Watershed Modeling Applications in South Texas

Introduction

Watershed models can be used to simulate natural and human-altered processes including the flow of water and associated transport of sediment, chemicals, nutrients, and microbial organisms within a watershed. Simulation of these processes is useful for addressing a wide range of water-resource challenges, such as quantifying changes in water availability over time, understanding the effects of development and land-use changes on water resources, quantifying changes in constituent loads and yields over time, and quantifying aquifer recharge temporally and spatially throughout a watershed.

The U.S. Geological Survey (USGS), in cooperation with State and Federal agency partners, developed simulation models for several watersheds in south Texas (fig. 1). These models provide the capability to simulate scenarios of possible future conditions and management alternatives to help water-resource professionals with planning decisions. The program used for creating these Texas watershed models is the Hydrological Simulation Program—FORTRAN (HSPF) (Bicknell and others, 2001). HSPF is one of the most comprehensive watershed modeling programs because it can simulate a variety of stream and watershed conditions with reasonable accuracy and enables flexibility in adjusting the model to simulate alternative conditions or scenarios (Donigian and others, 1995). The HSPF model provides time-series data simulating water movement (runoff from land surfaces, infiltration of water through soil layers, flow in stream channels) and water-quality parameter values and constituent concentrations associated with the water movement at any selected location in the watershed. Time-series outputs from an HSPF simulation are continuous (for example, hourly or daily). Continuous models provide the advantage of simulating watershed processes for a full range of streamflow conditions. Continuous models can illustrate how processes that appreciably affect water-quality conditions during low flows might have relatively minor effects on water-quality conditions during high flows.

This fact sheet presents an overview of six selected watershed modeling studies by the USGS and partners that address a variety of water-resource issues in south Texas. These studies provide examples of modeling applications and demonstrate the usefulness and versatility of watershed models in aiding the understanding of hydrologic systems.

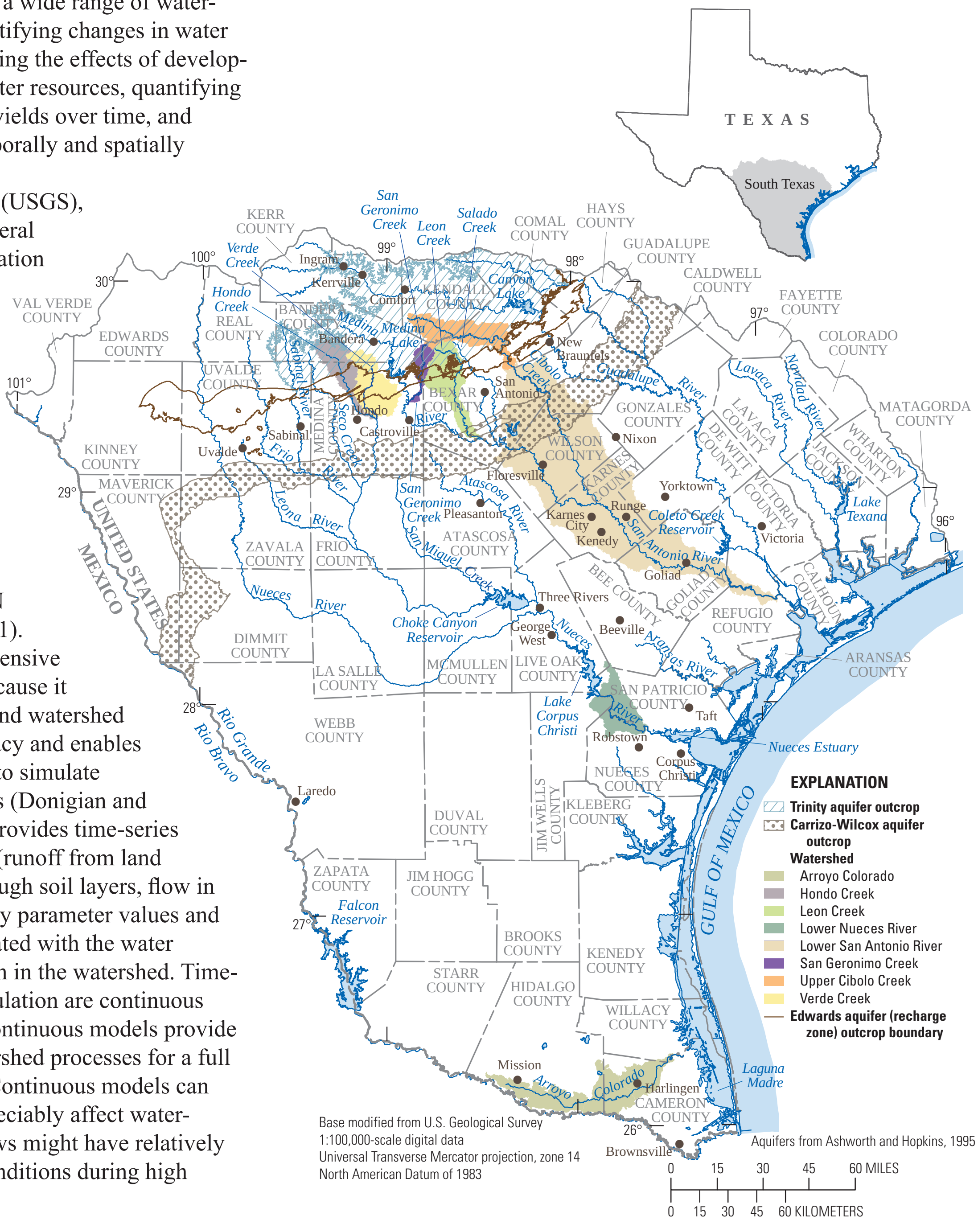
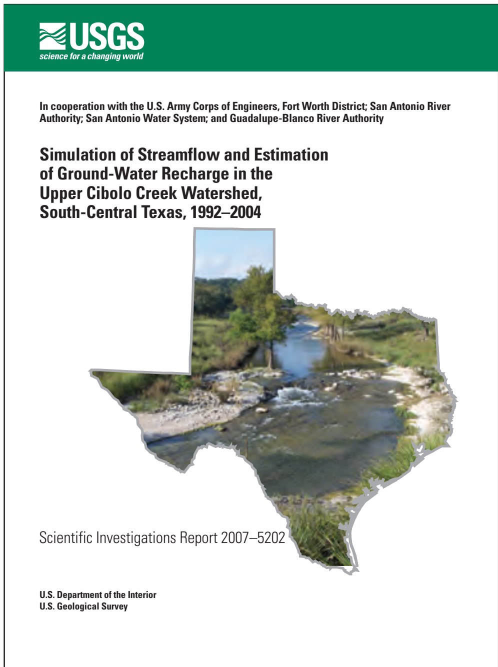


Figure 1. Locations of Hydrological Simulation Program—FORTRAN (HSPF) models in south Texas.

Simulating the Effects of Recharge-Enhancement Structures—Cibolo Creek



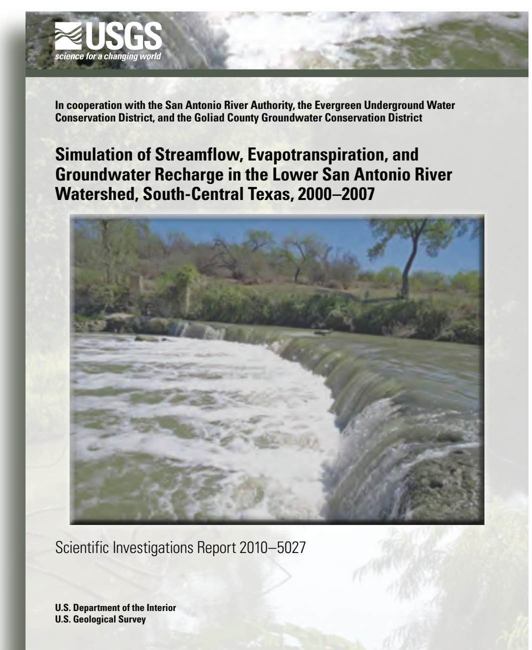
An HSPF watershed model was developed, calibrated, and tested by the USGS—in cooperation with the U.S. Army Corps of Engineers, San Antonio River Authority, San Antonio Water System, and Guadalupe–Blanco River Authority—to simulate streamflow and estimate groundwater recharge for the approximately 274-square-mile upper Cibolo Creek watershed (fig. 1) (Ockerman, 2007). Rainfall, evapotranspiration, and streamflow data were collected during 1992–2004 for model calibrations and simulations. Estimates of average groundwater recharge during 1992–2004 from the simulation were 79,800 acre-feet (5.47 inches) per year or about 15 percent of the area rainfall. Simulation of flood-control/recharge-enhancement structures in Cibolo Creek showed that certain structures might decrease flood peaks and increase recharge. Simulation of individual structures on tributaries showed relatively little effect. Larger structures on the main stem of Cibolo Creek were more effective than were structures on tributaries, in terms of both flood-peak reduction and recharge enhancement. One simulated scenario that incorporated two main-stem structures resulted in a 37-percent reduction of peak flow at the watershed outlet and increases in stream-channel recharge of 6.6 percent in the Trinity aquifer outcrop and 12.6 percent in the Edwards aquifer (recharge zone) outcrop.

- 2007 USGS Scientific Investigations Report 2007–5202: http://pubs.usgs.gov/sir/2007/5202

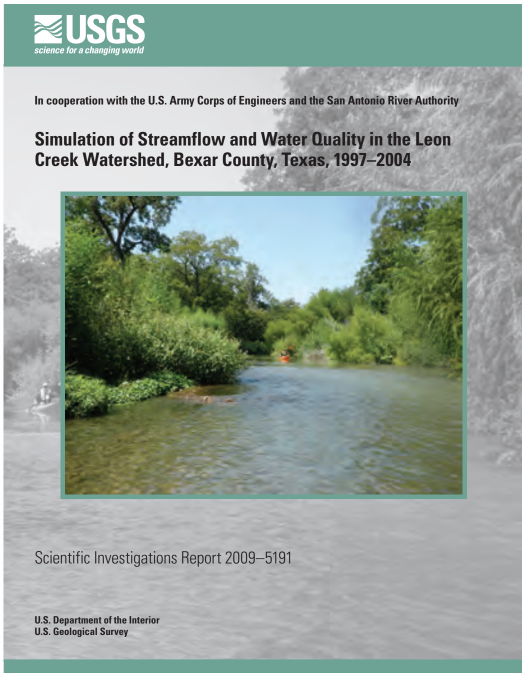
A River System Water-Budget Analysis—Lower San Antonio River

The USGS—in cooperation with the San Antonio River Authority, the Evergreen Underground Water Conservation District, and the Goliad County Groundwater Conservation District—configured, calibrated, and tested a watershed model for a study area consisting of about 2,150 square miles of the lower San Antonio River watershed (fig. 1) (Lizarraga and Ockerman, 2010). The model simulated streamflow, evapotranspiration, and groundwater recharge to the Carrizo–Wilcox aquifer outcrop in the lower San Antonio River watershed. The mean annual rainfall on the outcrop during 1961–2008 was 26.5 inches. Of this rainfall, it was determined that about 92 percent evapotranspires, less than 7 percent becomes groundwater recharge, and less than 2 percent becomes runoff. Mean annual recharge varied spatially throughout the watershed, ranging from 1.0 to 2.7 inches per year and generally increasing from west to east.

- 2010 USGS Scientific Investigations Report 2010–5027: http://pubs.usgs.gov/sir/2010/5027



A Contaminant-Loading Model for an Urban Stream—Leon Creek



The USGS—in cooperation with the U.S. Army Corps of Engineers and the San Antonio River Authority—configured, calibrated, and tested an HSPF watershed model for the approximately 238-square-mile Leon Creek watershed in Bexar County, Texas, and used the model to simulate streamflow and water quality (focusing on loads and yields of selected constituents) (fig. 1) (Ockerman and Roussel, 2009). Streamflow in the model was calibrated and tested with available data from five USGS stream-gaging stations.

Water-quality properties and constituents (water temperature, dissolved oxygen, suspended sediment, and dissolved and total lead and zinc) in the model were calibrated by using available data from 13 sites in and near the Leon Creek watershed for varying periods of record during 1992–2005.

The Leon Creek watershed model was used to simulate streamflow constituent loads and yields for suspended sediment, dissolved nitrate nitrogen, and total lead at the mouth of Leon Creek (outlet of the watershed) for 1997–2004. The average suspended-sediment yield was 0.34 ton per acre per year. The average load of dissolved nitrate at the outlet of the watershed was 802 tons per year; the corresponding yield was 10.5 pounds per acre per year. The average load of lead at the outlet was 3,900 pounds per year; the average lead yield was 0.026 pound per acre per year.

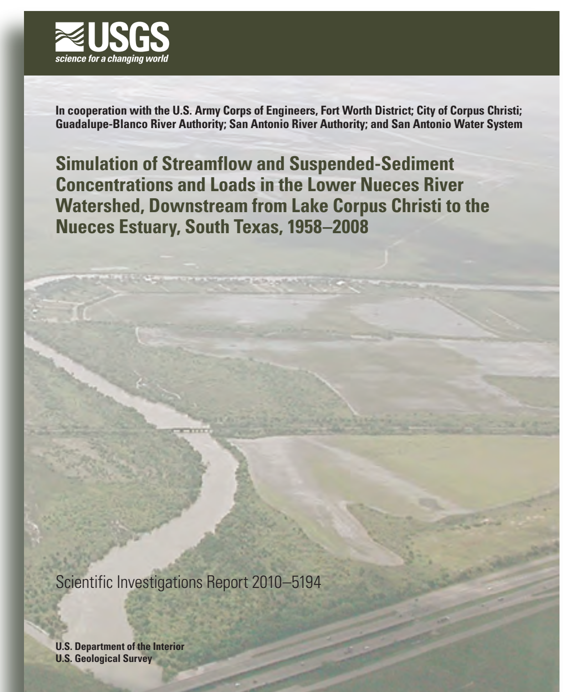
- 2009 USGS Scientific Investigations Report 2009–5191: http://pubs.usgs.gov/sir/2009/5191

Modeling Suspended-Sediment Loads to Bays and Estuaries—Lower Nueces River

The USGS—in cooperation with the U.S. Army Corps of Engineers, City of Corpus Christi, Guadalupe–Blanco River Authority, San Antonio River Authority, and the San Antonio Water System—compiled and assessed available data on suspended-sediment loads in the lower Nueces River and developed, calibrated, and tested an HSPF watershed model for the approximately 216-square-mile lower Nueces River watershed to simulate streamflow and to estimate suspended-sediment loads to the lower Nueces River and Nueces Estuary (fig. 1) (Ockerman and Heitmuller, 2010).

The watershed model also was designed to account for sources of suspended sediment delivered to the Nueces River and Nueces Estuary. On average, during 1958–2008, about 31.6 percent of the suspended-sediment load that entered the lower Nueces River was carried by releases from Lake Corpus Christi. Erosion and washoff of suspended sediment from cropland (in the watershed downstream from Lake Corpus Christi) accounted for 37.7 percent of the total sediment load. Erosion and washoff from all other land types downstream from Lake Corpus Christi accounted for 11.9 percent of the total sediment load. Channel erosion accounted for 18.7 percent of the total sediment load.

- 2010 USGS Scientific Investigations Report 2010–5194: http://pubs.usgs.gov/sir/2010/5194



A Total Maximum Daily Load (TMDL) Model—Arroyo Colorado

The USGS—in cooperation with the Texas Commission on Environmental Quality (TCEQ) and the Nueces River Authority—developed an HSPF watershed model to simulate flow and water quality for selected properties and constituents for the Arroyo Colorado from the city of Mission to the Laguna Madre, Texas (fig. 1) (Raines and Miranda, 2002). The model was used to estimate a total maximum daily load (TMDL) for selected properties and constituents in the Arroyo Colorado. Specific objectives of the study were (1) to set up a model of the Arroyo Colorado Basin that would allow for simulation of different best management practices in order to estimate the TMDL for selected constituents to meet dissolved oxygen water-quality standards and (2) to calibrate and test a set of process-related model parameters with available streamflow and water-quality data for the Arroyo Colorado.

- 2002 USGS Water-Resources Investigations Report 02–4110: http://pubs.usgs.gov/wri/wri02-4110/

Modeling Recharge to the Edwards Aquifer—Hondo Creek, Verde Creek, San Geronimo Creek

The USGS—in cooperation with the San Antonio Water System—constructed three HSPF watershed models to simulate streamflow and estimate recharge to the Edwards aquifer in the Hondo Creek, Verde Creek, and San Geronimo Creek watersheds (fig. 1) (Ockerman, 2005). The three models were calibrated and tested with available data collected during 1992–2003. Streamflow and recharge were simulated for 1951–2003. Estimated average annual Edwards aquifer recharge for the Hondo Creek, Verde Creek, and San Geronimo Creek watersheds for 1951–2003 was 37,900 acre-feet (5.04 inches); 26,000 acre-feet (3.36 inches); and 5,940 acre-feet (1.97 inches), respectively. Most of the estimated recharge (about 77 percent for the three watersheds together) occurred as streamflow channel infiltration. Estimated diffuse recharge (direct infiltration of rainfall to the aquifer) accounted for the remaining 23 percent of recharge. For the Hondo Creek watershed, the HSPF recharge estimates for 1992–2003 averaged about 22 percent less than those estimated by the Puente method (Puente, 1978), a method the USGS has used to compute annual recharge to the Edwards aquifer since 1978. HSPF recharge estimates for the Verde Creek watershed averaged about 40 percent less than those estimated by the Puente method.

- 2005 USGS Scientific Investigations Report 2005–5252: http://pubs.usgs.gov/sir/2005/5252/

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Publishing support provided by
Lafayette Publishing Service Center