Gain/Loss Studies in the Texas Hill Country—Observations and Lessons Learned

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ABSTRACT

Synoptic gain/loss studies have been a primary method for determining surface water/groundwater interactions in Texas Hill Country streams. The Meadows Center has participated in numerous studies in recent years and has learned scientific and logistical lessons during these studies.

Very little historical spatial or temporal water discharge and quality data exists for many of the medium- and small-sized watersheds. Sparse data sets are sometimes available for larger streams. For many streams, these recent studies represent the only comprehensive data available. As the population of the Hill Country increases, these studies help create a baseline for future studies.

As most lands in Central Texas are privately owned, many landowners are reluctant to permit researchers on their property. Gaining access to live water on private lands with suitable monitoring locations and wells is the most time-consuming task in these studies. One often needs to visit landowners several times to gain trust and access and develop networks of landowners. This process needs to start at the beginning of the project. Performing several synoptic gain/loss studies under varying base flow conditions can be very revealing when flows are low. Higher flows tend to obscure some gaining and losing stream reaches. Dye trace studies can aid in determining direct recharge and loss areas.

Surface water/groundwater interactions are happening in every stream, creating base flow, and are directly related to geology and geologic structure. The measurement of groundwater levels in wells can be as important as stream flow discharge measurements in determining surface water/groundwater interactions. In Central Texas, groundwater flows tend to fol-

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low regional structural dips. Springs often occur due to fracturing and faulting, creating vertical flow paths. Base flow water quality is generally good. The lack of large-scale regional development and lack of phosphorus in the aquifer equates to clear flowing streams.

INTRODUCTION

The Texas Hill Country is a unique region where rivers and springs rise out of a complex system of multiple and overlapping aquifer systems. Many Hill Country rivers and springs are at a crossroads as rapid growth intersects a fragile groundwater-fed ecosystem. The combined effects of increased groundwater pumping, extended droughts, and climate change influence recharge and spring flow from the aquifers and springs in the area.

Over the past several years, the Meadows Center for Water and the Environment (the Meadows Center) has been working to answer the question—How much water is in the Hill Country? Although this seems like a straightforward question that merits a straightforward answer, the reality is that the largely hidden and unknown complexities of the Hill Country hydrogeology make it challenging to answer.

Inflows generally consist of storm flow and base flow from streams and rivers. Storm flow is typically a short duration event based on rainfall. Base flow in streams is the result of groundwater/surface interactions, as base flow originates from the underlying aquifers. The interaction of groundwater and surface water in this part of Texas is complex and not fully understood.

METHODS

The goal of this research series stemmed from the creation of a scientific methodology that can be applied to Hill Country streams to determine groundwater/surface water interactions. Recent studies in Hill Country basins have demonstrated that detailed hydrogeologic studies are necessary to understand groundwater/surface water interactions with confidence (Wierman, 2010).

Researchers focused the study area to include four watersheds generally underlain by the Hill Country Trinity and Edwards aquifers in Hays, Blanco, Gillespie, Kendall, Travis, and Bandera counties. In general, the stream segments studied started at the headwaters and extended to the Balcones Fault Zone. These reaches are thought to be the most active for groundwater/surface water interactions. The following river systems have been studied to date: Cypress Creek (Wimberley), Onion Creek, the Blanco River, the Medina River, the Pedernales River, the Guadalupe River, Cypress Creek (within the Pedernales watershed), and Little Cypress Creek (a tributary of the Colorado River and partial source of Krause Springs).

The goal of any hydrogeologic study is to understand the geologic setting and how groundwater and surface water interact with the local geology. Based on literature reviews, interviews, and experience in the Hill Country, the hydrogeologic tools that are generally effective in understanding the hydrogeologic setting of Hill Country rivers include:

(1) State Well Reports (SWRs);
(2) Classification of drill cuttings;
(3) Downhole geophysical logs;
(4) Geologic mapping;
(5) Water level monitoring;
(6) Water quality monitoring;
(7) Stream gain/loss studies; and
(8) Dye tracing studies.

Researchers also conducted extensive research to determine the types of data currently available and what data gaps exist in our understanding of Hill Country groundwater/surface water interactions.

Gain/Loss Studies: The interconnectivity of groundwater and surface water can be quantified through gain/loss studies, also known as base flow studies. In the Trinity Aquifer, where streams flow across areas of exposed rock (outcrops), gains indicate aquifer discharge and losses indicate aquifer recharge. Gain/loss studies are conducted by measuring stream flow at two points, one upstream and one downstream, and comparing the difference. If the downstream point has more flow, the stream is gaining. Conversely, if the downstream flow is lower, the stream is losing. Flow measurements are made using instruments such as a FlowTracker handheld Acoustic Doppler Velocimeter generally following U.S. Geological Survey protocols.

Performing multiple synoptic gain/loss studies under varying base flow conditions can be most revealing when flows are low. Higher flows tend to obscure some gaining and losing stream reaches due to short term storm water runoff. For example, a gain/loss study performed on the Little Cypress Creek in March 2020 showed a gaining stream. However, when a gain/loss study was repeated during low water levels in December 2020, parts of the creek had dried up.

Gain/loss studies performed over multiple years can allow for a comparison of river conditions over time. For example, Figure 1 is a gain/loss study performed in August 2016, on the Pedernales River (Weirman et al., 2017) and the only other basin-wide gain/loss study performed on the river published in 1964 (Holland and Hughes, 1964).

Water level monitoring: Groundwater levels can be used to develop hydrographs showing water level trends over time as well as potentiometric surface maps indicating groundwater elevations and groundwater flow directions. Unfortunately, in the Hill Country, there are few wells with a long period of record (over 20 years), making it difficult to determine long-term water level trends.

In 2016, 43 wells were identified within the Pedernales watershed by the team (Wierman et al., 2017) (Fig. 2). Depth-to-water measurements were collected at 42 wells using either an

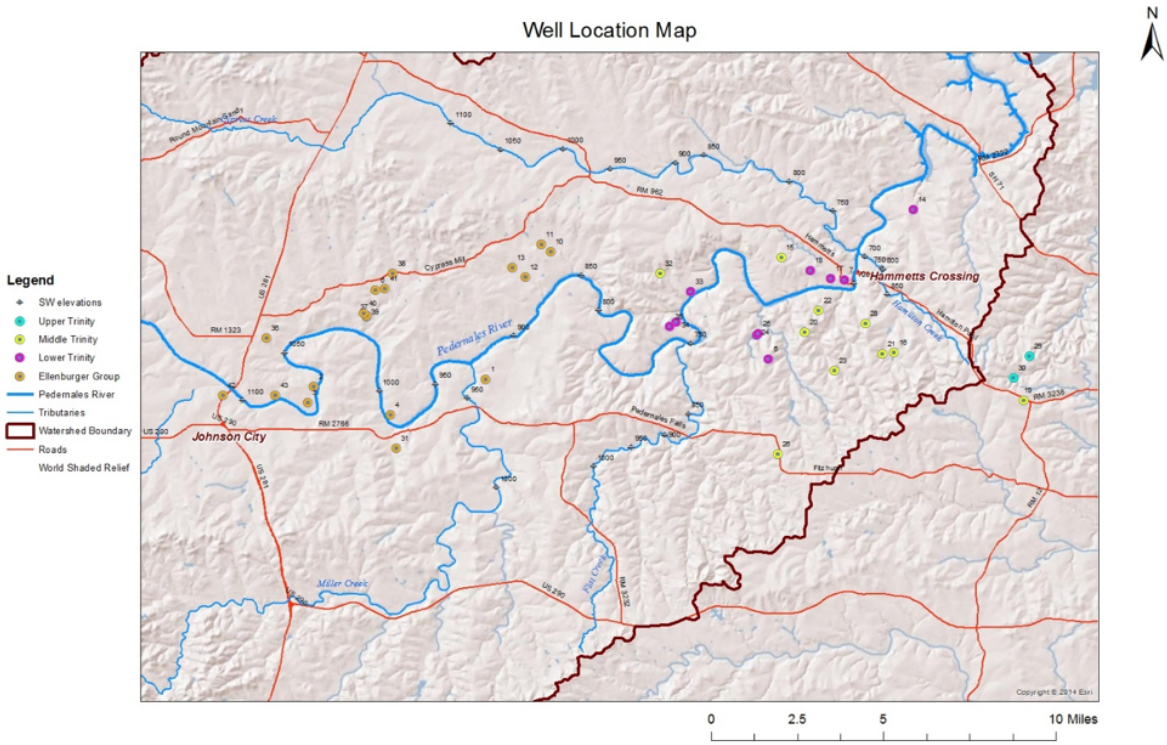

Figure 1. Pedernales River gain/loss studies, 1963 (Holland and Hughes, 1964) and 2016 (Wierman et al., 2017).

electric e-line or sonic water level measurement meter. Well surface elevations were obtained from U.S. Geological Survey maps or Google Earth®. River and tributary creek elevations were obtained from Google Earth®. Water elevations were hand-contoured to develop a potentiometric surface map of the study area. Geologic maps, SWRs (where available), water levels, well depths and local knowledge were the primary tools for determining into which aquifer a given well was completed.

Water quality monitoring: Water quality monitoring not only informs us about the health of Hill Country rivers, but also shows if surface water, spring flow, and groundwater quality are similar, indicating the same source, or not. Water with slightly different water quality signatures can indicate different sources. For example, Carbon 14 isotopic age dating shows the springs and groundwater in the vicinity of Krause Springs Park to be very young (Wierman, et.al., 2021). Stable water isotopes also indicate young water. Young water is indicative of a nearby recharge area and water that has not been in storage in the aquifer for long periods of time.

RESULTS

Working with landowners can be a rewarding and informative experience. Most landowners are supportive once they understand the goals and necessary steps of the study. In-person landowner project kickoff meetings can be helpful to present the goals and project scope and connect with the appropriate landowners and neighbors. Coordination of river accessibility through private property can be time-intensive to meet with individuals and plan site logistics in advance but is necessary. Most landowners, over time, offer valuable background knowledge about spring and river flow patterns, well locations, and best access points. They are also usually eager to offer an oral history of their land and the region. Some landowners remain unsupportive but are often appreciative of the final report.

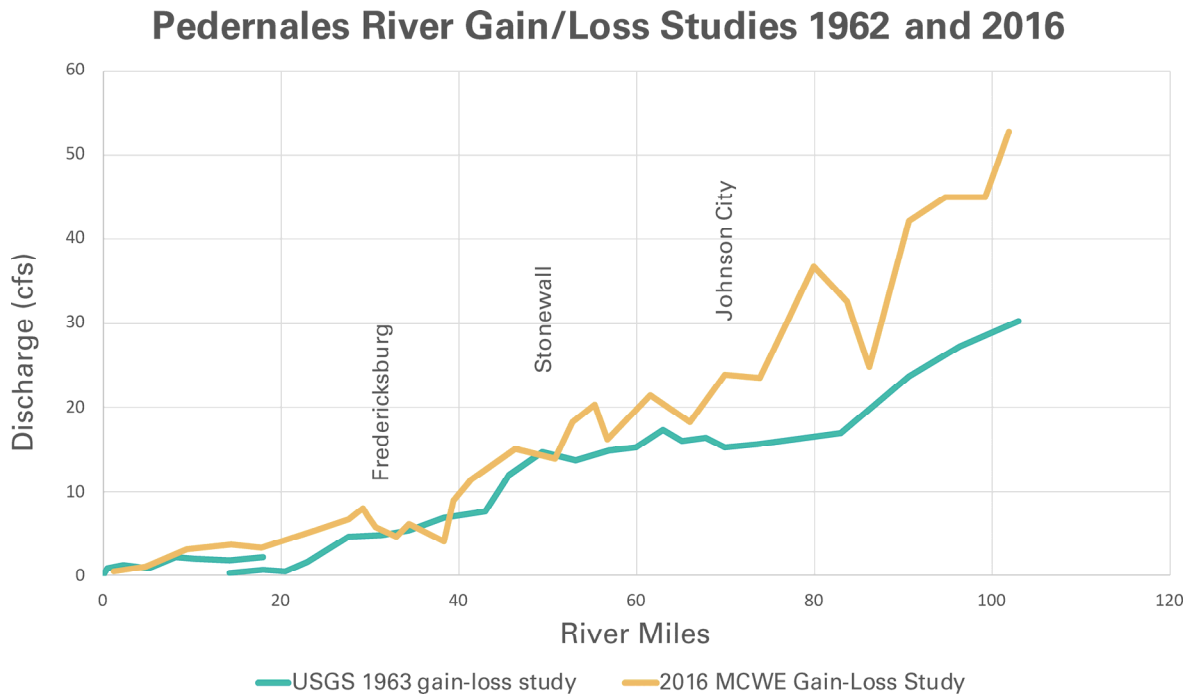

Figure 2. Pedernales Watershed study area and well locations.

Gain/loss studies can offer valuable insight into the source of base flows in different stretches of a river system. For example, results of this research confirms that the groundwater from the Paleozoic and Cretaceous aquifers contribute significant base flow to the Pedernales River and Lake Travis (Wierman et al., 2017). Approximately half of the inflow into Lake Travis from the Pedernales River originates in the study area, or approximately 12 percent of the total inflow into Lake Travis. Shallow depths to groundwater and apparently high-modeled recharge rates indicate the Paleozoic strata, primarily on the northern side of the river, contribute most of the inflow to the river. Future groundwater management actions in this area need to consider the importance of this area to maintaining adequate water supplies.

In general, water quality in the rivers under base flow conditions is good. For example, while there have been changes in water quality in the Pedernales River, at least partly due to human impact, there have not been significant changes since the original 1962 study (Wierman et al., 2017). Analysis of several water chemistry parameters indicate water chemistry is influenced by geology and land cover.

SUMMARY AND CONCLUSIONS

The "How Much Water is in the Hill Country?" research series provides critical data regarding the hydrogeology of Hill Country streams. Our analysis suggests that water quality in the rivers and creeks studied is generally in good condition and now is the time to protect it. A more complete understanding of these complexities facilitates more effective water resource utilization and land management from both a water quality and quantity perspective. Further understanding these interactions informs decision-making for sustainable water management strategies. Detailed stream gain and loss delineations provide insight into appropriate and scaled on-the-ground practices that can effectively conserve and maintain Hill Country water resources.

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