WATER PLAN OF REGION C - CONSIDERATIONS AND CONTRIBUTIONS OF ACTIONS FOR THE INCREASE OF SURFACE AND GROUNDWATER

1. INTRODUCTION

Texas is a well-organized state, particularly regarding its water resources. Through agencies like the Texas Water Development Board (TWDB), the mission is to spearhead efforts in ensuring a secure water future for Texas. According to the TWDB, certain regions of the State of Texas may face significant water shortages as early as 2030 if measures are not implemented to enhance water availability to meet the needs of all users, including Region C.

With the current regional water supply availability at 1.7 million acre-feet annually, the region faces a potential annual shortfall of over 1.3 million acre-feet by 2080, absent the development of new water supplies.

The draft version of the 2026 Region C Water Plan proposes expanding surface water reservoirs and increasing groundwater extraction.

However, studies indicate that large-scale surface storage and intensified groundwater use are suboptimal for ensuring Texas's long-term water security.

Region C has great potential for 'surface freshwater production' through the Trinity River, which runs through the region from north to south.

We must restore damaged water sources and soil using systems that collect and direct rainwater to well-positioned underground storage tanks to reach their full potential.

2. JUSTIFICATIONS

Our assessment of Texas's climatic conditions reveals high gross evaporation rates from surface reservoirs (see Section 2.2).

Furthermore, in Nature Cities, Ohenhen et al. (2025) report that groundwater extraction has caused land subsidence across 28 major U.S. cities.

Utilizing space geodetic measurements, the study quantified subsidence rates and assessed infrastructure vulnerability due to differential ground movement, which can compromise foundations and structural integrity.

The researchers claim: "*We estimate that at least 20% of the urban area is sinking in all cities, mainly due to groundwater extraction, affecting ~34 million people. Additionally, more than 29,000 buildings are in high and very high damage risk areas, indicating a greater likelihood of infrastructure damage. These datasets and information are crucial for developing ad hoc policies to adapt urban centers to these complex environmental challenges.*"

The study also mentions that, on average, 25 out of the 28 US cities are experiencing sinking at varying rates. Specifically, in nine of the 25 sinking cities (New York, Chicago, Houston, Dallas, Fort Worth, Columbus, Seattle, and Denver), an average subsidence of more than 2 mm per year was found. Several cities in **Texas**—the fastest growing state in the United States—including **Houston**, **Fort Worth,** and **Dallas**, exhibit the highest measured subsidence rates among all cities, with average subsidence rates exceeding **4 mm per year**.

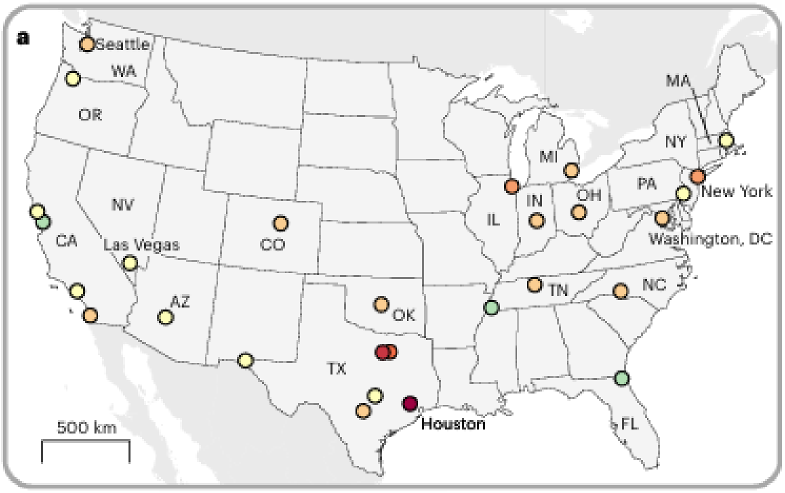


Fig. 1 - Urban land subsidence in US cities - Source: https://www.nature.com/articles/s44284-025-00240-y

With a more detailed evaluation of the micro basins of the West Fork Trinity River, the Elm Fork Trinity River and the East Fork Trinity River, which are located upstream of Greater Dallas, it is observed that there is great potential for the supply of fresh water to this region, as can be seen in Figure 2.

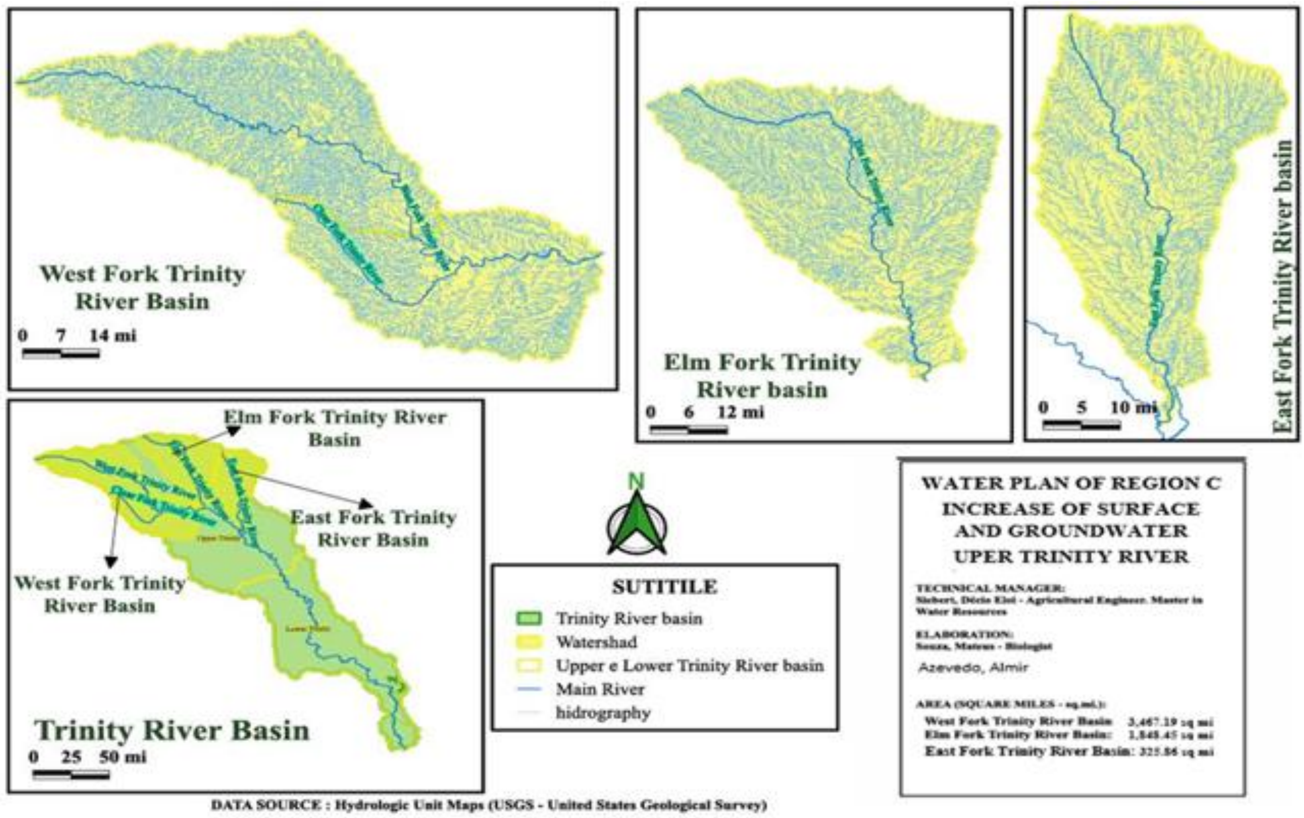


Fig. 2 – Watersheds Upper Trinity River Basin

The West Fork Trinity River, Elm Fork Trinity River, and East Fork Trinity River basins have a total area of 5,641.50 square miles, equivalent to 3,616,962.89 acres. The average annual rainfall in this region over the past 70 years has been 35 inches/year.

Taking a work carried out by IPAC in Brazil as an example, there will be an annual increase in water in these three hydrographic basins of 527,475.39 acre-feet per year, after the completion of the proposed work, which is presented in this document in tables and graphs, as well as the details of the annual increase in water.

If the proposed work is implemented throughout the Trinity River basin, along with groundwater recharge enhancers for stormwater drainage in urban areas, it could generate an even greater water volume per year.

Available data allows us to mention six factors that contribute to this situation:

1) State´s growth.

2) Weather conditions.

3) Degraded river springs.

4) Soil types and little infiltration of rainwater.

5) Poor soil conservation.

6) Small number of riparian forests.

This document aims to present the main causes of water deficit in the State of Texas and in the area covered by Region C, together with proposals for actions that can effectively increase surface and underground water availability.

3. MAIN CAUSES OF THE PREDICTED WATER DEFICIT FOR TEXAS REGIONS

2.1 State´s growth

Besides the highly variable climate, Texas's sustained population growth is a fundamental reason why the state has been at the forefront of long-range water supply planning since the 1960s.

Texas is the second most populous state in the U.S. and has attracted more new residents than any other state since 2000, mainly because of its thriving economy and expanding metropolitan areas. Texas has grown faster than the national average every decade since the 1850s.

The projections adopted by the Texas Water Development Board on November 9, 2023, reveal that Texas's population is projected to increase by more than 70 percent during the planning horizon, from 29.7 million in 2020 to more than 52.3 million in 2080.

At a county level, 29 Texas counties are projected to double in population between 2020 and 2070. Most of this population growth will occur in regions C, H, and L, representing 63.86%. For example, the City of

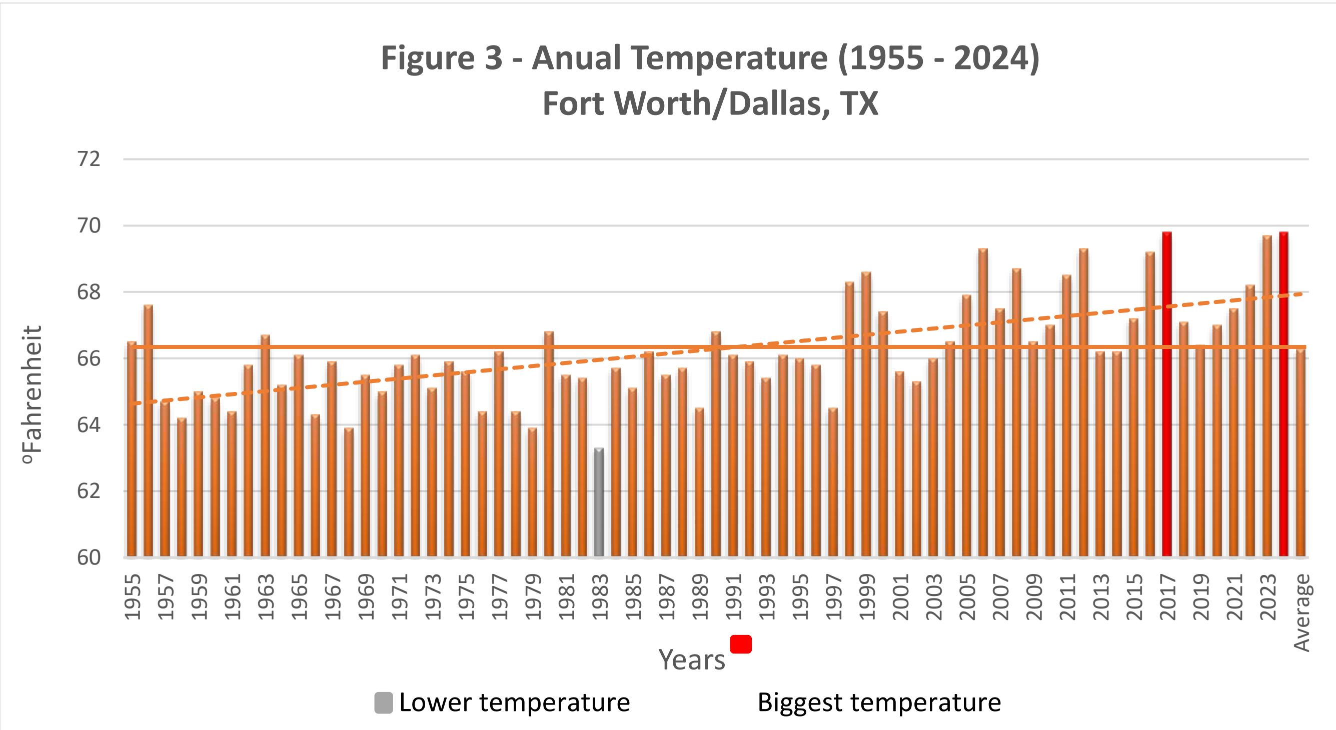
Celina—located in Collin and Denton counties—experienced a population increase of over 158% between 2020 and 2023, growing from 16,739 to 43,317 residents.

Statewide water demand is projected to increase by approximately 49 percent, from 5.9 million acre-feet per year in 2030 to 8.8 million acre-feet per year in 2080. Irrigation is the largest water demand category in each planning decade through 2050. However, municipal demand is expected to surpass irrigation demand by 2060. With the state's population booming, data indicates the state's water supply is falling behind. According to the state's 2022 water plan, water availability is expected to decline by 18%, with groundwater experiencing the steepest drop.

3.2 Weather conditions

According to data from the National Weather Service at Fort Worth/Dallas Station for the last 70 years, the average annual temperature in this period was 66.28 °F. The lowest average annual temperature was recorded in 1983 (63.3°F), and the minimum daily temperature was 5°F, on December 24 and 25, 1983. The highest average annual temperatures in this period were recorded in 2017 and 2024 (69.8 °F), and the maximum daily temperatures recorded were 112 °F, on June 26 and 27, 1980, and on July 22, 2018.

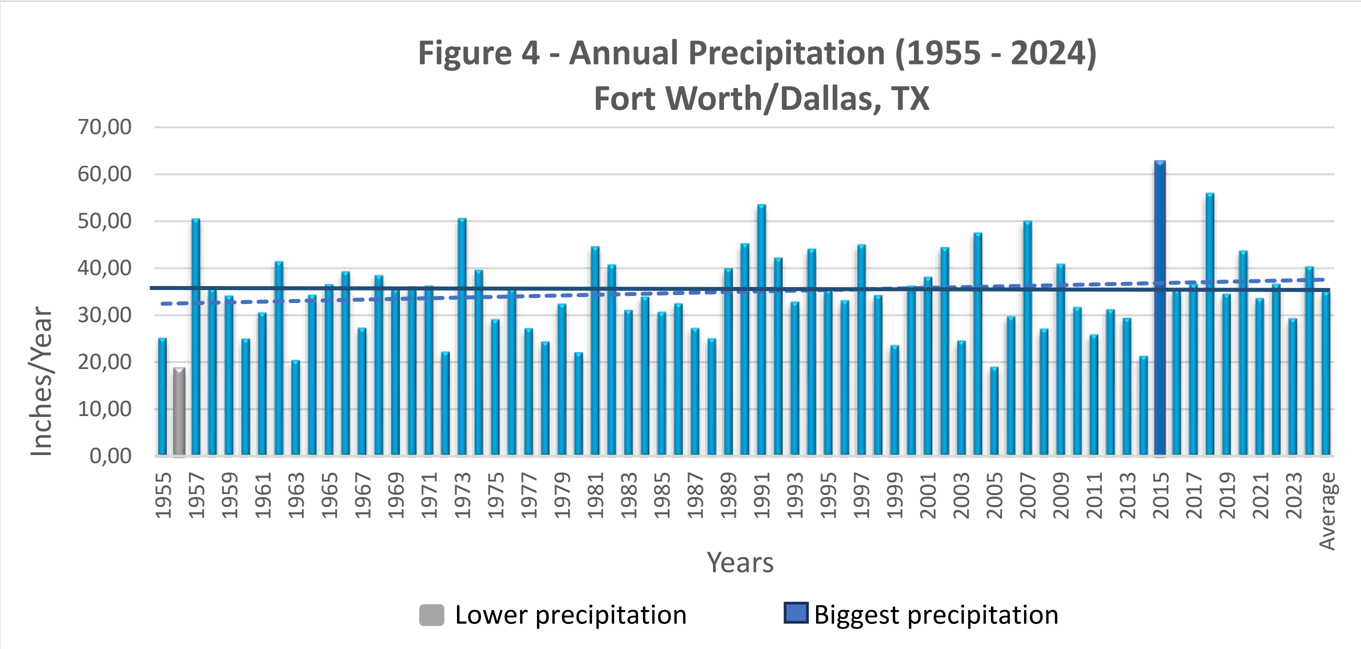
In Figure 3 presented below, the average annual temperatures from 1955 to 2024 can be observed:



Source: https://www.weather.gov/fwd/dmotemp
Elaboration: Siebert, Décio Eloi

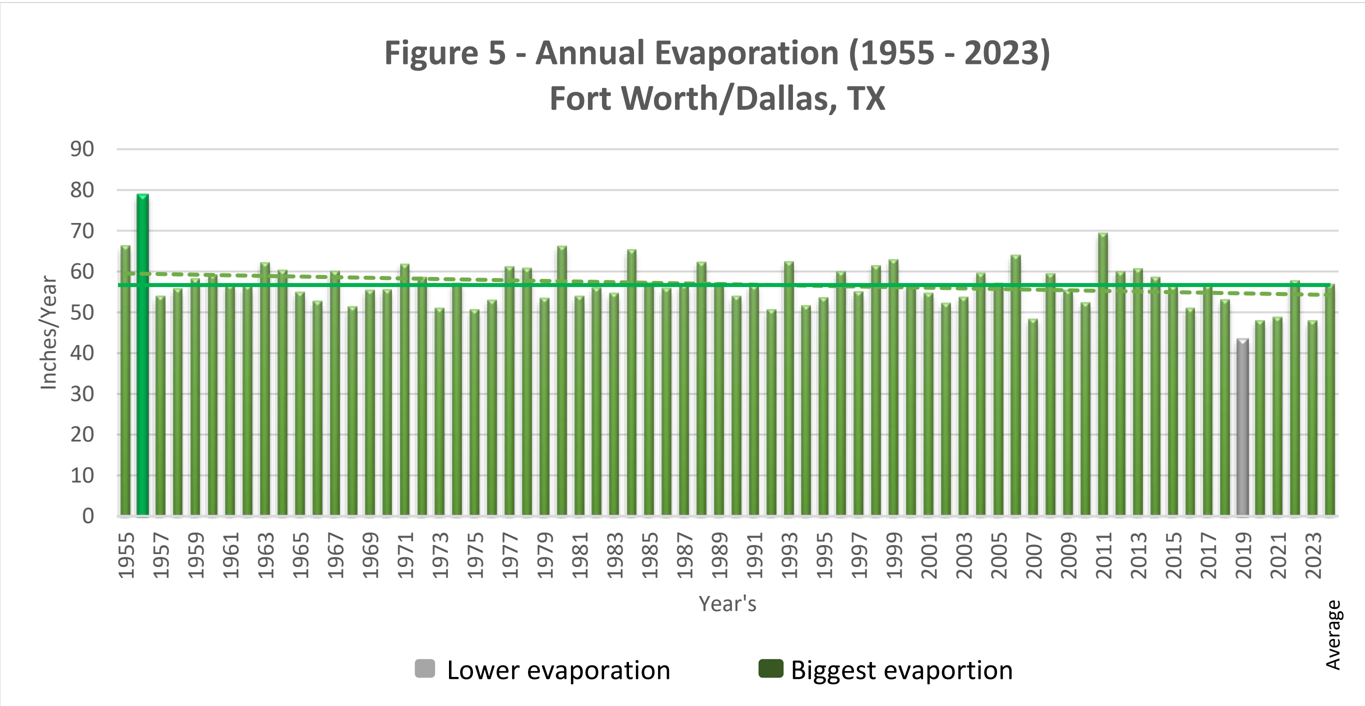
This graph shows that temperatures increased over time, as indicated by the dotted trendline. It also shows that from 1998 to 2024 (27 years), temperatures were recorded above the historical average in 22 years, representing 81.48% of the period.

The average annual rainfall from 1955 to 2024 was 35.00 inches per year. The highest average annual rainfall during this period was recorded in 2015, at 66.61 inches, and the lowest in 1956, at 18.55 inches. The data are presented in the following graph.



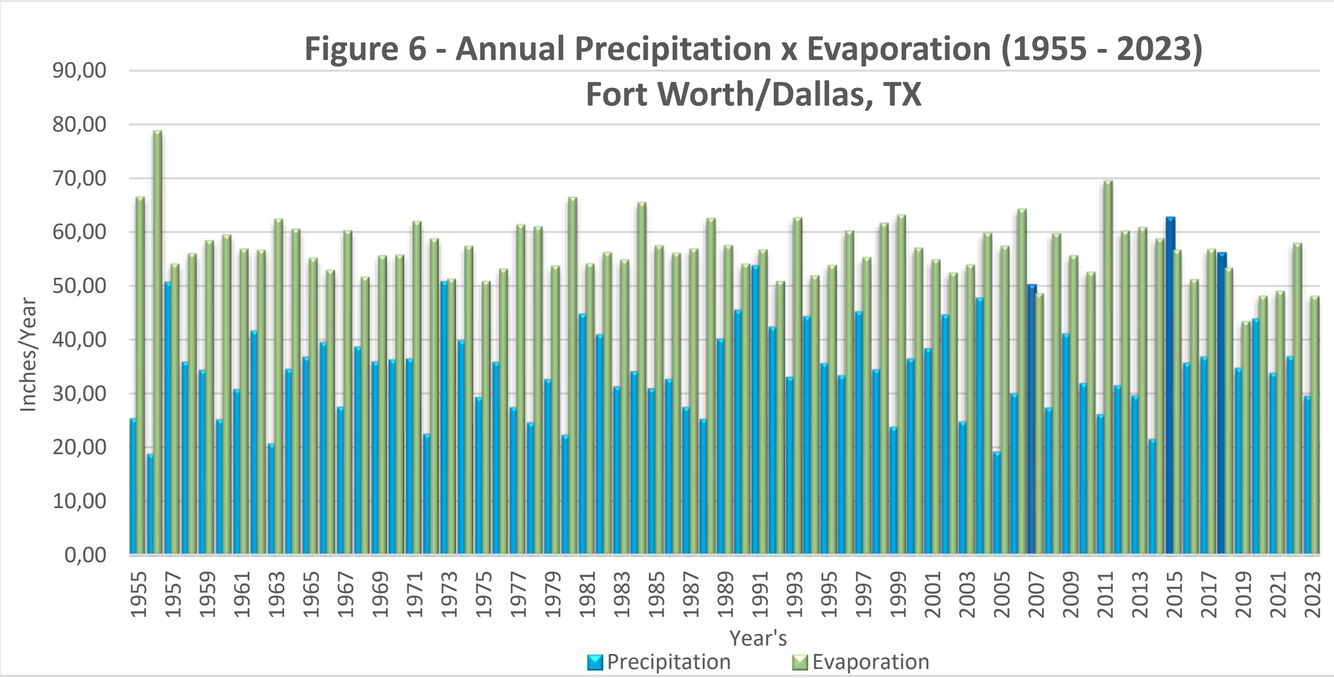
Source: https://www.weather.gov/fwd/dmoprecip
Elaboration: Siebert, Décio Eloi

This graph shows that annual precipitation over the past 70 years has remained relatively stable, with no significant changes from the average. The average annual gross evaporation from 1955 to 2023 was 56.90 inches per year. The highest yearly average evaporation occurred in 1956 (78.64 in), while the lowest was recorded in 2019 (43.18 in).



Source: https://waterdatafortexas.org/lake-evaporation-rainfall
Elaboration: Siebert, Décio Eloi

Figure 6 shows a comparison of annual precipitation and gross evaporation:



Source: https://www.weather.gov/fwd/dmoprecip - https://waterdatafortexas.org/lake-evaporation-rainfall
Elaboration: Siebert, Décio Eloi

In Texas, gross evaporation has consistently exceeded precipitation over the years, as shown in the graph above. Between 1955 and 2023, precipitation surpassed gross evaporation in only three years. For over 95% of the time, evaporation was greater than rainfall.

As a result, storing rainwater in underground reservoirs is generally more effective than using surface reservoirs, like large dams, since deeper water bodies experience higher evaporation rates, particularly during elevated temperature periods.

3.3 Degraded River Springs

Springs are an important source of freshwater and play a critical role in the hydrological cycle. They are primarily formed and sustained by water percolating through soil and rock layers, supplied by underground aquifers (porous and permeable geological formations that store and transmit groundwater). Its formation depends on specific topographic features, geological structures, and climatic conditions.

The recharge area is where water infiltrates the ground and percolates through the soil and rock formations before emerging as a spring. Identifying a spring's recharge area is essential for understanding the groundwater sources that supply it and managing land use practices that may affect water quality and availability.

According to article KUMAR (2020), "The sustainable management of springs requires the protection of their recharge areas, regular monitoring of their health, and the implementation of restoration and water allocation strategies that prioritize the needs of different user groups".

The recovery of a spring that has degraded or been damaged due to anthropogenic activities involves restoring the flow and quality of its water.

Some methods can be used for spring recovery, such as the “Caxambu Method”, developed by the Agricultural Research and Rural Extension Company of Santa Catarina – Epagri (Brazil). This method consists of cleaning the spring and building a channeling structure for the water.

3.4 Soil types and rainwater infiltration capacity

Different soil types are also important challenges for water filtration and retention. Soils originate under the influence of five factors: climate, topography, living organisms, time, and source material (rocks and sediments. Soil can have varying infiltration capacities, influencing water table stability and groundwater recharge. When infiltration is slow, it becomes more challenging to recharge groundwater and aquifers.

The soil´s infiltration capacity depends on its texture and porosity and is greatly influenced by the local geology and how weathering has altered the source material. Depending on the type of rock and sediment, water can percolate more easily: for example, sandbags allow faster infiltration than areas dominated by silty or clay materials.

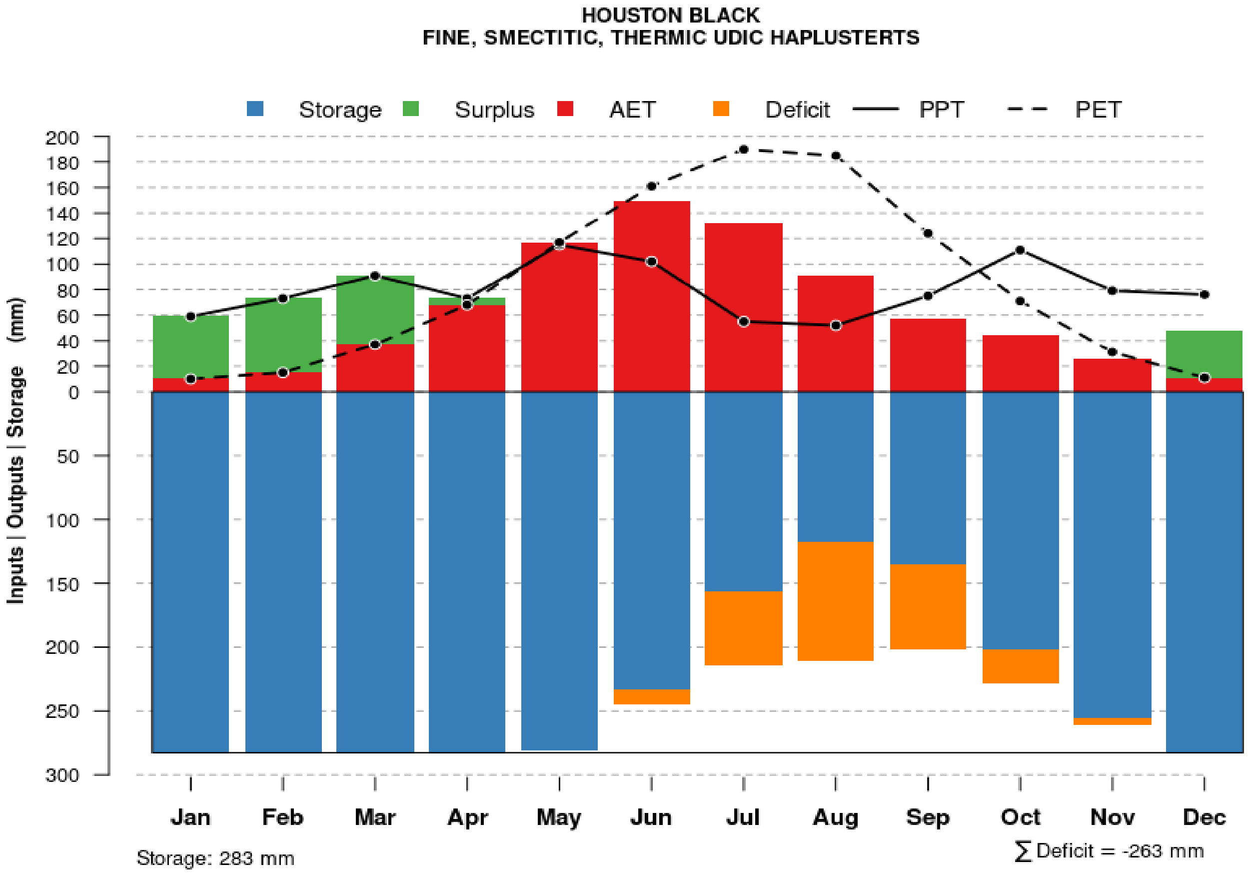
Another factor that can increase infiltration is the presence of geological faults and fractures, which create additional paths for groundwater storage. Regarding the climate, the longer the soil is exposed to atmospheric agents, the greater its permeability and, therefore, the more effective the infiltration will be. Areas with diverse geological formations and complex soil structures often face greater difficulties in meeting water supply demands.

Texas has a rich variety of soil types, classified into 61 soil series, organized into 15 major land resource areas. Each area represents regions with soil characteristics, native vegetation, weather patterns, and specific topographic characteristics that need to be known.

For Region C, counties have the following soil groups: Bluegrove-Bonti-Truce (number 17), Windthorst-Chaney-Duffau (number 35), Gasil-Crosstell-Callisburg (number 36), Aledo-Sanger-Bolar (number 38), Houston Black-Heiden-Wilson (number 39), Woodtell-Crockett (number 43), Edge-Tabor-Silstid (number 44), Wolfpen-Pickton-Cuthbert (number 49), and Tinn-Trinity-Kaufman (number 52), shown on the following map provided by the United States Department of Agriculture (USDA). These different soil groups play an important role in Texas’s agricultural economy and reflect the transitional landscape of central and eastern Texas, from prairies to forest, and from drylands to bottomlands.

In Figure 7 below, the balance of water in the soil is observed, considering precipitation, evaporation, storage, and water deficit in the soil.

Figure 7 – BALANCE OF WATER IN THE SOIL



Source: https://casoilresource.lawr.ucdavis.edu/sde/?series=houston%20black#water-balance

3.4 Soil Conservation Practices

Soil conservation encompasses all the strategies, techniques, and practices employed to prevent soil erosion, reduce the loss of soil fertility, and ensure sustainable land use. Soil erosion happens when water, wind, or human activities strip away the top layer of soil, the most fertile part. This reduces crop yields, fills rivers and streams with sediment, increases flooding, and causes land loss. Different soil conservation methods can be used, depending on the area's soil type, climate, and specific needs. According to the USDA, "Seventy percent of the nation's land is privately owned, and conservation of our nation's private lands results in healthy soil, water, air, plants, animals and ecosystems, it also provides productive and sustainable working lands".

Soil helps control where rain, snowmelt, and irrigation water go. Water flows over the land or into and through the soil. Proper soil conservation practice increases the efficiency of water use and precipitation storage.

In 1939, the Texas State Soil and Water Conservation Board (TSSWCB) organized the state into different soil conservation districts. Today, there are 216 Soil and Water Conservation Districts (SWCDs) organized across the state.

However, in many river basins, there are problems of a lack of soil conservation, which causes erosive processes and silting of rivers, which can cause a decrease in the volume of surface water.

3.5 Small number of Riparian Forests

According to the Texas Parks and Wildlife Department (TPWD), “Riparian areas are the margins of streams, rivers, and intermittent draws, where water´s presence strongly influences vegetation. Riparian-dependent plant communities differ markedly from those immediately surrounding non-riparian habitats”.

> *The Benefits of a Healthy Riparian Area*
>
> “Riparian areas perform key ecological functions that contribute to the health of the entire ecosystem. Nutrients, detritus, and water are transported into a riparian system from runoff. … Stems and roots of riparian vegetation stabilize the soil by reducing water velocity and minimizing erosion”.

Three important aspects can be highlighted concerning the benefits of the Riparian Forest: Water quality, Wildlife Habitat, and Economics.

Riparian Forest enhances water storage and slows the physical movement of water across the landscape, increasing the residence time of water, providing sources of water for plant transpiration, soil-water and plant-water storage, and seepage to groundwater.

Riparian forests act as regulators of surface and subsurface water flows, as well as maintaining their quality, by filtering water (MARTINS, 2005).

In Texas, riparian forest law is governed by various regulations and rights associated with riparian areas, which are the margins of streams and rivers.

However, the existing laws have not been sufficient to maintain minimum and desirable levels of riparian forests.

According to TPWP, “Major factors that contribute to degradation of riparian zones in Texas include construction of roads, dams, reservoirs and impoundments, uncontrolled grazing, point and non-point pollution, urban development and timber cutting”.

3. PROPOSAL FOR INCREASE SURFACE AND GROUNDWATER (IPAC SYSTEM)

3.1 Springs Rehabilitation

River rehabilitation is an increasing priority for water authorities and river managers worldwide. Springs—natural discharge points where groundwater reaches the surface—are essential to rivers´ formation. Restoring these springs can rapidly boost river flow and support groundwater recharge.

In Texas, established spring restoration methods have proven effective in significantly enhancing both the quantity and quality of surface water.

3.2 Terrace Build

The construction of terraces is a soil conservation practice applied to prevent the runoff of rainwater, allowing erosion to be controlled**.**

Terraces provide many ecosystem services, including the reduction of runoff and sediment, and the improvement of grain yields and soil moisture.

Terracing allows enhanced water infiltration in the soil, which increases groundwater recharge.

3.3 Retention Basins Build

Retention basins are management practices designed to mitigate stormwater runoff.

The retention basin is important for the recharge of groundwater, especially the water table, as it favors the infiltration of water into the soil, as well as the protection of terraces.

3.4 Erosion Control and Recovery of Degraded Areas

Containment of erosive processes and recovery of degraded areas, especially in the surroundings of water bodies to be recovered, are actions of fundamental importance to reduce the transport of sediments to riverbeds and water reservoirs.

To this end, it is necessary to identify the places affected by the erosive processes, and, in each place, to know the causes and consequences of the erosive manifestation with a view to the implementation of known techniques appropriate to the discipline of the runoff waters.

3.5 Groundwater Recharge

Groundwater recharge is a hydrologic process where water moves downward from surface water to groundwater. Recharge is the primary method through which water enters an aquifer.

According to the United States Geological Survey, groundwater can be recharged naturally and artificially.

Natural groundwater recharge occurs as precipitation falls on the land surface, infiltrates into soils, and moves through pore spaces down to the water table.

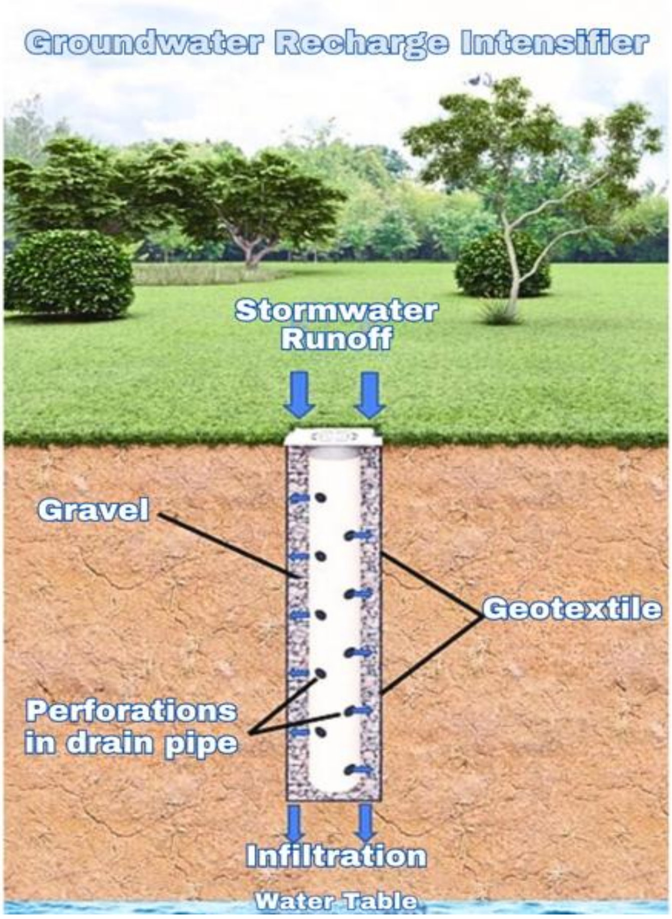
Artificial recharge can be done through the injection of water through wells. This method is often applied to recharge aquifers where application of water to the land surface is not effective at recharging these aquifers.

The technical team from the Institute for Environmental Protection and Conservation (IPAC) developed a mechanism for artificial water table recharge: the Groundwater Recharge Intensifier, which does not require pumping.

The Recharge Intensifiers must be installed on the terraces and in the rainwater containment basins located in the recharge areas of the water table.

In Figure 8, it is possible to observe the drawing of an intensifier of groundwater recharge.

Figure 8 – Design of the Groundwater Recharge Intensifier*



Source: Decio Eloi Siebert

3.6 Recovery of Riparian Forests

The restoration of forests through natural regeneration can be an economical approach to expanding buffer zones of protected areas or forest reserves, creating new forest fragments and riparian zones, as well as creating biological corridors to connect existing protected areas (CHAZDON, 2017).

A strip of 100 feet will be isolated along the banks of the river for natural regeneration.

4. DETAILS OF THE IPAC RESTORATION SYSTEM AND RESULTS

The present work was prepared by technicians who are members of the non-profit organization, in the Brazilian Institute of Environmental Preservation and Conservation-IPAC (before: Pantanal Amazônia Conservation Institute -IPAC).

The IPAC is an organization founded on June 25, 2004. Since 2006, IPAC has participated in collegiate bodies such as the State Council for Water Resources of Mato Grosso (Brazil) and the Watershed Committee of the Sepotuba River. It also participated in Workshops for the Review of the National Water Resources Plan of Brazil (2009 and 2010).

It has executed several projects aimed at the preservation and recovery of water resources, as can be seen on its website: www.ipac.eco.br.

4.1 – Results of the IPAC Restoration System at the spring of Queima-Pe River (Brazil)

The IPAC Restoration System was implemented at the main spring of the Queima-Pe River (Brazil). The results of this work can be observed in the flow measurement data collected in periods following the restoration, as shown in Table 1.

Table 1. Flow measurement of the Queima Pe River Spring (Brazil)

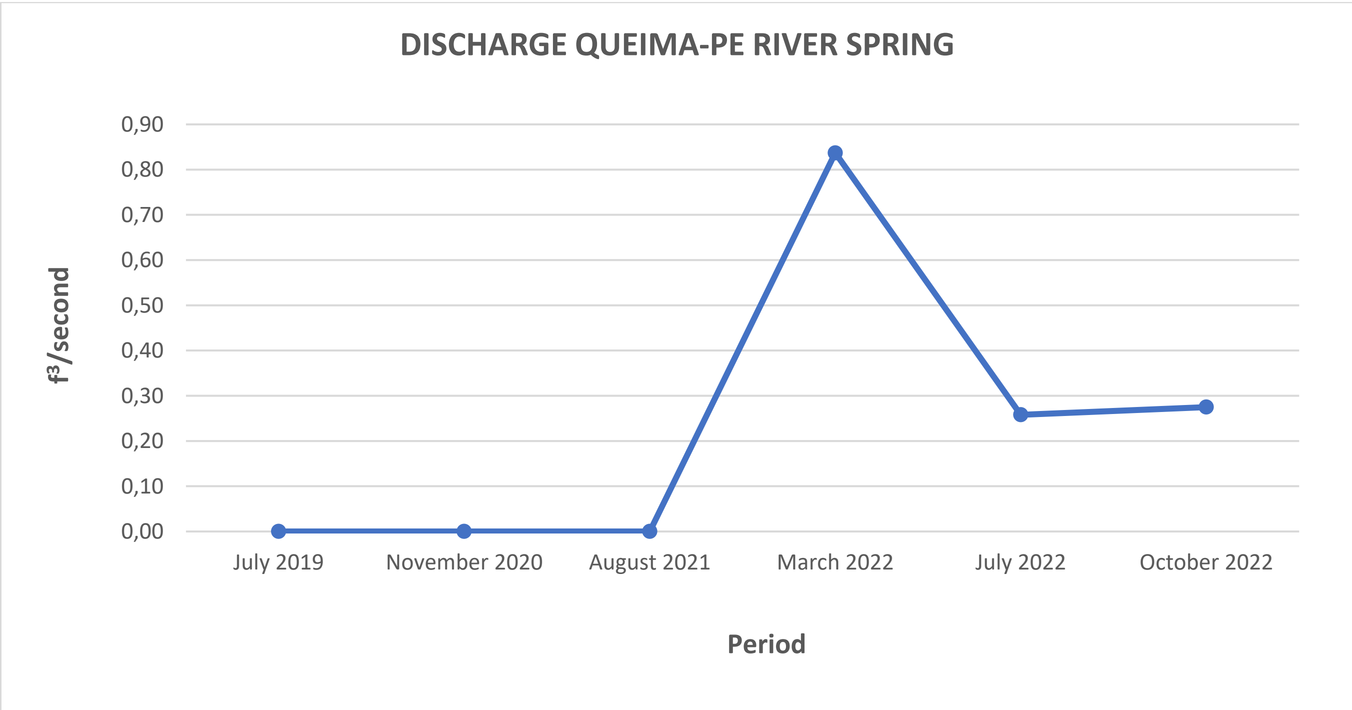
Period	Discharge	
	Litter/second	Cubic feet/second
Mar-22	23.7	0.837
Jul-22	7.3	0.258
Oct-22	7.8	0.275

Source: CBH Sepotuba River Hydrographic Basin Committee

Coordinator: Ibraim Fantin da Cruz - PhD in Water Resources and Environmental Sanitation

Professor at the Federal University of Mato Grosso- UFMT

Figure 9 – DISCHARGE QUEIMA-PE RIVER SPRING (BRAZIL)



In figures 10 and 11 presented below, one can observe the situation of the Queima-Pe River Spring during the periods of November 2020 and August 2021, which are prior to the implementation of the IPAC Restoration System.

Fig. 10 – November 2020 – Source: Lauro Soccoloski

Fig. 11 – August 2021 – Source: Decio E. Siebert

In figures 12 and 13 presented below, one can observe the situation of the Queima-Pe River spring during the periods of July 2022 and March 2025, which are after the implementation of the IPAC Restoration System, which was carried out in September and October 2021.

Fig. 12 – July 2022 – Source: Decio E. Siebert


Fig. 13 – March 2025 – Source: Decio E. Siebert

4.2 – PROPOSED AREA FOR THE EXECUTION OF WORK IN REGION C

The area considered for this proposal is in the region called Upper Trinity, which includes the West Fork Trinity River, Elm Fork Trinity River, and East Fork Trinity River Hydrographic Basins.

The work presented here was based on data and studies from official institutions in Texas, on surveys conducted in some watersheds in this region, and on the experiences of IPAC in Brazil.

For the calculations of water production, an index of 5% of the total annual precipitation volume in each watershed will be considered and developed for three scenarios (SC):

Scenario (SC) 1 - Implementation of the IPAC Restoration System in 90% of the water sources of the 3 watersheds.

Scenario (SC) 2 - Implementation of the IPAC Restoration System in 60% of the water sources of the 3 watersheds.

Scenario (SC) 3 - Implementation of the IPAC Restoration System in 30% of the water sources of the 3 watersheds.

4.2.1 Area

- Elm Fork Trinity River Basin: 1,848.45 square miles = 1,189,408.00 acres.

- West Fork Trinity River Basin: 3,467.19 square miles = 2,219,001.60 acres.

- East Fork Trinity River Basin: 325.86 square miles = 208,553.29 acres.

- Total: 5,641.50 square miles = 3,616,962.89 acres.

4.2.2 Average annual rainfall (70 years) = 35.00 inches

4.2.3 – CALCULATION MEMORANDUM

– Elm Fork Trinity River Basin

Total Annual Rainfall = 1,189,408.00 Acres × 35.00 inches/year = 3,469,117.49 Acre-Feet/year.

Total Annual Recharge Potential = 3,469,117.49 Acre-Feet/year × 5% = 173,455.87 Acre-Feet/year

– West Fork Trinity River Basin

Total Annual Rainfall = 2,219,001.60 Acres × 35.00 inches/year = 6,472,108.14 Acre-Feet/year.

Total Annual Recharge Potential = 6,472,108.14 Acre-Feet/year × 5% = 323,605.47 Acre-Feet/year

– East Fork Trinity River Basin

Total Annual Rainfall = 208,553.29 Acres × 35.00 inches/year = 608,282.32 Acre-Feet/year.

Total Annual Recharge Potential = 608,282.32 Acre-Feet/year × 5% = 30,414.12 Acre-Feet/year

4.3 EXECUTION SCHEDULE

Before the execution, there will be a planning phase using the following methodology:

a) Analysis of Satellite Images.

b) Studies of the work by Soil and Water Conservation Districts (SWCDs).

c) Field surveys to assess the condition of springs, soil conservation, the occurrence of erosion processes, and riparian forests.

d) Training and organization of work teams.

4.3.1 – Elm Fork Trinity River Basin

The total period anticipated for the execution of the IPAC Restoration System on the Elm Fork Trinity River Basin is 6 years, and the planning and preparation of the project can be carried out in 2026, and the implementation of the actions from 2027, according to what is established in Table 2.

Table 2. Actions to be carried out and deadlines for execution

ACTIONS	YEARS					
	I	II	III	IV	V	VI
Planning						
Project Preparation						
Springs Restoration						
Terrace Build						
Retention Basins Build						
Erosion Control and Recovery Degraded Areas						
Installation of groundwater refill intensifiers						
Riparian Forest (Isolation area)						

4.3.2 – West Fork Trinity River Basin

The total deadline anticipated for the execution of the IPAC Restoration System in the West Fork Trinity River Basin is 9 years, with the planning and preparation of the project to take place in 2027 and the implementation of actions starting in 2028, according to what is established in Table 3.

Table 3. Actions to be carried out and deadlines for execution

ACTIONS	YEARS								
	I	II	III	IV	V	VI	VII	VIII	IX
Planning									
Project Preparation									
Springs Restoration									
Terrace Build									
Retention Basins Build									
Erosion Control and Recovery Degraded Areas									
Installation of groundwater refill intensifiers									
Riparian Forest (Isolation area)									

4.3.3 – East Fork Trinity River Basin

The total deadline anticipated for the IPAC Restoration System in the East Fork Trinity River Basin is 3 years, with the planning and project development to be carried out in 2028 and the implementation of actions starting from 2031, according to what is established in Table 4.

Table 4. Actions to be carried out and deadlines for execution

ACTIONS	YEARS		
	I	II	III
Planning			
Project Preparation			
Springs Restoration			
Terrace Build			
Retention Basins Build			
Erosion Control and Recovery Degraded Areas			
Installation of groundwater refill intensifiers			
Riparian Forest (Isolation area)			

4.4 ESTIMATED GROUNDWATER RECHARGE

4.4.1 – Elm Fork Trinity River Basin

The estimation of the IPAC Restoration System is presented in Tables 5, 6, and 7 below:

Table 5. Water Production Estimate - Elm Fork Trinity River Basin – SC 1

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	**Unit**	**Cumulative Volume**
First year	Partial	Acre/feet	21,140.4735
Second year	12 months (1) + Partial	Acre/feet	52,362.5309
Third year	24 months (1) + Partial	Acre/feet	83,584.5883
Fourth year	36 months (1) + Partial	Acre/feet	114,806.6457
Fifth year	48 months (1) + Partial	Acre/feet	146,028.7031
TOTAL RECHARGE (2027 to 2031)			**146,028.7031**

From 2032, the annual recharge may be 156,110.29 acre-feet/year.

Table 6. Water Production Estimate - Elm Fork Trinity River Basin – SC 2

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	**Unit**	**Cumulative Volume**
First year	Partial	Acre/feet	14,093.6490
Second year	12 months (1) + Partial	Acre/feet	34,908.3539
Third year	24 months (1) + Partial	Acre/feet	55,723.0589
Fourth year	36 months (1) + Partial	Acre/feet	76,537.7638
Fifth year	48 months (1) + Partial	Acre/feet	97,352.4687
TOTAL RECHARGE (2027 to 2031)			**97,352.4687**

From 2032, the yearly recharge may be 104,073.52 acre-feet/year.

Table 7. Water Production Estimate - Elm Fork Trinity River Basin – SC 3

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	Unit	Cumulative Volume
First year	Partial	Acre/feet	7,046.8245
Second year	12 months (1) + Partial	Acre/feet	17,454.1770
Third year	24 months (1) + Partial	Acre/feet	27,861.5294
Fourth year	36 months (1) + Partial	Acre/feet	38,268.8819
Fifth year	48 months (1) + Partial	Acre/feet	48,676.2344
TOTAL RECHARGE (2027 to 2031)			**48,676.2344**

From 2032, the annual recharging may be 52,036.76 acre-feet/year.

4.4.2 – West Fork Trinity River Basin

The estimated recharge of the IPAC Restoration System is presented in Tables 8, 9, and 10 below:

Table 8. Water Production Estimate - West Fork Trinity River Basin – SC 1

Execution period Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	Unit	Cumulative Volume
First year	Partial	Acre/feet	24,650.2589
Second year	12 months (1) + Partial	Acre/feet	61,055.8672
Third year	24 months (1) + Partial	Acre/feet	97,461.4755
Fourth year	36 months (1) + Partial	Acre/feet	133,867.0838
Fifth year	48 months (1) + Partial	Acre/feet	170,272.6921
Sixth year	60 months (1) + Partial	Acre/feet	206,678.3004
Seventh year	72 months (1) + Partial	Acre/feet	243,083.9087
Eighth year	84 months (1) + Partial	Acre/feet	279,489.5170
TOTAL RECHARGE (2028 a 2035)			**279,489.5170**

From 2036, the annual recharge may be 291,244.87 acre-feet/year.

Table 9. Water Production Estimate - West Fork Trinity River Basin - SC 2

Execution period Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	Unit	Cumulative Volume
First year	Partial	Acre/feet	16,433.5059
Second year	12 months (1) + Partial	Acre/feet	40,703.9115
Third year	24 months (1) + Partial	Acre/feet	64,974.3170
Fourth year	36 months (1) + Partial	Acre/feet	89,244.7225
Fifth year	48 months (1) + Partial	Acre/feet	113,515.1281
Sixth year	60 months (1) + Partial	Acre/feet	137,785.5336
Seventh year	72 months (1) + Partial	Acre/feet	162,055.9392
Eighth year	84 months (1) + Partial	Acre/feet	186,326.3447
TOTAL RECHARGE (2028 a 2035)			**186,326.3447**

From 2036, the annual recharge may be 194,163.24 acre-feet/year.

Table 10. Water Production Estimate - West Fork Trinity River Basin – SC 3

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	**Unit**	**Cumulative Volume**
First year	Partial	Acre/feet	8,216.7530
Second year	12 months (1) + Partial	Acre/feet	20,351.9557
Third year	24 months (1) + Partial	Acre/feet	32,487.1585
Fourth year	36 months (1) + Partial	Acre/feet	44,622.3613
Fifth year	48 months (1) + Partial	Acre/feet	56,757.5640
Sixth year	60 months (1) + Partial	Acre/feet	68,892.7668
Seventh year	72 months (1) + Partial	Acre/feet	81,027.9696
Eighth year	84 months (1) + Partial	Acre/feet	93,163.1723
TOTAL RECHARGE (2028 a 2035)			**93,163.1723**

From 2036, the annual recharge may be 97.081,62 acre-feet/year.

4.4.3 – East Fork Trinity River Basin

The estimated recharge of execution of the proposed actions is presented in Tables 11, 12, and 13 below:

Table 11. Water Production Estimate - East Fork Trinity River Basin – SC 1

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	**Unit**	**Cumulative Volume**
First year	Partial	Acre/feet	6,178.02
Second year	12 months (1) + Partial	Acre/feet	15,302.26
Third year	24 months (1) + Partial	Acre/feet	24,426.49
TOTAL RECHARGE (2031 a 2033)			**24,426.49**

From 2034, the annual recharge may be 27,372.70 acre-feet/year.

Table 12. Water Production Estimate - East Fork Trinity River Basin – SC 2

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	**Unit**	**Cumulative Volume**
First year	Partial	Acre/feet	4,118.68
Second year	12 months (1) + Partial	Acre/feet	10,201.51
Third year	24 months (1) + Partial	Acre/feet	16,284.33
TOTAL RECHARGE (2031 a 2033)			**16,284.33**

From 2034, the annual recharge may be 18,248.47 acre-feet/year.

Table 13. Water Production Estimate - East Fork Trinity River Basin – SC 3

Execution period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)		
	Recharge Time/Year	**Unit**	**Cumulative Volume**
First year	Partial	Acre/feet	2,059.34
Second year	12 months (1) + Partial	Acre/feet	5,100.75
Third year	24 months (1) + Partial	Acre/feet	8,142.16
TOTAL RECHARGE (2031 a 2033)			**8,142.16**

From 2034, the annual recharge may be 9,124.20 acre-feet/year.

4.5 CONSOLIDATED DATA

In Table 14, the consolidated data of the estimated water production from the three river basins in three scenarios are shown:

Table 14. Water Production Estimate – Consolidated data

Period	WATER PRODUCTION – GROUNDWATER RECHARGE (1)								
	Elm Fork Basin (Acre/feet)			West Fork Basin (Acre/feet)			East Fork Basin (Acre/feet)		
	SC 1	SC 2	SC 3	SC 1	SC 2	SC 3	SC 1	SC 2	SC 3
2027	21,140.5	14,093.6	7,046.8						
2028	52,362.5	34,908.3	17,454.2	24,650.3	16,433.5	8,216.8			
2029	83,584.6	55,723.1	27,861.5	61,055.9	40,703.9	20,352.0			
2030	114,806.6	76,537.7	38,268.9	97,461.5	64,974.3	32,487.2			
2031	146,028.7	97,352.5	48,676.2	133,867.1	89,244.7	44,622.4	6,178.02	4,118.68	2,059.34
2032	156,110.3	104,073.5	52,036.7	170,272.7	113,515.1	56,757.6	15,302.26	10,201.51	5,100.75
2033	156,110.3	104,073.5	52,036.7	206,678.3	137,785.5	68,892.8	24,426.49	16,284.33	8,142.16
2034	156,110.3	104,073.5	52,036.7	243,083.9	162,055.9	81,028.0	27,372.7	18,248.47	9,124.2
2035	156,110.3	104,073.5	52,036.7	279,489.5	186,326.3	93,163.1	27,372.7	18,248.47	9,124.2
2036	156,110.3	104,073.5	52,036.7	291,244.8	194,163.2	93,163.1	27,372.7	18,248.47	9,124.2

From 2037 onwards, the volumes are the same as in 2036.

Figure 14. - Water Production Upper Trinity Basins – SC 1*

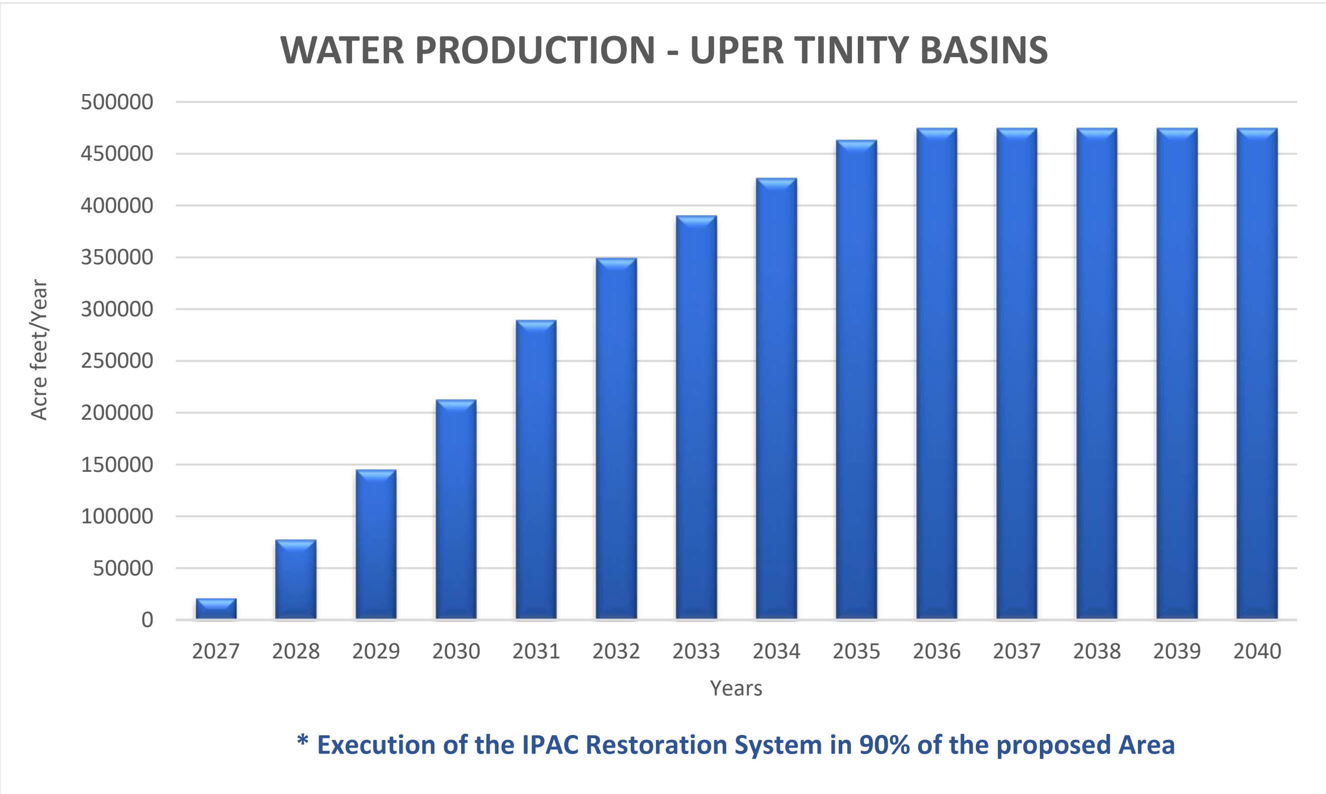


Figure 15. - Water Production Upper Trinity Basins – SC 2*

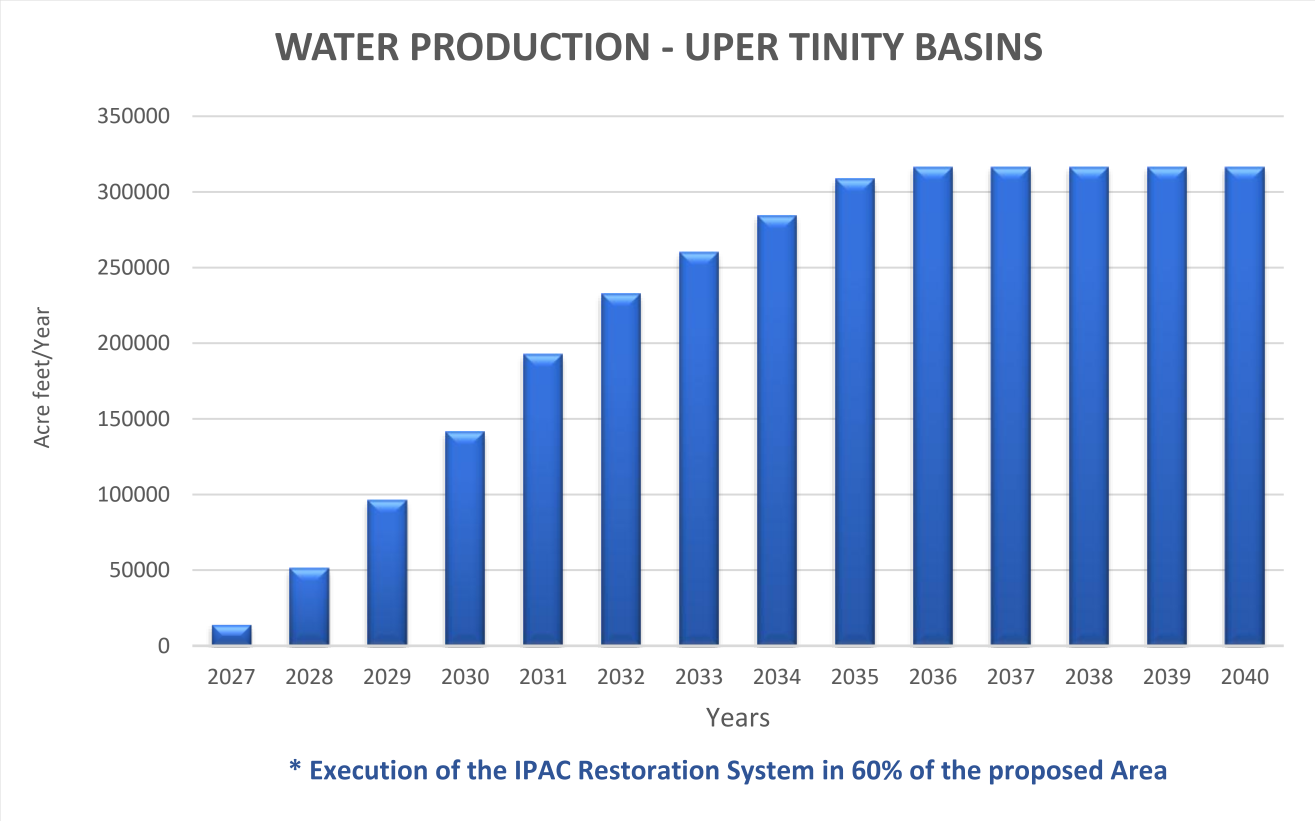
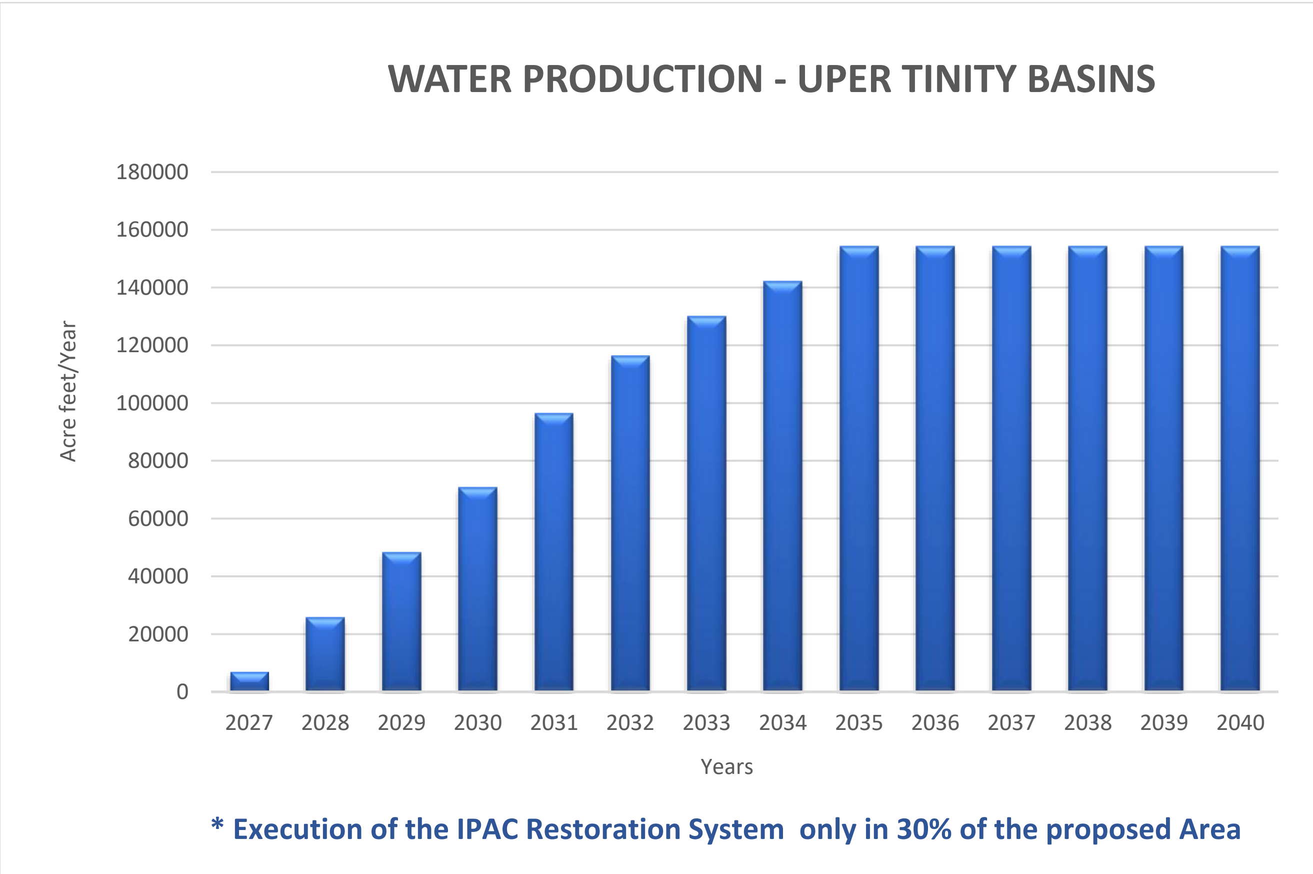


Figure 16. - Water Production Upper Trinity Basins – SC 3*



5 COMPARISON OF WATER PRODUCTION TO TOTAL DEMAND REGION C

The following figures show comparative surface water production that can be achieved with the actions proposed with the Total Demand of Region C until 2080.

Figure 17. Comparison of Water Produced to Total Demand Region C – SC 1*

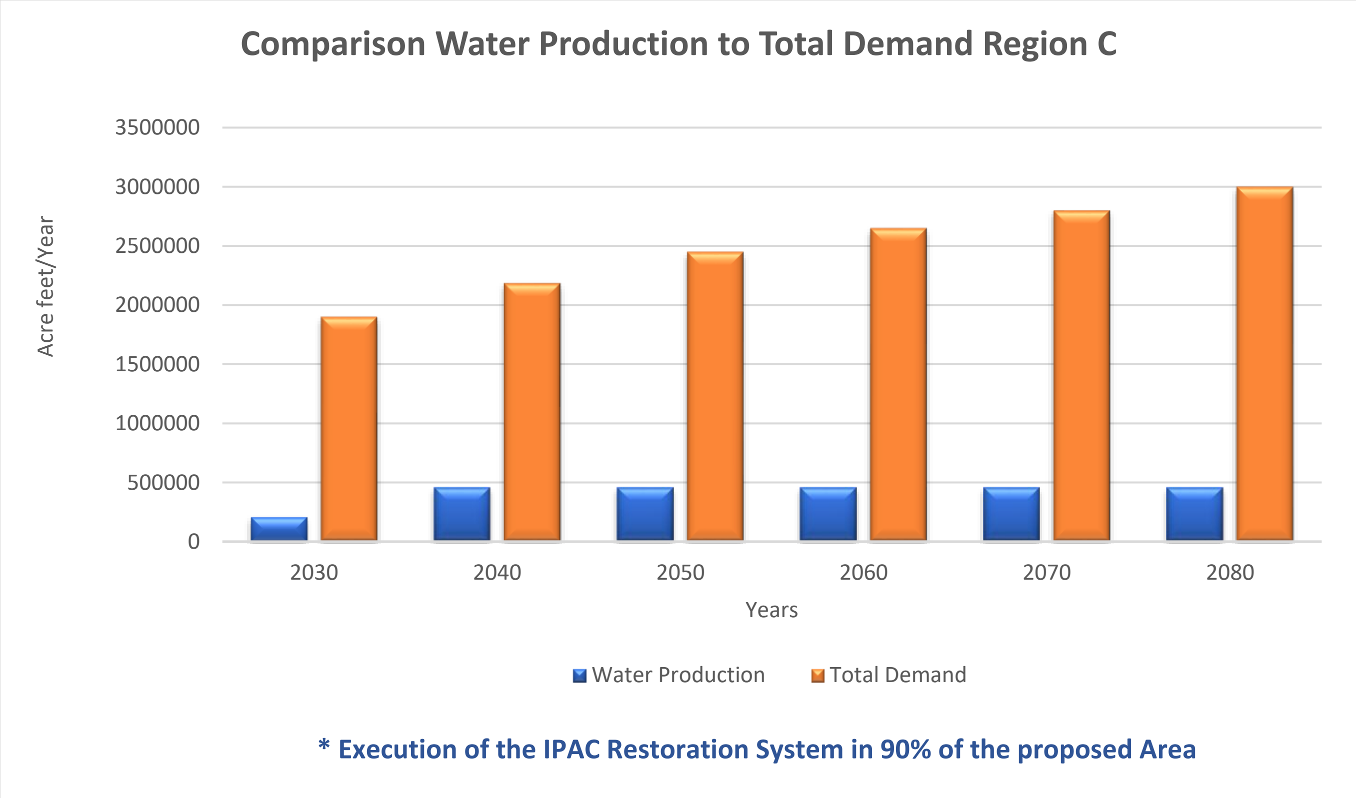


Figure 18. Comparison of Water Produced to Total Demand Region C – SC 2*

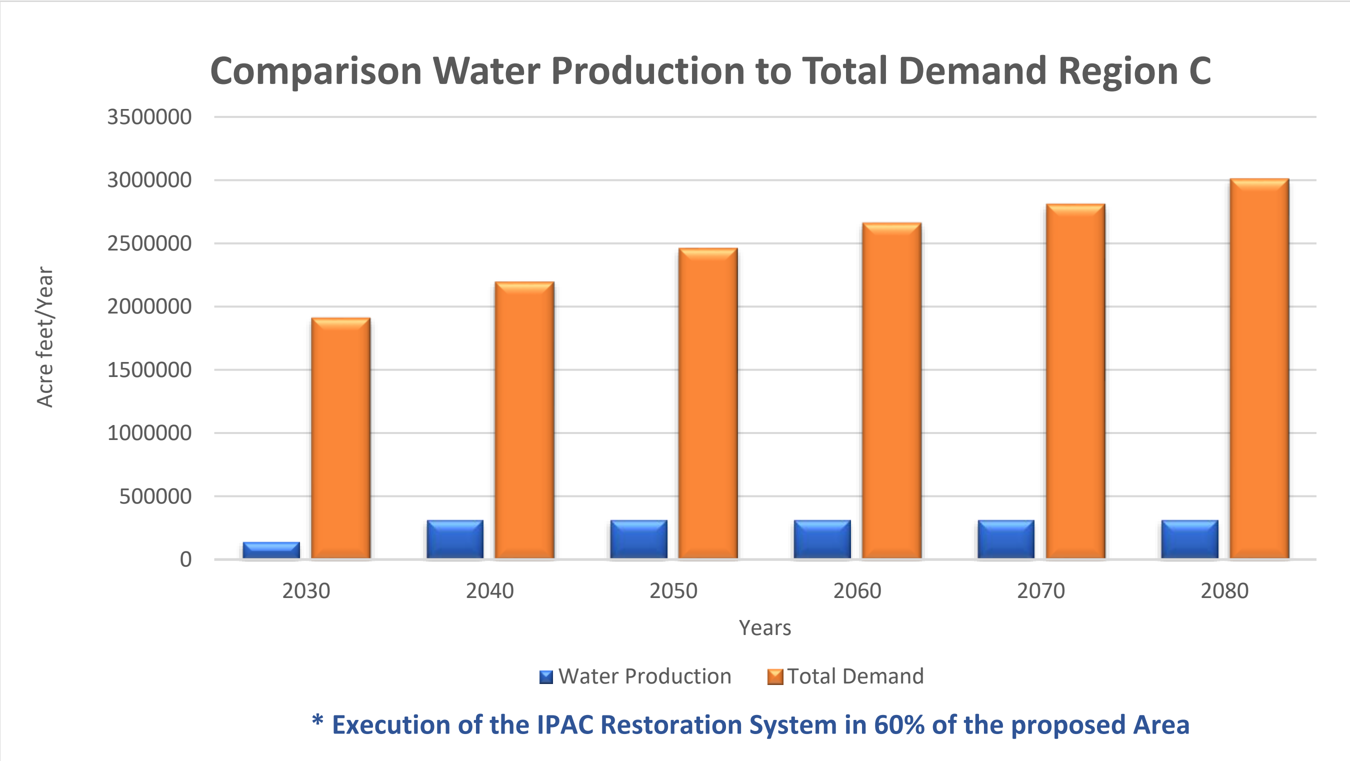


Figure 19. Comparison of Water Produced to Total Demand Region C – SC 3*

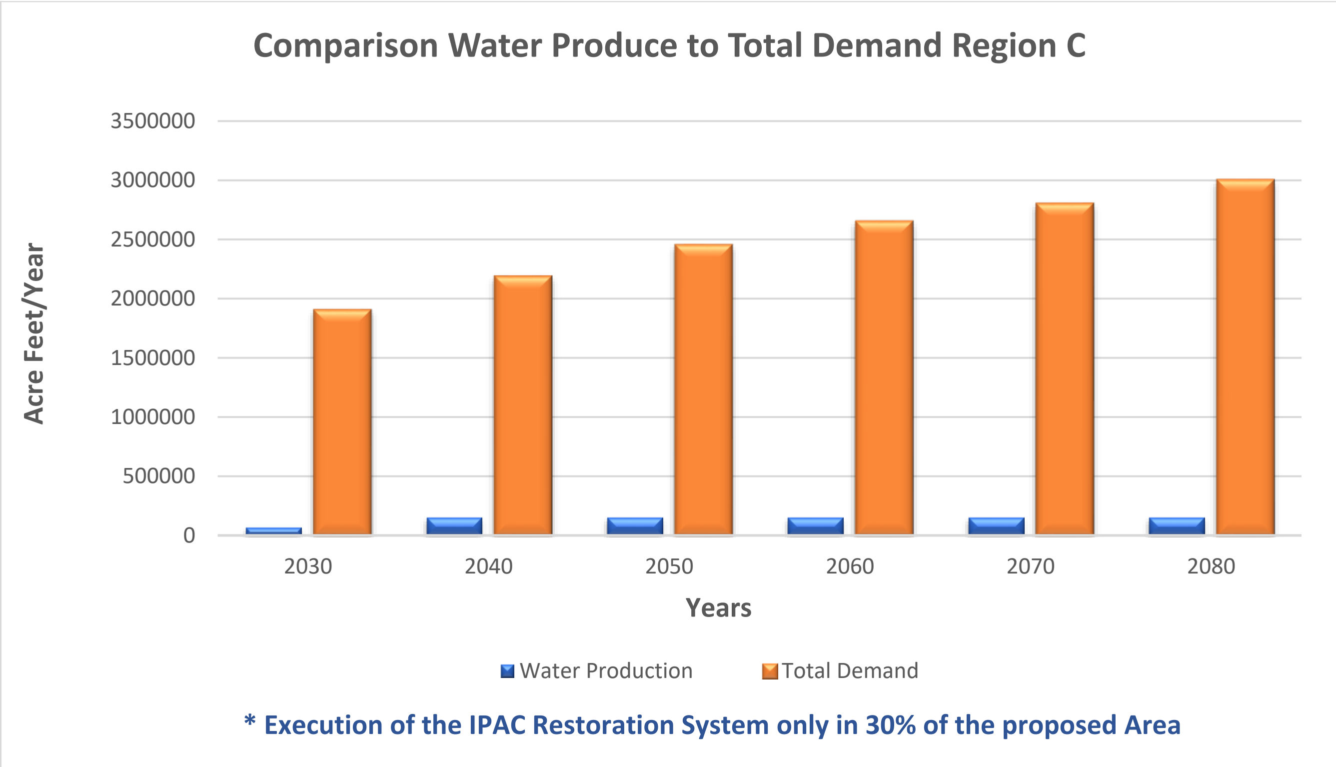


Figure 20 – Comparison 2026: Initially Prepared Region C Water Plan Strategies to IPAC Restoration System (Execution in 90% of the Area)

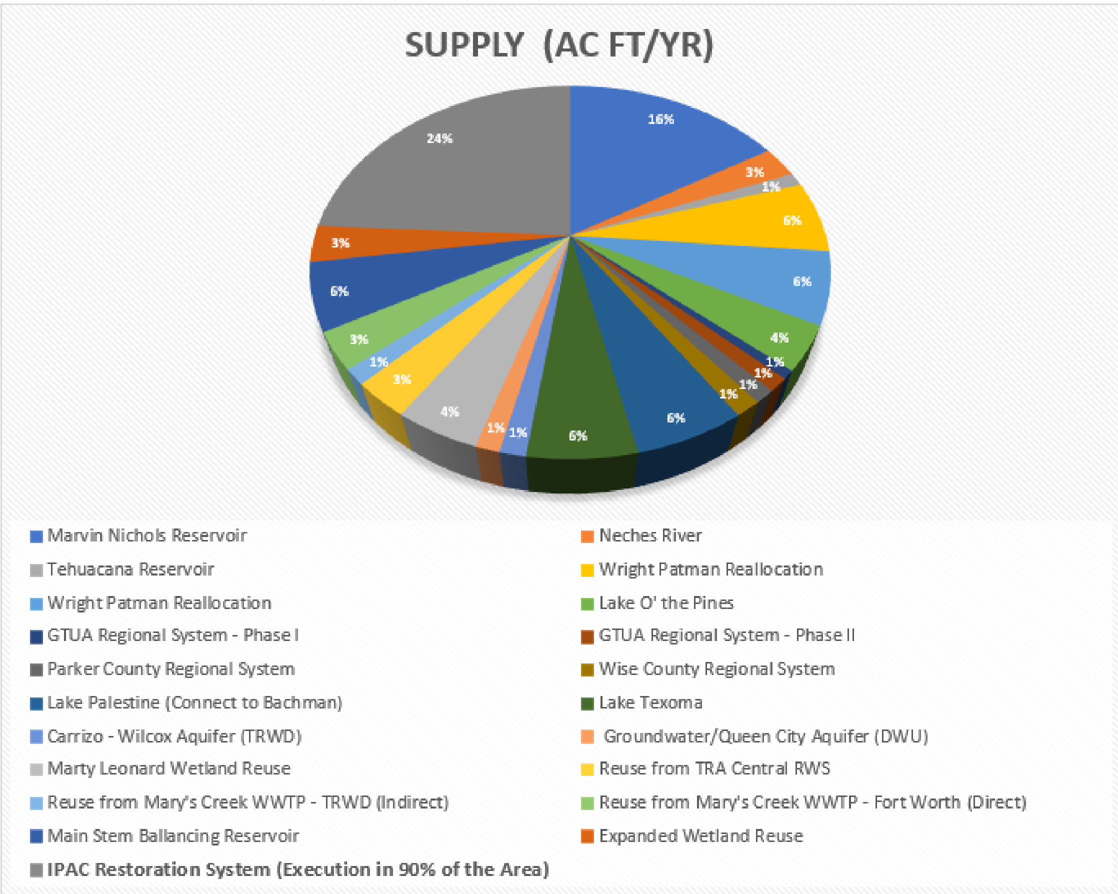


Figure 21 – Comparison 2026: Initially Prepared Region C Water Plan Strategies to IPAC Restoration System (Execution in 60% of the Area)

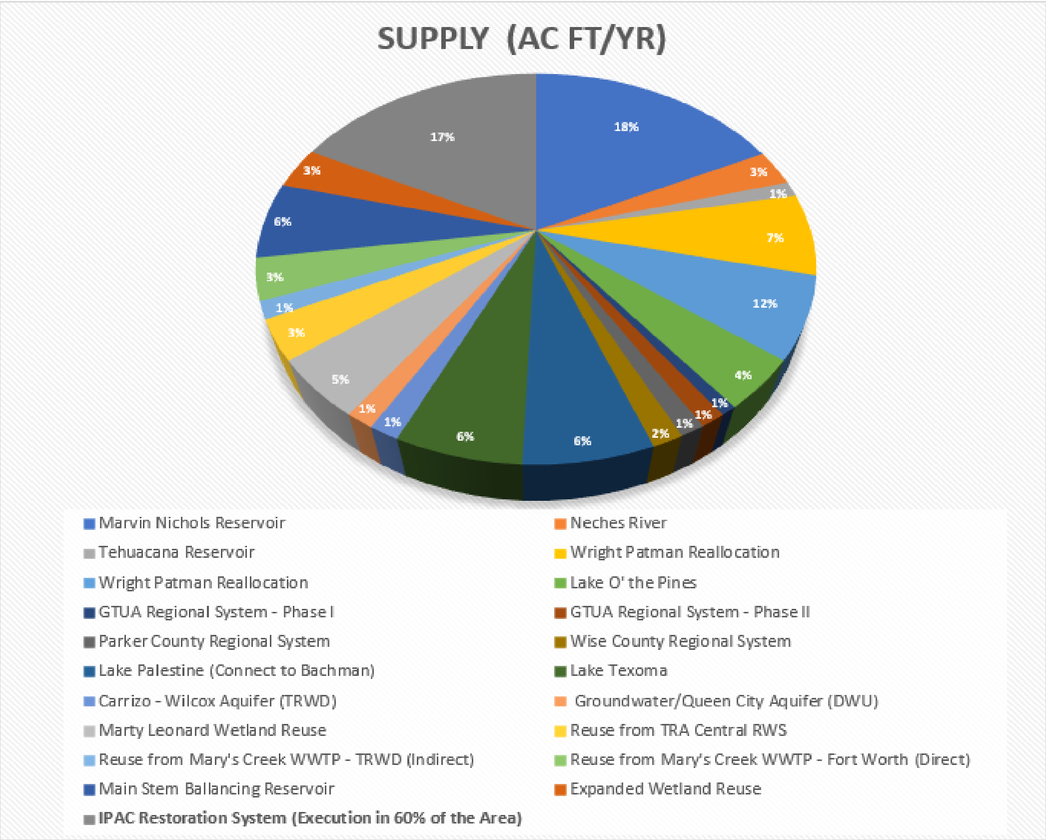
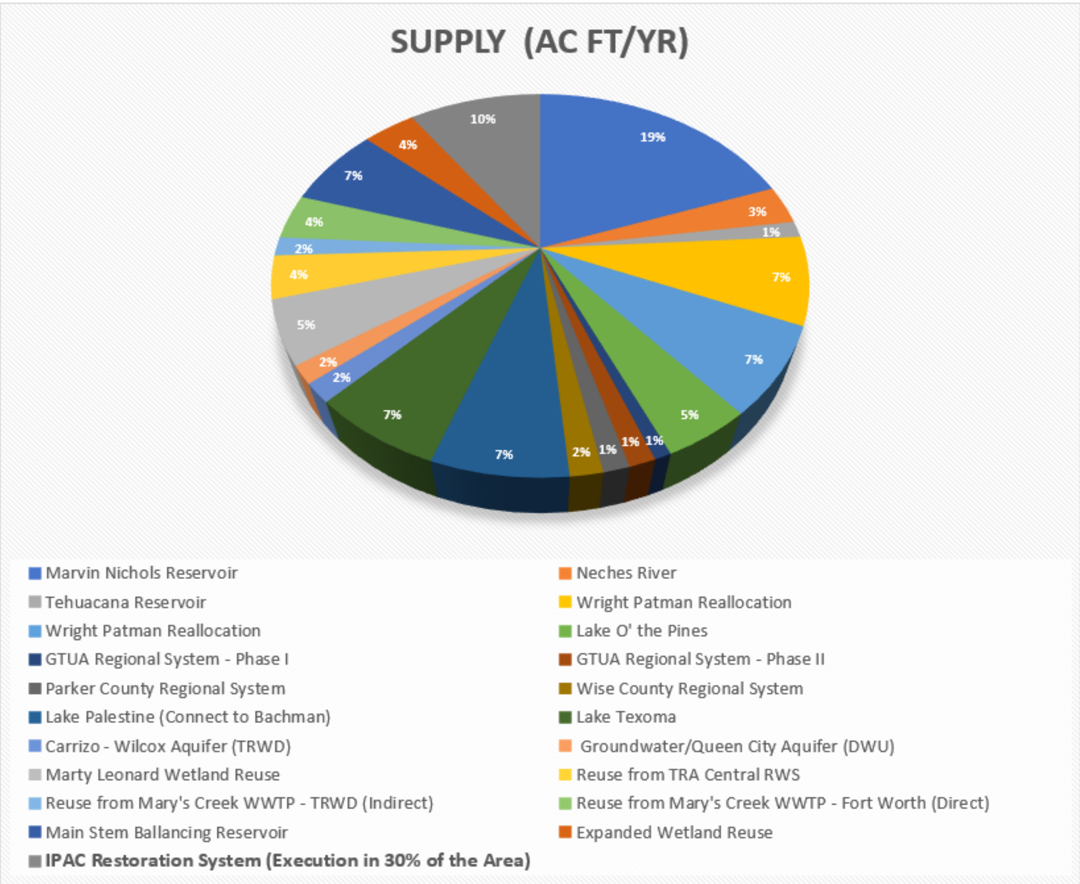


Figure 22 – Comparison 2026: Initially Prepared Region C Water Plan Strategies to IPAC Restoration System (Execution in 30% of the Area)



6 COSTS FOR THE IMPLEMENTATION OF THE IPAC RESTORATION SYSTEM

We present below an estimate of costs for the implementation of the IPAC Restoration System for the recovery of the watersheds.

Table 15. Estimated cost for the implementation of the IPAC Restoration System

Activity	Unit	Quantity	Unit Value (USD)
Recharge intensifier (material and installation)	Unit	1	$208,00
Springs recovery (material, machines and labor)	Unit	1	$4.270,00
Stormwater contains/terrace	Unit	1	$1.310,00
Riparian Forest (natural regeneration – Demarcation area)	Km	1	$500.00
Erosion control	f^2	1	$0,05

Based on a study of the Milam Creek Basin, which is a tributary of the Elm Fork Trinity River and has an area of 9,921.04 acres and 55 springs, it was concluded that the total cost was $694.000.00. The amount of water production of 1,446.82 acre-feet/year (5% of Total Annual Rainfall) was considered.

Considering that the areas of the Upper Trinity River basins show similar conditions to the Milam Creek basin, the estimated cost for the recovery of all these basins will be identical.

6.1 - Elm Fork Trinity River Basin

Total Annual Recharge Potential = 3,469,117.49 AC FT/YR × 5% = 173,455.87 AC FT/YR

Total cost for the execution of IPAC Restoration System = USD 83,199,089.60

Table 16. Estimated costs/Acre-Feet/Year

YEAR	TOTAL COAST (USD)	POTENTIAL WATER PRODUCE (ACRE-FEET)	COAST/ACRE-FEET (USD)
2027	16,639,817.92	23,488.99	708.41
2028	16,639,817.92	58,180.45	286.00
2029	16,639,817.92	92,871.78	179.17
2030	16,639,817.92	127,562.89	130.44
2031	16,639,817.92	162,254.11	102.55
TOTAL	**83,199,089.60**	**464,358.22**	**179.17**

The relationship between the total investment cost from 2027 to 2031 and the water production potential in the same period, considering a groundwater recharge of 5%, with a cost of USD 179.17 per acre-foot.

Starting in 2032, the potential water production is 173,455.89 acre-feet/year at no cost.

6.2 - West Fork Trinity River Basin

Total Annual Recharge Potential: 6,472,108.14 Acre-Feet/year × 5% = 323,605.47 Acre-Feet/year.

Total cost for the execution of IPAC Restoration System: USD 155,224,362.60.

Table 17. Estimated costs/Acre-Feet/Year

YEAR	TOTAL COAST (USD)	POTENTIAL WATER PRODUCE (ACRE-FEET)	COAST/ACRE-FEET (USD)
2028	19,403,045.33	27,388.89	708,43
2029	19,403,045.33	67,839.89	286,01
2030	19,403,045.33	108,290.56	179,18
2031	19,403,045.33	148,741.22	130,45
2032	19,403,045.33	189,191.22	102,56
2033	19,403,045.33	229,642.56	84,49
2034	19,403,045.33	270,093.22	71,84
2035	19,403,045.33	310,543.89	62,48
TOTAL	**155,224,362.60**	**1.351.731,45**	**114,83**

The relationship between the total investment cost from 2027 to 2031 and the water production potential in the same period, considering a groundwater recharge of 5%, with a cost of USD 179.17 per acre-foot.

Starting in 2036, the potential water production is 323,605.47 acre-feet/year at no cost.

6.3 - East Fork Trinity River Basin

Total Annual Recharge Potential: 608,282.32 Acre-Feet/year × 5% = 30,414.12 Acre-Feet/year.

Total cost for the execution of IPAC Restoration System = USD 14,588,791.42.

Table 18. Estimated costs/Acre-Feet/Year

YEAR	TOTAL COAST (USD)	POTENTIAL WATER PRODUCE (ACRE-FEET)	COAST/ACRE-FEET (USD)
2031	4,862,930.47	6,864.47	708,42
2032	4,862,930.47	15,302.26	317,79
2033	4,862,930.47	27,140.54	179,18
TOTAL	**14,588,791.42**	**49,307.27**	**295,88**

The relationship between the total investment cost from 2031 to 2033 and the water production potential in the same period, considering a groundwater recharge of 5%, with a cost of $295.88 per acre-foot.

Starting in 2034, the potential water production is 30,414.11 acre-feet/year at no cost.

The estimated average costs for the three basins of the Upper Trinity River during the execution period are: $196.63/Acre-feet ($0.6034/1000 Gallon). Starting from the year 2036, the cost will be zero, for a potential production of 527,475.47 acre-feet/year.

The effective cost of recovering the water bodies in each watershed will be defined after the planning phase, during which topographical surveys, assessment of the situation of each spring, riparian forests, and the occurrence of erosive processes are planned.

RECOMMENDED MAJOR WATER MANAGEMENT STRATEGIES FOR REGION C

STATEGGY	SUPPLY (AC FT/YR)	SUPPLIER CAPITAL COAST	SUPPLIER UNIT COAST ($/1000 GALLON)	SUPPLIER UNIT COAST ($/AC FT/YR)
New Surface Water				
Marvin Nichols Reservoir	320,360	$7,364,971,000	4.62	1,505.43
Neches River (Run-of-the-River)	53,800	$719,027,000	3.96	1,290.37
Tehuacana Reservoir	22,330	$457,095,000	3.32	1,081.83
Wright Patman Reallocation	122,200	$4,760,029,000	7.59	2,473.21
Sabine River Off-Channel Reservoir	74,200	$903,296,000	3.08	1,003.62
Connection of Existing Supplies				
Lake O' the Pines	75,000	$1,345,792,000	4.05	1,319.70
GTUA Regional System - Phase I	14,150	$779,925,000	15.35	5,001.82
GTUA Regional System - Phase II	22,330	$827,790,000	12.45	4,056.85
Parker County Regional System	22,000	$593,307,000	7.40	2,411.30
Wise County Regional System	27,463	$680,554,000	6.92	2,254.89
Lake Palestine (Connect to Bachman)	114,337	$586,902,000	1.21	394.28
Lake Texoma	111,693	$1,232,712,000	2.64	860.25
New Groundwater				
Carrizo - Wilcox Aquifer (TRWD)	26,800	$356,209,000	3.75	1,221.94
Groundwater/Queen City Aquifer (DWU)	25,000	$694,882,000	6.05	1,971.40
Reuse strategies				
Marty Leonard Wetland Reuse	88,059	$68,938,000	2.00	651.70
Reuse from TRA Central RWS	60,000	0	0.39	127.08
Reuse from Mary's Creek WWTP - TRWD (Indirect)	25,928	$68,938,000	0.64	208.54
Reuse from Mary's Creek WWTP - Fort Worth (Direct)	62,559	$66,155,000	2.57	837.44
Main Stem Ballancing Reservoir	114,000	$1,767,099,000	3.71	1,208.91
Expanded Wetland Reuse	62,559	$37,510	5.05	1,645.55

Source: Adapted from 2026 Initially Prepared Region C Water Plan

Figure 23 - Comparison of New Surface Water Strategies to IPAC Restoration System

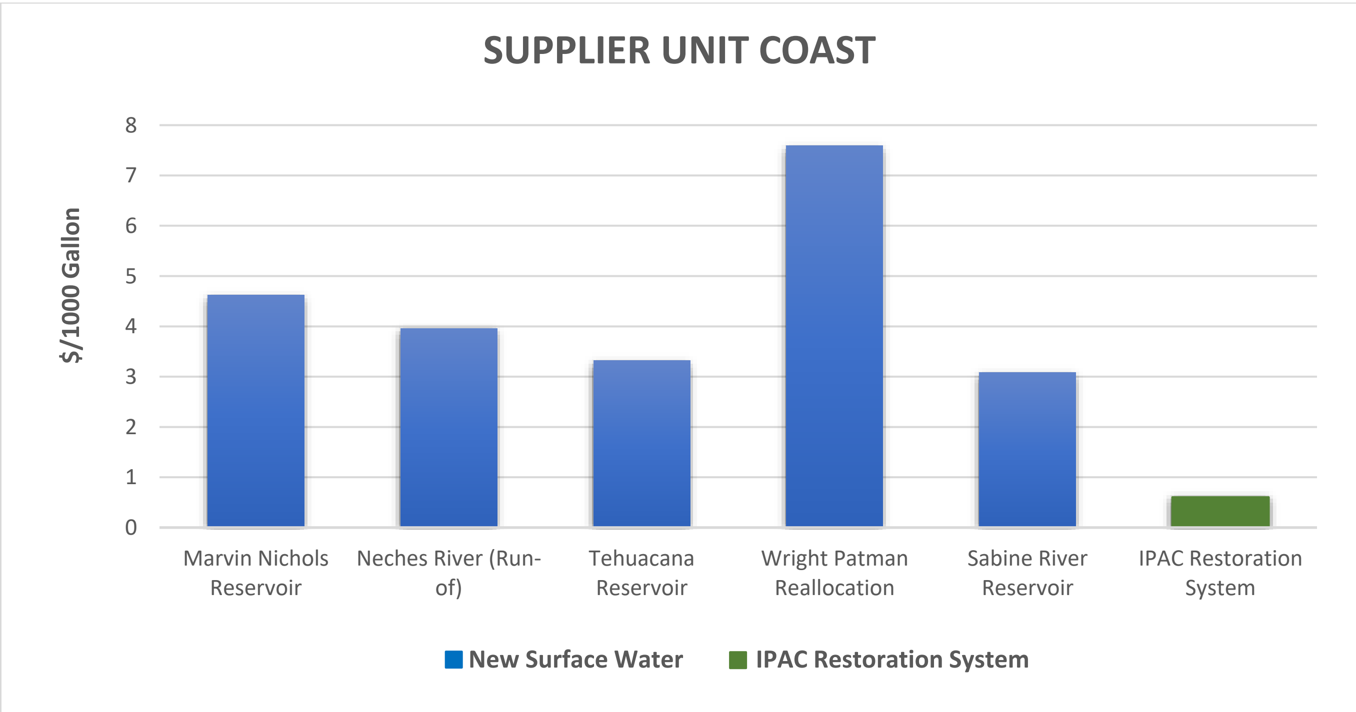


Figure 24 - Comparison of Connection Existing Supplies Strategies to IPAC Restoration System

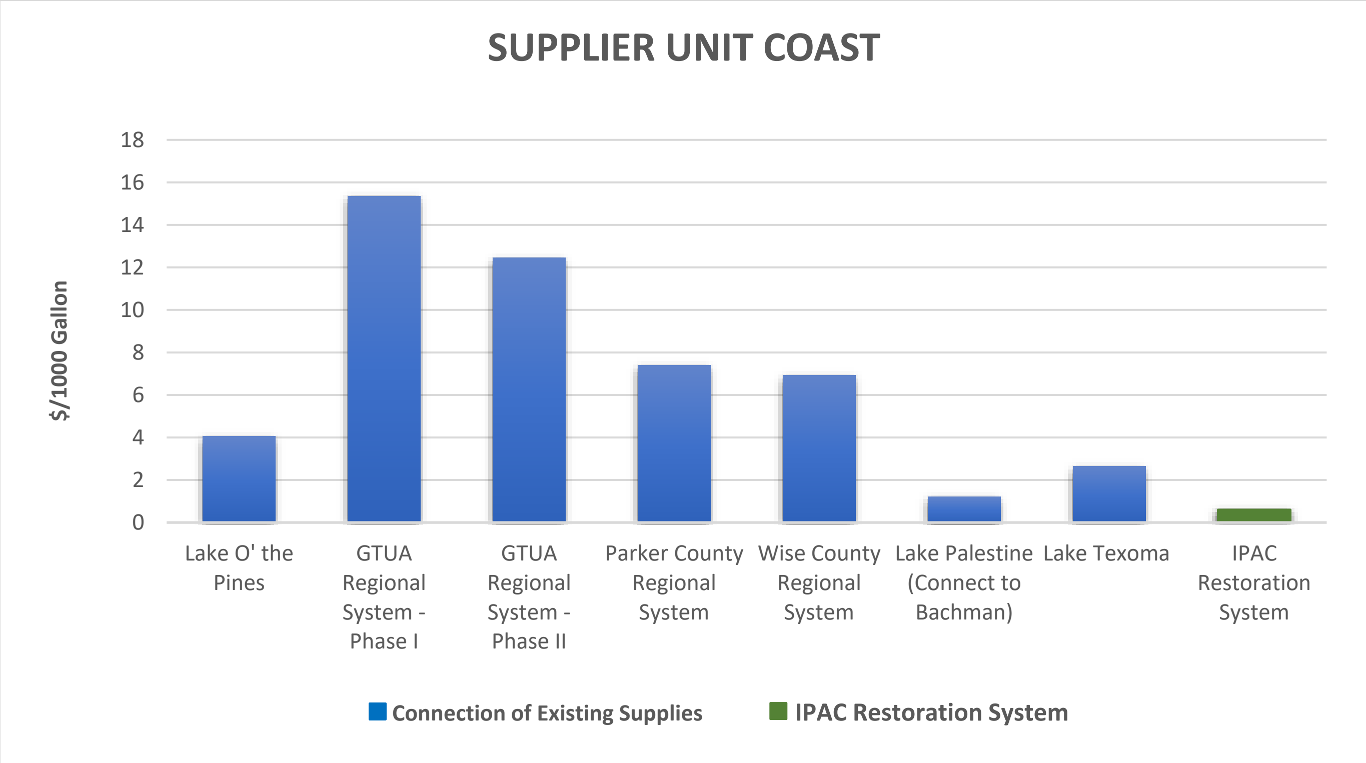


Figure 25 - Comparison of New Groundwater Strategies to IPAC Restoration System

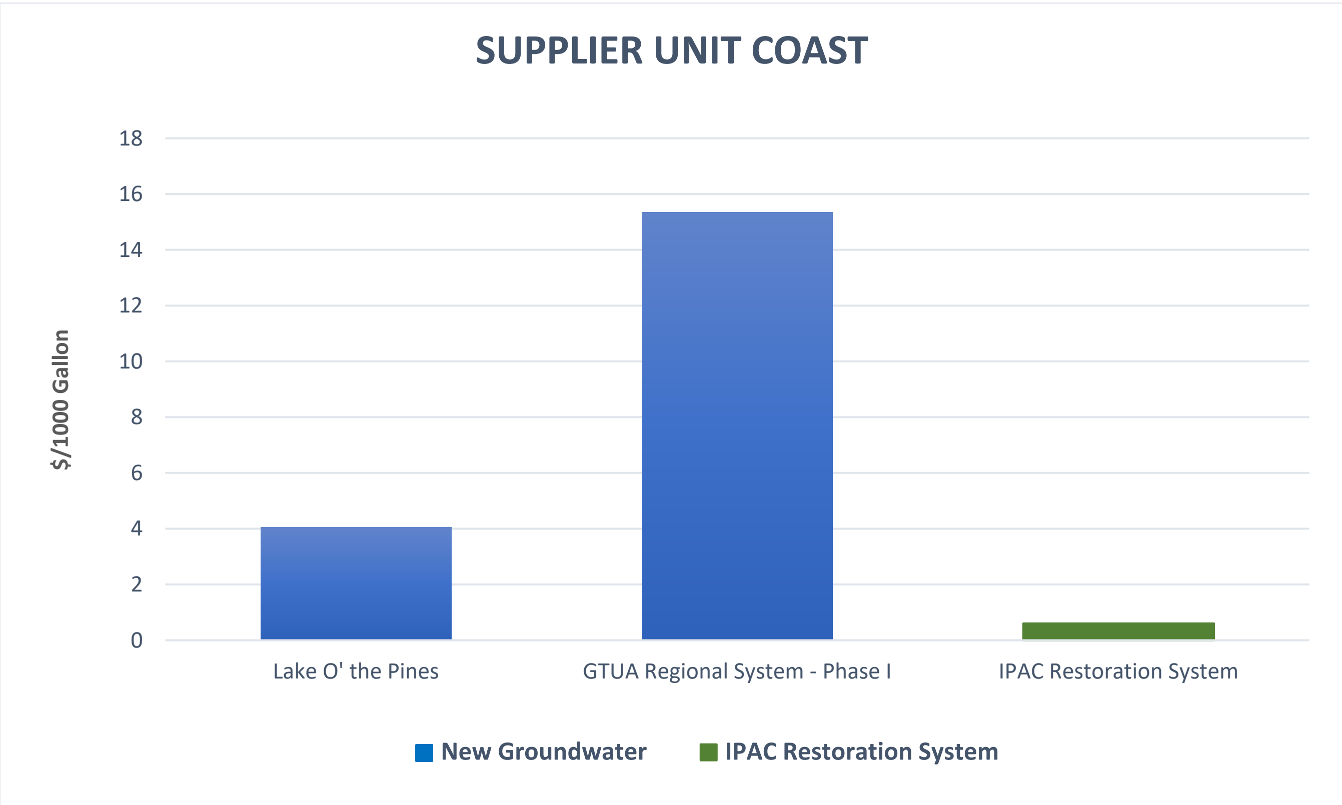
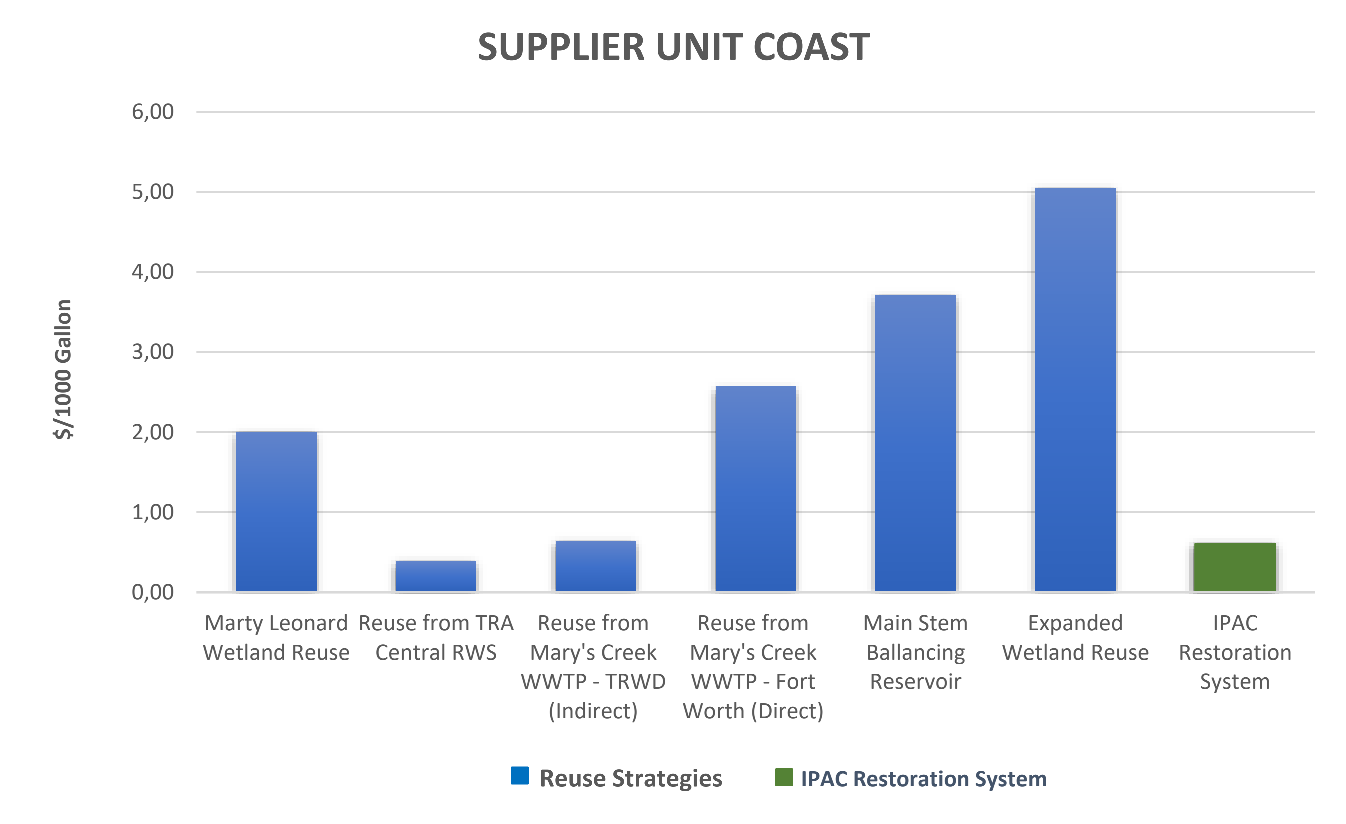


Figure 26 - Comparison of Reuse Strategies to IPAC Restoration System



7 STRATEGIES FOR ENGAGING LANDOWNERS

To gain the involvement of landowners in the regions of the West Fork Trinity River, Elm Fork Trinity River, and East Fork Trinity River for the proposed action projects, mechanisms can be created to incentivize soil and water conservation, in partnership with the Texas State Soil and Water Conservation Board (TSSWCB) Districts 5 and 3, through payment for environmental services for each action implemented on their property.

Payment for Ecosystem Services Programs is created in watersheds of strategic importance for a given

region and focus on reducing erosion, improving water quality, and increasing river flows. The beneficiaries are landowners who, through authorization for the implementation of conservation practices and soil management, the installation of mechanisms for accelerating water infiltration into the soil in recharge areas of the aquifer, as well as improving vegetation cover on their properties, thus contributing to the effective reduction of erosion and sedimentation and to the increase of water infiltration into the soil, according to the provider-receiver concept.

There are several ways to value environmental services, usually considering the positive impact caused by the executed action.

Funding for environmental service payments can be generated by adding a small percentage fee to consumers' water bills and establishing a dedicated fund to manage the collected resources. This fund would

compensate landowners who voluntarily participate in the program. Management could be overseen by representatives from water utilities, Soil and Water Conservation Districts, and the counties involved.
Another way to encourage landowners to consent to the actions for the recovery of natural resources on their properties is to establish priority in granting permits for water usage for irrigation of rural areas to those who join the proposed projects.
An incentive program can be established for urban property owners who implement rainwater infiltration measures on their properties. This program could offer property tax discounts, with specific mechanisms defined by local governments at the city and county levels.

To ensure the success of such initiatives, it is important to enact laws that support and regulate the proposed strategies.

8 CONCLUSION

Considering that:

a) The soil in several regions of Texas has low permeability.

b) The climatic conditions of Texas promote high evaporation rates from surface reservoirs.

c) Recent studies show that the large extraction of groundwater is causing an average subsidence of 4 mm per year in some cities in Texas (Dallas and Fort Worth).

d) Based on work carried out by the Institute for Environmental Protection and Conservation (IPAC), using appropriate methodology and the suggested measures implemented, it was possible to achieve an increase in Surface and Groundwater of at least 5% per year in the watershed worked.

e) The technology recommended for water production through the recharge of the water table is low-cost, presenting a very good cost-benefit ratio.

It is concluded that this proposal is an alternative that can be implemented to increase the availability of surface and groundwater.

McKinney-TX, June 05, 2025

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