Chapter 19

Low Flow Gain-Loss Study of the Colorado River in Texas

Geoffrey P. Saunders, P.G., C.G.W.P.[1]

Introduction

Most natural rivers gain or lose water as they interact with underlying groundwater aquifers. Lower Colorado River Authority (LCRA) and San Antonio Water Systems (SAWS) are working together on a project to benefit areas served by both agencies. Low flow gains and losses are relevant to the LCRA-SAWS Water Project, because surface water availability and water quality are most sensitive to impacts during low flow conditions such as drought. This study is designed to provide information on the base flow rate of the lower Colorado River at key locations and the gain-loss of flow in reaches between those locations. After accounting for all known additions and subtractions from measured streamflow, the net gain-loss is attributed to interaction with groundwater aquifers.

Study Area

The study area, located in South-central Texas, contains several major and minor aquifers designated by the Texas Water Development Board (Ashworth and Hopkins, 1995; TWDB, 2002) as shown in Figure 19-1. Some of the aquifers designated by the TWDB, such as the Carrizo-Wilcox and Gulf Coast aquifers, are subdivided on the study area map using geologic mapping of producing zones (Bureau of Economic Geology, 1974). Also shown are locations of streamflow gauging stations and reaches between these stations.

Methodology

Earlier gain-loss studies were reviewed (Slade and others, 2002). In recent years since the record flood in 1991–1992, after which LCRA's Water Management Plan has been used as a guide in regulating low flows, the driest and lowest flow period occurred during the winter of 1999–2000.

[1] Lower Colorado River Authority

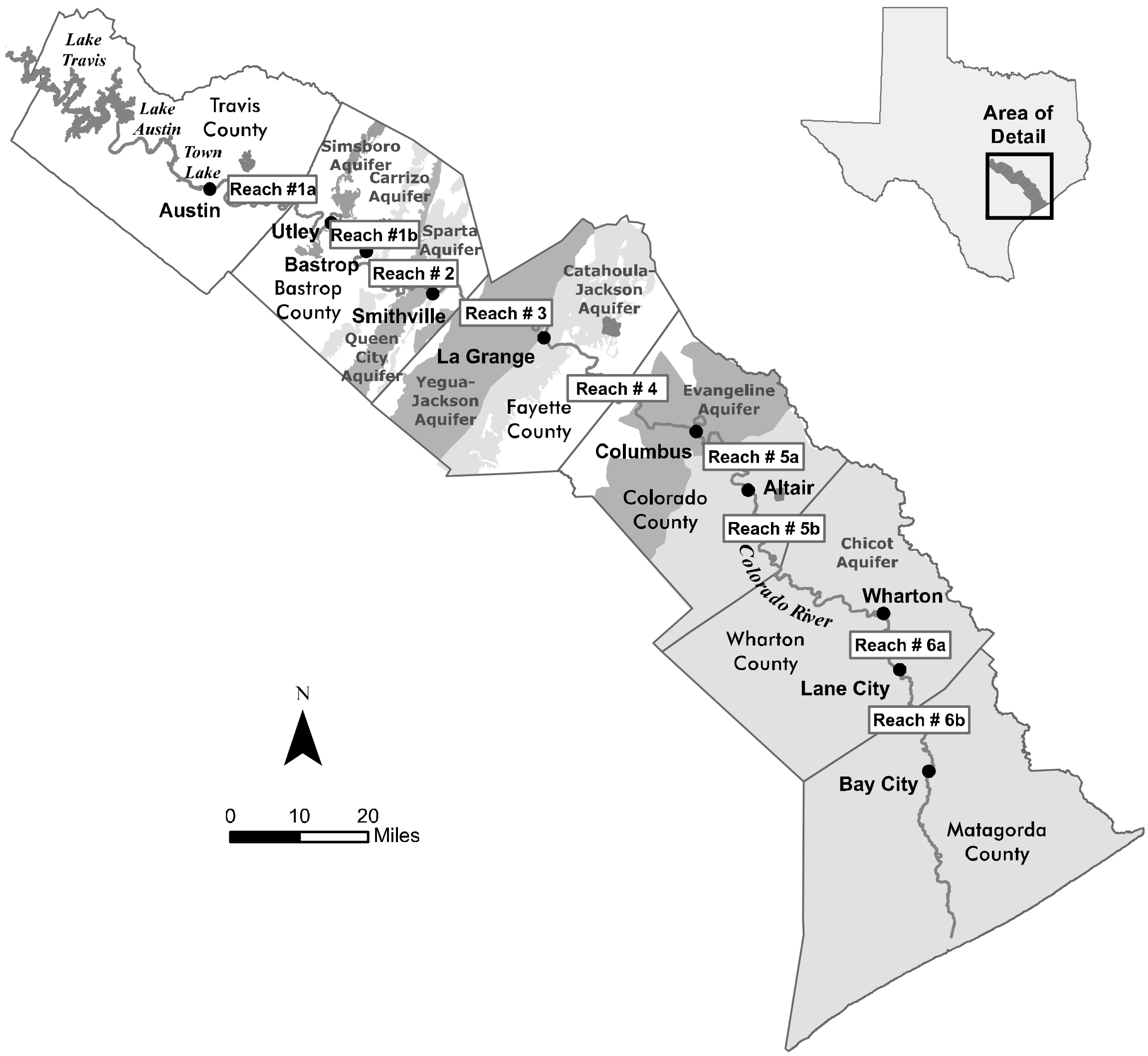

Figure 19-1. Lower Colorado River gain-loss study area, showing outcrops of major and minor aquifers, Colorado River channel, streamflow gauging stations, and study reaches. Source of aquifer outcrop areas: Geologic Atlas Sheets (Bureau of Economic Geology, 1974).

Streamflow data for the period October 1, 1999, through March 31, 2000, has been published by the U.S. Geological Survey, and rainfall records have been published by the National Weather Service. Considering patterns of reservoir releases, rainfall, and runoff, the month of November 1999 had stable low flow conditions. These conditions were ideal for low-flow investigations, although the dataset was relatively small (30 days). To bolster the historical record, a field investigation was conducted during similar low flow conditions in November of 2005.

Field measurements of streamflow were collected and used to update the stage-discharge ratings at each river station. Mean daily streamflow values were obtained from the U.S. Geological Survey; data on diversions were obtained from the Lower Colorado River Authority; and reported values for permitted discharges were obtained from the Texas Commission on Environmental Quality. The data sets were staggered by travel time between river stations, as indicated by unique patterns of streamflow, thus synchronizing the hydrographs.

A mass balance analysis was used on the staggered datasets. Tributary inflows and discharges to the river, as well as withdrawals, diversions, and evapotranspiration from the river, were accounted for. The adjusted daily values were compared to determine gains or losses in streamflow attributable to groundwater interaction.

Results

During dry periods, tributary inflows to the lower Colorado River were insignificant compared to mainstem streamflow rates. Withdrawals from the river were minimal, and discharges to the river were nearly constant. Evapotranspiration rates were noteworthy but an order of magnitude less than total gain-loss values. With all other factors accounted for, the differences in flow between mainstem gauging stations (adjusted gain-loss values) were attributed to groundwater contribution. The attribution of streamflow gains and losses are summarized in Table 19-1.

Table 19-1. Estimates of groundwater contribution to the lower Colorado River.

Reach	Description	River miles	Water-bearing units	Larger aquifer	Median adjusted gain-loss (cubic feet per second)
#1	Austin-Bastrop	53.5	Simsboro	Carrizo-Wilcox	-9
#2	Bastrop-Smithville	24.8	Calvert Bluff, Carrizo, Queen City, Sparta	Carrizo-Wilcox, Queen City, Sparta	+59
#3	Smithville-LaGrange	36	Yegua-Jackson	Yegua-Jackson	-22
#4	LaGrange-Columbus	40.9	Catahoula, Oakville, Goliad	Gulf Coast	+81
#5	Columbus-Wharton	68.5	Goliad, Willis, Lissie	Gulf Coast	+10
#6	Wharton-Bay City	34.1	Lissie, Beaumont	Gulf Coast	+98
				Total Gain:	**+217**

Similar results were obtained from the larger dataset representing the period October 1, 1999 through March 31, 2000. However, several small rainfall-runoff events occurred during the longer period of study, and daily wastewater discharges over the longer period may have been more variable than indicated by monthly reports submitted by the municipalities. In addition, U.S. Geological Survey records from the Bay City streamflow gauge were classified as “fair” as compared to “good” for all other stations. The most reliable estimates were derived from the month of November, 1999.

In 2005, LCRA conducted a low flow investigation with the following results in Table 19-2. The field investigation generally confirmed earlier estimates of travel time and streamflow gain. An interesting finding was that travel time, according to the hydrographs and river miles between gauges, appeared to exceed measured velocities of streamflow. This could be due to underflow in the alluvium, allowing some component of the water to flow down-gradient to the southeast without having to follow bends and meanders in the river channel.

Error in the historical data analysis is due primarily to inaccuracy in streamflow gauge ratings of approximately eight percent. For the total of 217 cubic feet per second (cfs), this estimated error would result in a range of approximately 200 to 235 cfs of streamflow gain between Austin and Bay City.

Table 19-2. November 2005 low flow measurements.

Location	Date	Time	Travel Time	Flow (cfs)
Colorado River near Utley	Nov. 7, 2005	15:40	0 day	332
Colorado River at Bastrop	Nov. 8, 2005	14:10	1 day	430
Colorado River at Smithville	Nov. 9, 2005	11:50	2 days	382
Colorado River at LaGrange	Nov. 10, 2005	12:35	3 days	404
Colorado River at Columbus	Nov. 11, 2005	11:30	4 days	475
Colorado River near Altair	Nov. 12, 2005	10:38	5 days	471
Colorado River at Wharton	Nov. 14, 2005	10:10	7 days	531
Colorado River near Lane City	Nov. 14, 2005	13:32	7 days	578
Colorado River near Bay City	Nov. 15, 2005	10:18	8 days	542

cfs = cubic feet per second

Conclusions

The lower Colorado River is a gaining stream that receives groundwater contribution from major and minor aquifers. Although there are some reaches that apparently do not contribute groundwater to the river, the net gain is approximately 200 to 235 cfs between Austin and Bay City under short-term drought conditions. Long-term severe drought conditions, under which groundwater aquifers may be stressed or slightly depleted, may produce somewhat less groundwater contribution to the Colorado River. However, such effects have lag time in years that exceeds the period of drought, and therefore may not be a factor during times of low flow.

Acknowledgments

This study is funded by the Lower Colorado River Authority and the LCRA/SAWS Water Project. The efforts of LCRA and LSWP project staff are gratefully acknowledged. Field work was conducted by members of LCRA hydrology field operations staff including David Murdock, Keith Ging, Gene Taylor, Matt Ables, John Jecmenek, and Steven Clark.

References

Ashworth, J. B., and Hopkins, J., 1995, Aquifers of Texas: Texas Water Development Board Report 345, 69 p.

Bureau of Economic Geology, 1974, Geologic atlas of Texas, Austin sheet, Sequin sheet and Beeville–Bay City sheet: The University of Texas at Austin, 1 plate plus explanation pamphlet per sheet.

Slade, F. M., Jr., Bentley, J. T., and Michaud, A., 2002, Results of streamflow gain-loss studies in Texas, with emphasis on gains from and losses to major and minor aquifers: U.S. Geological Survey Open-File Report 02-068, published on CD-ROM.

Texas Water Development Board, 2002, Water for Texas—2002: Texas Water Development Board Document No. GP-7-1, 155 p. plus appendices.

This page intentionally blank.