Prepared in cooperation with the San Antonio Water System

Origin and Characteristics of Discharge at San Marcos Springs Based on Hydrologic and Geochemical Data (2008–10), Bexar, Comal, and Hays Counties, Texas

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conditions when aquifer recharge is likely occurring from local streams. Geochemical modeling results for the wet period (routine samples) yielded a range for the contribution of local recharge sources (based on the Blanco River) to San Marcos Springs discharge from 0 to 28.9 percent; the range was narrower for Deep Spring (0–17.5 percent) than for Diversion Spring (0–24.4 percent), which is consistent with a more muted response at Deep Spring to changes in hydrologic conditions (table 7). The median value for the midpoint of the range of the local recharge contribution for modeled dates during the wet period was 7.8 percent for Deep Spring and 10.9 percent for Diversion Spring. Model results indicate that the proportion of local stream recharge contributing to San Marcos Springs increased from the dry period to the wet period (fig. 23; table 6). The geochemical response at San Marcos Springs to storm events, when focused local recharge is most likely to occur, was minor (figs. 13 and 19). For example, mixing models for storm 3, a named tropical storm (Hermine) and the largest storm to occur during the study, indicate that recharge from the Blanco River composed less than 10 percent of discharge at San Marcos Springs immediately following the storm and for several months afterwards (fig. 24). These results place further constraints on the higher proportion of local recharge estimated by PHREEQC and indicate that the local recharge component is likely not more than 10 percent. Mixing models indicate that San Marcos Springs is not notably affected by storm recharge from local focused recharge sources moving rapidly through transmissive flow paths. This hypothesis is supported by time-series data for wells located to the north of San Marcos Springs that might be along flow paths between the Blanco River and San Marcos Springs (Neff and Aqua wells) and that do not show marked changes in geochemistry from the dry period to the wet period (table 5; fig. 15). Local recharge sources contributing to San Marcos Springs would likely vary in their contribution with changes in hydrologic conditions, antecedent conditions for rainfall and recharge events, storm characteristics, aquifer levels, and flow paths. For the large range of hydrologic conditions that occurred during this study, results indicate that discharge at San Marcos Springs is dominated under all conditions by regional flow.

Summary

The Edwards aquifer in south-central Texas is a productive and important water resource. Several large springs issuing from the aquifer are major discharge points, provide habitat for threatened and endangered species, and are locations for recreational activities. Spring discharges from two of these springs, Comal and San Marcos Springs (the first and second largest spring complexes in Texas), are used as thresholds in groundwater management strategies for the Edwards aquifer. Comal Springs is generally understood to be supplied by regional flow paths. In contrast, the hydrologic connection of San Marcos Springs with the regional Edwards aquifer flow system is less understood, and there is interest in improving the understanding of the hydrogeology and sources of water to San Marcos Springs. The U.S. Geological Survey (USGS) conducted a hydrologic and geochemical study of San Marcos Springs in cooperation with the San Antonio Water System during November 2008–December 2010. The primary objective of the study was to identify and characterize sources of discharge at San Marcos Springs by evaluating hydrologic and geochemical data from streams, groundwater, and springs in the vicinity of San Marcos Springs in Bexar, Comal, and Hays Counties. Springs included three orifices at San Marcos Springs (Deep, Diversion, and Weissmuller Springs) that were selected to be representative of larger springs within the spring complex.

An initial sampling effort characterized surface water, groundwater, and springs in the study area. A subset of sites was selected for periodic (routine; every 3–7 weeks) sampling to characterize temporal changes in water quality in response to hydrologic conditions; these were two streams, eight wells, one spring orifice each at Comal and Hueco Springs, and the three spring orifices at San Marcos Springs (Deep, Diversion, and Weissmuller Springs). To characterize changes in water quality in response to storms, samples were collected (depending on flow) in response to three major storms (storms 1–3) from nearby streams that might contribute recharge to San Marcos Springs and from Comal, Hueco, and San Marcos Springs. The storms varied in size, antecedent moisture conditions, and resulting stream (discharge and recharge) and spring (discharge) response. Storm 1 marked the transition from the dry period to the wet period and occurred following the driest antecedent moisture conditions. Storm 3, a named tropical storm (Hermine), was the largest climatic and hydrologic event during the study with respect to rainfall amount and resulted in large streamflows and aquifer recharge.

Collection of routine and storm-associated samples from streams, wells, and springs over the 25 months of the study provided an opportunity to investigate the hydrogeology of San Marcos Springs under a large range of hydrologic conditions. In addition to routine and storm sample collection, discharge and selected physicochemical properties were measured continuously at a site on the Blanco River and at the three San Marcos Springs orifices; water-table altitude and selected physicochemical properties were measured continuously at two wells near San Marcos Springs. During this study, hydrologic conditions changed from exceptional drought to wetter-than-normal conditions. In this report, the period between November 1, 2008, and September 8, 2009, is referred to as the "dry period," and the period between September 9, 2009, and December 31, 2010, is referred to as the "wet period." Hydrologic and geochemical variability at San Marcos Springs was compared with that at Comal Springs and Hueco Springs, which is illustrative based on the small range of variability observed at Comal Springs and the large range of variability observed at Hueco Springs.

Streams in the vicinity of San Marcos Springs were evaluated as potential recharge sources. Recharge estimates were computed daily for the Blanco River (2009–10), Cibolo Creek (2008–10), and Dry Comal Creek (2008–10) by using discharge at stations in each basin. Gain/loss estimates also were computed for the Guadalupe River. For the Blanco River, recharge estimates were compared for two station pairs (at Wimberley and Kyle and at Halifax and Kyle), and results were similar. Recharge estimates for these local streams indicate that the amount of recharge to the aquifer varied markedly through the study period with the largest recharge occurring from Dry Comal Creek and the smallest from the Blanco River. The Guadalupe River was largely a gaining stream, which is consistent with previous hypotheses that it does not contribute substantial recharge to the Edwards aquifer or to San Marcos Springs. Sink Creek and Purgatory Creek were dry during most of the study and did not contribute substantial recharge to the Edwards aquifer or to San Marcos Springs on the basis of their short periods of flow and the relatively minor amounts of flow that occurred.

The geochemistry of surface water in sampled streams varied markedly through the study period from the dry period to the wet period and in response to changes in rainfall and corresponding stream discharge. Large and rapid decreases in specific conductance and increases in turbidity occurred in response to rain events. Geochemical constituents in surface-water samples, including major ions, trace elements, and isotopic compositions, changed following the onset of the wet period in response to dilution from increased rainfall and runoff.

Water-table altitude and specific conductance values at two groundwater wells near San Marcos Springs changed following the onset of the wet period: water-table altitudes increased, reflecting increasing water levels, and specific conductance decreased, reflecting dilution. Both wells had higher specific conductance values than did other Edwards aquifer groundwater wells during the dry period, indicative of contributions from a saline groundwater source. Most groundwater wells in the Edwards aquifer and the Trinity aquifer showed few geochemical changes from the dry period to the wet period. These results indicate that sampled wells were not affected by focused local recharge moving along transmissive (karst conduit) flow paths but were dominated by matrix (diffuse) flow. An exception was the Solar well (LR–67–01–403), where numerous geochemical constituents change markedly at the beginning of the wet period, indicating that groundwater from this well was affected by mixing with a different and more saline groundwater source and (or) the influence of different geochemical processes. Toward the latter part of the wet period to the end of the study, the geochemical composition of the Solar well returned to a composition similar to that observed during the dry period.

Differences in the geochemistry of Comal Springs, Hueco Springs, and San Marcos Springs from the dry period to the wet period provide information on flow paths and recharge sources supplying the springs. During the dry period, little recharge was occurring regionally or locally, and spring discharge from all of the springs predominantly reflects draining of matrix groundwater. There were, however, some notable geochemical differences between the springs during the dry period that likely reflect differences in flow paths and sources of spring discharge. The geochemistry of Hueco Springs during the dry period differed from that of Comal Springs and San Marcos Springs and also varied notably through the dry period, likely reflecting evaporation of the recharge sources supplying Hueco Springs. The geochemistry of Comal Springs and San Marcos Springs was generally similar during the dry period, which is consistent with regional flow paths supplying both springs. There were some notable differences between the geochemistry of Comal Springs and San Marcos Springs, however, which indicate that San Marcos Springs also was influenced by mixing with other water sources (specifically, a source or sources with lower water temperature and lower concentrations of strontium and nitrate plus nitrite). Well 4D (DX–68–16–707), located between Comal Springs and San Marcos Springs in the Comal Springs Fault Block and likely along regional flow paths that supply San Marcos Springs, also had lower temperature and lower concentrations of strontium and nitrate plus nitrite. Samples from Comal Springs and well 4D, which are upgradient from San Marcos Springs, are likely representative of regional groundwater flow paths that contribute to San Marcos Springs. At San Marcos Springs, the geochemistry of the Deep and Diversion Springs orifices during the dry period was similar, although some differences indicate that Deep Spring was more influenced by a small component of saline groundwater.

Changes in hydrologic conditions at the beginning of the wet period were characterized by large changes in spring discharge at all of the springs (Comal, Hueco, and San Marcos Springs). At Hueco Springs, increases in discharge during the wet period were accompanied by large changes in geochemistry. Changes in geochemistry at Comal and San Marcos Springs were minor in comparison, with fewer significant differences or smaller ranges of variability between the dry and wet periods and mostly nominal changes in response to storms. Comal and Hueco Springs are representative of two endmember spring types, with Hueco Springs dominantly affected by more locally sourced conduit flow (quick flow) and Comal Springs dominantly affected by more regionally sourced flow paths (slow flow). These endmember spring types are consistent with time-series results of geochemical variability for Hueco Springs and Comal Springs. At San Marcos Springs, Deep and Diversion Springs orifices responded differently to changes in hydrologic conditions. Deep Spring was not strongly influenced by changes in hydrologic conditions, which indicates that, similar to Comal Springs, discharge at Deep Spring is likely dominated by regional groundwater flow paths. Diversion Spring was more responsive to changes in hydrologic conditions than was Deep Spring, although the range of variability for most geochemical constituents was small, indicating that Diversion Spring was affected by small changes in discharge sources as hydrologic conditions changed. For many geochemical constituents the correlation with spring discharge at Diversion Spring was inverse to that for Hueco Springs, which indicates that, rather than dilute surface-water recharge, Diversion Spring was influenced by a more saline groundwater component.

Inverse modeling with the geochemical model PHREEQC was used to evaluate the potential for mixing of different source-water compositions (regional groundwater flow, local stream recharge, saline-zone groundwater, and Trinity aquifer groundwater) and mass-transfer processes (mineral dissolution/precipitation and ion exchange) that could account for the composition of discharge from San Marcos Springs (Deep, Diversion, and Weissmuller Springs orifices). Modeling results for the routine samples collected during the wet period yielded a range for the contribution of local stream recharge (specifically from the Blanco River) to San Marcos Springs discharge from 0 to less than 30 percent. Additional two-component mixing models using conservative tracers further constrain these results and indicate that the proportion of local recharge is likely lower than the highest values estimated by PHREEQC. The modeled contribution of local stream recharge was narrower for Deep Spring than for Diversion Spring, which is consistent with a more muted response at Deep Spring to changes in hydrologic conditions. The median value for the midpoint of the range of the local recharge contribution for modeled dates (using PHREEQC) during the wet period was 7.8 percent for Deep Spring and 10.9 percent for Diversion Spring. The modeled proportion of local stream recharge accounting for San Marcos Springs discharge increased from the dry period to the wet period.

The geochemical response at San Marcos Springs to storm events, when focused local recharge is most likely to occur, was small. Stable isotope values for rainfall and stream samples associated with storm 3 were distinct from other samples; recharge to the Edwards aquifer in response to storm 3 would reflect these low isotopic values and provide a tracer of recent recharge. Mixing models for storm 3 indicate that recharge from the Blanco River composed less than 10 percent of discharge at San Marcos Springs directly following the storm and for several months afterwards. These results indicate that the effect of storm recharge from local focused recharge sources moving rapidly through transmissive flow paths to San Marcos Springs is small. This conclusion is further supported by time-series data for wells located to the north of San Marcos Springs that might be located along flow paths between the Blanco River and San Marcos Springs and that do not show marked changes in geochemistry from the dry period to the wet period.

The geochemistry of water samples collected routinely and in response to storms from streams, groundwater wells, and springs was used to characterize sources of discharge from San Marcos Springs. Recharge from local surface-water sources does not strongly influence the geochemistry of San Marcos Springs discharge. Rather, results of this study indicate that discharge at San Marcos Springs is dominated by regional recharge and groundwater flow paths, even during wet hydrologic conditions when aquifer recharge is occurring from local streams. A small component of saline groundwater contributes to San Marcos Springs discharge under all hydrologic conditions.

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