and where they came from.

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