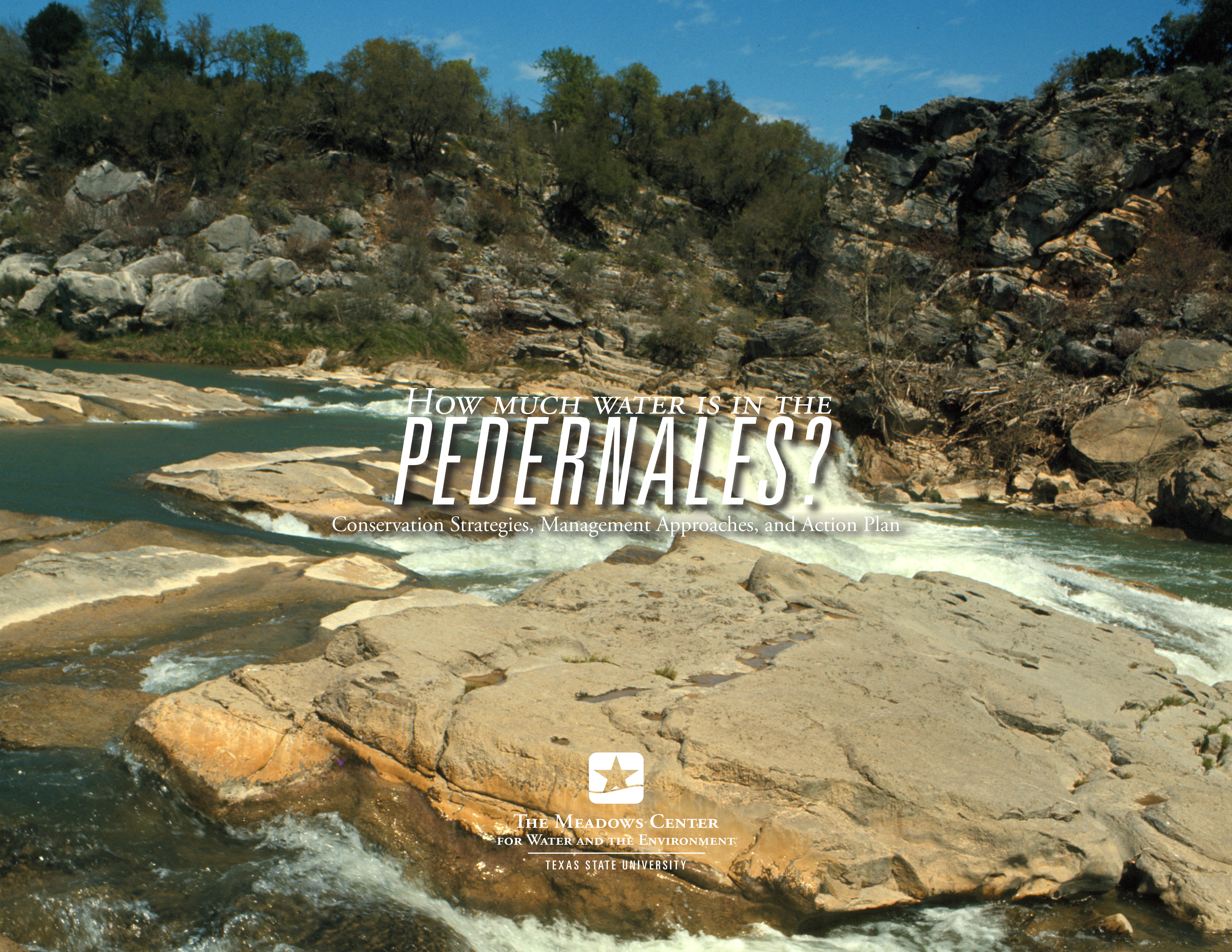

How much water is in the PEDERNALES?

Conservation Strategies, Management Approaches, and Action Plan

The Meadows Center for Water and the Environment
Texas State University

This report was made possible through the generous support of

The Cynthia & George Mitchell Foundation

How much water is in the PEDERNALES?

Conservation Strategies, Management Approaches, and Action Plan

September 2015

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The Meadows Center for Water and the Environment
Texas State University

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

FIGURES

TABLES

ACRONYMS

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BPGCD Blanco-Pedernales Groundwater Conservation District (www.blancocountygroundwater.org)

CISMA Cooperative Invasive Species Management Area (an alliance of stakeholders addressing invasive species management in the Hill Country)

CTGCD Central Texas Groundwater Conservation District (www.centraltexasgcd.org)

GCD Groundwater Conservation District (www.twdb.texas.gov/groundwater/conservation_districts)

GMA Groundwater Management Area (www.twdb.texas.gov/groundwater/management_areas/)

HCA Hill Country Alliance (www.hillcountryalliance.org)

HTGCD Hays Trinity Groundwater Conservation District (haysgroundwater.com)

LCRA Lower Colorado River Authority (www.lcra.org)

MCWE The Meadows Center for Water and the Environment (www.meadowscenter.txstate.edu/)

NRCS Natural Resources Conservation Service (www.nrcs.usda.gov)

TCA Texas Conservation Alliance (www.tcatexas.org)

TCEQ Texas Commission on Environmental Quality (www.tceq.state.tx.us)

TNC The Nature Conservancy (www.nature.org/Texas)

TSSWCB Texas State Soil and Water Conservation Board (www.tsswcb.texas.gov)

TWDB Texas Water Development Board (www.twdb.texas.gov)

USDA US Department of Agriculture (www.usda.gov)

USGS United States Geological Survey (www.usgs.gov)

EXECUTIVE SUMMARY

The Pedernales River is at a cross-roads as rapid growth in the Austin region spreads west into the Hill Country and extended droughts and potential climate change reduce rainfall, recharge, and springflow, negatively affecting the river's character and health. Land fragmentation is already evident as urban dwellers acquire ranches, altering the habitat and land management activities. What will the future hold for this river? What happens in this watershed can be an indicator of the potential change coming to other Hill Country rivers as San Antonio and many suburban cities continue to consume ranches and woodlands with an expanded thirst for more water.

In the face of this land use change many opportunities exist to better understand our rivers and how they interact with the local aquifers leading to new development practices and land strategies that can change the way we use water while sustaining the economic vitality of the region. The challenge is illustrating the potential water crisis, its cost, and efficient management and conservation measures that are recognized and accepted by the Hill Country's residents and visitors.

How Much Water is in the Pedernales? dives into the surface and groundwater resources and the threats to their continued sustainability by examining the Summer Hydro-Blitz findings to help us better define the primary water sources and potential management and conservation activities to protect and enhance the river flow and quality. The Hydro-Blitz occurred over a two-day period in early August as numerous teams fanned out across the watershed to visit 931 sites where roads crossed the river and its tributaries. If water was found, a later sampling effort in mid-August collected field parameters and water samples for a detailed water quality analysis. A future gain-loss study will determine how the river may have changed from the gain-loss studies conducted in 1956 and 1963. Further studies may also target tributaries, as they provide an estimated 60% of the flow in the Pedernales.

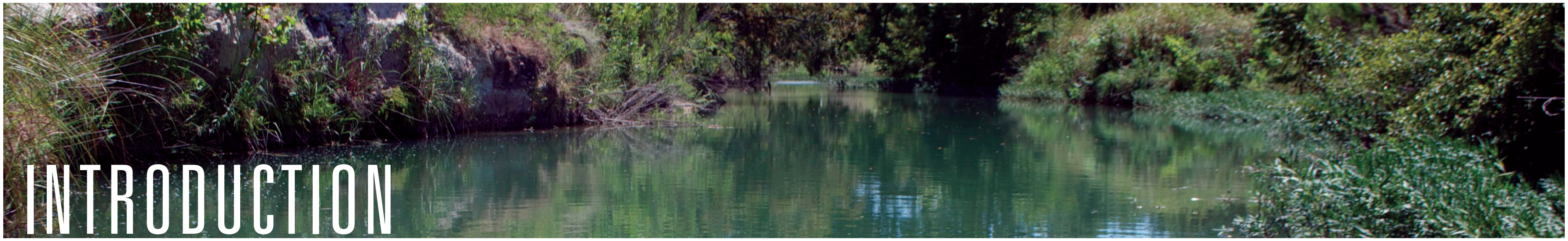
While the cities in the watershed are not growing at the pace of Austin or San Antonio, their steady growth, combined with the increasing number of small ranches, expanding tourism, and thriving agricultural industry, are expected to increase the water demands by about 30% over the next 50 years. The regional Groundwater Management Area has established a Desired Future Condition for the aquifer, which is that no more than 30 feet of average groundwater level decline should occur over the next 50 years. Even this decline in aquifer levels will have a significant negative impact on springflow and the river itself, underscoring the need for an updated gain-loss study to define groundwater-surface water interactions and the continuance or implementation of new measures to sustain flow in the Pedernales River basin.

Other threats in the watershed include:

- Invasive species along the river and brush growth throughout the watershed that can change the hydrology and adversely affect natural riparian areas;
- Sand and gravel operations along or in the river that impair water quality and damage riparian and aquatic habitat;
- Wastewater discharges to the river and tributaries that degrade water quality if the treatment plants are not properly permitted, operated, and maintained; and
- Land use and management practices and construction methods that cause downstream water quality and sedimentation issues that affect recharge and river flows.

To counter these threats, a wide-array of management, conservation and other opportunities are available to reduce water demands, protect land and water resources, and enhance habitat and the river's ecological health. These measures can work hand-in-hand with economic development planners and business leaders to protect the watershed while providing opportunities for all. If the river and springs run dry from water depletion, the reasons for visiting and living in the Hill Country are diminished, thus, business leaders should be informed and involved in the creation of practices to sustain their businesses and way of life. This report recommends the following next steps to initiate activities that manage our water use and natural resources to benefit the river and residents for generations to come:

- Conduct a new gain-loss study with a hydro-geologic component to document the groundwater - surface water interaction to understand how the watershed has changed and potential impacts to water supplies and springs;
- Develop a technical resource team that can actively participate in the ongoing Region K water planning process and get involved in GMA 9 water planning activities to re-evaluate the current desired future condition that suggests an acceptable aquifer drawdown of 30 feet;
- Initiate an education outreach effort with landowners and cities that are presently affected or about to be affected by invasive species. Follow the Neuces River Authority model to manage giant cane (Arundo donax) to restore riparian areas and prevent increased flooding;
- Begin reducing water demands and increasing recharge by creating a technical assistance program led by a technical coordinator to provide expertise in the Pedernales basin and across the Hill Country;
- Adopt the LCRA Highland Lakes Watershed Ordinance Quarry and Mines section to effectively manage the potential water quality impacts of these activities that are proposed from time to time in and near the river and tributaries; and
- Coordinate project activities with LCRA's efforts to update the Pedernales River Soil and Water Assessment Tool (SWAT) and Lake Travis water quality model to enhance calibration and verification of the gain-loss study and provide improved water quality data and other information valuable to watershed scale planning.



INTRODUCTION

Thanks to the generous support from the Cynthia and George Mitchell Foundation over the past several years, the Meadows Center for Water and the Environment has been working to answer the question – How much water is in the Hill Country? At first blush this seems like a very straightforward question that merits a straightforward answer. However, the reality is that the largely hidden and unknown complexities of Hill Country hydrogeology make it challenging to answer.

In 2015, the Meadows Center focused its efforts on understanding the intricacies of the Pedernales watershed and underlying hydrogeology. It is important to first note that over the years, various aspects of the Pedernales River have been studied by several entities dating as far back as the 1950s. One such report, the Hill Country Alliance's "*The State of the Pedernales: Threats, Opportunities and Research Needs*" report released in early 2015, provides an overview of the main characteristics of the watershed and summarizes many of these studies, their findings, and further research needs.

The gain-loss study conducted by the USGS in 1962 confirmed the 1956 study that the Pedernales River is a gaining stream, in other words, as one moves downstream from the headwaters, the flow rate increases due to springs, seeps, and inflows from the tributaries. Since the 1950's, land use activities have changed that can affect the flow in the river and the groundwater-surface water interaction. Due to these changes and a large number of wells now pumping from the basin's aquifers, it is important to know how land use change, groundwater pumpage, and the increase in demands affect the river flow today and long into the future. By further refining a gain-loss study with groundwater information using current hydrology we will be able to better identify threatened or critical river segments to guide management efforts to protect and enhance recharge, maintain river and tributary flows, and sustain the current high river water quality.

One of the first steps to determine how much water is in the Pedernales River was the Summer 2015 Hydro-blitz that is summarized in this interim report. Observations were made at 931 river and tributary sites to document the existence of flows in the river and tributaries during a summer dry spell to establish the groundwork for a future gain-loss study. An important outcome of the Hydro-blitz was the confirmation of the previous gain-loss studies' findings that over 20 major tributaries play a vital role in sustaining and adding to the river flows, resulting in the realization that a future gain-loss study should extend into key tributaries to pinpoint priority water management areas and appropriate strategies. This will benefit the landowners, tourism, growing cities, agricultural practices and preserve the river ecology to ensure the Pedernales River continues to be one of the landmarks of the Texas Hill Country.

PURPOSE

The technical scope of the *How Much Water is in the Pedernales?* focused on addressing the data gaps that were identified in our 2014 report *How Much Water is in the Hill Country?* These gaps were identified through a process of assessing existing hydrogeologic data through established scientific techniques that can be applied to any Hill Country stream or river. In the first phase of this study, the Meadows Center sought to understand both where water is normally located within the Pedernales River and its outlying tributaries, and to determine where flows within the watershed are spring-fed. By gathering these data and synthesizing them with geology and land use/land cover data within the Pedernales Watershed, we can eventually conduct a gain-loss study that explains the surface-groundwater interactions and identify specific best management or conservation practices at a localized scale. An in-depth technical report will be released in late 2015.

Based on recent studies, field work, data collection and evaluations, and input from stakeholders across the watershed regarding the Pedernales River, its health and uses, this report focuses on the highest priority and regionally appropriate actions that will improve and sustain water resources.

Specifically this report:

- Summarizes recent studies and reports;
- Identifies water supply and quality threats and their locations;
- Suggests approaches to manage and mitigate the threats and/or enhance the river;
- Identifies existing programs and activities to stretch resources; and
- Compiles this information to help guide the allocation of future resources to initiate the most effective and efficient projects and programs to protect the river, tributaries, and springs.

WHAT WE KNOW — WATERSHED SUMMARY

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The Pedernales River begins in northern Kerr County at the edge of the Edwards Plateau, a large limestone outcropping that covers much of West Texas. Surface flow begins at a spring near the Edwards/Upper Glen Rose contact near Harper. The fractured and conduit-filled karstic Edwards Plateau creates areas for groundwater recharge, capturing stormwater runoff and ultimately directing water to the headwaters of the Pedernales River. Land use across the watershed is primarily in a range or natural condition with extensive areas of brush.

Pedernales River Facts

- Drainage Area = 1,280 square miles (819,200 acres)
- Land use: Rangeland/farming 70%, Ashe juniper (cedar) 15%, floodplain 5%, floodplain 5%, conserved land 3%, urban 1%, parks 1%
- Home to 19 rare plant and six salamander species
- Aquifers: Edwards Trinity, Trinity, Ellenburger – San Saba, Hickory, Marble Falls
- Estimated 1,272 springs with about 3/4 of the springs found in Travis County
- The Pedernales provides about 30% of inflows to Lake Travis, the primary water supply for Austin and central Texas
- Parks: LBJ National Historic Park, Pedernales River Park, Pedernales Falls State Park, Westcave Preserve, Hamilton Pool Park, Reimers Ranch Park, and Pace Bend Park
- 54 active permits for surface water withdrawals totaling over 5,000 acre-feet of water

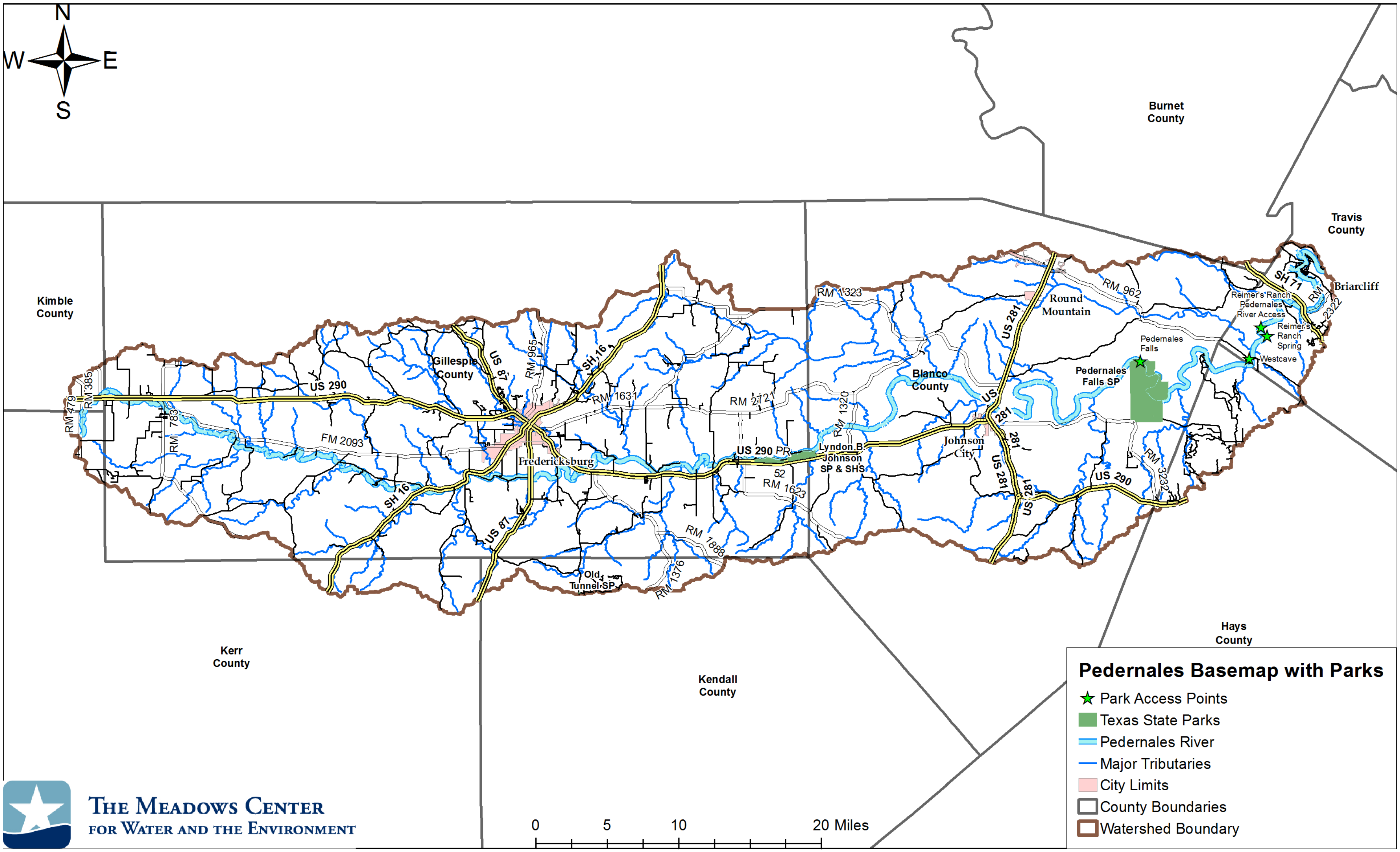

Figure 1 – Study area in the Pedernales watershed, including roads, parks, the Pedernales River, and its tributaries

From its headwaters, the Pedernales River flows eastward through Gillespie, Blanco, Hays, and Travis counties into Lake Travis just west of Austin. Lake Travis is a reservoir on the Colorado River formed by Mansfield Dam and serves as the primary drinking water source for the City of Austin and surrounding areas.

The river can be one of extremes since it is prone to flash flooding and extreme drought with the highest peak flow rate of 452,000 cubic feet per second (3.4 million gallons per second) in 1952 and the river going completely dry in 2011. This was witnessed again in May 2015 after seven years of severe drought was interrupted by an extreme flood as intense rains overwhelmed the thin soils and steep slopes and generated a peak rate near 150,000 cfs when only days before the river flow was about 10 cfs. Figures 2 and 3 below show the same stretch of this river in extreme drought and flood conditions.

Throughout its 106-mile course, the River drops more than 1,200 feet in altitude, flowing from its headwaters across porous limestone through a valley of clay and compacted sand in the eastern half of Gillespie County and across shale and limestone into Lake Travis. Major tributaries include Wolf Creek, Live Oak Creek, South Grape Creek, Barons Creek, Miller Creek, Flat Creek, Cypress Creek and Hamilton Creek.

Figure 2 – A stretch of the Pedernales in drought conditions (photo courtesy of HCA, Scott Gardner)

Figure 3 – A stretch of the Pedernales during flood conditions (photo courtesy of HCA, Scott Gardner)

Geology

River flow originates near the Edwards/Upper Glen Rose contact near Harper. Over a relatively short distance, the river down cuts through the upper and Lower Glen Rose and into the Hensel Sand. The river flows across the Hensel Sand through the city of Fredericksburg to western Blanco County. At this point, the river runs through outcrops of Ordovician and Cambrian strata that flank the southern edge of the Llano Uplift. The eastern river portion in Blanco, Hays, and Travis Counties flows through the lower Cretaceous formations to the confluence with Lake Travis (Colorado River).

Past Gain-Loss Studies

Detailed gain-loss studies were conducted in the watershed 1956 and 1962-3 by the USGS. The first study was completed during significant drought (the drought of record) and the later study was performed under more "normal" rainfall conditions. The population, level of development and water usage in the watershed were considerably less than they are today. Discharge in the main stem of the river and contributions from tributaries were measured. The 1962-3 found that 66 percent of the total river discharge originated from tributaries, mostly in the eastern portion of the watershed (with only 33% originating from gains in the main channel of the river). Water losses in the main channel were primarily noted between Stonewall and Johnson City. The map in Figure 6 summarizes the results from the 1962-3 study.

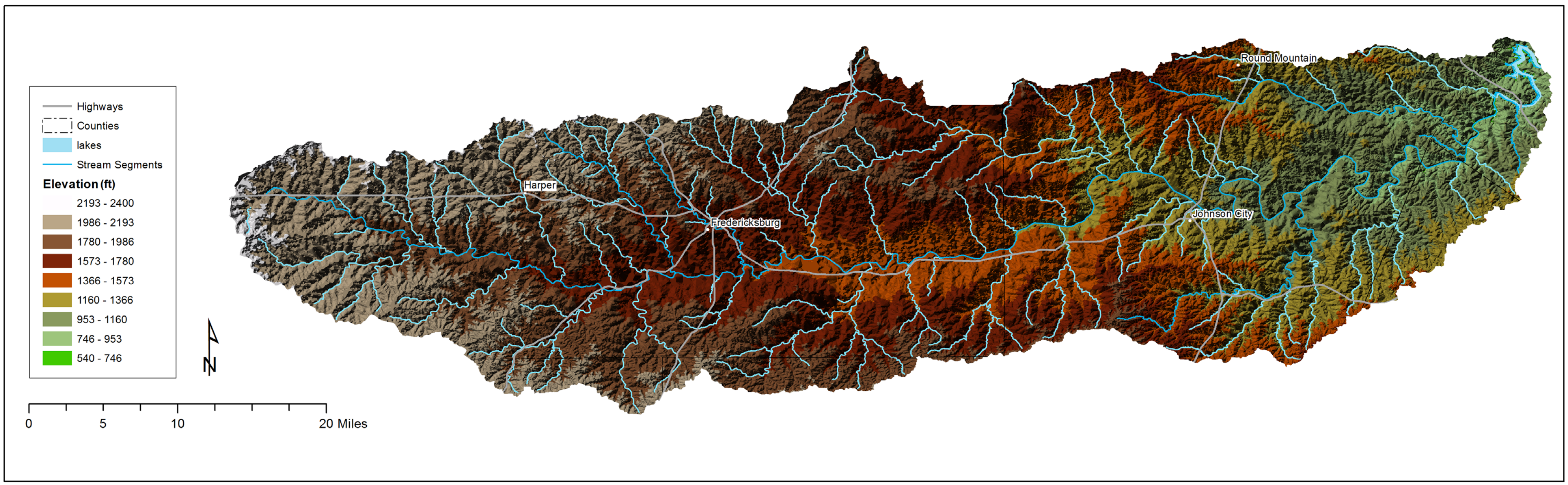

Figure 4 – Elevation change across the watershed

The Figures below show surface geology and gains and losses recorded during both studies. The HCUGCD conducts ongoing surface water flow measurements along a reach of the river in the vicinity of Fredericksburg.

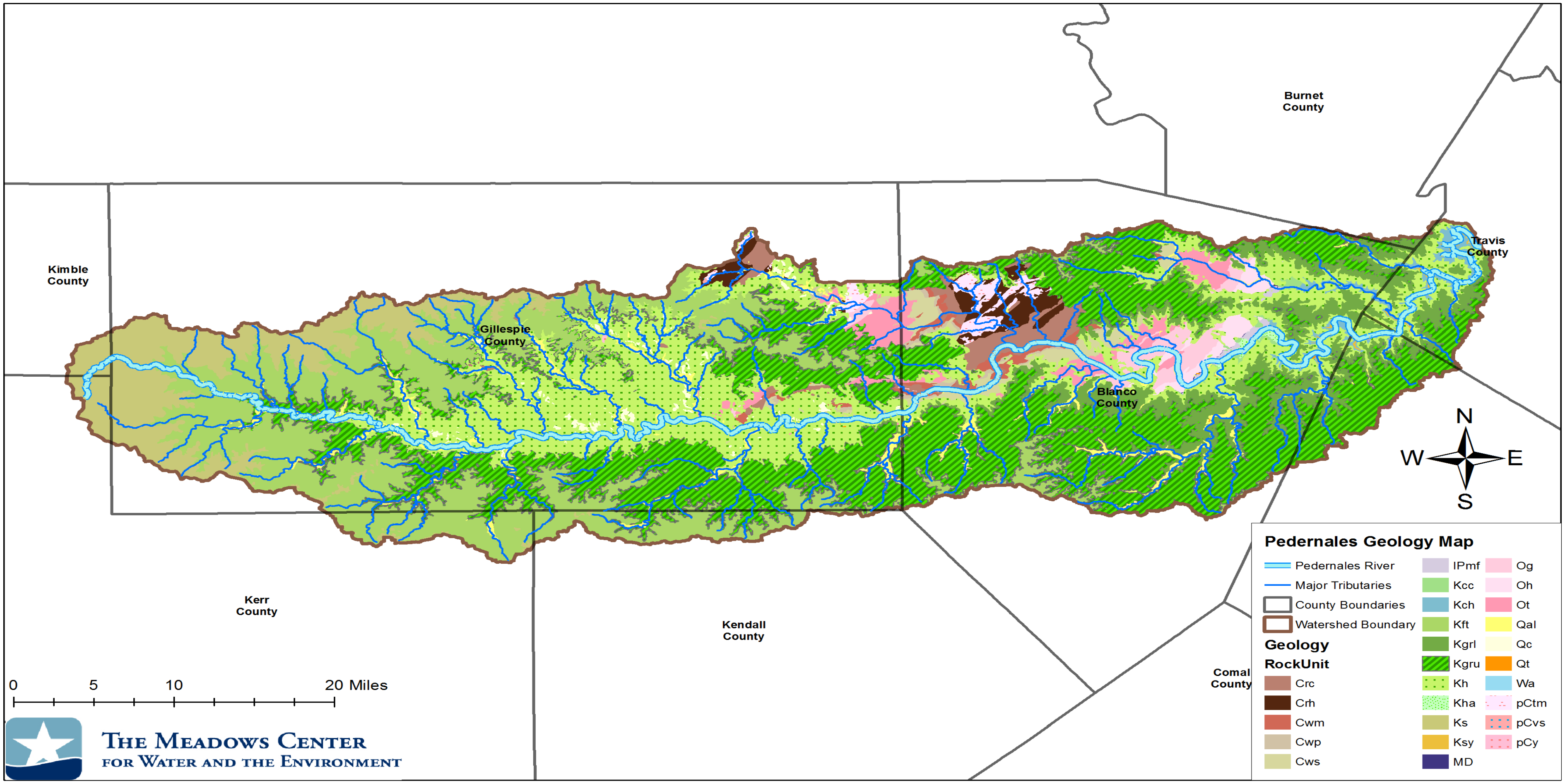

Figure 5 – Surface rock type across the watershed

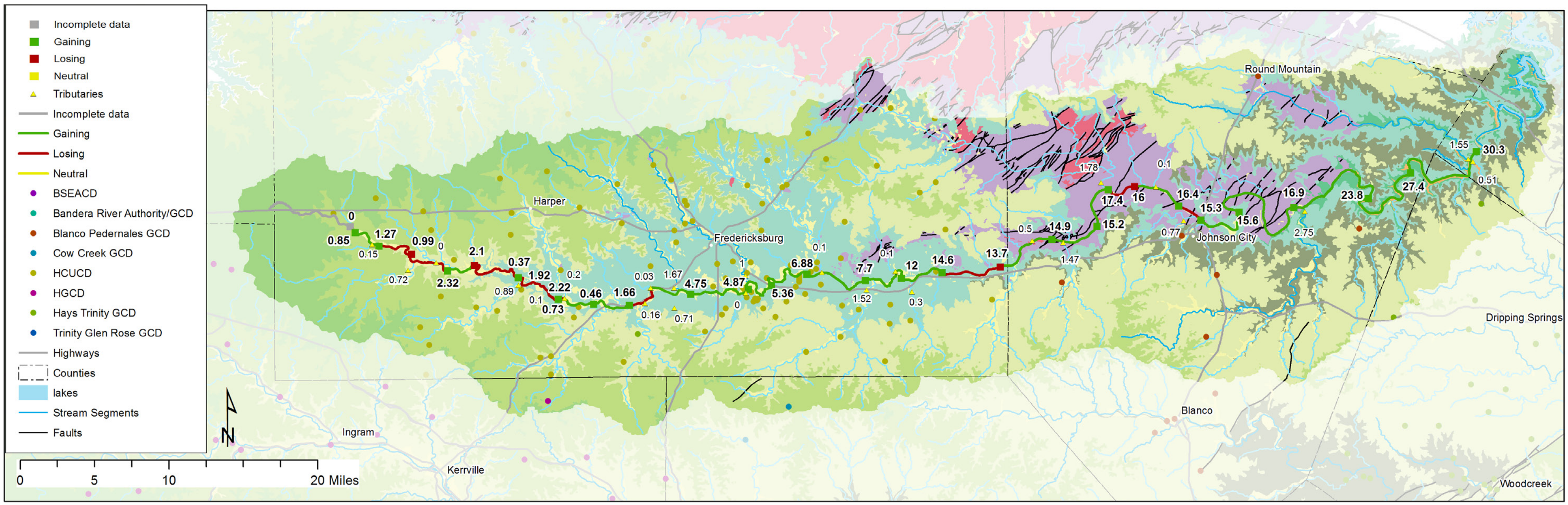

Figure 6 - Historical gain-loss data within the Pedernales watershed

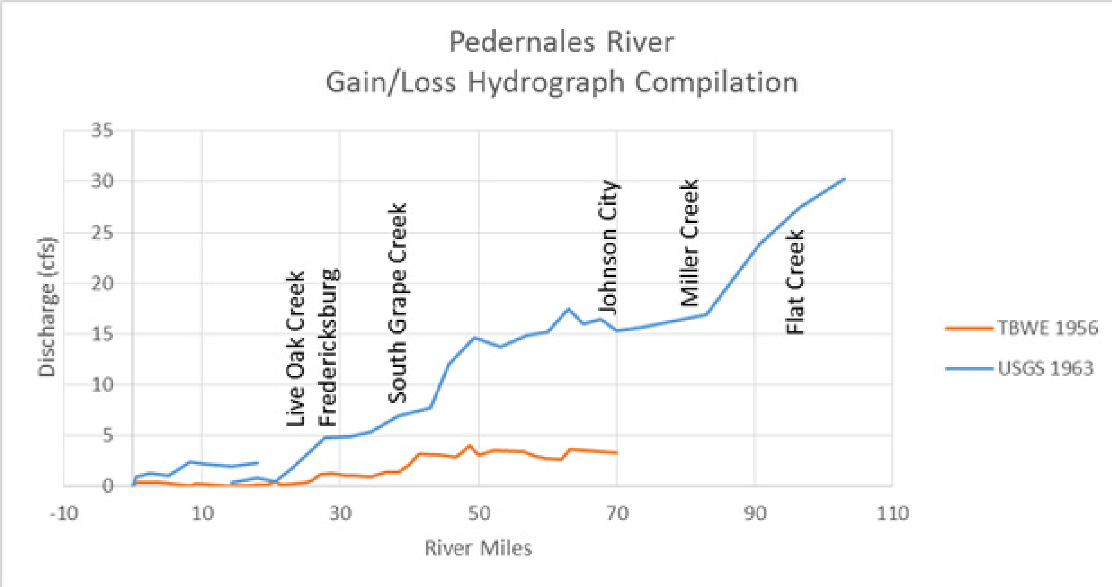

Figure 7 – Pedernales River gain-loss hydrograph compilation 1956, 1963 (Courtesy of Texas Board of Water Engineers)

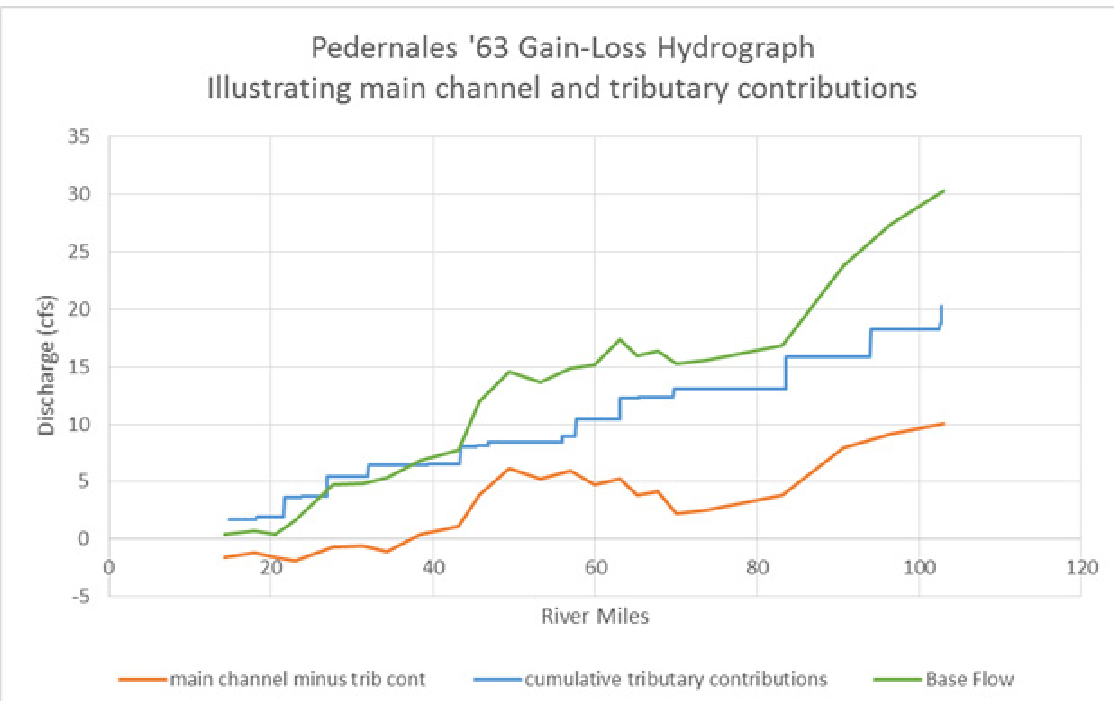

Figure 8 – Pedernales River 1963 gain-loss hydrograph with main channel and tributary contributions (Courtesy of Texas Board of Water Engineers)

Population Growth and Water Use

Gillespie and Blanco Counties comprise the majority of the watershed area and although their populations are small, they are expected to nearly double in the next 50 years, increasing groundwater pumping as well. Municipal water demand in Blanco and Gillespie Counties is projected to increase by more than 25%. Municipal water demand in the City of Fredericksburg is projected to increase from well less than 3,000 acre-feet to 4,058 acre-feet by 2070. Population growth estimates and changes in land cover shown below in the tables and figures below point to steady growth in urban and suburban (county) areas of the watershed.Table 1 - 2016 Regional Water Plan population growth projections by county, 2020-2070. Population growth estimates and changes in land cover shown below in the tables and figures below point to steady growth in urban and suburban (county) areas of the watershed.

Table 1 - 2016 Regional Water Plan population growth projections by county, 2020-2070

County	2020	2030	2040	2050	2060	2070
BLANCO	13,015	15,475	16,917	17,672	18,175	18,472
GILLESPIE	26,795	28,852	30,548	32,536	34,365	36,142
TOTAL	**39,810**	**44,327**	**47,465**	**50,208**	**52,540**	**54,614**

Table 2 - 2016 Regional Water Plan population growth projections by city, 2020-2070

City	2020	2030	2040	2050	2060	2070
JOHNSON CITY	2,053	2,441	2,668	2,787	2,867	2,914
FREDERICKSBURG	11,318	12,146	12,829	13,630	14,367	15,083
TOTAL	**13,371**	**14,587**	**15,497**	**16,417**	**17,234**	**17,997**

Table 3 - 2016 Regional Water Plan water demand projections for 2020-2070, Blanco County (Acre-feet)

Demand Category	2020	2030	2040	2050	2060	2070
IRRIGATION	256	240	225	217	213	204
LIVESTOCK	564	564	564	564	564	564
MANUFACTURING	20	20	20	20	20	20
MINING	5	5	5	5	5	5
MUNICIPAL	1,811	2,094	2,254	2,336	2,398	2,438
Blanco County Total	**2,656**	**2,923**	**3,068**	**3,142**	**3,200**	**3,231**

Fredericksburg demand increases by nearly 30% and Johnson City by a similar amount. These communities' water supply needs are met by local aquifers.

The population in nearby urban centers that could utilize the Pedernales River for water supplies is increasing rapidly. Population in the Cities of Austin and Dripping Springs is expected to double by 2070, while their municipal water demands will increase by nearly 125,000 acre-feet between 2020 and 2070. Thus, with the Pedernales providing nearly 30 percent of the inflows to Lake Travis, a major water source for central Texas, there is increased importance for sound land and water management activities across the watershed to benefit the region.

Table 4 - 2016 Regional Water Plan water demand projections for 2020-2070, Gillespie County (Acre-feet)

Demand Category	2020	2030	2040	2050	2060	2070
IRRIGATION	2,058	2,031	2,003	1,978	1,953	1,928
LIVESTOCK	1,062	1,062	1,062	1,062	1,062	1,062
MANUFACTURING	1,049	1,102	1,151	1,192	1,276	1,366
MINING	4	4	4	4	4	4
MUNICIPAL	4,969	5,225	5,438	5,737	6,043	6,349
Gillespie County Total	**9,142**	**9,424**	**9,658**	**9,973**	**10,338**	**10,709**

Table 5 - 2016 Regional Water Plan municipal water demand projections for 2020-2070, city (Acre-feet)

City	2020	2030	2040	2050	2060	2070
JOHNSON CITY	354	411	444	461	473	481
FREDERICKSBURG	3,146	3,327	3,476	3,672	3,866	4,058
TOTAL	**3,500**	**3,738**	**3,920**	**4,133**	**4,339**	**4,539**

Within the watershed, it is estimated that approximately 30 percent of the water wells in Gillespie County and 35 percent of the wells in Blanco County tap the Middle Trinity Aquifer. There are approximately 4,200 documented water wells in the watershed. The wells are widely distributed throughout the watershed, with noticeable concentrations in urban areas, as shown below. Unfortunately, there is no available estimate of exempt or undocumented wells in the watershed, nor is there any information on the level of pumpage or types of usage for those unknown wells. Although wells used for domestic or livestock use are considered exempt under state rules, many of them were drilled prior to organizations such as GCDs keeping up-to-date records. Accurate record keeping of exempt wells in has only come about within the last 10-15 years in the state of Texas. Some GCDs also vary in the accuracy of their well number estimates. Although many GCDs have estimates of well water usage available, they rarely group them together by watershed.

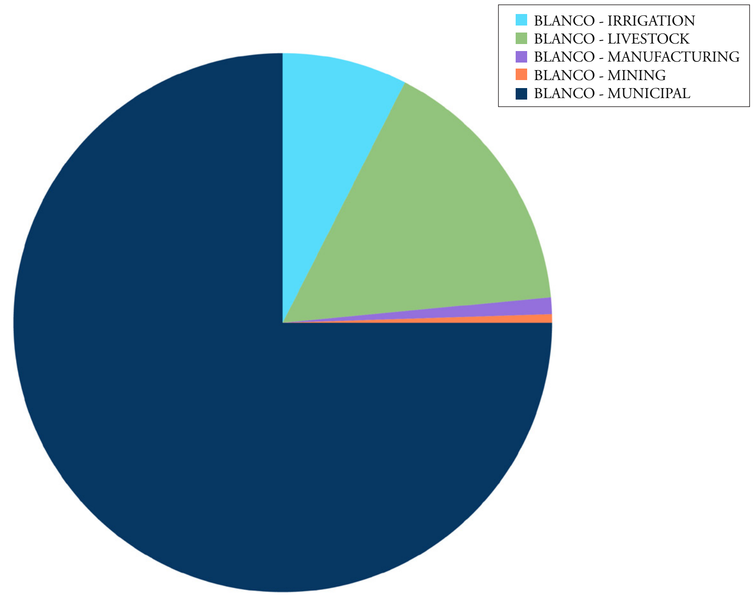

Figure 9 – Blanco County projected water demand, 2070 (courtesy of 2016 Regional Water Plan)

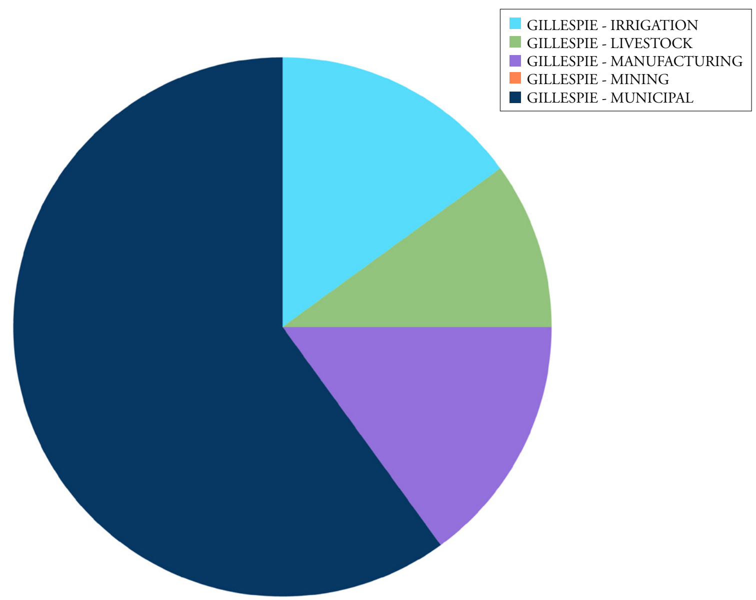

Figure 10 – Gillespie County projected water demand, 2070 (courtesy of 2016 Regional Water Plan)

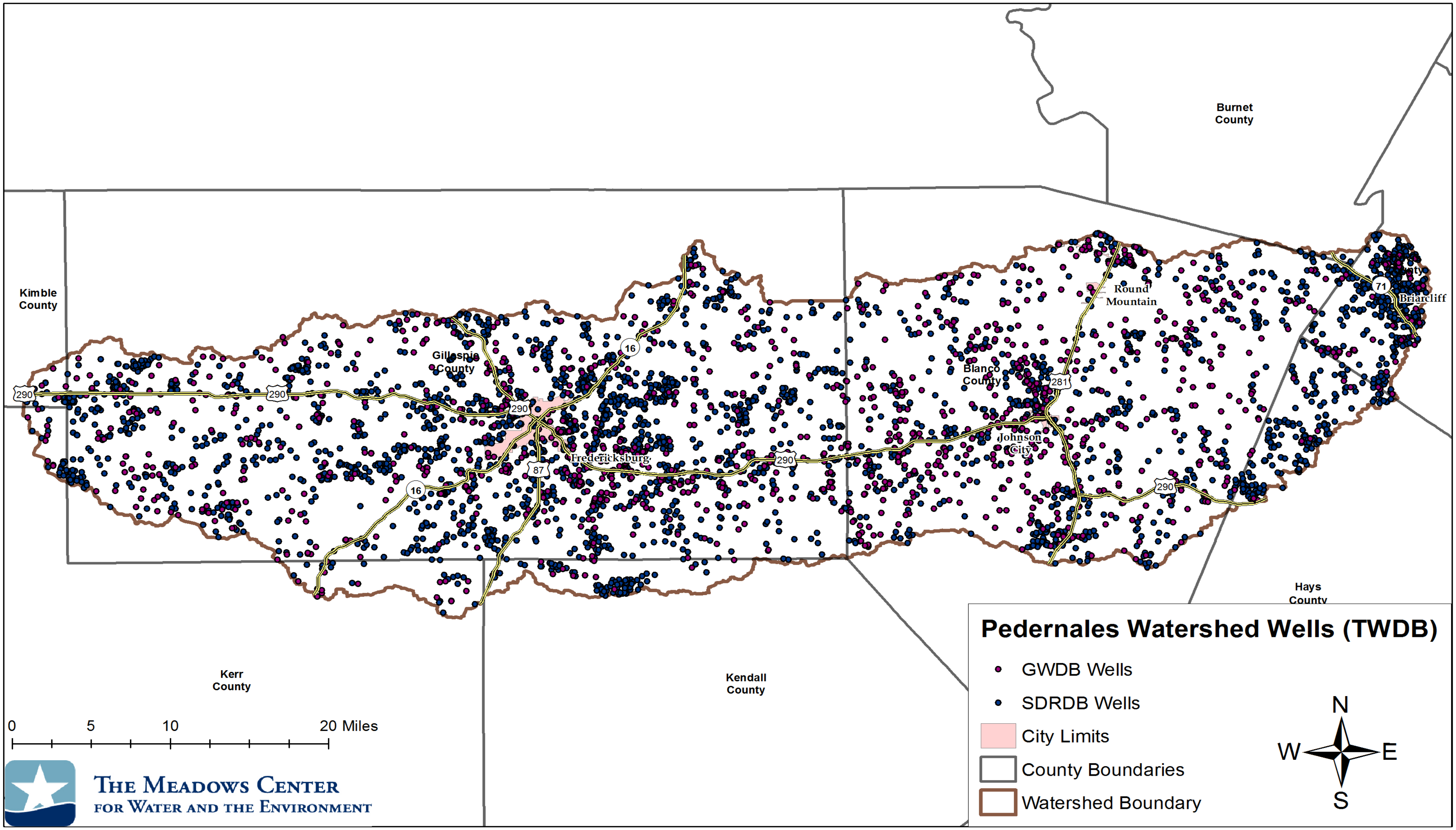

Figure 11 - Registered wells within the Pedernales watershed (TDWB)

Water Supply Issues and Options

The current period of prolonged drought depleted many reservoir levels to historic lows and created a growing reliance on groundwater to support the escalating population of Central Texas. Since there are few regulations that can be placed on aquifer pumping, there is a possibility that unsustainable groundwater development and drought could endanger major springs that are instrumental to the base flow of the major rivers in the Hill Country region. Continued drought and increased groundwater pumping could lead to municipal and agricultural supply shortages. There is still much to learn about the interconnected nature of these aquifers, rivers and lakes.

Figure 12 - Grapes at Becker Vineyards outside of Fredericksburg, TX (photo by Nan Palmero)

In 2010, LCRA assessed multiple new water supply options throughout the Colorado River Basin with one studied option being a groundwater development project in Gillespie County to help meet projected future water demands. This project included a pipeline from the well field to Fredericksburg and was estimated to cost $14.9 million and provide about 1,120 acre-feet per year. At this time, LCRA is not considering this option for implementation. In the 1968 Texas State Water Plan, a reservoir was proposed on the Pedernales River with a water supply volume of about 220 acre-feet, however, it is no longer included in the Region K Water Plan due to water right, maintenance and permitting challenges that would make this facility very difficult to implement. Thus, an important water management measure to meet current demands during drought and sustain supplies for future generations is the conservation and augmentation of local groundwater and river supplies with appropriate strategies guided by cities, groundwater conservation districts, river authorities, and other agencies.

Water Quality

Both Fredericksburg and Johnson City discharge treated wastewater into the river. Both facilities are permitting, regulated, and subject to inspection by the Texas Commission on Environmental Quality (TCEQ). Fredericksburg is permitted to discharge 2.5 million gallons per day into Barons Creek, although much of the effluent can be used for golf course irrigation. The City has recently reduced the amount of nutrients discharged to the Creek which helps protect the water quality of the Pedernales River. Johnson City has a permit to discharge 0.3 million gallons per day into Town Creek, another tributary to the Pedernales.

The LCRA evaluated various water quality parameters to assess current water quality conditions and compared those to past data through a trend analysis at five sites along the river that had sufficient data. Two of the five sites showed an increasing trend in total phosphorus while no other water chemistry trends were detected. With respect to phosphorus, the water quality is showing signs of degradation which could result from stormwater runoff and wastewater discharges.

Currently, water quality is considered to be in good condition along the river and its tributaries and no segments are listed on the State 303 (d) list of impaired water bodies.

The majority of land in the watershed is undeveloped, agricultural, ranch land, or range land and many large tracts are still in place. Vast stretches of the river are lined by privately owned ranches and remain largely free of development, making the Pedernales a top priority conservation area. Developed land in the watershed is residential, with most being low-density single-family and future growth will change land use in those areas from predominantly rural to suburban. There has been a large increase in agricultural usage of groundwater by newly planted vineyards. The vineyards and associated wineries can place additional stress on the aquifers.

Figure 13 - Algae and biofilm, tributary of Pedernales River (MCWE)

Figure 14 - Cows along a creek in the Pedernales Watershed (MCWE)

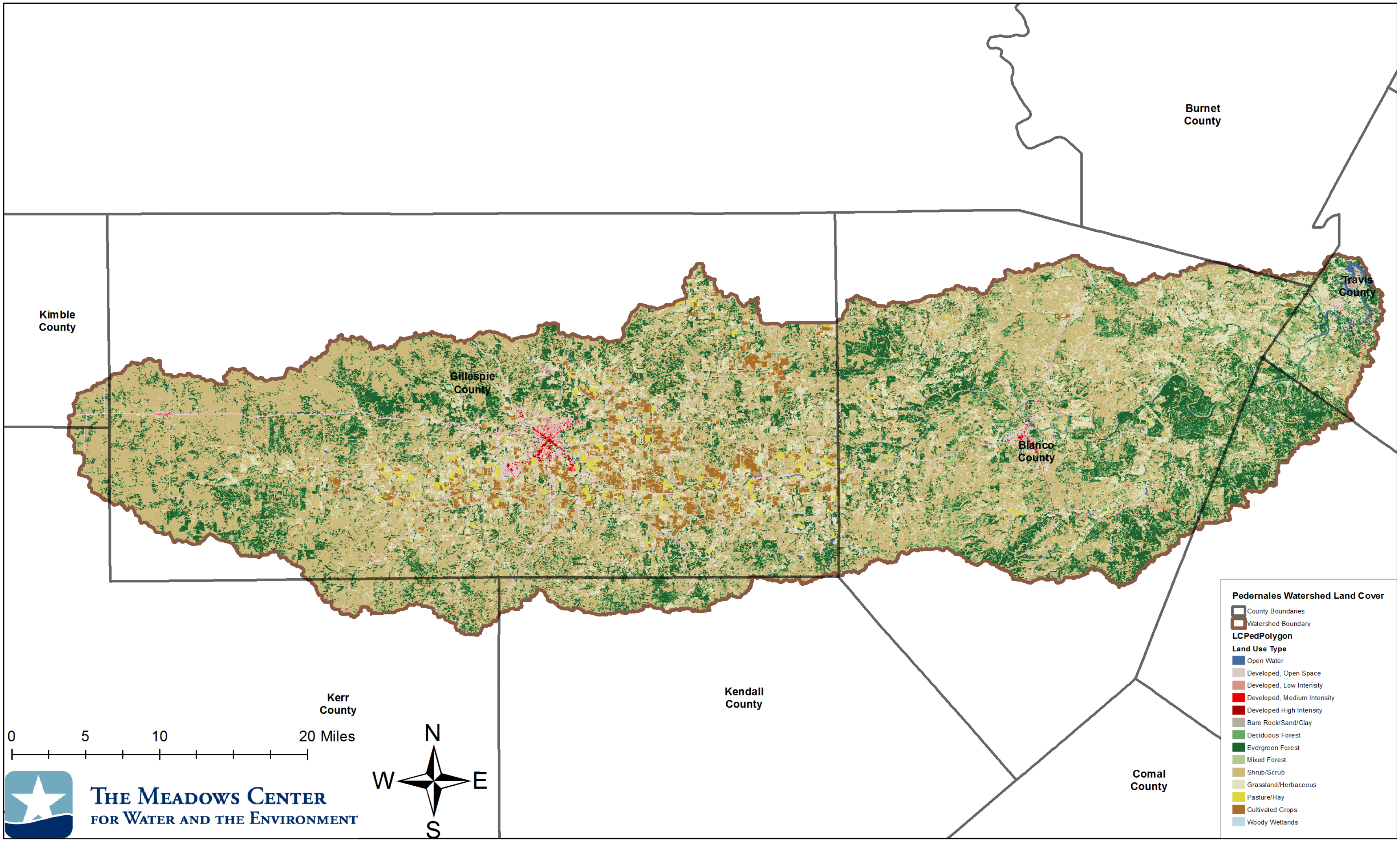

Figure 15 - 2011 Land cover map of Pedernales watershed

Invasive Species and Ashe Juniper

While some baseline hydrologic and water quality data exist for the river, little data is found on the ecological health of the system. The encroachment of invasive species such as giant cane (Arundo donax) and elephant ear (Colocasia esculenta) could impact the river's natural hydrology, affect flood flow conveyance, and crowd out native plants that support the local habitat and environment. A high-level survey of giant cane is near completion and illustrates the extent of this invasive plant along the river and tributaries and is summarized below.

Table 6 - Arundo stands observed on sampled sites in the Pedernales River and tributaries, August 2015

Water Body	Length Surveyed	# of Arundo Stands	Stands Per Mile
BARONS CREEK	17.3 miles	144 stands	8.32
TOWN CREEK	2 miles	7 stands	3.5
PALO ALTO CREEK	16.2 miles	11 stands	0.67
PEDERNALES RIVER	82 miles	127 stands	1.56
TOTAL	**117 miles**	**289 stands**	**2.47**

Baron's Creek, which flows through Fredericksburg, has by far the highest infestation with more than 8 stands per mile. Without effective management, this plant can rapidly colonize the riparian areas, increase flooding, and limit river access for recreational and agricultural purposes.

The Neuces River Authority currently directs the "Project Arundo Control", a three year program that is a landowner-driven approach that involves a community volunteer effort, with support from state, federal and foundation partners designed to effectively halt the Arundo invasion and reverse the damage already incurred. Lessons learned from this effort could be applied to the Pedernales River basin to halt the growth of giant cane and restore affected riparian areas.

Figure 16 - Noted stands of Arundo donax in the western portion of the Pedernales watershed (photo courtesy of HCA, 2015)

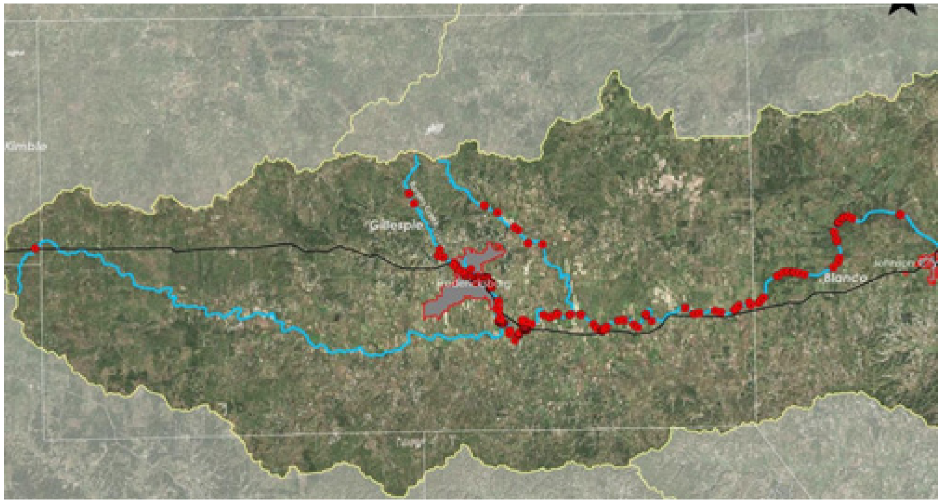

Figure 17 – 2015 sightings of Arundo donax near Fredericksburg, Texas in the Pedernales watershed (courtesy of Hill Country Alliance)

Figure 18 - Tributary downstream from Bamberger Ranch (MCWE)

Brush Management

While various viewpoints exist on the water supply value generated by brush management, it is recognized that cedar (ashe juniper) can limit the ability of rainwater to reach the ground in the Texas Hill Country. A five-year study across 10 sites found that roughly 40 percent of rainfall was intercepted either in the tree canopy or leaf litter, thus, potentially affecting the amount of water reaching the tributaries, aquifers, and the river. It is recognized by all parties that brush management must be done in a way to preserve soil and encourage native species growth to avoid river sedimentation and enhance local habitat.

The Texas State Soil and Water Conservation Board has directed the Pedernales Water Enhancement Project since 2002 and has worked with landowners in this cost sharing effort to treat approximately 72,485 acres of cedar at an expense of about $5.7 million. Today, the State of Texas provides about $2.6 million per year to fund brush management programs across the State and the Pedernales basin is seeking another $200,000 per year for the next two years to fund additional activities in the basin. The State will let the local districts know by early October 2015 if the funds were awarded to the Pedernales basin projects.

One success story is the Bamberger Ranch in Blanco County, as the ranch has become one of the largest habitat restoration projects in the state, winning numerous awards from the State and the Nature Conservancy for its brush management of 5,500 acres to benefit water supplies, habitat, and cattle grazing. When acquired, the ranch's creeks did not have running water, today, there 27 stock tanks supported by the live springs and creeks that now flow most of the time except in extreme drought. Overflow from the springs and seeps produce flow for Miller Creek, a major tributary to the Pedernales River. Qualitative observations made by Hydro-Blitz participants at Bamberger Ranch suggested that more water was available at or near the ranch compared to adjacent ranches, and sub-basins. They also suggested a possible water variety of fish as well as aquatic and riparian animals near or at Bamberger Ranch. The Bamberger Ranch today is protected from future development through the Bamberger Ranch Preserve, a 501(c)(3) organization that hosts nearly 3,000 visitors per year to illustrate land management and conservation measure success to schools, tour groups, and landowners.

WATER PLANNING

A combination of agencies and organizations manage ground and surface waters within the Pedernales River basin and are summarized below.

Groundwater Management

The Pedernales River watershed includes portions of seven groundwater conservation districts that generally follow county lines. The two districts with the most land area in the basin are the Blanco-Pedernales Groundwater Conservation District and the Hill Country Underground Water Conservation District which have jurisdiction over Blanco and Gillespie Counties, respectively. By statute, wells used solely for domestic or livestock purposes and that are capable of producing no more than 10,000 to 25,000 gallons per day are exempt from GCD permitting. Therefore, many wells in the basin are exempt from permitting due to their size and land use.

Groundwater Water Management Areas (GMAs) were established by the State in 2005 so GCDs could work together to conduct joint planning to maintain shared aquifers. The Pedernales watershed is divided between two GMAs, GMA 7 and GMA 9, so management of its aquifers can be difficult as illustrated by GMA 9 adopting a desired future condition that would allow for a region-wide water level decline of an additional 30 feet through the year 2060 while GMA 7 agreed to a maximum 7-foot drawdown. Thus, one can see the difficulties in establishing goals and management activities with separate desired future conditions for the same aquifer systems and the potential adverse impact to springs and the river flow with a drawdown of 30 feet. The groundwater management areas will enter into another phase of planning and will need to revisit their desired future conditions. This process provides an excellent opportunity for GCDs and the public to share their vision for sustainable groundwater management.

Because Texas Water Law allows land owners to maximize the beneficial use of their groundwater, there is the threat that large water producers could seek permits to pump and convey groundwater to other interests/growing cities outside the Pedernales River basin. Although not in the Pedernales basin, a similar situation arose in GMA 9, south of Austin, when the Electro-Purification drilled wells and announced plans to pump up to 5 million gallons of water per day to serve new development and growing cities along the IH-35 corridor.

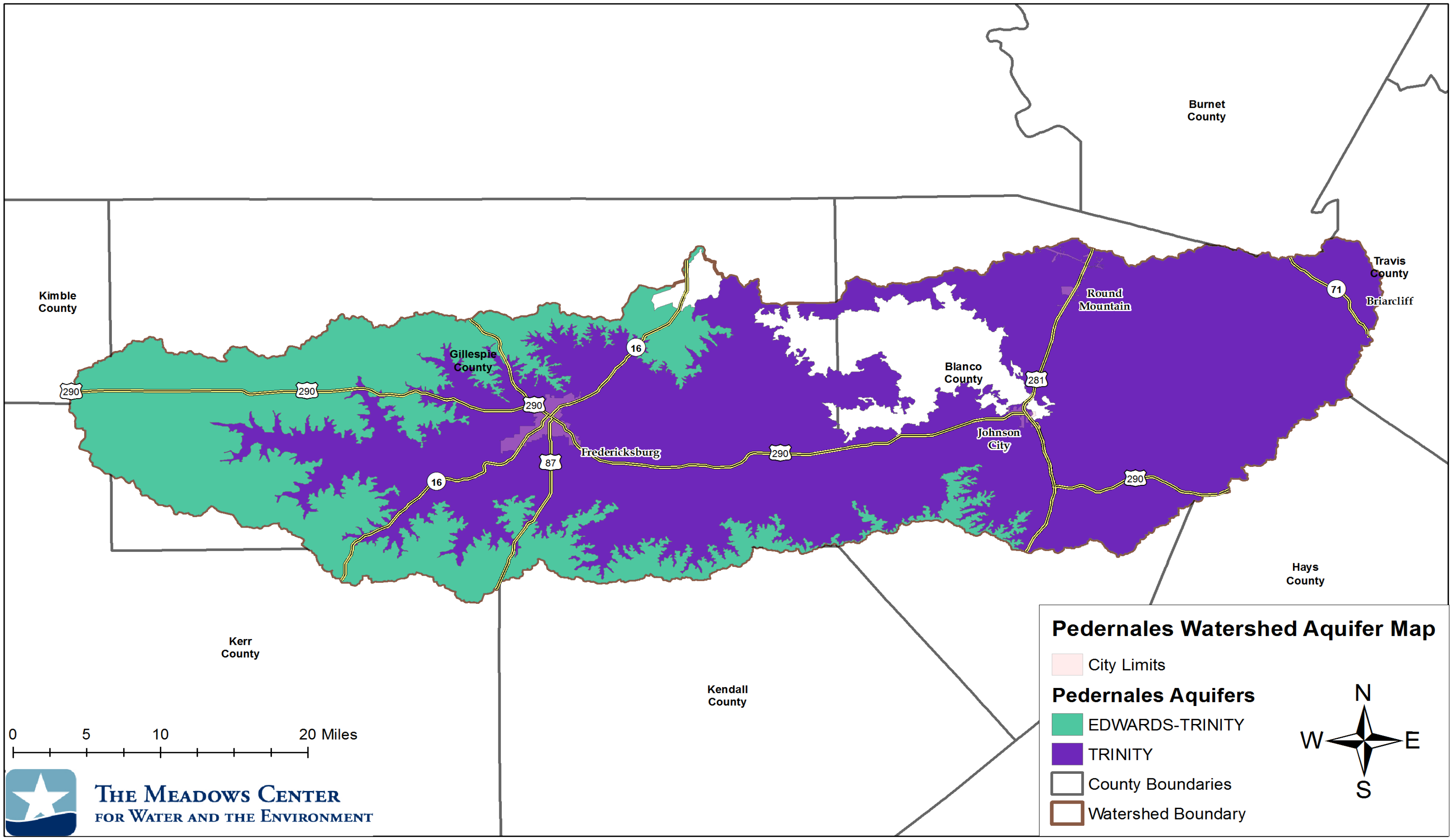

Figure 19 - Surface aquifers and outcrops in the Pedernales watershed

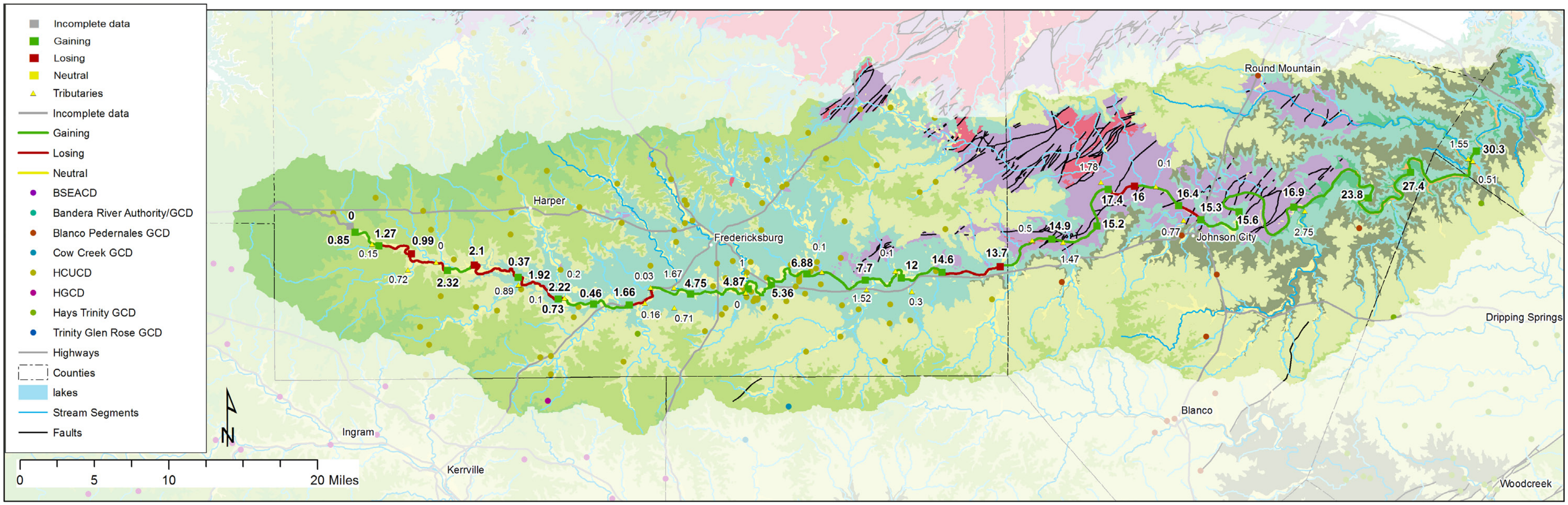

Figure 20 - Most recent Pedernales River gain-loss studies (1963)

In addition to the GMA planning process, there are Regional Water Planning Groups (RWPG) that guide the formation of the Texas State water plan every five years. This effort combines surface water and groundwater resources to meet projected future water demands to the year 2070.

The majority of the Pedernales River basin is found in Region K, also known as the Lower Colorado RWPG. The RWPG is currently working on the regional plan update that will ultimately become part of the 2017 State Water Plan. The RWPG host meetings on a near monthly basis that is led by a stakeholder committee composed of water utilities, municipalities, agricultural interests, environmental interests, GCDs. counties, industry, and landowner groups. These meetings are open to the public and upcoming meetings provide the opportunity to provide input on the recently completed 2016 Initially Prepared Region K Plan. The final Region K Plan is due to the Texas Water Development Board in December 2015.

WHAT WE LEARNED — SUMMER 2015 HYDRO-BLITZ SUMMARY

The groundwater/surface water interactions in the Pedernales River are not well documented. Detailed gain-loss studies were performed on the Pedernales River in 1956 and 1962. The 1956 study was performed during the drought of record, while the 1962 study was performed during a more "normal" rainfall period. These studies were performed when the population and water use was considerably less than at present. Development, land fragmentation, and establishment of a robust wine industry since the 1960s have likely altered the local hydrogeology.

Under the direction of Mr. Douglas A. Wierman, P.G. and Dr. Benjamin Schwartz, the Meadows Center developed an approach that will help us better understand the complex interactions between groundwater, surface water, geology, local land use/ and land cover, and other relevant hydrogeographic characteristics of the Pedernales River watershed. The Meadows Center and local communities, volunteers, and partner organizations "blitzed" the entire Pedernales River -- from west of Fredericksburg to east of Johnson City— in early August to collect information about the river and its environment. We also will use this project as a road map for pooling scarce financial and staff resources among regional Non-Governmental Organizations (NGOs) and stakeholders so that similar projects using similar methods can be replicated elsewhere in the Hill Country region and across the state of Texas.

In the summer of 2015, The Meadows Center for Water and Environment led a preliminary hydrologic inventory of water data at 931 sites throughout the basin, from small tributaries to the main river channel. The study identified sites that had flowing water, standing water, and no water at all. In addition, water quality field parameters were measured at 85 sites to define water quality parameters and current tributary/river health. Water quality samples for more detailed water quality testing were collected at these and additional spring sites. They are currently being analyzed for a series of water quality parameters. This data will be essential in guiding a future gain-loss study by ensuring the extension of data collection into the tributaries that are generating significant runoff to the Pedernales.

Pedernales "Hydro-Blitz" Sampling Process

Environmental, geologic, and hydrologic GIS data was compiled from multiple sources to create watershed characterization maps. The locations of all points where TXDOT public roads/right-of-ways intersect a National Hydrography Dataset flowline, river or tributary were extracted and mapped. In preparation for the Hydro-Blitz, the watershed was divided into eight "regions" with road crossing (intersecting with a waterway) noted as an inventory location.

Volunteers, Master Naturalists and The Meadows Center staff, Texas State University Department of Biology professors and students were trained in a inventory protocol, including recording characteristics such as flow, turbidity, defined river channels, presence of invasive plant species and detrimental land use practices. Please refer to the Appendix for field data sheets and sampling methodologies. Seven two person teams sampled all identified sites on Monday, August 10 and Tuesday, August 11.

The inventory was postponed multiple times due to uncharacteristic heavy precipitation events throughout the early summer months of 2015. Our initial target was to collect samples during the month of June, but we were forced to reschedule the Hydro-Blitz until early August to better simulate the conditions of the 1963 USGS gain-loss study. The tributaries and springs that were flowing at the time may not have been entirely representative of levels of discharge in what would be considered a "normal" rainfall pattern. The table below compares the flows recorded in the 1962-3 gain-loss study (which occurred during a period) with the flow levels during our sampling events.

Table 7 - Comparison of flow at selected locations in Pedernales Watershed, 1962 and 2015

Sampling Location	1962 (May)	2015 (August)
Fredericksburg @ HWY 87	4.8 cfs	2.0 cfs
Johnson City @ HWY 281	15.3 cfs	18.0 cfs
Reimer's Ranch, downstream of Cypress Creek	30.3 cfs	27.8 cfs

Landowners across the Pedernales watershed were contacted via phone and e-mail with requests to access any springs and/or wells that they have on their property. Those efforts ultimately led to water quality sampling at multiple ranches, parks, and private properties throughout the watershed. The Meadows Center and Hydro-Blitz staff partnered with numerous organizations in various roles, such as data acquisition or project coordination. Those partner organizations include the Hill Country Alliance, The Nature Conservancy, Alamo Area Master Naturalists, Lower Colorado River Authority, Texas Parks and Wildlife, Hill Country Underground Water Conservation District, and the Texas State University's Department of Biology.

For further details and results of the Hydro-Blitz, please see the "Pedernales Hydro-Blitz Sampling - Phase 1" section of the Appendix.

Water Quality Sampling

A second phase of sampling consisted of visiting almost 100 sites chosen from the initial 931 intersections based on whether accessing the stream channel was possible from the public road and whether flowing water was present. The Meadows Center staff and Texas State University Department of Biology students partnered together in groups of two to visit these locations. Basic water quality parameters such as pH, dissolved oxygen, conductivity, and water temperature were measured at each site using ExTech probe kits. A 32 ounce water sample was also taken at each site and submitted to the Edwards Aquifer Research and Data Center/Texas State Department of Biology laboratory for analysis by graduate student Saj Zappitello and Biology professor Dr. Benjamin Schwartz. They will analyze each sample's water chemistry and evaluate water quality indicators, including total suspended sediments, and forms of nitrogen and phosphorus. Other water geochemistry parameters, including major ions and stable isotopes, also will be analyzed and incorporated into Ms. Zappitello's master's thesis comparing the chemical signature of the Pedernales River and tributaries to the chemical signature of the underlying aquifers. This study will assist in understanding the relationship of groundwater to surface water in Pedernales River basin. Raw data from the analyses will be available by November 2015, and Ms. Zappitello's thesis and analysis is anticipated to be complete in spring of 2016.

After the initial inventory was conducted during the "hydro-Blitz" phase, some tributaries with a small amount of water dried up before they could be sampled for water quality. This is typical during low flow conditions without rain. In cases where the targeted sample site was not flowing, alternative sites were sampled. The road crossing sample locations were supplemented with spring samples from private property owners in the river basin.

For maps of each water quality sampling location and a breakdown of those locations by sampling region, please see the Appendix.

Water Threats

Based on the Summer 2015 Hydro-blitz, recent reports/studies that are listed in the Selected Reference Section, and input from various interests that have knowledge of the Pedernales River watershed, potential threats to the health and quantity of water were identified and shown in the following Table (8).

Table 8 – Pedernales watershed and river threats

Threats	Location	Potential Water Impact	Potential Land Impact	Potential Strategy/Approach
Limited knowledge of surface – groundwater interaction	Entire basin	Limits ability to define priority spring sources and areas	Landowners unaware of land/ water connection could conduct activities that diminish springs and flows that adversely impact land, vegetation	Conduct gain-loss study with groundwater well monitoring
Population growth and land development	Fredericksburg and Johnson City areas	Increased water demands, reduced recharge, reduced aquifer levels, impaired water quality	Loss of ranchland, reduction in recharge areas with impervious cover, soil loss, vegetation loss	Incentives/credits to conserve water and enhance recharge
Aquifer Desired Future Condition (DFC) 30-foot drawdown over next 50 years	Blanco and Travis Counties (GMA 9)	Significant reduction in spring and river flows	Reduced vegetation	Conduct gain-loss study with groundwater monitoring to inform GMA 9
Invasive species – Arundo donax (Giant Cane)	Along river and tributaries	Reduction in flow	Reduce native species	Complete mapping and initiate management practices. Provide guidance to riparian landowners
Ashe juniper (cedar)	Primarily eastern basin	Increased evapotranspiration, potential reduced water recharge	Reduced native grasses/vegetation and increased soil erosion	Brush management programs, land owner guidance
Sand/gravel activity in river/ tributaries	All river and tributaries	Impaired water quality, adversely impacted riparian areas	Soil erosion/vegetation loss	Adoption of LCRA Highland Lakes Watershed Ordinance Quarry Regulations
Land fragmentation	Entire basin	Increased water demands, increased septic systems	Increase brush cover, restrict wildlife movement	Expand conservation easement programs, landowner technical assistance
Wastewater discharges to river and tributaries	Fredericksburg and Johnson City	Reduced water quality	Create hyper-eutrophic conditions that facilitate excessive plant growth, loss of native species	Expanded wastewater reuse for beneficial purposes
Improper land use/ management and construction practices	Entire basin	Reduced water quality, water quantity, adversely impacted riparian areas	Degraded riparian and recharge areas, reduced land productivity	Implementation of Conservation Strategies and Management Measures/ Practices

Table 9 - Action Plan and strategies to protect flow, water quantity and quality

Approaches, Strategies, Management Measures	Potential Implementer	Potential Water Benefit	Potential Partners	Constraints and Issues
Conduct gain-loss study with groundwater monitoring	Meadows Center, Mitchell Foundation, Meadows Foundation	Define spring sheds, recharge areas, key stream segments to focus management activities	USGS, BPGCD, CTGCD, HTGCD	Cost, Private land ownership may limit access to tributaries and groundwater wells
Regulatory incentives/options for new development	Fredericksburg and Johnson City areas	Reduce water demands with conservation landscaping, increase recharge with stormwater basins and manage local flooding, promote low impact and conservation development	LCRA (expanded Highland Lakes Watershed Ordinance?), MCWE	Developer resistance, added local government expense
Participate in GMA 9 water planning activities	GMA 9	Attempt to decrease the current 30-foot DFC drawdown to protect springs and river flows	Groundwater conservation districts	Next planning process has not been determined, need enhanced groundwater modeling, cost
Arundo donax mapping and management	Landowners	Maintain river/tributary flows, retain native riparian vegetation	Land trusts, parks, local government, The Nature Conservancy	Private property access to document extent, cost to manage species, removal program success
Ashe juniper (cedar) management	TSSWCB*	Reduce evapotranspiration, potentially increase tributary flows, manage soil erosion	LCRA, land owners, land trusts	Scientific recharge debate, improper clearing can increase soil erosion
Other invasive plant management	TSSWCB, CISMA, USDA/NRCS, TCA	Maintain or increase river/tributary flows, retain native riparian vegetation; Reduce evapotranspiration, manage soil erosion	Land trusts, parks, local government, landowners, CISMA partners	Private property access to document extent and treat, cost to manage species, removal program success
Adopt LCRA Highland Lakes Watershed Ordinance Quarry Measures	Local governments	Minimize river and tributary disturbance to protect water quality and springs/recharge areas	LCRA, TCEQ	Industry resistance, added local government expense
Expand Conservation Easements, Purchase of Development Rights and purchase of watershed lands	The Nature Conservancy, Hill Country Alliance	Manage growth in water demands, protect spring sheds and key tributary river segments	Hill Country Land Trust, Texas Land Conservancy, Mitchell Foundation	Expand conservation easement programs, landowner technical assistance

Table 9 - Action Plan and strategies to protect flow, water quantity and quality (continued)

Approaches, Strategies, Management Measures	Potential Implementer	Potential Water Benefit	Potential Partners	Constraints and Issues
Expand wastewater reuse for beneficial purposes	Fredericksburg and Johnson City	Improve tributary and river water quality, reduce water demands	TWDB	Cost, identifying customers with need for effluent
Enhanced Groundwater Conservation District operations	GCDs	Manage groundwater pumpage, improve customer conservation to reduce demands,	Local governments	Resistance to new regulations and fees to implement and fund
Hill Country Water Coordinator and Education and Outreach	MCWE	Coordinate various water planning activities, provide technical assistance to local governments, prepare grant applications	Mitchell Foundation, HCA, local governments	Cost, willingness of local governments/water providers to support effort
Watershed Protection Planning	TSSWCB, National Fish and WIldlife Foundation, Private NGOs	Coordinate water planning activities, create comprehensive and voluntary management plan for water quality and quantity, ecosystem preservation (Implementation of Conservation Strategies and Management Measures/ Practices)	Hill Country Underground Water Conservation District, MCWE, HCA, The Nature Conservancy, Cities, Municipal governments, LCRA, Pedernales and GIllespie Soil and Water Conservation Districts	Cost, willingness of partners to support efforts

*To date, TSSWCB has managed over 70,000 acres of brush and LCRA has been involved in managing more than 33,00 acres of ranch land.

Many of the above management approaches could be funded in part of in whole by foundations and other philanthropic entities. Often, this funding could be matched with existing programs/funds/grants to stretch resources to implement meaningful measures to change the way water is used and conserved in the Pedernales River basin.

Initial analysis and research regarding the field data and water quality sampling was accepted for presentation at the upcoming 2015 Geological Society of America Annual Meeting. Ms. Zappitello will give a presentation titled "Groundwater-Surface Water Interactions in the Pedernales River Basin, Texas." The abstract will be published in the GSA Program, Vol. 47, No. 7 and a scientific and management applications paper will be submitted for publication.

NEXT STEPS

The Summer Hydro-Blitz provided the groundwork to develop a future gain-loss study to assess the interaction between surface water and groundwater and extend this investigation into the tributaries to identify priority management areas. From the identification of potential threats and management approaches, we can combine this information with our current knowledge of the river and aquifer systems to suggest the following next steps to protect and preserve the water in the Pedernales River:

1. Conduct a new gain-loss study with a hydro-geologic component to document the groundwater - surface water interaction to understand how the watershed has changed and potential impacts to water supplies and springs. This would include:

    - Monitoring river and tributary flows during low flow conditions and when demands from the river are low or non-existent;
    - Monitoring four to five groundwater wells for continuous water level measurement;
    - Conducting analysis of river and groundwater levels to determine long-term trends;
    - Coordinating with LCRA to exchange hydrologic and water quality data and watershed modeling information to support the calibration and verification effort of the study;
    - Identifying how increases in water consumption are affecting surface and groundwater levels;
    - Determining if groundwater levels are declining and if this connects directly to declining base-flow; and
    - Defining recharge and discharge river/tributary segments to focus future management activities.

2. Develop a technical resource team that can actively participate in the ongoing Region K water planning process and get involved in GMA 9 water planning activities to re-evaluate the current desired future condition that suggests an acceptable aquifer drawdown of 30 feet.

    - Providing technical resources and materials to illustrate appropriate measures and strategies to reduce water demands;
    - Obtaining or develop groundwater protection materials and share with the public to encourage their involvement and participation in the DFC process; and
    - Attempting to have representatives selected for committee panels.
    - Initiate an education outreach effort with landowners and cities that are presently affected or about to be affected by invasive species, namely giant cane (Arundo donax). Follow the Neuces River Authority model to begin the management effort to restore riparian areas and prevent increased flooding.Begin reducing water demands and increasing recharge by create a technical assistance program led by a technical coordinator to provide expertise in the Pedernales basin and across the Hill Country, roles include:
    - Initiating water conservation measures and evaluation of water supply lines to determine potential line loss and leakage;
    - Suggesting and provide model ordinances to modify land development codes and criteria to offer water saving incentives and development credits;
    - Preparing grant applications and seek partnerships to extend resources and program reach;
    - Advocating for existing agencies and programs to help secure future funding and water protection measures;
    - Coordinating and connecting the numerous studies to avoid redundancy and better manage funds; and
    - Working directly with cities, counties, groundwater conservation districts, TSSWCB, and river authorities to reduce water demands/manage water more wisely and recognize priority water management areas.

3. Adopt the LCRA Highland Lakes Watershed Ordinance Quarry and Mines section to effectively manage the potential water quality impacts of these activities that are proposed from time to time in and near the river and tributaries. The entire HLWO has been effective in the Travis County portion of the Pedernales since the early 1990s and has not slowed development or growth patterns along Highway 71. The cities and counties could consider adoption of the development incentives and stormwater credits found in the HLWO to incentivize low water use development and conservation landscaping while managing stormwater runoff through more natural systems.

4. Investigate wastewater reuse opportunities with treatment plant operators to expand existing programs or initiate new ones to provide high quality effluent to local customers and reduce groundwater demands.

5. Coordinate with LCRA's current efforts to update its Pedernales River SWAT model and Lake Travis water quality model. Beyond aligning activities with LCRA to enhance calibration and verification of the gain-loss study, sharing information and participating in efforts to update these models will potentially yield water quality benefits and other information valuable to watershed scale planning.

Other next steps may be available when the opportunities are presented as many of the management measures could be low cost and rely on an educational component to inform landowners of issues and potential opportunities. This could involve watershed organizations, local government, universities, and foundations/land conservation entities to expand the water protection message and provide technical and financial resources to individual landowners to change water use behaviors in the basin to protect groundwater levels and flow in the Pedernales River basin.

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This report is available online at MeadowsWater.org/Research/Reports.

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