Regulation and Changing Conditions of the Edwards Aquifer

Abby Pfeiffer

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Introduction

The Edwards Aquifer is an important water resource in South Central Texas. For those who grow up in San Antonio, the aquifer is well known and ballot provisions related to the protection of the aquifer and regulations on development in the aquifer region are often approved. This area has been growing rapidly in the past thirty years. This population increase has led to increased development in areas that lie on top of the important recharge zone. The goal of my project is to analyze the change in land cover and population over the Edwards Aquifer

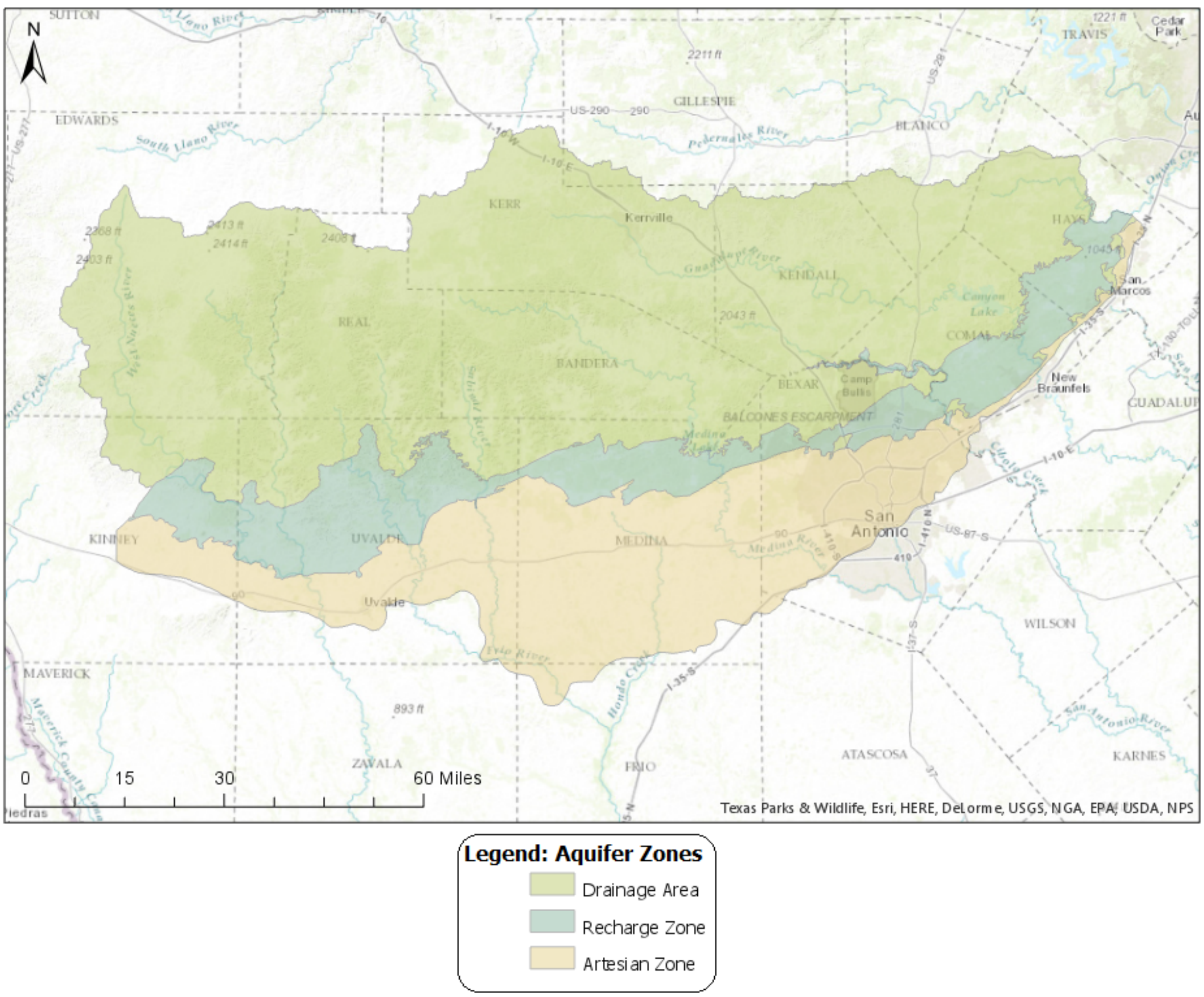

Figure 1.

region between 2000 and 2011. These changes will be discussed in relation to regulatory limitations and the usage patterns of the aquifer over the same time frame. I will ultimately consider how effective the aquifer's regulatory structures are at maintaining the sustainability of this important water resource given the dramatic population growth and notable development increase over the region.

Edwards Aquifer Overview

The Edwards Aquifer is a naturally recharging karst aquifer located in South-Central Texas and one of the region's most important water resources. It provides water for agricultural irrigation, industrial uses, and municipal supply for San Antonio and several surrounding towns. Water is also discharged from the aquifer in many natural springs. These springs feed pools and rivers, which provide notable recreational revenue to the greater San Antonio area. As San Antonio is one of the fastest growing cities in America, the number of people using the aquifer for their main municipal water source has increased significantly over the last thirty years.

In the map above, the northern-most region is the Drainage Area or the Contributing Area. This area is defined by the catchment areas for the streams that flow into the aquifer's Recharge Zone (see figure 2 below). Generally speaking, rainfall and runoff over the Drainage Area is a significant source of the water that fills the aquifer.

The Recharge Zone is the blue area in the middle of the aquifer area. In this zone, the limestone of the aquifer is exposed at the surface such that sinkholes and other aquifer inlets are visible. I calculated this area to be about 1,250mi^2. This area makes the Edwards Aquifer particularly vulnerable to contamination from spills or other human activities.

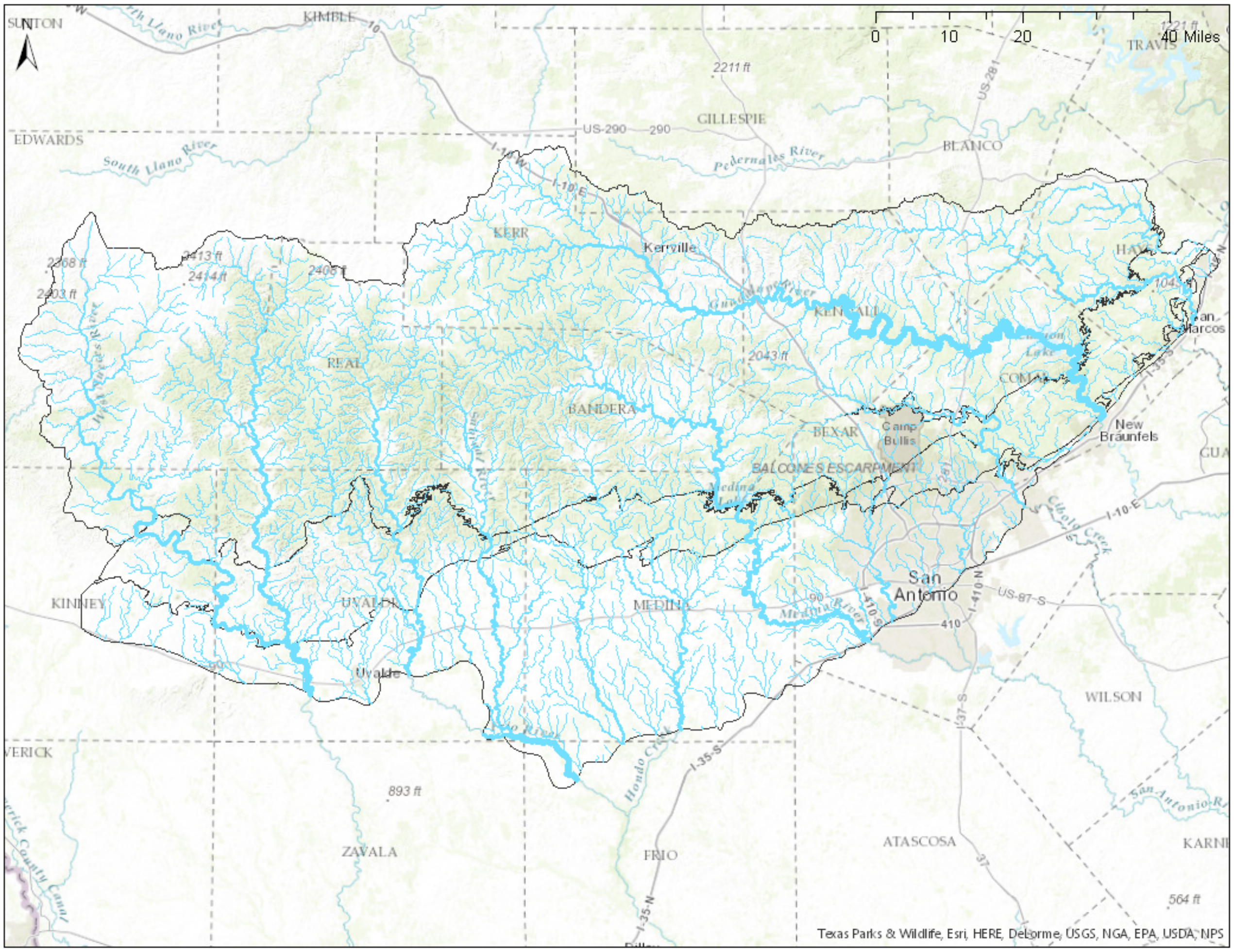

Figure 2.

The southern-most portion of the Edwards Aquifer is the Artisan Zone. This is defined by the aquifer being back underneath a layer of rock such that it is not exposed at the surface. This area is characterized by artesian springs where the pressure from the rock layer above the aquifer causes natural springs to form as water is compressed and shoots back up to the surface. The southern boundary of the artesian zone is the salt line, where the water becomes brackish and not safe to drink.

Regulatory History

For much of the history of the city of San Antonio and the development of surrounding communities, there were no comprehensive regulations on the aquifer and no managing authority. Groundwater in Texas is considered to be owned by the owner of the property the water lies underneath. The “rule of capture” allows this landowner to pump up as much water as he or she wishes, regardless of its impacts on the water use of neighboring landowners. Due to the vast size of the water reserves in the Edwards Aquifer, these laws were sufficient to provide water for both agricultural and municipal use for many decades.

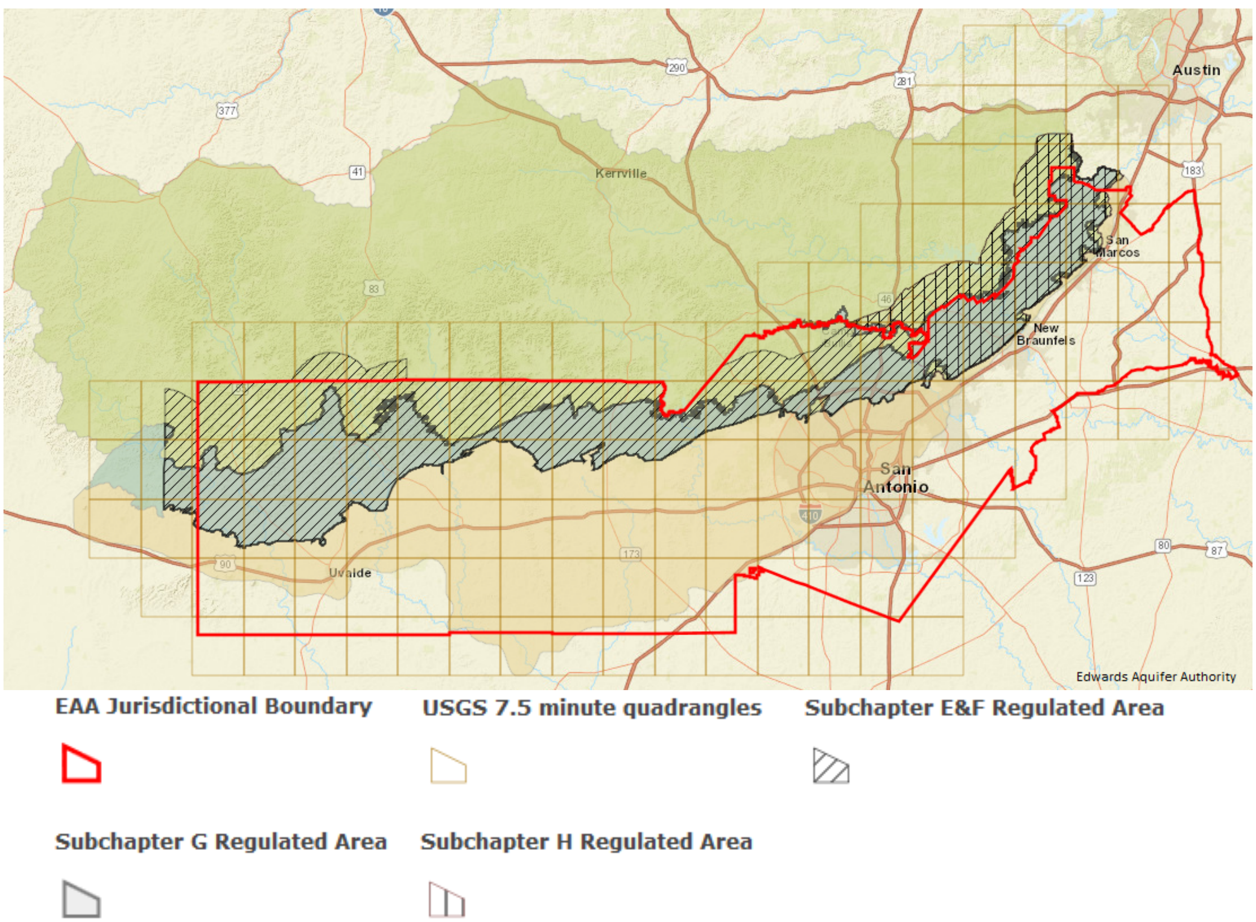

Figure 3.

In the 1950s, Texas saw one of its worst droughts on record. Several of the Artisan Zone springs ran dry and many wells were no longer deep enough to reach the depleted water table. This prompted the creation of the Edwards Underground Water District in 1959, which focused on creating maps of the aquifer and assisting licensing authorities in matters related to the aquifer. Since the creation of aquifer oversight authorities, data about aquifer flows, depths, and water quality has been well-tracked and is readily available.

The water district did not focus on water quality efforts until the Texas Water Quality Board issued new rules in the 1970s requiring protection of aquifer recharge and buffer zones in Texas. Throughout the 1970s and 1980s a slew of regulations were implemented related to water quality including required water pollution abatement plans, underground storage tank restrictions, and sewer line testing requirements. There are several types of legislative restrictions now: Subchapter E: Spill Reporting; Subchapter F: Regulated Substances Registration, Storage, and Planning; Subchapter G: Above and Underground Storage Tank; and Subchapter H: Prohibitions on Coal Tar.

Conservation and use quantity regulations came into play in the 1990s following the possible federal takeover of aquifer authority under the Endangered Species Act. The federal government and the EPA found that there were numerous endangered species living in the aquifer, and that increasing use of aquifer water put the habitat for these animals at risk. By creating the Edwards Aquifer Authority in 1993 and mandating a capped water permit system, the state was able to maintain control of the aquifer, and continues to protect the habitat of the endangered species. Figure 3 shows the geographic boundaries of the various regulatory laws and agencies related to the aquifer.

Population Growth

San Antonio is one of the fastest growing cities in the country; its population has more than doubled since 1970, and surrounding areas continue to grow as well. Because the Edwards Aquifer is the primary source of drinking water for San Antonio and surrounding communities, this growth translates into increased usage of water. Indeed, the San Antonio Water System (SAWS) reports an increase of between 15% and 20% when compared to usage in the mid-1980s. However, this increase was mitigated by water conservation efforts: per person usage fell from 225 gallons per person per day in 1982 to only 140 in 2012.

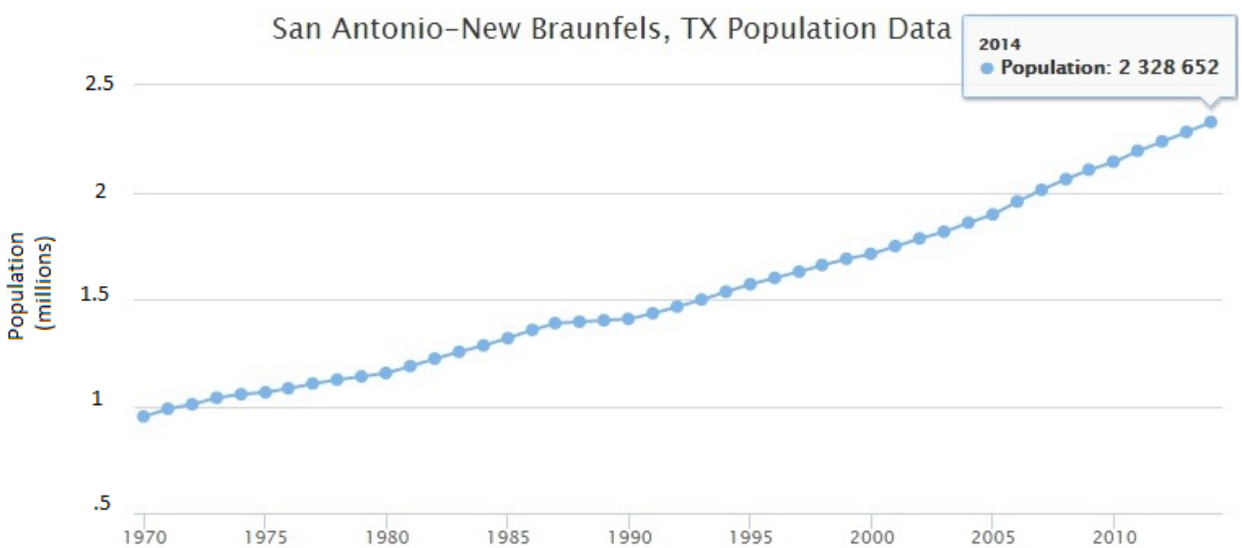

Figure 4.

The population over the entire area of the aquifer region is also of interest. A GIS analysis of the 2010 population shows that approximately 1.82 million people live over the Edwards Aquifer region. While not dissimilar to the population total of the City of San Antonio, this population represents only a portion of actual San Antonio Residents is dispersed over the area as a whole. This population figure helps us to get a better idea of how many people live over areas that impact the aquifer. As seen in figure 5, wells into the aquifer are distributed over all three of the aquifer zones and match up with areas of development.

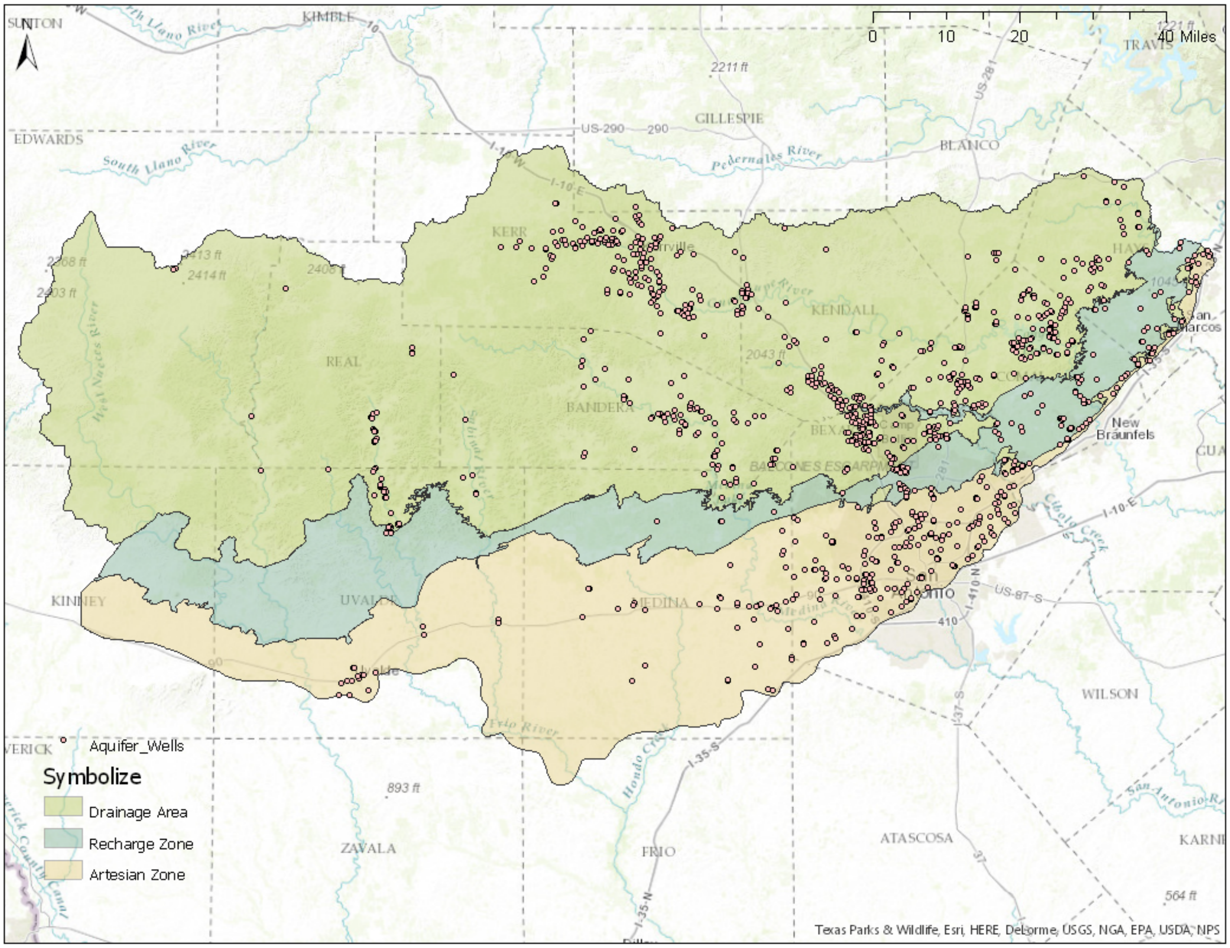

Figure 5.

About 264,000 of the people living over the aquifer region live over the recharge zone, the area most vulnerable for the introduction of contaminants. This area contains the rapidly growing northwest portion of San Antonio, but all construction permits over the recharge zone (Subchapter G Regulated Area) require approval by the Texas Commission on Environmental Quality. This helps to mitigate the possibility of contamination despite growth in this area.

I intended to do the same population analysis I did for 2010 for 2000 to measure the scope of the change, however encountered several technical difficulties. I was unable to find block-level census data for 2000 like in 2010 (see figure 6) and the tract-level data would not properly join to the 2000 census tracts shapefile.

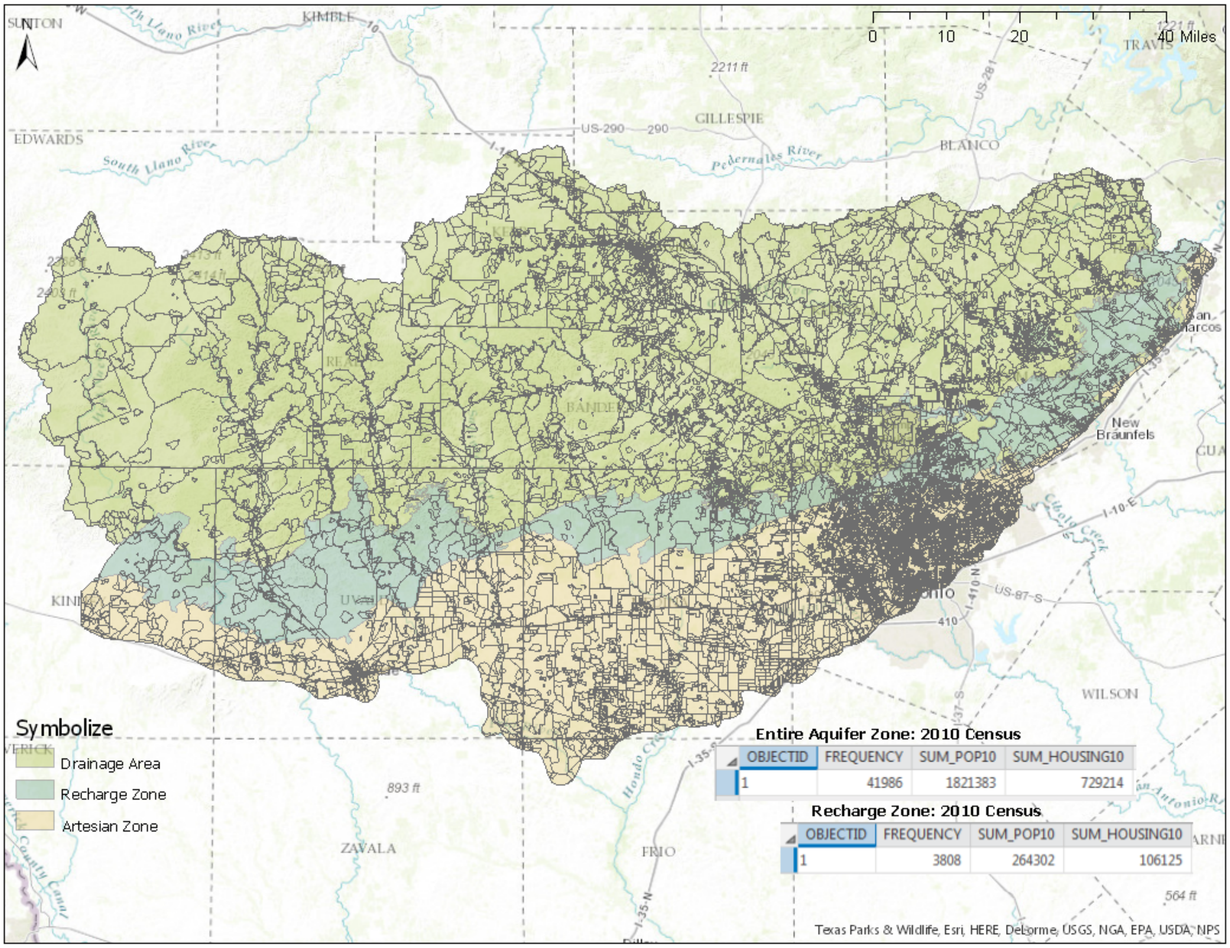

Figure 6

Land Cover

As population has increased, it is unsurprising that the percentage of area over the aquifer that is developed has increased as well. For this analysis, changes from 2001 to 2011 are analyzed through use of the National Land Cover Database. The growth of the red area in the two maps below represents increasing developed, urban land area. These areas are concentrated northwest of San Antonio and along the 1-10 corridor headed northwest from the city towards smaller towns like Kerrville.

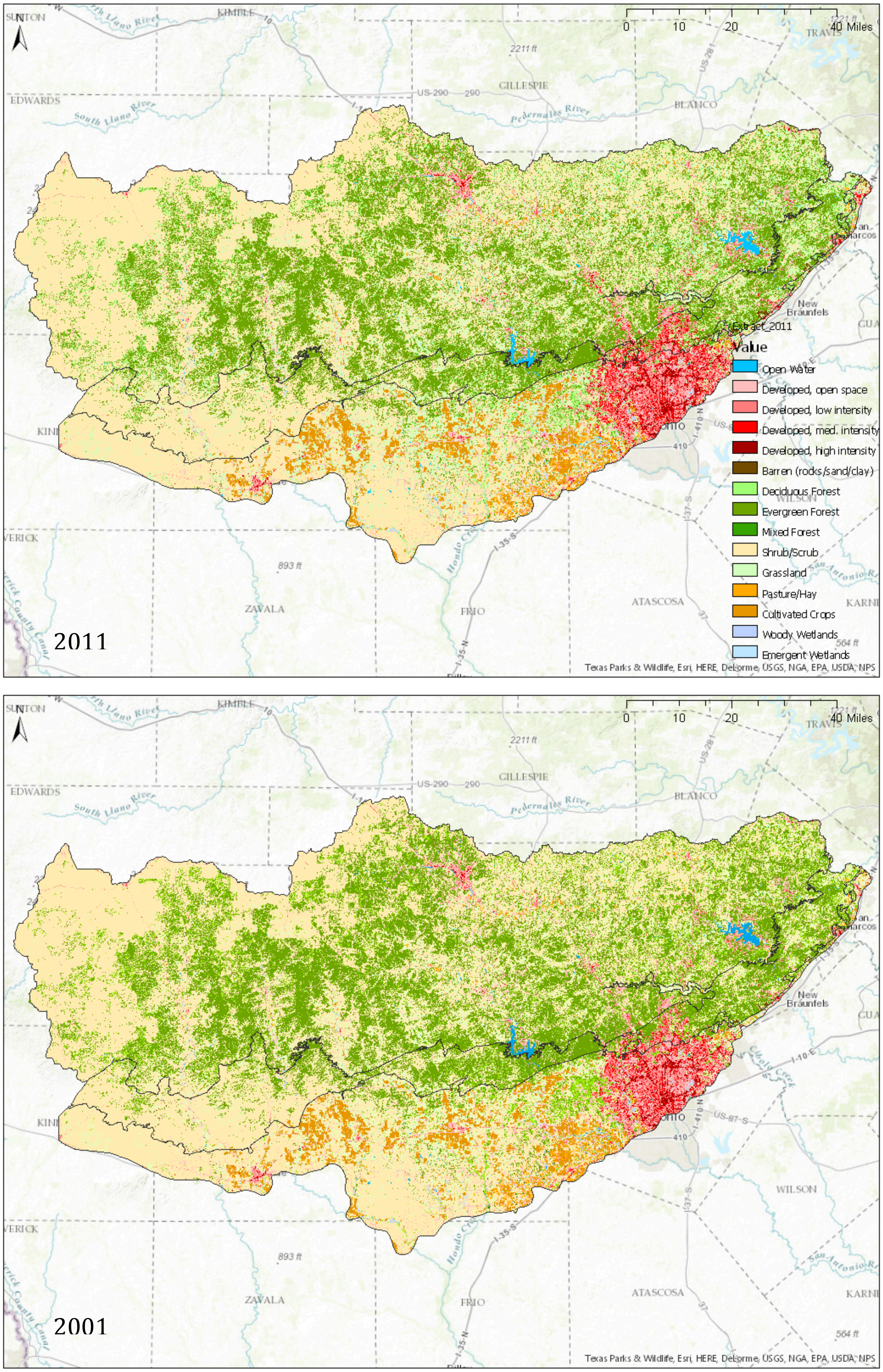
0 10 20 40 Miles
Extract_2011
Value
Open Water
Developed, open space
Developed, low intensity
Developed, med. intensity
Developed, high intensity
Barren (rocks/sand/clay)
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Wetlands
2011
Texas Parks & Wildlife, Esri, HERE, DeLorme, USGS, NGA, EPA, USDA, NPS
KIMBLE
GILLESPIE
EDWARDS
BLANCO
TRAVIS
New Braunfels
WILSON
ZAVALA
FRIO
ATASCOSA
2001
Texas Parks & Wildlife, Esri, HERE, DeLorme, USGS, NGA, EPA, USDA, NPS

Figure 7

While the change near the city is easily seen, there is not much change over the area as a whole during this time. Overall, areas of development increased 9.37% to increase from 7.8% of the total land area to 8.5% of the total. The percentage increase in barren land is quite significant, but as barren areas are rather rare, the increase is only about eight square miles. The increase in agricultural land cover (cultivated crops and pasture/hay) is also of note as aquifer water is used for agricultural irrigation and agriculture is a potential source of contamination.

Land Cover Change, 2001 - 2011							
Land Class	**2001 Count**	**2001 SqMi**		**2011 Count**	**2011 SqMi**		**% Change**
Open Water	98,239	34.14	34.14	99,528	34.59	34.59	1.31%
Developed, open space	1,227,868	426.67	691.83	1,223,601	425.19	756.62	9.37%
Developed, low intensity	429,277	149.17		478,582	166.30		
Developed, medium intensity	218,762	76.02		321,088	111.58		
Developed, high intensity	115,008	39.96		154,116	53.55		
Barren Land (rocks/sand/clay)	27,186	9.45	9.45	51,475	17.89	17.89	89.34%
Deciduous Forest	1,559,423	541.89	2,846.16	1,464,100	508.76	2,702.39	-5.05%
Evergreen Forest	6,620,015	2,300.40		6,302,271	2,189.99		
Mixed Forest	11,147	3.87		10,457	3.63		
Shrub/Scrub	11,642,507	4,045.68	4,045.68	11,760,747	4,086.77	4,086.77	1.02%
Grassland	2,443,185	848.99	848.99	2,472,981	859.34	859.34	1.22%
Pasture/Hay	161,606	56.16	294.77	163,240	56.72	313.38	6.31%
Cultivated Crops	686,660	238.61		738,582	256.65		
Woody Wetlands	99,703	34.65	35.14	98,560	34.25	35.18	0.11%
Emergent Herbacious Wetlands	1,428	0.50		2,686	0.93		

Table 1.

The only type of land cover to decrease over this time period was forested area, which decreased just over five percent. The other major categories of land cover changed insignificantly and shouldn’t have much of an impact on the overall aquifer. Nonetheless, the analysis of the changes to land cover, when combined with our knowledge of the population changes, clearly indicate that there is a pattern of growth in terms of impediments to recharge and to the demands made by municipal and agricultural uses.

Water Use

Water use data is among the available information from the Edwards Aquifer Authority. In figure 8 below, we can see that the recharge to the aquifer fluctuates to a much greater degree

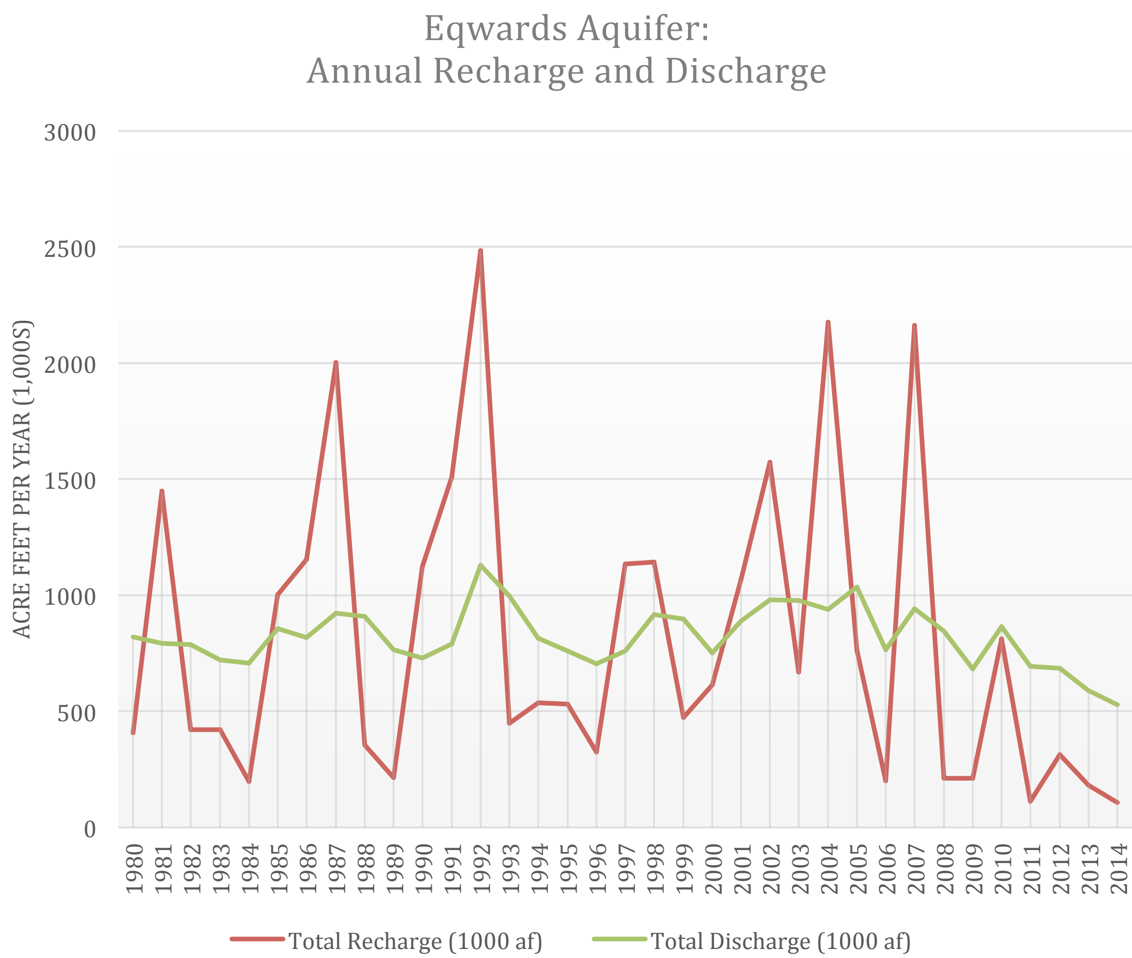

Figure 8.

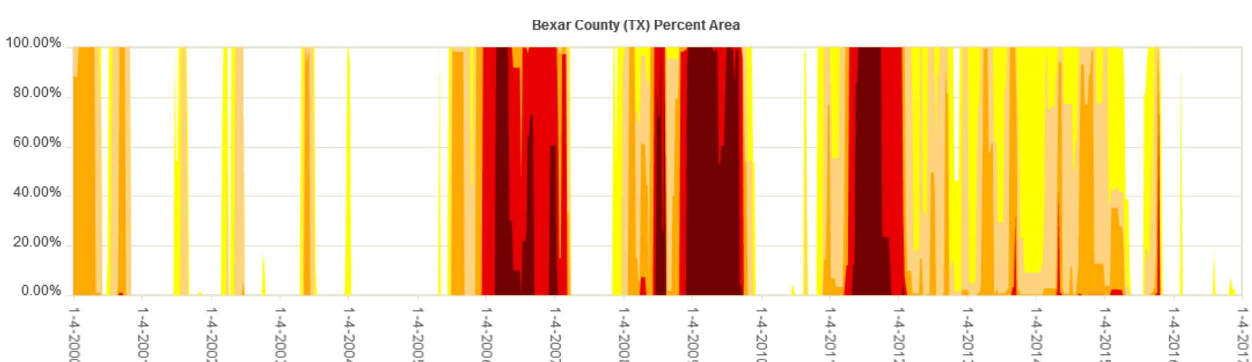

Figure 9. Yellow indicates slight drought while dark red is a severe drought.

than does the discharge. A quick comparison to the drought monitor data for Bexar County, where San Antonio is located, (figure 9) helps explain why. In periods of drought—2003 – 2004, 2008 - 2009, and 2011—we can clearly see that recharge levels fall when rainfall levels are low.

Discharge, on the other hand, is reliant on a number of factors. Agricultural use falls when rain levels are high, but during these times the spring flows are much higher than normal. For the most part, domestic and livestock, municipal, and industrial uses are constant throughout periods of drought.

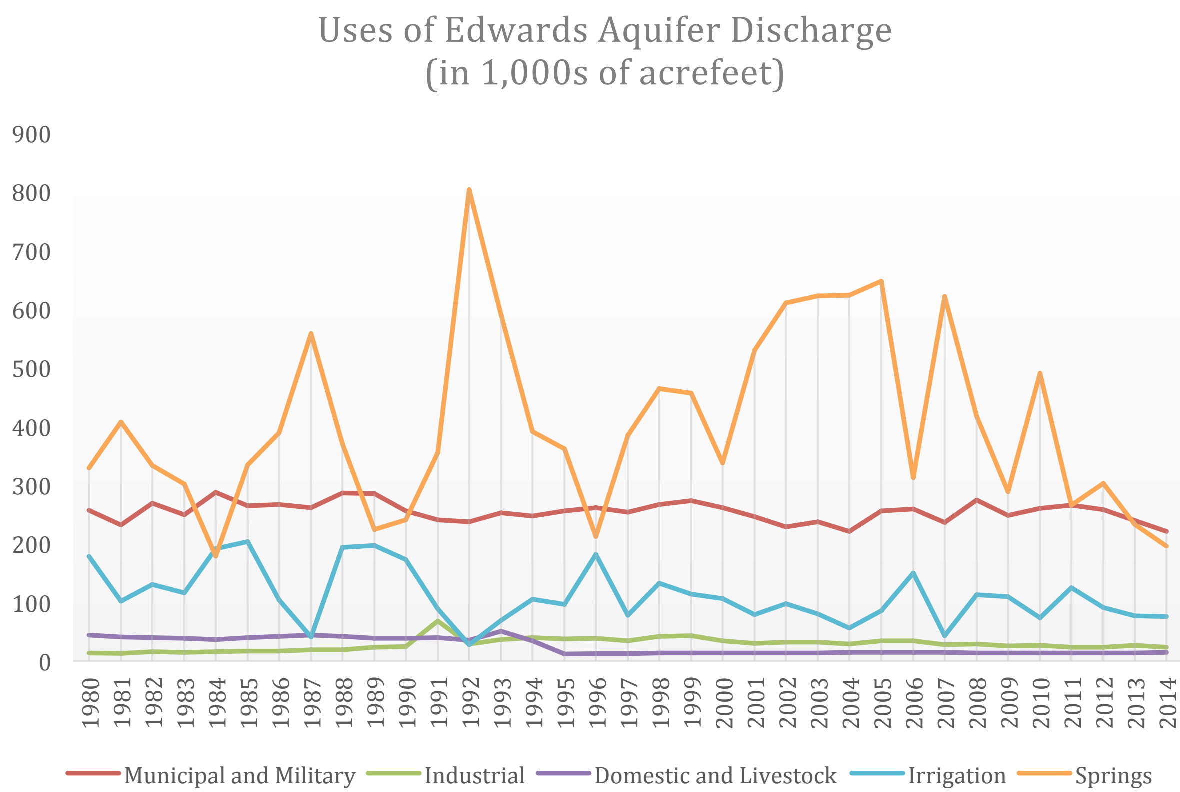

Figure 10.

Of interest for this report, municipal uses have not increased dramatically with the larger population and patterns development we analyzed above. If any trend can be gleaned from figure 10, municipal uses are actually slightly downward trending since 2010. This is exciting given the population growth and can most likely be attributed to an increase in water conservation measures. This measure also includes military uses; an analysis of changes in military activity in San Antonio would be a good addition to future analysis of changes to the aquifer and its usage.

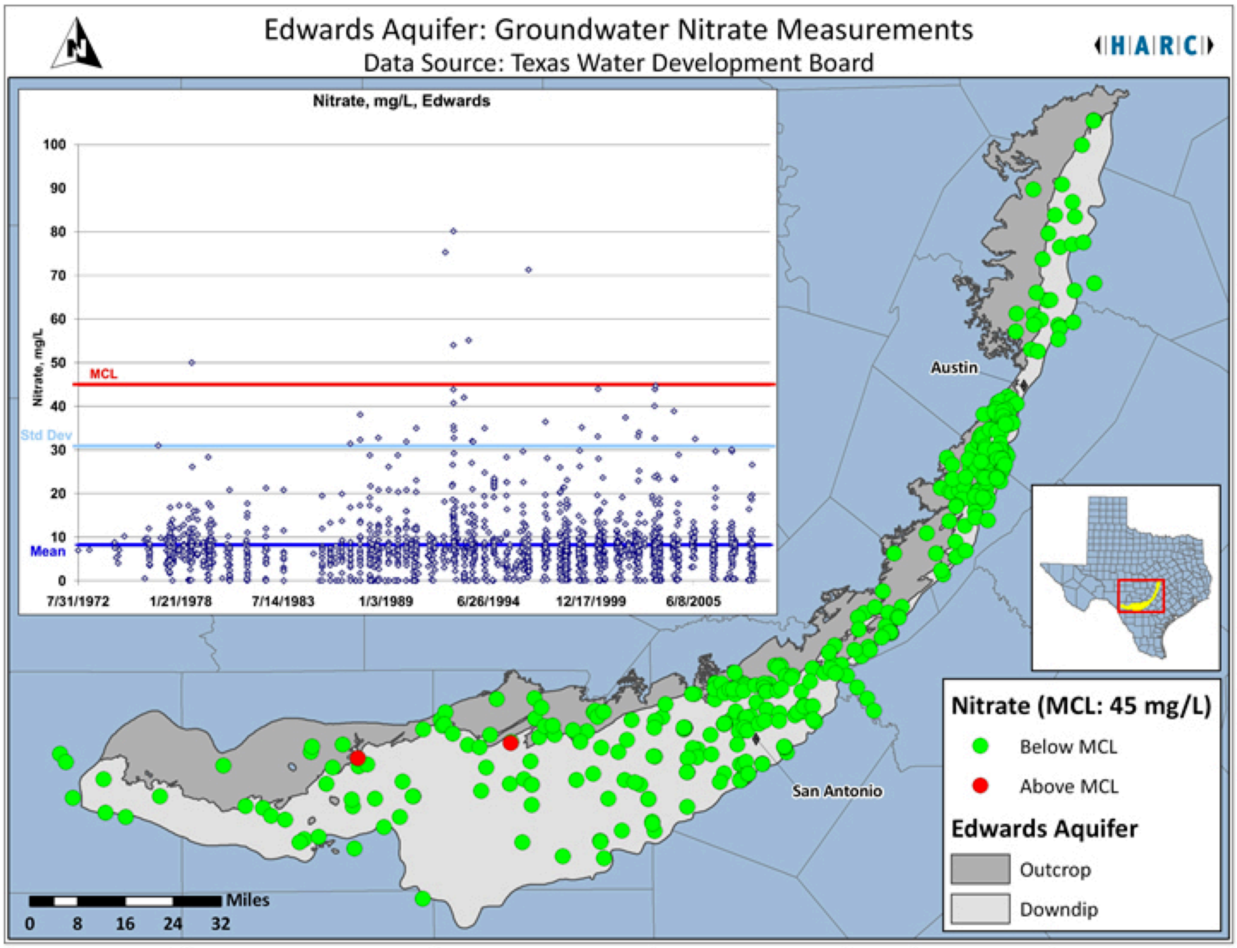

Figure 11.

We also know that regulations on the aquifer are focused on maintaining its pristine quality, particularly given the uncertainties of groundwater movement patterns. As seen in figure 11, water quality measures such as groundwater nitrate concentration have remained consistently good over time indicating that the increased threats to water quality from development and population increase have successfully been mitigated through regulations.

Conclusions

Karst aquifers like are particularly vulnerable to human activity. Yet, their porous nature and the vast size of underwater caverns and ravines make aquifers like the Edwards Aquifer particularly important water resources. This analysis of the changing conditions around and over the Edwards Aquifer has shown that the City of San Antonio, the State of Texas, and the Edwards Aquifer Authority have been able to manage the rapid growth of San Antonio and the surrounding areas while still maintaining sustainable use of this resource. While land cover becomes increasingly developed and more people live over the aquifer, we find that municipal water use has not shown patterns of increase and water quality has remained high. Regulations have successfully helped to preserve this natural resource and the water supply for millions of people.

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