Chapter 18

Assessment of Shallow Recharge and Groundwater-Surface Water Interactions for the LSWP Study Region, Central Texas Coast

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Introduction

The LCRA-SAWS Water Project (LSWP) represents a partnership between the Lower Colorado River Authority (LCRA) and San Antonio Water System (SAWS) with the goal of conserving and developing water for the San Antonio region and the Lower Colorado River Basin in the 21st century. This project includes the development of a groundwater model of the Chicot and Evangeline aquifers in the study region. The study region includes Colorado, Wharton, and Matagorda counties, as well as adjacent counties, including Lavaca, Jackson, Austin, Fort Bend, and Brazoria counties.

As part of the development of a conceptual groundwater model of the study region, an analysis of shallow recharge and baseflow discharge was completed. In dipping aquifers, like the Chicot and Evangeline, recharge occurs in the outcrops where the aquifers are unconfined. The groundwater system in the outcrop can often act as a classical topographically-driven recharge/discharge system, where recharge primary occurs in the areas of higher elevation, and discharge occurs in the areas of lower elevation through streams, seeps, and groundwater evapotranspiration. The recharge to the water table that discharges relatively quickly in the surficial groundwater system does not have a significant impact on the deeper, confined aquifer system. Therefore, recharge can be conceptually divided into two different types, “shallow” recharge, which discharges relatively quickly through baseflow and other surficial discharge components, and “deep” recharge, which moves into the confined system and exits, under predevelopment conditions, through cross-formational flow. This paper discusses the analysis of the shallow recharge that discharges primarily to streams through baseflow. Understanding this part of the hydrologic system allows for the development of baseflow targets for the groundwater model as well as improving the implementation of recharge in the model.

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Hydrograph Separation Analyses

Hydrograph separation is a methodology whereby streamflow hydrograph data is analyzed and surface runoff is partitioned from the stream baseflow component. The basic premise is that in the streamflow hydrograph, sharp peaks represent surface runoff events, whereas the smooth, constant portion of the streamflow hydrograph represents baseflow.

Baseflow separation studies were performed on 15 stream gages in the study area that had some historical unregulated period. The code BFI (Wahl and Wahl, 1995) was used to perform the automated separation analysis. Figure 18-1 shows the subwatersheds analyzed in the study area, along with the corresponding gages. Only data from unregulated years were analyzed, based on Slade and others (2002). An attempt was made to perform an analysis on at least one gage in each subwatershed. However, unregulated gages were not available in all subwatersheds.

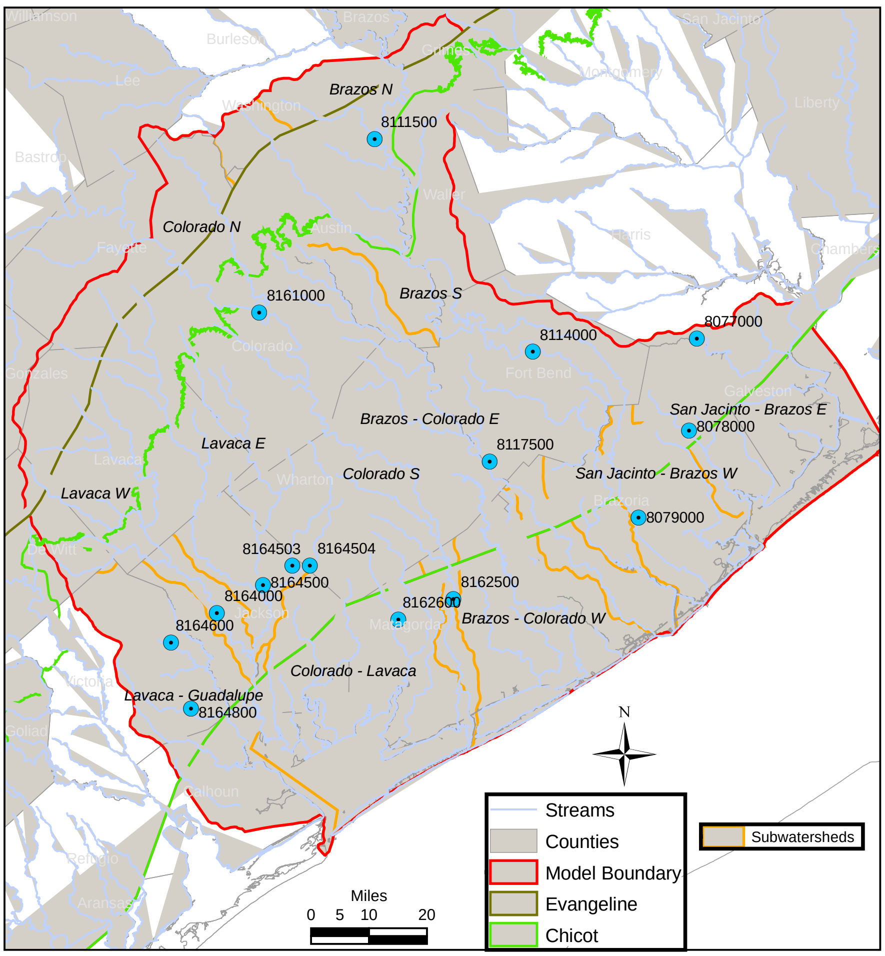

Figure 18-1. Location of gages for hydrograph separation analyses.

Four of the subwatersheds shown in Figure 18-1 do not originate in the study region. These are the northern and southern portions of the Colorado and Brazos river basins. In practice, even with an upstream gage, it is difficult to determine what portion of the baseflow originates in the study area for these rivers, since the incremental addition of baseflow in the study area may be small compared to the overall inflow. Also, in some subwatersheds, the results from gages representing only a portion of the overall drainage area had to be upscaled based on the ratio of the partial to overall catchment area.

The analysis of gage data was done with the understanding that the hydrographs are affected by diversions. Some estimate of the total diversions for a particular subwatershed was known, but an accurate history of the timing of the diversions was unknown. The analysis approach weighted the total diversion amount by the fraction of time that most of the streamflow is considered baseflow, thus crudely approximating the portion of the diversion that might affect the baseflow estimate.

Table 18-1 shows the long-term average annual results of the baseflow analyses. In general, baseflow estimates were in the range of one to two inches per year when averaged over the gage drainage area. Not all subwatershed results are reported, due to problems with some analyses. For example, the Colorado and Brazos subwatersheds were affected strongly by inflows from outside the region. Also, the Colorado River has the highest diversions, which also affected the results.

Table 18-1. Hydrograph separation results.

Basin	Area (mi^2)	Upscaled baseflow (afy)	Diversion adjusted baseflow (in/yr)
Lavaca W	896	45,193	0.95
Lavaca E	1,424	64,286	0.85
Lavaca - Guadalupe	905	18,635	0.39
Colorado - Lavaca	1,271	106,622	1.57
Brazos - Colorado E	1,029	106,942	1.95
San Jacinto - Brazos E	1,109	140,311	2.37

mi = mile
afy = acre-feet per year
in/yr = inches per year

Correlation of Baseflow with Precipitation

We attempted to derive a relationship between baseflow and precipitation, mostly as a surrogate to predicting shallow recharge as a function of precipitation. For each subwatershed, the annual estimates of baseflow were converted to fluxes by dividing by the catchment area and then plotted against historical annual precipitation. Equation (1) provides a relationship derived from semi-log plots, with baseflow on the log scale. The final estimated relationship for the study area was valid between approximately 20 inches per year and 60 inches per year, yielding baseflow (or minimum shallow recharge) estimates of between 0.25 and 2.0 inches per year.

$$\log(\text{baseflow}) = 0.05(\text{precipitation}) - 2.46 \qquad (1)$$

where baseflow and precipitation have units of inches per year.

Low Flow Study

Low-flow studies have traditionally been used to estimate gaining or losing conditions in a stream. These methods basically perform a flow balance between two stream control points. The net gain, or loss, of flow between the two control points is considered to be a result of stream-aquifer gain or loss, depending upon the sign. The key to this method is the assumption that surface runoff is negligible, and that is why the studies are performed at low-flow conditions. The study was performed based upon a historical analysis the first six months of water year 2000 with emphasis on the month of November 1999 which was found to have the most stable low flow conditions since 1992.

There are a significant number of tributaries, diversions, and return flows related to wastewater treatment plants (WWTPs) along the 257.8 mile river stretch. As a result, the study attempted to add and subtract these effects accordingly. Tributary inflows were estimated where not gaged. Inflows and discharge data for WWTPs were obtained from the TCEQ. In November 1999, diversions for irrigation or other uses that would provide return flows were negligible. River water pumping for industrial use, basically isolated to power plants, was minimal as estimated from LCRA records. It was determined that for the month of November 1999, tributary inflows, daily return flow, and daily diversions were insignificant compared to mainstream streamflow rates. Evapotranspiration was also found to be at least an order of magnitude below gain/loss estimates. Table 18-2 provides the November 1999 Colorado River median gain/loss estimates for the river reach between the cities of Austin and Bay City.

Table 18-2. Low flow study results.

Reach	Length (mi)	Gain/loss (afy)	Gain/loss (afy/mi)
Austin-Bastrop	53.5	-4,347	-81
Bastrop-Smithville	24	42,742	799
Smithville-LaGrange	36	-15,938	-664
LaGrange-Columbus	40.9	58,680	1,630
Columbus-Wharton	68.5	7,244	177
Wharton-Bay City	34.1	70,996	1,036
		159,378	

mi = mile
afy = acre-feet per year
afy/mi = acre-feet per year per mile of river

Results and Conclusions

Hydrograph separation analyses provided estimates of long-term average baseflows for several watersheds adjacent to the lower Colorado River. Hydrograph separation in the Lower Colorado River was unsuccessful due to significant inflow from outside the study area combined with large diversions in the study area. In general, the streams in the region are gaining, with an average shallow recharge return flow of one or two inches per year.

Annual estimates of baseflow from the hydrograph separation analyses correlated positively with annual precipitation. A semi-log relationship was derived from this correlation that can be used to vary predicted shallow recharge based on precipitation. This study also provided an estimated baseflow for the lower Colorado River through a low-flow analysis. The lower Colorado River was found to gain about 160,000 acre-feet per year (afy) over the reaches between Austin and Bay City. This is a measurement for a single point in time, and may vary somewhat from the long-term average.

In general, the study provided a good conceptual foundation for shallow recharge and discharge in the model region and also provided guidance for surface water/groundwater calibration targets for model calibration.

References

Slade, R. M., Jr., Bentley, J. T., and Michaud, D., 2002, Results of stream flow 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, 136 p.

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