INTEGRATED WATER SUPPLY PLAN UPDATE

Final Report

August 2025

Tarrant Regional Water District

INTEGRATED WATER SUPPLY PLAN UPDATE

Final Report

FINAL / August 2025

TBPE Firm No. 882

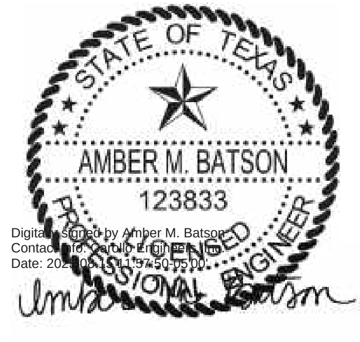
TBPE Firm No. 23074

TBPE Firm No. 2144

TBPE Firm No. 13214

Amber Batson
Carollo Engineers
10375 Richmond Avenue, Suite 1625
Houston, Texas 77042

Sealing: Development of Written Report; Cost estimates summarized in Chapter 6 and as presented in Appendix F for DPR, Conservation, Second RC Wetlands, ASR, Lake Ringgold, Arkansas Water.



Nick Mander
Hydros Consulting
1628 Walnut Street
Boulder, CO 80302

Sealing: RiverWare modeling as presented in Appendix A used in support of Chapters 5, 6, and 7.

Spencer Schnier
Rivulous
900 East Pecan Street, Suite 300-111
Pflugerville, TX 78660

Sealing: Safe yield estimates for Marvin Nichols and Wright Patman as presented in Chapter 6; Cost summarized in Chapter 6 and as presented in Appendix F for Marvin Nichols, Marvin Nichols with Wright Patman, and Wright Patman.

Lissa Gregg
Freese and Nichols
801 Cherry Street, Suite 2800
Fort Worth, Texas 76102

Sealing: Costing Tool as presented in Appendix B; Cost estimates summarized in Chapter 6 and as presented in Appendix F for Toledo Bend, Mainstem OCR, TRWD Developed Groundwater, Lake Palestine Purchase, Tehuacana, Parallel IPL, Parallel Eagle Mountain Connection.

Acknowledgements

Staff

Dan Buhman, P.E., General Manager
Rachel Ickert, P.E., Chief Engineering Officer
Jason Gehrig, P.E., Director of Infrastructure Engineering
Zach Huff, P.E., Director of Water Resources Engineering
Darrel Andrews, Director of Environmental Services (retired)
Jennifer Owens, Director of Environmental Services
Nicole Rutigliano, P.E., Water Supply Manager
Dustan Compton, Conservation Manager
Amy Kaarlela, P.H., Water Supply Planner
Vinicius de Oliveira, PhD, Water Resources Engineer

Board of Directors

Leah M. King, President
Paxton Motheral, Vice President
C.B. Team, Secretary
Skylar O'Neal, Member
Johnathan Killebrew, Member

Consultant Team

David Harkins, PhD, P.E., Principal in Charge
Amber Batson, P.E., Engineer of Record
Jessica Fritsche, Project Manager
John Rehring, P.E. (*not licensed in Texas)
Inge Wiersema, P.E., ENV SP (*not licensed in Texas)
Charlie He (*not licensed in Texas)
Eva Steinle-Darling, PhD, P.E.
Tony Smith, P.E.
Powell Hinson, P.E.
Julia Schmidt, P.E., ENV SP (*not licensed in Texas)
Warren Grecco
Wen Zhao, P.E. (*not licensed in Texas)

Spencer Schnier, P.E.
Angelica Huerta, EIT

Lissa Gregg, P.E.
Kristal Copp, P.E.

Nick Mander, P.E.
John Carron
John Craven, P.E.

A LETTER FROM OUR GENERAL MANAGER…

Tarrant Regional Water District has a long history of providing outstanding service to the public. Whether it's ensuring a reliable, sustainable water supply, vital flood protection or outstanding recreational opportunities, our goal is to enrich the lives of the people in the communities where we work, live and play. Proactive planning for our future is key to the District's continued success.

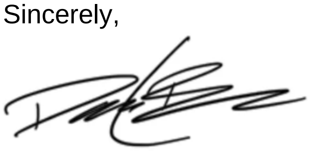
Beginning in the 1950s, the District has developed long range water supply plans that have been updated periodically. The most recent version was the 2014 Integrated Water Supply Plan (IWSP). This document is an update to that IWSP, allowing us to take a fresh look at how to best meet the needs of the District for the next 50 years and beyond. The IWSP allows the District to evaluate a wide range of water supply options, combined with potential new policies and management strategies to meet our long-term water supply needs.

In the following document you will find the results of countless hours of work to identify the best solutions for the District's future water supply. We have outlined a plan that will meet the goals and objectives of our District, including:

- Reliability – Ensuring that water supply is delivered to TRWD's customers whenever they need it.
- Implementation – Selecting the long-term water supply options that can be successfully built, integrated into our system, and operated.
- Affordability – Providing cost-effective solutions for TRWD's customers, looking both at today's costs and what the future may hold.
- Community Alignment – Developing water supply solutions that will be accepted by stakeholders and end users.

We are committed to the success of the communities we serve. This 50-year water supply strategy gives us a path forward to ensuring everyone enjoys the life-altering benefits of clean, reliable water.

Sincerely,



Dan Buhman, General Manager

trwd Tarrant Regional Water District

Contents

Appendices

Tables

Figures

Abbreviations

$M	million dollars
AF	acre-feet
AFY	acre-feet per year
ANRA	Angelina and Neches River Authority
ASR	Aquifer Storage and Recovery
AWPF	advanced water purification facility
BB2	Benbrook Booster Pump Station
BL	Baseline (water demand scenario)
Carollo	Carollo Engineers
CIP	capital improvement plan
Costing Tool	a modified version of the Unified Costing Model used in this report
cu ft	cubic foot
DPR	direct potable reuse
DWU	Dallas Water Utilities
EM2	Parallel Eagle Mountain Connection
ExFlo	Excess Flow (permits)
GCD	Groundwater Conservation District
gpcd	gallons per capita day
gpm	gallons per minute
hp	horsepower
IDC	interest during construction
Initially Prepared Plan	2026 Draft Region C Water Plan
IPL	integrated pipeline
IPL2	Parallel Integrated Pipeline
IWSP	Integrated Water Supply Plan
kgal	thousand gallons
kWh	kilowatt-hour
kWh/AF	kilowatt-hour per acre-foot
LMA	Land Management Assistance
LRWSP	Long Range Water Supply Plan
MAG	modeled available groundwater
Marketer	confidential water marketer
MCDA	multi-criteria decision analysis
MG	million gallons
mgd	million gallons per day
msl	mean sea level
N/A	Not Applicable

NPV	net present value
NTMWD	North Texas Municipal Water District
OCR	off-channel reservoir
O&M	operations and maintenance
PMF	probable maximum flood
RO	reverse osmosis
ROW	right-of-way
S3	Suburban Sprawl with Stressors (demand scenario)
SRA LA	Sabine River Authority in Louisiana
SRA	Sabine River Authority in Texas
SRBA	Sulphur River Basin Authority
Strategy	Water Management Strategy
TCEQ	Texas Commission on Environmental Quality
TCWSP	Tarrant County Water Supply Project
TRA	Trinity River Authority
TRWD	Tarrant Regional Water District
TWC	Texas Water Code
TWDB	Texas Water Development Board
UCM	Unified Costing Model
U.S.	United States
USACE	U.S. Army Corps of Engineers
UTRWD	Upper Trinity Regional Water District
VCWWTP	Village Creek Wastewater Treatment Plant
WAM	Water Availability Model
WMS	Water Management Strategy/Strategies
WSP	Water Supply Project
WTP	water treatment plant
Yield Update Report	2024 Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update

EXECUTIVE SUMMARY

ES.1 Introduction

Tarrant Regional Water District (TRWD) provides wholesale raw water supplies to an 11-county region in North Texas. TRWD is one of the largest raw water suppliers in Texas, providing water to over 2.5 million people, as well as providing irrigation, mining, and industrial water. Supply is delivered directly to 52 wholesale customers, including the cities of Arlington, Fort Worth, and Mansfield, and the Trinity River Authority (TRA), who then distribute treated water to approximately 70 cities. Beyond water supply, TRWD provides flood control, recreation opportunities, and environmental benefits to the region.

TRWD's mission is to deliver a reliable, resilient, and sustainable supply of water to the public at the lowest cost and highest quality possible.

TRWD's service area spans the upper portion of the Trinity River Basin. Average annual precipitation increases from west to east from about 34 to 40 inches per year. Surface water is the primary source of supply in the region and the only source utilized by TRWD. The upper Trinity River Basin hydrologic conditions vary significantly from year to year, and surface water supplies are subject to severe droughts.

Over the past 100 years, TRWD has emerged as an organization with the crucial role of supplying water to the growing communities in North Texas. In total, TRWD owns and operates four water supply reservoirs: Lake Bridgeport, Eagle Mountain Lake, Cedar Creek Reservoir, and Richland-Chambers Reservoir. Raw water is conveyed from Richland-Chambers and Cedar Creek to Tarrant County via more than 250 miles of pipelines. Additionally, TRWD utilizes Lake Arlington, Lake Benbrook, and Lake Worth for storage; has a reuse project in operation at Richland-Chambers Reservoir; and has another planned at Cedar Creek Reservoir. These projects and infrastructure have enhanced water security for the entire region and ensured water supply is available when and where it is needed to support the growing North Texas economy and population. TRWD's service area, water supply sources, and infrastructure are depicted in Figure ES.1.

In 2014, TRWD completed its first Integrated Water Supply Plan (IWSP), establishing a planning platform that has served TRWD well. The evaluation included the identification and assessment of more than a dozen new water supply options analyzed against a range of demand projections. At the conclusion, the report documented a recommended suite of near-term strategies for implementation. The following identified strategies from the 2014 IWSP are either complete or currently underway:

- In 2014, TRWD began the operation of the George W. Shannon Wetlands, also referred to as the Richland-Chambers Wetlands.
- TRWD has obtained Excess Flow (ExFlo) permits for Benbrook Lake, Eagle Mountain Lake, Richland-Chambers Reservoir, and Cedar Creek Reservoir. These ExFlo permits allow TRWD to divert additional water supply during periods when specific reservoirs are above the conservation pool, and excess flows are available.
- TRWD has made considerable progress on the construction of the Integrated Pipeline (IPL) in conjunction with Dallas Water Utilities (DWU). At full project build-out, the 150 miles of newly constructed pipeline will provide TRWD with an additional 200 million gallons per day (mgd) of conveyance capacity to move water from TRWD's East Texas reservoirs to the metroplex.
- The Marty Leonard Wetlands at Cedar Creek Reservoir (or Cedar Creek Wetlands), an additional reuse project similar to the Richland-Chambers Wetlands, has been permitted, and design is currently underway. The new wetlands project will have a capacity of 150 mgd and will be online around 2032.
- TRWD has actively led the region in water conservation for almost two decades through municipal customer support, education and public awareness campaigns, efficiency, and accurate accounting in TRWD operations, and offerings of classes, programs, and landscape efficiency initiatives.

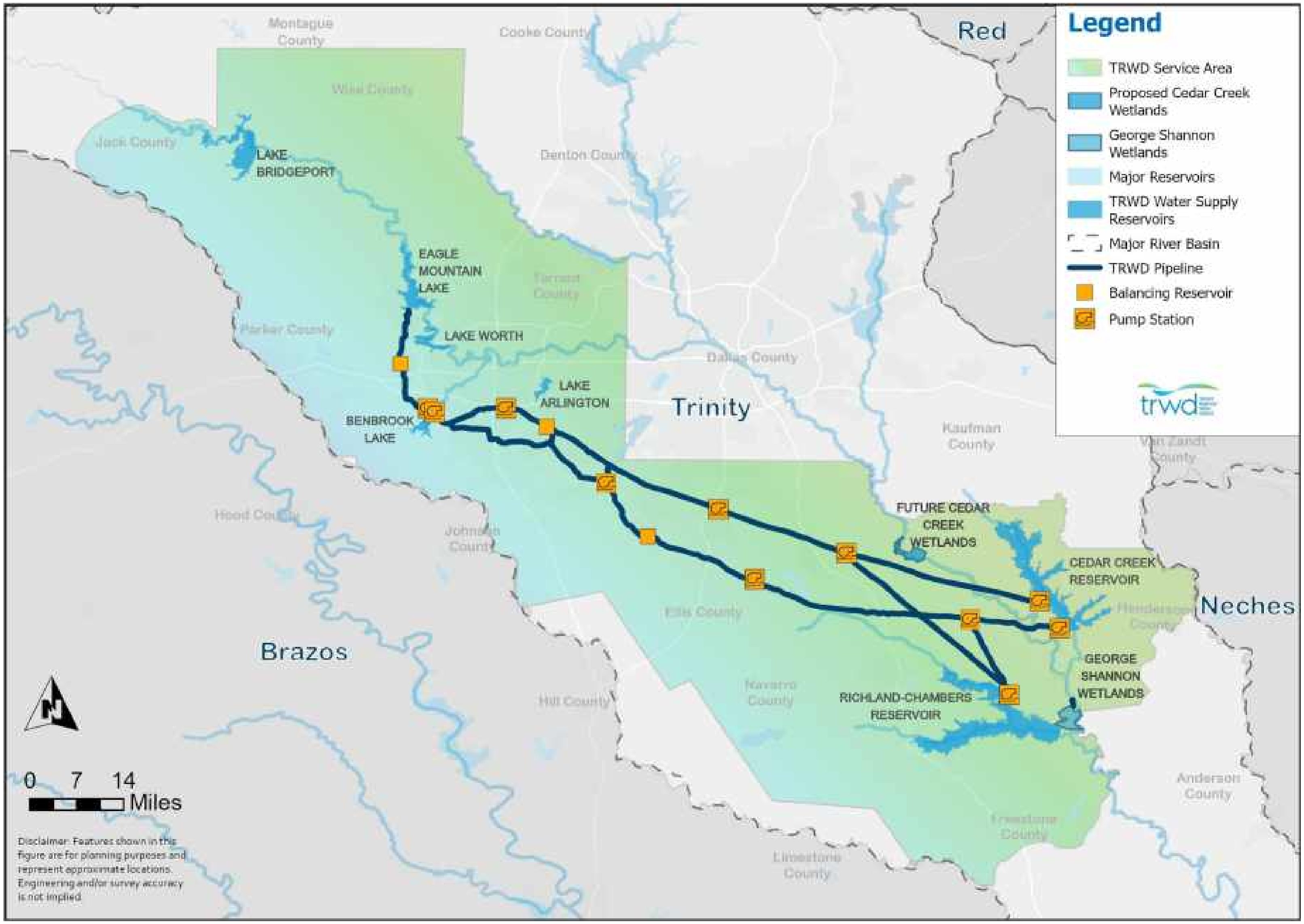
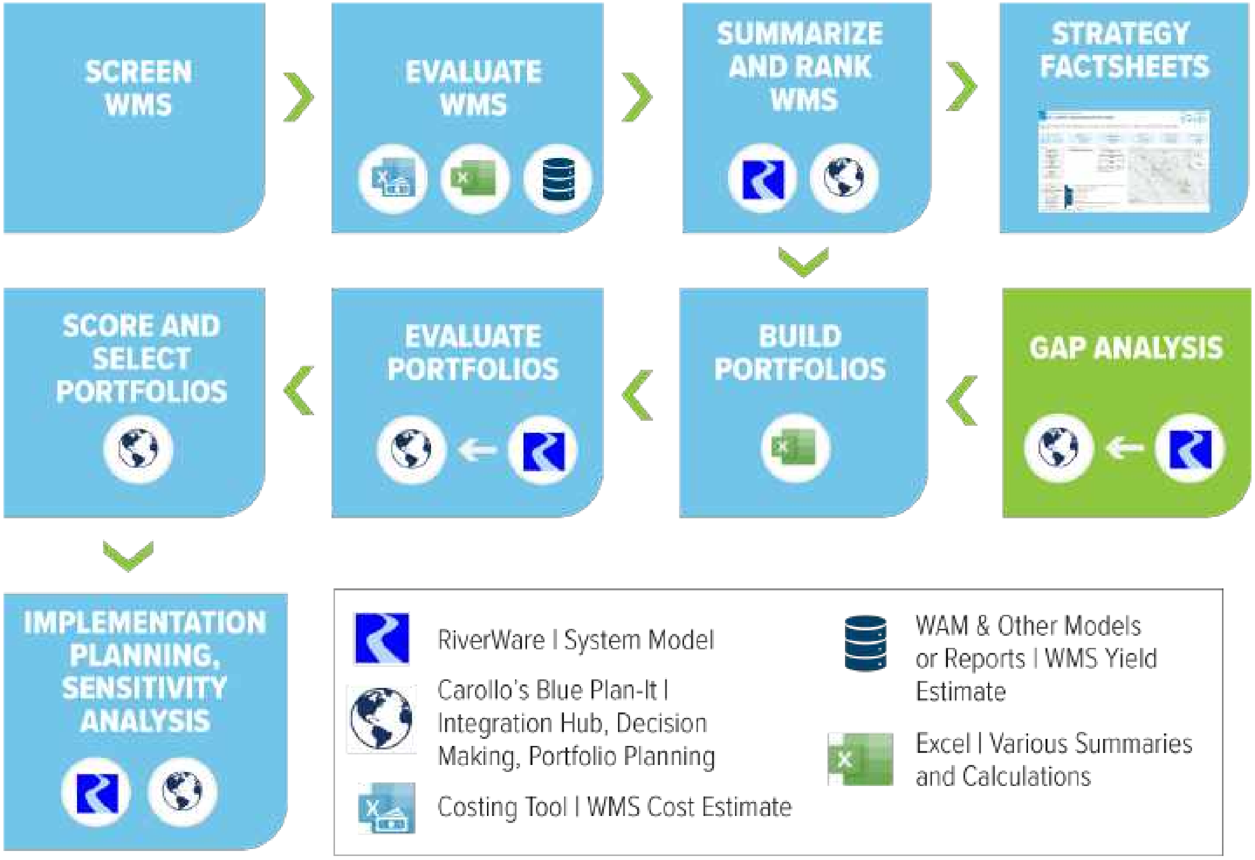


Figure ES.1 TRWD Baseline Water Supply System

ES.2 IWSP Update Approach

The work of planning for new supplies is an ongoing, continuous effort. Even with the recent expansions in supply and conveyance, as well as advancements in operations and efficiency, TRWD must continue to proactively develop additional supplies to meet future needs. Today's uncertainties are unmatched, with rapid population growth projected to continue and evolving technological, environmental, hydrological, and political conditions. TRWD has undertaken this IWSP Update to establish an updated roadmap for future supply development against this deep uncertainty while striving to meet multiple water supply objectives.

The IWSP Update looks holistically at TRWD's water supply system, comparing supply availability and conveyance capacity to projected water demands through 2080, and identifies future alternatives of combined water management strategies (WMS or strategies) to best meet objectives. The study employs a probabilistic modeling approach and explores TRWD's water supply reliability goals against affordability metrics. The primary modeling tools used to develop the IWSP include an adapted version of TRWD's existing RiverWare water supply model, a costing tool that reflects TRWD's recent bids for construction and financial assumptions, and a custom application of Carollo Engineers' (Carollo) Blue Plan-it for data integration and decision-making, as shown in Figure ES.2.



Notes: WMS = Water Management Strategy; WAM = Water Availability Model.

Figure ES.2 IWSP Update Key Components and Modeling Tools

For each simulated future year, the modeling framework was designed to generate 82 years of potential outcomes for each month based on hydrologic records from 1941 through 2022. The simulation includes historical hydrologic inflows, evaporation rate, and seasonal patterns superimposed against conditions for future demands at TRWD delivery nodes, supplies, permits, operational rules, reservoir conditions (e.g., reservoir evaporation and storage), and infrastructure limitations. This process is repeated in 10-year increments for a forecast horizon from 2030 to 2080.

The key components of the IWSP Update include:

- Identify and screen strategies available to TRWD, with detailed focus and analysis on selected strategies with the greatest potential to meet the projected gap in supply while balancing other objectives.
- Quantify the yield potential and cost-related information for each selected strategy and qualitatively score these strategies based on other key evaluation criteria.
- Using RiverWare, evaluate the existing and planned water supply system against projected growing demands, referred to as a gap analysis. Key outputs include system reliability statistics, quantification of the additional supply needed to meet growing demands, determination of when and where the supply is needed within the system, and identification of additional infrastructure needed for conveyance.
- Identify and present selected portfolios that best meet objectives, including implementation plans, sensitivity analysis, and adaptive planning triggers.

Reliability Goals and Supply Objectives

With Carollo's guidance, TRWD established this minimum threshold for reliability for the IWSP Update: a gap exists if more than 5 percent of system demands cannot be met during a repeat of the critical year of the historical drought of record (1956). The target, thus, is meeting 95 percent of demands or more during the critical drought year. This threshold guided the development of portfolios and was used to calculate the timing of when additional strategies must be implemented and how much water supply strategies must deliver. Per TRWD's Drought Contingency Plan, Stage 3 reservoir storage conditions correspond to restrictions that, when implemented by all customers, would result in approximately a 20 percent demand curtailment.[1] Thus, the 95 percent minimum reliability threshold represents a balance between water use reduction actions by consumers under extreme conditions and the high cost of meeting 100 percent demand during these extreme conditions.

Portfolios are evaluated against water supply objectives to ensure supply reliability, select implementable projects, maintain affordability, and align solutions with the community. Each objective has quantitative metrics associated with it to determine the relative performance of the portfolio for each objective (Table ES.1).

Table ES.1 Water Supply Objectives

Objective	Description
Reliability	Ensuring that the water supply is delivered to TRWD's customers when and where they need it.
Implementation	Selecting the long-term water supply options that can be successfully built and operated.
Affordability	Providing cost-effective solutions for TRWD's customers, examining today's costs and what the future may hold.
Community Alignment	Developing water supply solutions that will be accepted by stakeholders and end users.

[1] TRWD Water Conservation and Drought Plan 2024

ES.3 Incorporated Studies

As follows, the IWSP Update builds upon analysis conducted by TRWD over the past several years to update, set direction for, and/or refine estimates around specific components of water supply planning.

TRWD Service Area Demand Update. Historically, TRWD's demands rapidly increased year-over-year alongside population growth. In the mid-2000s, TRWD launched its conservation program, marking a critical step towards demand management, which was followed by State led efforts to improve the efficiency of plumbing fixtures, and regional irrigation restrictions allowing lawn watering no more than two days per week. Weather aside, water demands held steady throughout much of the period between 2008 and 2018, underscoring the combined impact of conservation efforts, efficiency standards, and drought-induced behavioral changes. To better plan, TRWD completed a detailed study of water demand in 2020, developing projections for five scenarios covering variations in growth, climate, and conservation. The highest scenario, referred to as the Suburban Sprawl with Stressors (S3), is the basis of the IWSP Update.

Since the conclusion of the demand study, the COVID-19 pandemic occurred and growth accelerated in the region. In 2022, after a very hot summer, TRWD recorded its highest demand to date, with annual deliveries reaching 428,600 acre-feet (AF). The demand record was surpassed the next year when TRWD's demands were 438,700 AF. In 2024, with weather closer to average, demands totaled 418,000 af. These recent trends indicate that TRWD's water demands are tracking along the highest scenario from the demand study but have significant range in variability due to weather.

IWSP Update Strategy Report. In 2020, TRWD commissioned an evaluation of changed conditions since the 2014 IWSP and identified activities needed to update the IWSP. The recommended tasks were comprehensive and covered hydrologic updates, exploring regional collaboration opportunities, refining strategies, prioritizing transmission system planning, and modeling considerations.

Hydrologic Risk Review. TRWD conducted a study (2022) to explore the prospect that more water may be permitted than would be available for withdrawal if future droughts are more severe than the 1950s recorded historical drought. The analysis focused on paleoclimate insights into past North Texas climate and droughts, future climate risk and uncertainty, modeling and planning guidelines, and best practices. Study methods included a literature review and expert panel discussions. The study highlighted the uncertainty around future climate, and the importance of maintaining safety factors to buffers against future drought and development of solutions that add resilience to the system.

Strategy Studies. In recent years, TRWD has sponsored or partnered on several feasibility-level studies analyzing cost and/or supply for certain strategies, such as Lake Ringgold, groundwater, and Marvin Nichols Reservoir and Lake Wright Patman. TRWD has several ongoing studies, including analysis to optimize system operations and investigate permitting additional return flows (referred to as "SyOps"), and a Regional Optimization Study with other North Texas water suppliers. TRWD is also in the process of implementing an Aquifer Storage and Recovery project and an additional reuse wetlands project.

Region C Plan. The Region C Water Planning Group is responsible for developing a comprehensive water supply plan to ensure sustainable and reliable water resources for the region's growing population. This planning effort, mandated by the Texas Water Development Board (TWDB), evaluates current and future water demands, identifies potential shortages, and proposes strategies such as conservation, infrastructure development, and alternative water sources. TRWD continues to play a crucial role in Region C Planning, and since this IWSP Update is more detailed and comprehensive, it will serve as valuable input for Region C. For some strategies and where noted, Region C planning information was utilized to develop the IWSP strategy evaluation.

ES.4 Water System, Supplies, and Demands

Key characteristics and elements of TRWD's baseline water supply system include the service area extent, water right holdings, water supply reservoirs, and infrastructure to move water from the reservoirs to the customer delivery points, as well as the yield of the reservoirs. Each of these characteristics and elements are foundational to determining the future water supply gaps and needs. The baseline system definition includes current and near-term planned water supply and conveyance elements.

TRWD service area includes all or part of Tarrant, Ellis, Navarro, Wise, Denton, Freestone, Henderson, Jack, Johnson, Kaufman, and Parker Counties. Water supply is captured in TRWD's water supply reservoirs and delivered to 95 customer take points along reservoirs and TRWD's pipelines.

ES.4.1 Supplies

TRWD's existing water rights are all within the Trinity River Basin, and annual water rights total just over 810,000 AF. About 71 percent of the water rights are in the East Texas reservoirs. In addition, TRWD administers some water rights held by others, including Lakes Arlington and Worth. Specific components of the TRWD water supply system include:

- TRWD East Texas water supply reservoirs.
  - Cedar Creek Reservoir.
  - Richland-Chambers Reservoir.
- TRWD West Fork water supply reservoirs.
  - Lake Bridgeport.
  - Eagle Mountain Lake.
- Terminal storage reservoirs utilized but not owned by TRWD.
  - Lake Arlington (provides some additional yield).
  - Benbrook Lake (provides some additional yield).
  - Lake Worth.
- Permitted return flow reuse projects.
  - George W. Shannon Wetlands, also referred to as the Richland-Chambers Wetlands.
  - Marty Leonard Wetlands, also referred to as the Cedar Creek Wetlands (to be constructed in the future but assumed to be part of the baseline TRWD supply system).
- ExFlo permits.
  - Benbrook Lake.
  - Eagle Mountain Lake.
  - Richland-Chambers Reservoir.
  - Cedar Creek Reservoir.
- Other sources.
  - Bed and banks authorizations.
  - Minor permits.

While TRWD's annual water rights exceed 800,000 AF, a water right is not a guarantee of available supply. Hydrologic conditions vary significantly from year to year in North Texas. Wet years bring excess water and flooding, while drought years put pressure on water supplies. Reservoir yield typically refers to the quantity of water from a reservoir projected to be available reliably during a critically dry period. Firm yield, specifically, is the maximum amount of water that can reliably be supplied during a repeat of the drought of record, regardless of how much water is permitted. Safe yield is the maximum amount of water that can be reliably supplied during a repeat of the drought of record, while retaining a minimum supply in reserve. For TRWD, the minimum reserved supply is enough to meet demand for 1 year. Region C provides firm and safe yield supply estimates for TRWD's major water supply reservoirs, as summarized in Table ES.2. Generally, the firm yield estimates reflect modeled sedimentation impacts that have likely occurred since reservoir construction and the continuation of that trend. TRWD's total firm yield is currently estimated at approximately 665,000 acre-feet per year (AFY). With the addition and anticipated buildout of Cedar Creek Wetlands, and including sedimentation impacts, the firm yield is projected to increase to just under 739,000 AF by 2080. Safe yield is estimated at just under 555,000 AFY, increasing to almost 625,000 AF by 2080.

Table ES.2 Firm and Safe Yield of Reservoirs in AFY

	2030	2040	2050	2060	2070	2080
Firm Yield						
Richland Chambers Reservoir	224,650	223,205	221,760	220,357	218,953	217,550
Richland Chambers Wetlands	100,465	100,465	100,465	100,465	100,465	100,465
Cedar Creek Reservoir	207,350	206,105	204,860	203,640	202,420	201,200
Cedar Creek Wetlands(1)	0	40,856	58,273	74,191	90,974	90,974
West Fork System	118,961	118,361	117,761	117,078	116,394	115,711
Benbrook Lake	4,271	4,271	4,271	4,271	4,271	4,271
Lake Arlington	9,500	9,350	9,200	9,067	8,933	8,800
Total Firm Yield	**665,197**	**702,613**	**716,590**	**729,069**	**742,410**	**738,971**
Safe Yield						
Richland Chambers Reservoir	190,000	188,266	186,531	184,781	183,030	181,280
Richland Chambers Wetlands	100,465	100,465	100,465	100,465	100,465	100,465
Cedar Creek Reservoir	157,150	155,340	153,530	151,797	150,063	148,330
Cedar Creek Wetlands(1)	0	40,856	58,273	74,191	90,974	90,974
West Fork System	96,161	95,561	94,961	94,428	93,894	93,361
Benbrook Lake	3,371	3,371	3,371	3,371	3,371	3,371
Lake Arlington	7,500	7,385	7,270	7,157	7,043	6,930
Total Safe Yield	**554,647**	**591,244**	**604,401**	**616,190**	**628,840**	**624,711**
90% Safe Yield	**499,182**	**532,120**	**543,961**	**554,571**	**565,956**	**562,240**

Notes:
Source: 2026 Region C Initially Prepared Plan, Volume II. Available at https://regioncwater.org/wp-content/uploads/2025/03/2026_Region_C_Initially_Prepared_Plan_Volume_II.pdf.
(1) The yield at Cedar Creek Wetlands ramps up over time to the full permitted value based on projected available return flows.

ES.4.2 Transmission System

The baseline TRWD water supply system also includes pumping and transmission facilities, including the "legacy pipelines" from Cedar Creek and Richland-Chambers Reservoirs and the IPL. The IPL is an intrasystem conveyance project constructed in partnership with DWU that increases capacity from the existing East Texas reservoirs. All portions of the IPL are anticipated to be complete around 2037. Additional pipelines include the Eagle Mountain Connection between Benbrook Lake, Eagle Mountain Lake, and Fort Worth's Westside WTP; and a pipeline from Benbrook Lake to Rolling Hills WTP.

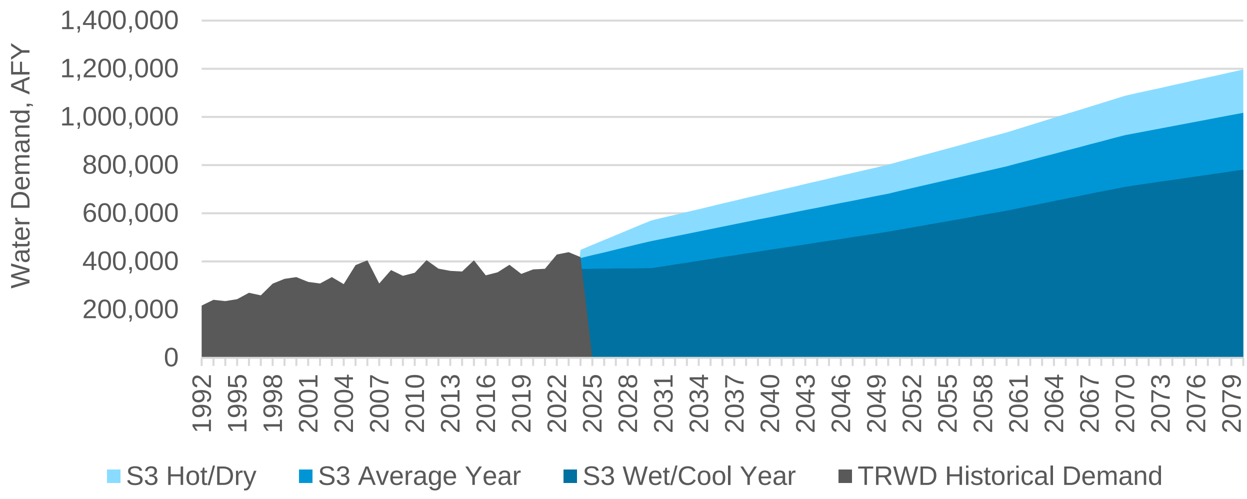
TRWD's system also includes three balancing reservoirs: Eagle Mountain Balancing Reservoir, Kennedale Balancing Reservoir, and Midlothian Balancing Reservoir. The balancing reservoirs do not provide a source of supply but rather facilitate transmission operations. Additionally, the baseline system includes 14 pump stations ranging in capacity from 120 to 350 mgd.

ES.4.3 Water Demand Projections

TRWD service area annual deliveries grew from 217,000 AF in 1992 to 418,000 AF in 2024, as shown in Figure ES.3. While demand fluctuates annually, on average demand grew by about 2 percent per year across the 32-year period. In 2022, after a very hot summer, TRWD recorded its highest demand to date, with annual deliveries reaching 428,600 AF. The demand record was surpassed the next year when TRWD's demands were 438,700 AF. In 2024, with weather closer to average, demands totaled 418,000 AF. Rapid growth in water demand occurred between 1992 and 2008, coinciding with an average year-over-year population increase of 43,000 people per year over the 16-year period.[2] Annual population growth slowed to an average increase of 25,000 people per year from 2008 to 2018. However, since 2018 population has increased to an average growth of 58,000 people per year, and since 2020 has increased by 65,000 per year. TRWD's conservation program combined with the U.S. Energy Policy Act of 1992 and the 2010 Texas Plumbing Fixtures Act contributed to lower per capita water use due to a combination of behavioral changes and plumbing fixture efficiency changes.

Demand assumptions were adopted from TRWD's 2020 Demand Study, with a few minor modifications to account for areas that have grown quicker than projected, adding a new user group in Wise County, and linearly extending to 2080. That study projected several scenarios of potential future water demands. The selection of a demand scenario for comparison of supplies affects the timing of strategy implementation for the IWSP Update. The "S3" scenario, the most aggressive growth scenario, was selected as TRWD's demands have tracked close to this projection line and it offers a conservative but realistic perspective on future needs. The S3 forecast assumes that future climate, demographic growth, and low-density development impact demand, with moderate adaptation assumed from water conservation.

Given the S3 growth conditions and other assumptions on climate and conservation, the 2080 range of water demand is between 781,000 and 1,200,000 AFY, representing demand growth of up to 750,000 AFY beyond the historical high demand of 438,700 AF (Figure ES.3). The projected growth is an increase of 175 percent during dry conditions over the next 50 years and represents continued population and economic growth across TRWD's 11-county service area.



Notes: S3 = Suburban Sprawl with Stressors demand scenario.

Figure ES.3 TRWD Historical Water Demand and Future Projections

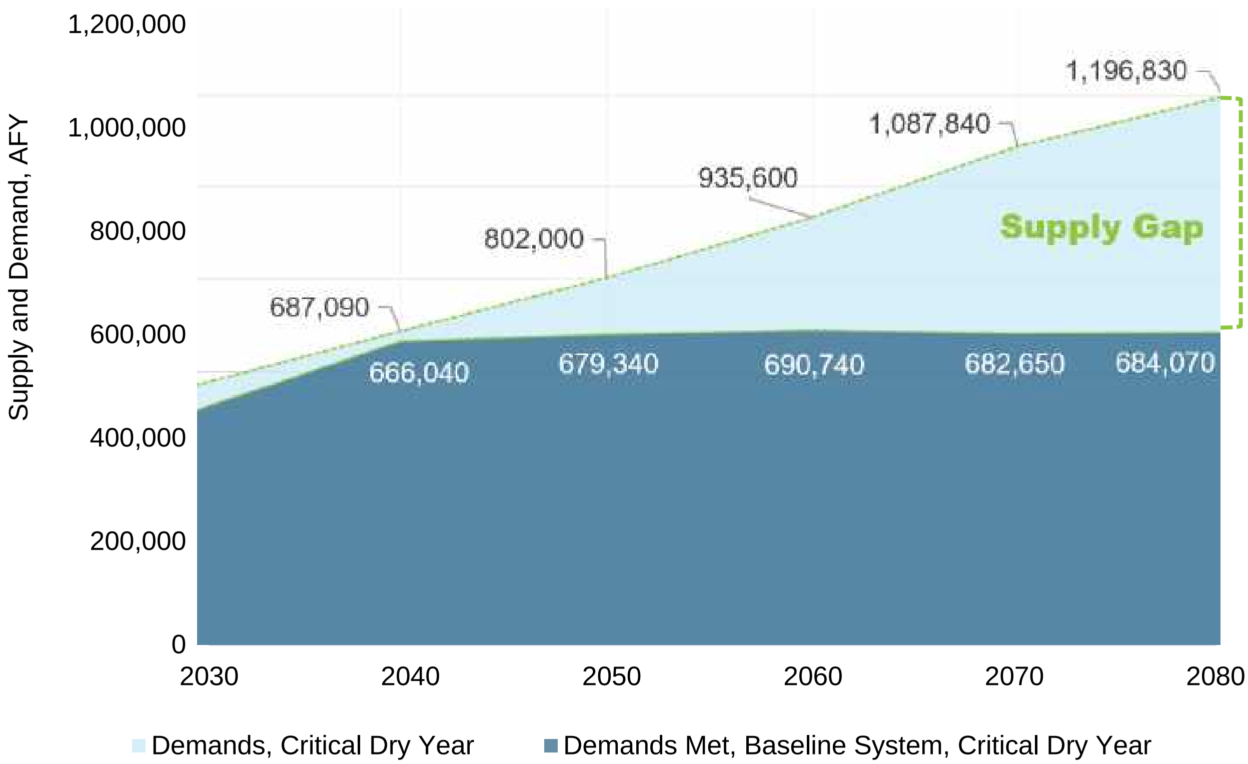
[2] TRWD. 2020. TRWD Service Area Demand Update: Water Demand Forecast Report. Prepared by CDM Smith.

ES.5 Needs Assessment

The TRWD RiverWare model was used to analyze future water supply system reliability with the projected demands and to quantify supply gaps, or shortages, without new water supply strategies and infrastructure beyond the near-term planned projects. Gaps are presented as the maximum volume of supply shortage that occurs during a repeat of the drought of record when demands are high due to hot and dry conditions, and supplies are lowest due to reduced surface water flows. The drought of record for TRWD water supply reservoirs occurred between 1949 and 1956. The critical drought year with the highest total system gap occurs at the end of that drought period in 1956.

The quantity of demand that can be met by the baseline water supply system varies over time. The demand that can be met is a function of assumptions around permit constraints, reservoir inflows, reservoir sedimentation, conveyance and pumping capacity, and operational rules and policies. The demand that can be met is further a function of where the demands are located within the system and the monthly peaking of demands. Given the future conditions assumed in the modeling, the critical dry year supply gap begins to increase starting in 2040 and continues along that trend through 2080, as shown in Figure ES.4. The gap magnitude is the difference between the system demand and met demand. The supply gap is just over 120,000 AF in 2050 and reaches 513,000 AF by 2080.

The modeling shows that a water supply shortage of 7 percent could occur in 2030 under critically dry conditions. This shortage could be mitigated by enacting TRWD's drought contingency plan, through operational changes, or acceleration of planned projects.



Notes: Calculated based on the critical year of the drought of record (1956) from the S3 demand scenario. The increase in demands met from 2030 to 2040 reflects the planned completion of the Cedar Creek Wetlands and the IPL. Results generated from RiverWare.

Figure ES.4 TRWD Critical Dry Year Supply Gap from RiverWare Analysis

ES.6 Water Management Strategy Options

Strategies are discreet, independent water supply options. Through workshops with TRWD staff and their customer stakeholders, more than 70 potential strategies were identified as an option for TRWD development. Some of these strategies have been previously identified, studied, and/or conceptualized. Others were entirely new and surfaced via brainstorming and through a review of innovative ideas across the world. Initial screening was conducted qualitatively through discussions with TRWD staff, management, and regional stakeholders to identify those most viable. Eighteen strategies plus two intrasystem, infrastructure-only projects were selected and carried forward for evaluation, as shown in Figure ES.5.

The strategies become the building blocks of meeting water supply objectives. No one strategy can meet the supply gap, so combinations of strategies must be considered. The strategies are described in terms of location, yield, cost, partnership opportunities, phasing potential, and implementation timing. Three strategies were identified as "No Regrets," indicating they are low risk, high value options that offer system flexibility and adaptability over time.

While these 18 strategies are evaluated as discreet options, many variations in the configuration of the strategies are possible. As an example, Toledo Bend was assumed at half the available yield with one partner. In reality, if infrastructure to convey Toledo Bend water to TRWD's service area was constructed, the amount of supply secured may go up or down and there may be one partner or several. Additionally, there are other strategies that did not move forward but may be worth future evaluation and monitoring, including (but not limited to) brackish groundwater, regional agreements for water sharing, negotiations or purchasing for more reuse supply, or other out of state options.

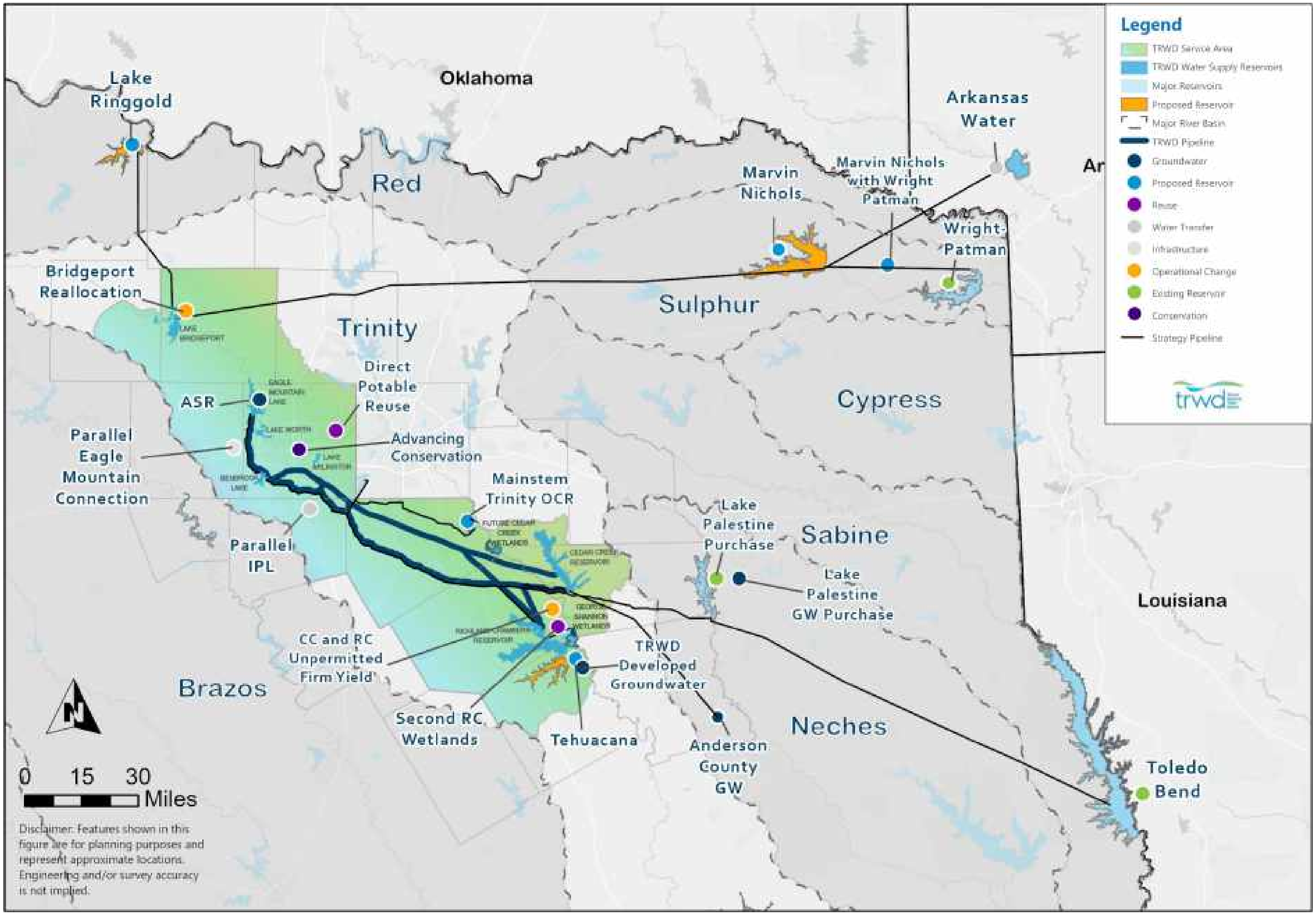


Figure ES.5 TRWD Water Management Strategy Locations

Advancing Conservation: The Advancing Conservation strategy involves developing and implementing a robust, cost-effective regional water conservation program in coordination with customer cities to offer direct-to-customer rebates, utility cost-share measures, expanded education, and assistance in passing key ordinances, all aimed at reducing demand, and improving efficiency. This strategy does not create a new water supply but rather stretches existing water supplies and infrastructure capacity further into the future. It scores high in the water supply objective criteria. The strategy is flexible and can be phased.

- Firm Yield: 90,500 AFY savings in an average year by 2080 (in addition to savings from current conservation efforts).
- Unit Cost after Debt Service: $750/acre-foot (AF) (assumed to be funded through annual budgets).
- Implementation Timeline: Ongoing through 2080.
- Identified as a No Regrets strategy.

Direct Potable Reuse (DPR): This strategy involves constructing an advanced water purification facility (AWPF) to treat a portion of the tertiary-treated flow from the Village Creek Water Reclamation Facility. The purified recycled water would augment the raw water supply sources of TRA's Tarrant County Water Supply Project (WSP). The treatment at the AWPF can be based on either reverse osmosis (RO) or a carbon-based treatment train. The cost estimate is based on the carbon treatment train because it does not create an RO brine that requires handling and disposal. Partnerships between TRWD, TRA, and the City of Fort Worth would be required. This strategy enhances water efficiency, optimizes local supplies, and reduces pumping needs from TRWD's East Texas reservoirs to the Fort Worth metroplex.

- Firm Yield: 20,500 AFY.
- Capital Cost: $394.6 million.
- Unit Cost with Debt Service: $1,917 per AF.
- Implementation Timeline: 18 years.

Second Richland-Chambers Wetlands: This strategy involves creating a second wetlands similar to the existing Richland-Chambers Wetlands to treat return flow in excess of TRWD's currently permitted reuse. The wetlands could be sourced through purchase of supply from a regional partner, new reuse opportunities from interbasin transfers, negotiation on the Lake Livingston agreement, or a System Operations permit. The strategy assumes a second IPL would be needed to transmit the supply from Richland-Chambers Reservoir to Benbrook Lake. Richland-Chambers Reservoir is estimated to be able to assimilate 90 mgd of additional reuse supply, so the wetlands would be sized at approximately 2,000 acres.

- Firm Yield: 100,890 AFY.
- Capital Cost: $1,545 million.
- Unit Cost with Debt Service: $1,143 per AF.
- Implementation Timeline: 20 years.

Cedar Creek and Richland-Chambers Unpermitted Firm Yield: This strategy focuses on obtaining a permit for the additional yield associated with the firm yield of the Cedar Creek and Richland-Chambers Reservoirs. This additional permitted supply would be available to TRWD during periods of drought. It assumes that a second IPL will be needed to transmit the additional supply to Benbrook Lake. The strategy yield would not be used during normal operations but rather only during extreme drought.

- Firm Yield: 21,920 AFY.
- Capital Cost: $252.3 million.
- Unit Cost with Debt Service: $864 per AF.
- Implementation Timeline: 3 years for permitting, additional time required for second IPL.
- Identified as a No Regrets strategy.

Bridgeport Reallocation: This strategy reallocates additional Lake Bridgeport supplies currently only permitted as releases to Eagle Mountain Lake to meet the demands of users at Lake Bridgeport. This strategy does not create new supplies and represents an operational change only. When implemented, it would be paired with other strategies that bring new supply to Eagle Mountain Lake.

- Firm Yield: 0 AFY.
- Capital Cost: $0.25 million.
- Unit Cost with Debt Service: $0 per AF.
- Implementation Timeline: 3 years.
- Identified as a *No Regrets* strategy.

Aquifer Storage and Recovery (ASR): ASR involves storing water in an underground aquifer and later recovering it for beneficial use. This conceptual strategy is evaluated to better understand the potential for ASR to improve system reliability. The strategy includes a 10 mgd conceptual ASR project around Eagle Mountain Lake using ExFlo water supply as the source of water to be injected and stored underground. ASR wells could be implemented over time for phased capacity.

- Firm Yield: 11,209 AFY.
- Capital Cost: $285.4 million.
- Unit Cost with Debt Service: $1,313 per AF.
- Implementation Timeline: 11 years.

TRWD Developed Groundwater: This strategy involves developing groundwater wells on land owned by TRWD in Freestone County. Water would be pumped to Richland-Chambers Reservoir. The strategy assumes that a second IPL will be needed to transmit the supply from Richland-Chambers to Benbrook Lake. Partnerships are not required for this strategy. TRWD Developed Groundwater project implementation could be phased.

- Firm Yield: 7,000 AFY.
- Capital Cost: $151.7 million.
- Unit Cost with Debt Service: $1,585 per AF.
- Implementation Timeline: 10 years, additional time required for second IPL.

Lake Palestine Groundwater Purchase: This strategy includes purchasing groundwater in Henderson County from a water marketer with a point of transfer in Lake Palestine. To convey the supply, this strategy assumes that DWU would be willing to allow TRWD to utilize a portion of DWU's IPL between Lake Palestine and the existing IPL for a fee. The strategy also assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake. Partnership would be needed with DWU for use of the IPL from Lake Palestine to Cedar Creek Reservoir. Lake Palestine Groundwater Purchase project implementation could be phased.

- Firm Yield: 15,000 AFY.
- Capital Cost: $286 million.
- Unit Cost with Debt Service: $1,917 per AF.
- Implementation Timeline: 10 years, additional time required for second IPL.

Anderson County Groundwater: The Anderson County Groundwater Strategy involves purchasing groundwater from a holding in Anderson County and conveying the supply to the IPL at Cedar Creek via a pipeline. This supply falls within the Neches and Trinity Valley Groundwater Conservation District. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake. Anderson County Groundwater does not require, but could involve, a partnership. This project is unlikely to be phased.

- Firm Yield: 42,000 AFY.
- Capital Cost: $1,324 million.
- Unit Cost with Debt Service: $2,359 per AF.
- Implementation Timeline: 10 years, additional time required for second IPL.

Lake Palestine Purchase: TRWD would purchase unused surface water from one or more entities with contracts for Lake Palestine supply. To convey the supply, this strategy assumes that DWU would be willing to allow TRWD to utilize a portion of DWU's IPL between Lake Palestine and Cedar Creek for a fee. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake. Partnership would be required with a willing contract holder such as DWU or City of Tyler for negotiation of the purchase or lease of 30,000 AFY from Lake Palestine. The amount of water purchased from a partner at Lake Palestine could be phased.

- Firm Yield: 30,000 AFY.
- Capital Cost: $572.1 million.
- Unit Cost with Debt Service: $1,507 per AF.
- Implementation Timeline: 9 years, additional time required for second IPL.

Toledo Bend: The Toledo Bend Strategy involves conveying available supplies from Toledo Bend, an existing reservoir in the Sabine River Basin, to TRWD's service area. This strategy assumes that TRWD and one regional partner would purchase and convey half of SRA's available supply, 480,000 AF. The infrastructure was assumed to be phased with dual pipelines. The strategy assumes that a second IPL will be needed to transmit the supply to Benbrook Lake. A partnership is assumed with one regional partner which could include NTMWD, DWU, or others. The construction of one pipeline and then the other would support phasing for the Toledo Bend strategy.

- Firm Yield: 240,000 AFY.
- Capital Cost: $7,278.6 million.
- Unit Cost with Debt Service: $2,268 per AF.
- Implementation Timeline: 18 years.

Wright Patman Reallocation: This strategy includes reallocating from flood storage to water supply in Wright Patman Lake. Six sponsors, including TRWD, are involved in this joint regional strategy. Reallocation at Wright Patman Lake is a change in the use of storage in an existing reservoir project from its present use as flood control to municipal and industrial use and includes a pool raise. Water from Wright Patman Lake would be conveyed to Lake Bridgeport and then released for downstream TRWD customers. Phasing is not considered viable for this strategy.

- Firm Yield: 65,067 AFY.
- Capital Cost: $2,456 million.
- Unit Cost with Debt Service: $2,545 per AF.
- Implementation Timeline: 22 years.

Marvin Nichols: Marvin Nichols Reservoir is a proposed water supply reservoir in the Sulphur River Basin. Total firm yield available to TRWD is estimated at 110,237 AFY, which assumes TRWD's portion of the total firm yield at 25.76 percent. This strategy includes regional partnerships with NTMWD, DWU, UTRWD, Irving, and a local partnership with SRBA. Phasing is assumed to be infeasible for a new reservoir project.

- Firm Yield: 110,237 AFY.
- Capital Cost: $3,062 million.
- Unit Cost with Debt Service: $1,907 per AF.
- Implementation Timeline: 30 years.

Marvin Nichols with Wright Patman: This strategy pairs construction of Marvin Nichols with reallocation of and supply from Wright Patman Lake. This joint, regional strategy, includes six sponsors, including TRWD. Water from Marvin Nichols and Wright Patman would be conveyed to Lake Bridgeport and then released for downstream TRWD customers. Although a new reservoir cannot be phased, the construction of a second pipeline to Wright Patman could allow for phasing.

- Firm Yield: 141,800 AFY.
- Capital Cost: $4,796 million.
- Unit Cost with Debt Service: $2,262 per AF.
- Implementation Timeline: 30 years.

Lake Ringgold: Lake Ringgold, a new reservoir on the Little Wichita River, would be constructed and supply conveyed to TRWD's system. TRWD would likely need to procure the full supply for the strategy to have a meaningful and worthwhile impact on TRWD's system yield. This strategy does not assume partnerships, although a partnership with the City of Wichita Falls could be considered. Phasing is assumed to be infeasible for any new reservoir project.

- Firm Yield: 28,000 AFY.
- Capital Cost: $1,037.8 million.
- Unit Cost with Debt Service: $2,497 per AF.
- Implementation Timeline: 25 years.

Tehuacana: Tehuacana involves the construction of a new reservoir on Tehuacana Creek, a tributary to the Trinity River in Freestone County. Tehuacana would be hydraulically connected to Richland-Chambers Reservoir with a small channel. Water from Tehuacana would be transported from Richland-Chambers and then into TRWD's transmission system. The strategy assumes that a second IPL will be needed to transmit the supply to Benbrook Lake. No partnerships are assumed for implementation. Phasing is assumed to be infeasible for any new reservoir project.

- Firm Yield: 27,514 AFY.
- Capital Cost: $1,175.4 million.
- Unit Cost with Debt Service: $2,875 per AF.
- Implementation Timeline: 25 years.

Mainstem Trinity Off-Channel Reservoir (OCR): The Mainstem Trinity OCR strategy involves construction of an OCR located near the mainstem of the Trinity River. The OCR would store approximately 300,000 AF of supply from DWU return flows or reuse water from other partners. Water would be diverted to the OCR and then conveyed via pipeline to Joe Pool Lake. This strategy assumes a 50/50 cost share with DWU for the construction of the OCR and pipeline to Joe Pool. Phasing is assumed to be infeasible.

- Firm Yield: 57,169 AFY.
- Capital Cost: $867.5 million.
- Unit Cost with Debt Service: $1,260 per AF.
- Implementation Timeline: 20 years.

Arkansas Water: The Arkansas Water strategy would involve submitting a legislative request for an out-of-state transfer of 260,000 AF of supply annually from Arkansas. The diversion would be just above Millwood Lake on the Little River in Arkansas, although a more optimal diversion point may be identified with additional study, and the supply would be conveyed to Lake Bridgeport. TRWD could implement this alone or with partnerships, although the strategy is assumed without partners. Arkansas Water could be phased, although there are some efficiencies in building out the full-size pipeline initially.

- Firm Yield: 260,000 AFY.
- Capital Cost: $10,239.8 million.
- Unit Cost with Debt Service: $2,761 per AF.
- Implementation Timeline: 25 years.

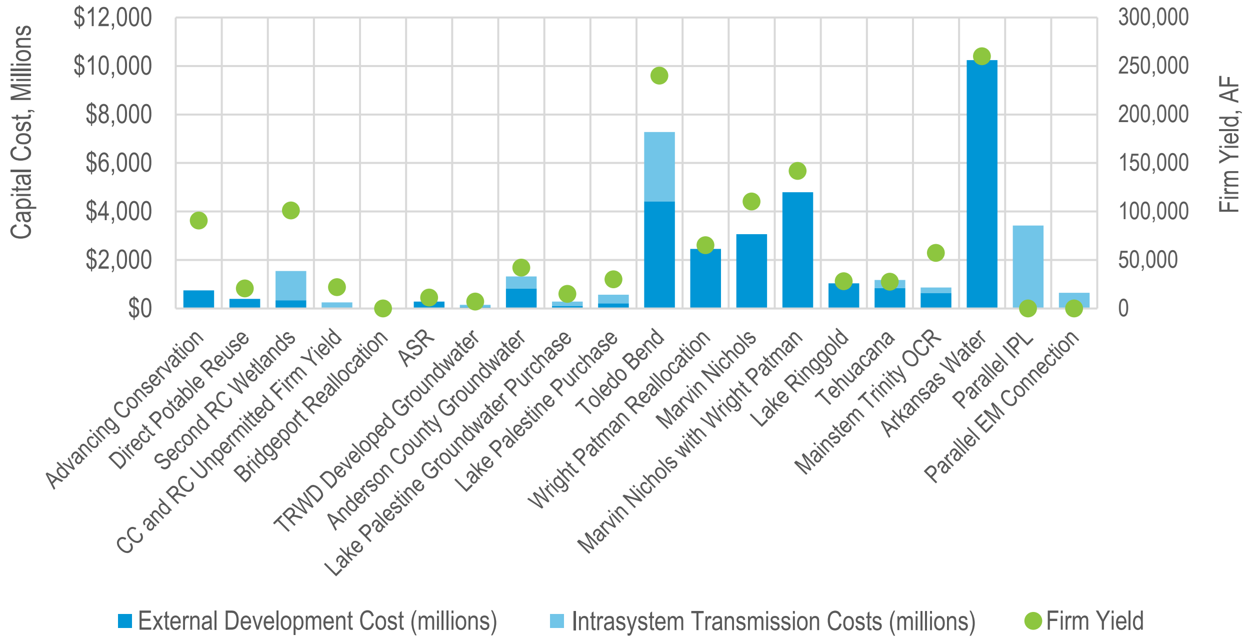
Parallel IPL: A second IPL (IPL2) would run parallel to the existing IPL. The IPL2 is assumed to be fully owned and developed by TRWD with a pumping capacity of 350 mgd. TRWD purchased a large enough right-of-way for two pipelines, which reduces the time and cost for land acquisition. The need for the IPL2 varies, depending on the strategy. For example, supplies coming from the north do not require the IPL2 for conveyance.

- Capacity: Pipeline capacity is 350 mgd.
- Capital Cost: $3,424.3 million.
- Implementation Timeline: 18 years.

Parallel Eagle Mountain Connection: A second Eagle Mountain Connection (EM2) may be needed in the future, depending on the location of the strategy, to transport supplies from Benbrook Lake to Eagle Mountain Lake. It would add capital cost but also flexibility and reliability within a portfolio. TRWD purchased a large enough right-of-way for two pipelines, which reduces the time and cost for land acquisition.

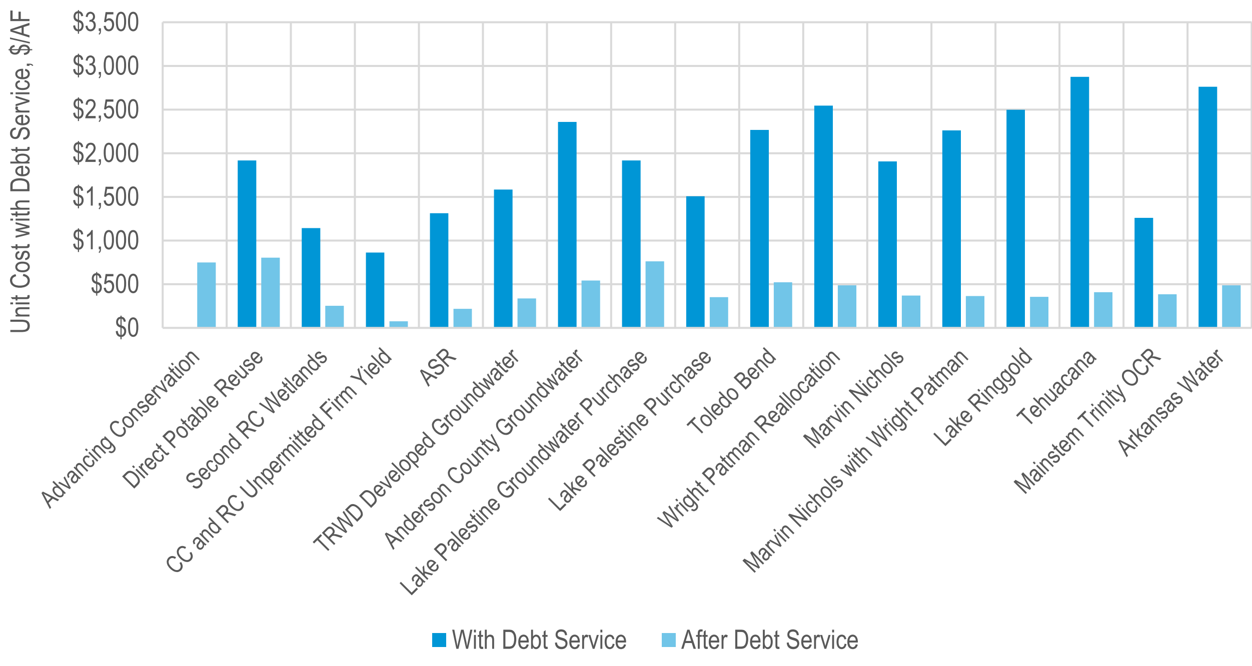
- Capacity: Pipeline capacity is 350 mgd.
- Capital Cost: $645.2 million.
- Implementation Timeline: 18 years.

Strategy Comparison: Capital costs range greatly across strategies, with the larger yield strategies having much higher investment costs, as shown in Figure ES.6. Unit costs of the strategies with debt service range from $850 per AF up to $2,900 per AF, as shown in Figure ES.7. After debt service is retired, the strategies have unit costs closer in range, at around $800 per AF or less.



Note: Values in September 2023$ to align with Region C Planning.

Figure ES.6 Strategy Capital Cost Comparison



Note: Excludes BP Reallocation, IPL2, and EM2 because those strategies have no associated yield. Values in constant September 2023 dollars to align with Region C Planning.

Figure ES.7 Strategy Unit Costs Comparison

ES.7 Supply Portfolios

A portfolio represents combinations of strategies designed to meet TRWD's water supply objectives. Evaluation and compilation of portfolios is a core component of the IWSP Update. Given the significant future water supply needs and the geographic span of TRWD's system, and with the inherent uncertainty in several of the larger supply volume strategies, there are numerous portfolios that could be possible, each with unique risk, cost, and yield profiles.

Given the robust modeling framework to develop this IWSP Update, many metrics were produced, including several on cost, reliability for the system, reliability for individual delivery points, and energy use, for examples. A subset of metrics was selected for this summary.

ES.7.1 Portfolios Evaluated

To address the supply gap, some combination of strategies is needed to have new supply sources online and operational ahead of the projected gap. Multiple iterations of portfolios were generated to explore reliability, system performance, and to balance these against affordability objectives. In all, more than 50 portfolios were simulated. With each iteration, supply timing, infrastructure timing, and variations in certain supplies were tested and adjusted to achieve improved portfolio performance.

There are many combinations of supply strategies possible, but five supply portfolios were selected based on performance. All portfolios include the No Regrets strategies. One portfolio includes only smaller strategies, and four of the five portfolios include one large supply project that comes online in 2060 and multiple smaller capacity strategies. Portfolios were defined as follows.

Mix of Smaller Portfolio: This portfolio combines multiple smaller strategies to demonstrate system performance without a large supply strategy. It includes Advancing Conservation, CC and RC Unpermitted Firm Yield, Bridgeport Reallocation, ASR, Lake Palestine Purchase, TRWD Developed Groundwater, Parallel EM Connection, Second RC Wetlands, Mainstem Trinity OCR, Direct Potable Reuse, Anderson County Groundwater, and Tehuacana. The portfolio requires both the Parallel IPL and Parallel EM Connection to convey new supplies to meet demands.

Toledo Bend Portfolio: The main supply source for this portfolio is Toledo Bend, coming online in 2060. The portfolio relies heavily on eastern supplies, requiring conveyance of water nearly 175 miles to Cedar Creek Reservoir and then another 80 miles to the metroplex. Other strategies include Advancing Conservation, CC and RC Unpermitted Firm Yield, Bridgeport Reallocation, Direct Potable Reuse, TRWD Developed Groundwater, Lake Palestine Purchase, Parallel IPL, and Parallel EM Connection.

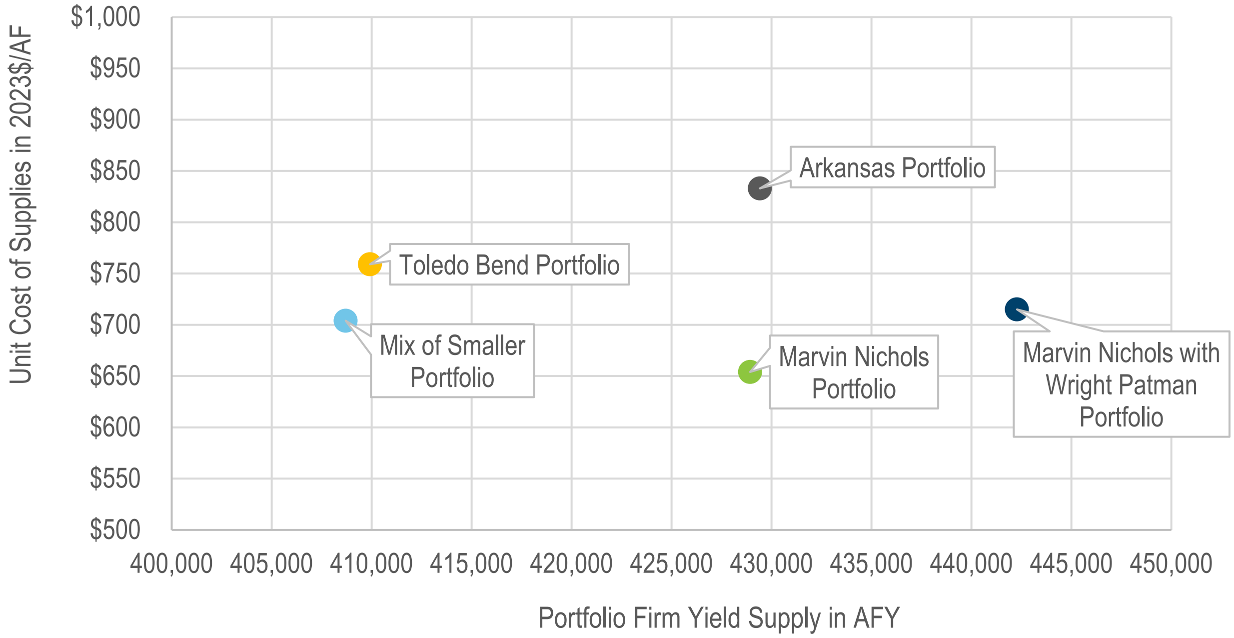
Marvin Nichols Portfolio: This portfolio includes the construction and conveyance of water from the proposed Marvin Nichols Reservoir to Lake Bridgeport via 192 miles of pipeline. It also incorporates several other strategies to meet reliability metrics, including Advancing Conservation, CC and RC Unpermitted Firm Yield, Bridgeport Reallocation, Lake Palestine Purchase, ASR, Mainstem Trinity OCR, TRWD Developed Groundwater, Second RC Wetlands and Parallel IPL. It is geographically balanced, with a new supply coming into Lake Bridgeport from the North, supplies from East Texas (Lake Palestine Purchase), and other smaller supplies spread out across TRWD's service area and just beyond.

Marvin Nichols with Wright Patman Portfolio: This portfolio expands upon the Marvin Nichols plan by adding Wright Patman reallocation, with water conveyed to Lake Bridgeport through 240 miles of pipeline. Other strategies include Advancing Conservation, CC and RC Unpermitted Firm Yield, Bridgeport Reallocation, Lake Palestine Purchase, Mainstem Trinity OCR, Second RC Wetlands and Parallel IPL.

Arkansas Portfolio: This portfolio centers around conveying water from Arkansas, just north of Millwood Lake, to Lake Bridgeport via 250 miles of pipeline. Other strategies include Advancing Conservation, CC and RC Unpermitted Firm Yield, Bridgeport Reallocation, Lake Palestine Groundwater Purchase, Anderson County Groundwater and Arkansas Water. This portfolio does not require the Parallel IPL nor the Parallel EM Connection.

ES.7.2 Portfolio Comparison

Portfolio supply potential, expressed in firm yield, compared to the unit cost of supplies is provided in Figure ES.8. Portfolio firm yield ranges from about 410,000 AF up to 442,000 AF. The weighted unit cost ranges from $654 to $833 per AF, expressed in constant 2023 dollars. Capital costs, if built today, range from $8,430 million up to $11,920 million. Four of the portfolios require the Parallel IPL, with the Arkansas portfolio uniquely not requiring a second IPL. Two of the five portfolios require the Parallel EM Connection, with those that have northern supplies not needing that additional conveyance.



Notes: The unit cost of supplies is expressed in constant September 2023 dollars per AF of firm yield (or equivalent) in the portfolio. For the portfolio, the value is weighted to account for the volume of supplies relative to the total portfolio supply. A second weighting is applied assuming 30 years of unit cost with debt service and 20 years of unit cost after debt service, respectively.

Figure ES.8 Comparison of Portfolio Unit Cost and Supply

ES.7.3 Adaptive Implementation

Adaptive implementation refers to a flexible, responsive approach to executing long-term infrastructure investments where underlying planning assumptions, infrastructure sizing and timing decisions are continuously updated based on changing conditions and emerging priorities. For example, if the projected population growth and water demands accelerate at a faster pace than assumed in this IWSP Update, the proposed timing of new water supply strategies would also need to be moved forward. Similarly, the estimated yield or implementation timeline assumed for individual supply strategies could increase or decrease in the future when more information becomes available, resulting in adjustments of the proposed timelines presented in this chapter. Or if a strategy that is planned for implementation encounters a fatal flaw during planning or permitting, another strategy may be needed instead.

For a comprehensive analysis of results, strategies were grouped by planning horizon and magnitude of the supply. Three general phases were identified, as shown in Figure ES.9, and described as follows.

- **Phase 1. Planned Supplies and Infrastructure:** TRWD's existing and planned supplies results in a firm yield projected to increase from 665,200 AFY in 2030 to 738,970 AFY in 2080. A firm yield gap of 36,000 AFY is expected in 2050, increasing to 384,000 AFY by 2080 without additional strategies. TRWD should implement the Cedar Creek Wetlands and completion of the IPL to avoid unexpected gaps in supply.
- **Phase 2. No Regrets Strategies:** Three strategies were identified with supply reliability benefits, low cost, and ease of implementation: Advancing Conservation, CC and RC Unpermitted Firm Yield, and Bridgeport Reallocation. These could address 29 percent of the supply gap by 2080. All three are assumed to be online by 2030 and should be implemented as planned. Conservation should be tracked closely to determine if planned reductions are achieved.
- **Phase 3. Supply Development Phase:** Additional water supply is needed by 2060 to avoid a potential 80,000 AFY supply gap. Of the five supply portfolios, one includes smaller strategies and four include a large supply project. The likelihood of all 12 small strategies being fully developed and brought online is very low and would not be ideal for future operations. Some of the smaller sources may be met with local resistance, permitting may not be successful, or TRWD may not be able to reach partnership agreements. Each new water source would require a separate permit and environmental review, increasing time and costs. Further, adding multiple small sources to the supply system would increase TRWD's operational complexity, as each small source would need its own monitoring, maintenance, permitting, accounting, and staffing. Thus, a larger supply is likely needed to be online by 2060.

Several of the larger strategies require initiation of planning as early as 2030. Toledo Bend planning can start as late as 2042, although TRWD would have to complete feasibility studies before then to ensure no roadblocks will be experienced. Therefore, TRWD and its potential regional partners have no more than five years (from 2025 until 2030) to explore the large supply strategies in more detail, resolve uncertainties, explore political and partnership support, and gather sufficient information to select which large strategy to move forward. However, some of the potential regional partners have a more accelerated time frame in which to make decisions on the next large water supply to be pursued. Many of these large supply options have been studied for decades, while others are relatively new ideas. This near-term timeframe should focus on filling any critical information gaps, detailed system integration studies, and working towards decisive action.

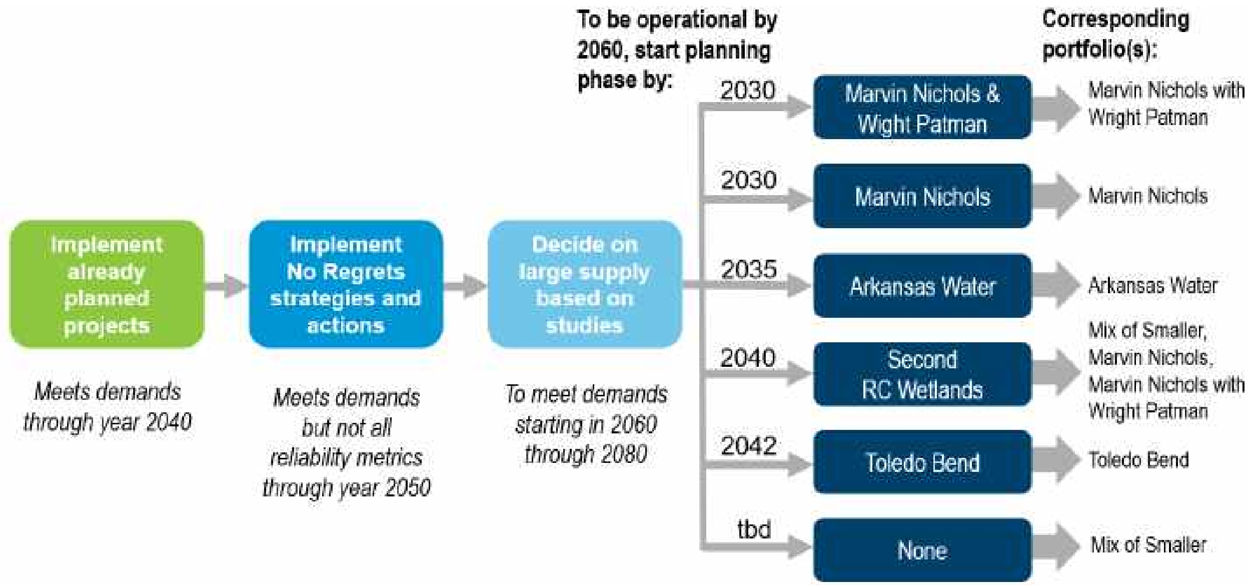


Figure ES.9 Timing and Phasing to Implement Supply Strategies

A general trigger-based implementation process is depicted in Figure ES.10. This schematic is an intentional oversimplification of all the decisions that will need to be made to focus on the key triggers, which are selection of a large supply, selection of small supply, and demand/supply balance. The No Regrets strategies are independent of any triggers and can be implemented in parallel with the additional feasibility studies around the large supply options until 2030 for some options. The decision on when and which other small strategies are implemented also has impacts on the timeline of selecting the next large supply. The actual demand growth and success of the water conservation program will determine the timing of additional supply needs. Once sufficient additional supplies are in place to meet the future projected demand, the decision tree comes to an end, or at least a temporary pause until the next planning cycle as represented by the grey box.

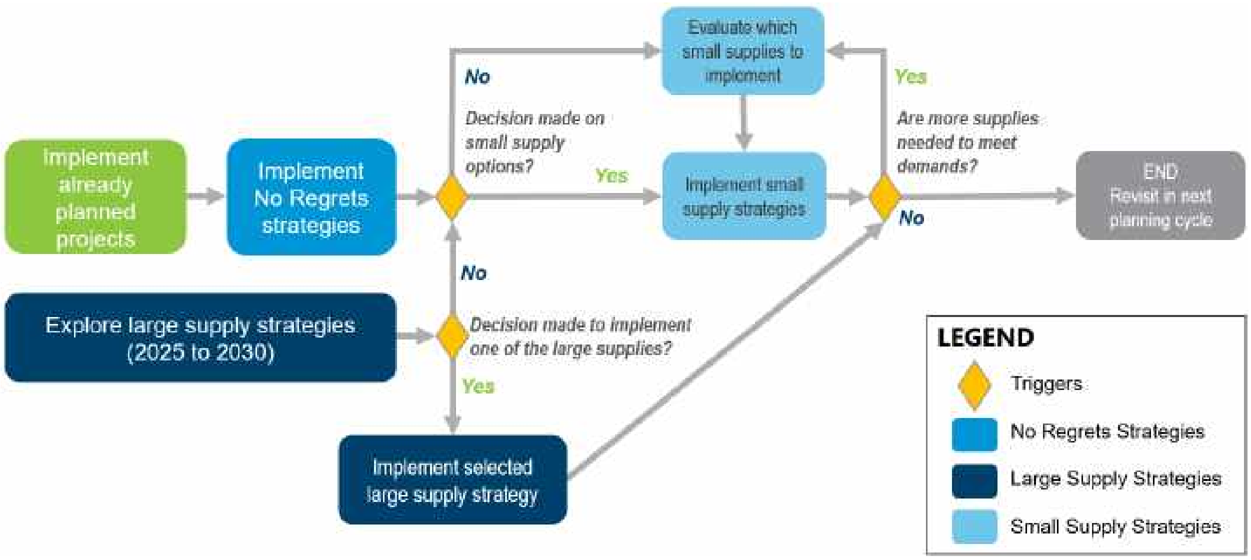


Figure ES.10 Trigger-based Implementation for All Strategy Planning

ES.8 Conclusions and Recommendations

The IWSP Update **does not recommend a single portfolio but recommends the adaptive implementation approach** to make a reasonable supply plan as more information becomes available. TRWD needs to **utilize the next 5 years to conduct detailed feasibility studies** to get a similar level of information about each of the large supply options, such that a decision can be made in conjunction with regional partners within a 5-year time frame. It will be important to study early triggers quickly to make an informed decision on which strategy to pursue. The phasing and timelines are based on meeting 95 percent of the critical dry year S3 demand forecast. It is likely that demand would either increase at a faster or slower pace than projected in this plan, which would shift timeline triggers forward or backward, respectively. In addition to growth driven by economic, demographic, and regulatory trends, the amount and pace of water conservation is another key variable that would impact implementation timelines.

The IWSP Update provides actionable recommendations for ensuring a reliable and sustainable water supply for TRWD customers. These recommendations are based on technical analysis, modeling, and water supply objectives. Key areas of focus include optimizing the baseline water system, demand and supply planning, and strategy-specific actions. The plan stresses the importance of adhering to project timelines, evaluating conveyance infrastructure, and securing additional return flows. It also highlights the **need for continuous monitoring of water demands, updating demand projections, and collaborating with regional partners.** Overall, **the IWSP Update serves as a roadmap** for prioritizing near-term actions and making adaptable, cost-effective decisions regarding water supply strategies.

For the baseline water supply system, the IWSP Update **recommends ensuring that projects assumed in the baseline are online as scheduled.** It also suggests **further evaluating the conveyance infrastructure system requirements and operational rule changes needed as planned water supplies become operational.** TRWD should study the 2030 condition more closely to determine if operational changes or acceleration of certain projects could alleviate a potential small water supply shortage. To further improve reliability from 2040 through 2070, TRWD should work towards securing additional return flows for the Cedar Creek Wetlands.

In terms of demand and supply planning, the IWSP Update **suggests prioritizing planning efforts on larger projects,** as smaller strategies are less likely to be fully developed. TRWD should start early planning steps for larger supplies now, as these take decades to develop and implement. Water demand and population growth should be closely monitored. Furthermore, reliability goals should be explored in partnership with customers to define an acceptable level of service and risk tolerance. Outcomes from ongoing studies should be analyzed within the IWSP context to inform near-term water supply decisions.

Strategy-specific recommendations include **preparing an Advanced Conservation Plan** and reevaluating modeling and gap analysis results as the Advancing Conservation strategy is implemented. TRWD should closely track Texas legislative actions that provide boosts in funding and support for specific types of water supply strategies. **Feasibility-level studies for the Toledo Bend and Arkansas Water should be conducted,** along with rate impact studies of the four large supplies. TRWD should develop smaller supplies to meet interim gaps before a large supply strategy is brought online, and study operations and conveyance to determine if certain supplies can be conveyed to users without the addition of the Parallel IPL. **Agreements with DWU on usage of the portion of the IPL that connects Lake Palestine to the existing IPL should be negotiated as well as the negotiation for a water purchase from a water right holder at Lake Palestine.** Finally, TRWD should **continue to pursue and track ASR studies.**

CHAPTER 1 INTRODUCTION AND BACKGROUND

Tarrant Regional Water District (TRWD) provides wholesale raw water supplies to an 11-county region of the upper Trinity River in North Texas. TRWD is one of the largest raw water suppliers in Texas, providing water to over 2.5 million people, as well as providing irrigation, mining, and industrial water. Supply is delivered directly to 52 wholesale customers, including Fort Worth, Arlington, Mansfield, and the Trinity River Authority (TRA), who then distribute treated water to over 70 cities and other municipal customers. Beyond water supply, TRWD provides flood control, recreation opportunities, and environmental benefits to the region.

Surface water is the primary source of supply in the region and the only source utilized by TRWD, though some customers have relatively small amounts of local groundwater supply. The upper Trinity River Basin hydrologic conditions vary significantly from year to year, and surface water supplies are subject to severe droughts. Average annual precipitation increases west to east from slightly more than 34 inches per year in Wise County to about 40 inches per year in Henderson County.[1]

TRWD's mission is to deliver a reliable, resilient, and sustainable supply of water to the public at the lowest cost and highest quality possible.

TRWD was initially created in 1924 to provide flood protection for Tarrant County but quickly expanded to include water supply. In the early 1930s, TRWD completed the construction of two reservoirs on the West Fork of the Trinity River, Lake Bridgeport and Eagle Mountain Lake, both as flood control and water supply projects. In 1965, TRWD constructed Cedar Creek Reservoir in Henderson and Kaufman Counties for water supply, with a connection to the metroplex via a pipeline completed in 1972. Located in Navarro and Freestone Counties, Richland-Chambers Reservoir was completed in 1987, almost doubling the available water supply, with the pipeline to convey the supply to Tarrant County completed in the same year.

TRWD's service area and water supply sources are depicted in Figure 1. In addition to the TRWD-owned reservoirs, TRWD utilizes Lake Arlington, Lake Benbrook, and Lake Worth for storage. TRWD has a wetland reuse project operational at Richland-Chambers Reservoir. The project naturally filters water from the Trinity River to remove sediments and nutrients and then the water is lifted back into the reservoir. Another wetland reuse project is planned at Cedar Creek Reservoir. Once collected in the reservoirs, raw water is conveyed from Richland-Chambers and Cedar Creek Reservoirs (collectively referred to as the "East Texas reservoirs") over 80 miles to Tarrant County via more than 250 miles of pipeline.

[1] Source: https://waterdatafortexas.org/

Figure 1.1 TRWD Service Area and Water Supply System

In 2014, TRWD completed its first Integrated Water Supply Plan (IWSP), establishing a planning platform that has served TRWD well over the past decade.[2] The study identified and evaluated more than a dozen new water supply options that were analyzed against a range of demand projections. Further, the IWSP outlined a series of decision trees to allow TRWD to adaptively plan in the face of uncertainty. The report documented a recommended suite of near-term strategies for implementation, referred to as *No Regrets*. The following *No Regrets* strategies from the 2014 IWSP are either completed or currently underway:

- In November 2014, amendments for both the Cedar Creek Wetlands, recently named the Marty Leonard Wetlands, and Richland-Chambers Wetlands, similarly named the George W. Shannon Wetlands, were obtained that increased the reservoir diversion capacity of reuse water by a combined 73,024 acre-feet per year (AFY) to utilize the firm yield of the water produced by the wetland systems.
- TRWD has obtained Excess Flow (ExFlo) permits for Benbrook Lake, Eagle Mountain Lake, Richland-Chambers Reservoir, and Cedar Creek Reservoir. These ExFlo permits allow TRWD to divert additional water supply during periods when specific reservoirs are above the conservation pool and excess flows are available.
- TRWD has made considerable progress on the construction of the Integrated Pipeline (IPL) in conjunction with Dallas Water Utilities (DWU). At full project build-out, the 150 miles of newly constructed pipeline will provide TRWD with an additional 200 million gallons per day (mgd) of conveyance capacity to move water from TRWD's East Texas reservoirs to the metroplex.
- The Cedar Creek Wetlands has been permitted, and design is currently underway. The new wetlands project will have a capacity of 156 mgd and will be online around 2032.
- TRWD has actively led the region in water conservation for almost two decades through municipal customer support, education and public awareness campaigns, efficiency, and accurate accounting in TRWD operations, and offerings of classes, programs, and landscape efficiency initiatives.

1.1 IWSP Update Approach

Even with the recent expansions in supply and conveyance, TRWD must continue to proactively develop additional supplies to meet future needs. Today's uncertainties are unmatched, with rapid population growth projected to continue and evolving technological, environmental, hydrological, and political conditions. TRWD has undertaken this IWSP Update to establish a refreshed roadmap for future supply development against this deep uncertainty while striving to meet multiple water supply objectives.

The IWSP Update looks holistically at TRWD's water supply system, compares supply availability and conveyance capacity to projected water demands through 2080, and identifies future alternatives of combined water management strategies (WMS or strategies) to best meet objectives. The specific components of the IWSP Update include:

- Update water demand projections through 2080 at all customer delivery locations.
- Consider existing and planned infrastructure, quantify the supply available to all delivery locations over time with TRWD's current water supplies.
- Quantify the additional supply needed to meet growing demands and determine when and where the supply is needed within the system (referred to as a Gap Analysis).
- Identify potential strategies to meet the projected gap in supply.

[2] TRWD. 2014. Integrated Water Supply Plan. Prepared by Buhman Associates, LLC, in cooperation with CDM Smith and Freese and Nichols.

- Establish a decision-making framework for which combinations of strategies (referred to as Portfolios) are objectively evaluated to meet TRWD's water supply objectives.
- Quantify the yield potential and cost-related information for strategies and qualitatively score each.
- Assess the additional infrastructure needed for a portfolio to convey water to where it is needed.
- Conduct probabilistic modeling of portfolios to quantify system reliability.
- Identify and present selected portfolios that best meet objectives.
- Define an implementation plan for strategies included in selected portfolios.
- Develop resources and tools for TRWD staff to refresh the IWSP on an ongoing basis once the project concludes. This includes building upon TRWD's existing RiverWare model, developing tools for estimating strategy costs, and developing a custom Blue Plan-it application for data integration and decision-making.

1.2 Incorporated Studies

The IWSP Update builds upon analyses conducted by TRWD over the past several years. The major studies are briefly described as follows.

TRWD Service Area Demand Update. Over the period from the mid-1990s to 2018, TRWD saw significant fluctuation in demand due to several factors, including population growth, the Great Recession of 2008, changes to the State plumbing code requiring high efficiency fixtures, the drought of 2011, and permanent conservation adoption. In response, TRWD decided to embark on a detailed study of water demand.[3] TRWD wanted to understand how various scenarios of demographic growth and conservation adoption would impact future demands. Further, TRWD was concerned with the potential for climate change to result in higher demands. The study analyzed water demand projections for five scenarios of growth, climate, and conservation, with projections generated at a detailed spatial scale, generally aligned with the boundaries of TRWD's direct and indirect municipal customers.

Since the conclusion of the 2020 Demand Study, the COVID-19 pandemic occurred, and growth accelerated in the region. In 2022, after a very hot summer, TRWD recorded its highest demand to date, with annual deliveries reaching 428,600 acre-feet (AF). The demand record was surpassed the next year when TRWD's demands were 438,700 AF. In 2024, with weather closer to average, demands totaled 418,000 AF. These recent trends indicate that TRWD's water demands are tracking along the highest scenario from the demand study but have significant range in variability due to weather.

The IWSP Update incorporates the water demand projections prepared in 2020, with minor revisions as needed and an extension to 2080. The most aggressive scenario, referred to as the Suburban Sprawl with Stressors (S3), is the basis of the IWSP Update. Chapter 4 details the water demand projections.

IWSP Update Strategy Report. In 2020, TRWD conducted an evaluation of changed conditions since the 2014 IWSP and identified activities needed to update the IWSP.[4] The recommended tasks included hydrologic updates, exploring regional collaboration opportunities, refining strategies, prioritizing transmission system planning, and modeling considerations. The IWSP Update described herein followed many of the recommendations from that study.

---

[3] TRWD. 2020. TRWD Service Area Demand Update: Water Demand Forecast Report. Prepared by CDM Smith.
[4] TRWD. 2020. Integrated Water Supply Plan Update Strategy. Prepared by Brown and Caldwell.

Hydrologic Risk Review. Based on recommendations from the IWSP Update Strategy Report, TRWD explored the prospect that more water may be permitted than would actually be available for withdrawal if future droughts are more severe than the 1950s recorded historical drought of record.[5] The analysis focused on paleoclimate insights into past North Texas climate, future climate risk and uncertainty, modeling and planning guidelines, and best practices, with recommendations offered for TRWD. Study methods included a literature review and expert panel discussion. The following study conclusions guided the analytical framework design for the IWSP Update:

- Future climate trends and the probability of extreme events cannot be known with certainty, nor can the risk be quantified.
- While paleoclimate reconstructions and future climate projections can provide valuable information, these models cannot confidently provide quantified potential yield reduction estimates or a probability of occurrence.
- Modeling future climate, likewise, has both benefits and limitations. Climate models cannot provide a probability or risk of occurrence. A dependable statistical probability of future climate or severe events cannot be accurately predicted.
- TRWD should continue to maintain safety factors and take a conservative approach to water supply planning to add buffers and security against future drought risks that could surpass the 1950s drought of record in duration or intensity.
- TRWD should further explore drought-resilient supplies; identify system constraints, sensitivities, and vulnerabilities; continue regionalization discussions; revisit the Drought Contingency Plan and drought operations; and adopt a One Water approach.

Strategy Studies. In recent years, TRWD has sponsored or partnered on several feasibility-level studies analyzing cost and/or supply for certain strategies. These studies included, for example, the Study of Impaired Groundwater Availability and Quality (2016), Ringgold Financial Viability Assessment (2019), Cable Mountain Lake Alternative Supply Cost Estimate (2022), Fairfield Lake Purchase (2023), and Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update (2023). TRWD has several ongoing studies at the time of this IWSP Update, including a study to optimize system operations and investigate permitting additional return flow (referred to as "SysOps"), and a Regional Optimization Study with other North Texas water suppliers. TRWD is also in the process of implementing an Aquifer Storage and Recovery (ASR) pilot project.

Region C Plan. The Region C Water Planning Group is responsible for developing a comprehensive water supply plan to ensure sustainable and reliable water resources for the region's growing population. This planning effort, mandated by the Texas Water Development Board (TWDB), evaluates current and future water demands, identifies potential shortages, and proposes strategies such as conservation, infrastructure development, and alternative water sources. By addressing the needs of municipalities, industries, agriculture, and the environment, Region C planning aims to balance economic growth with water resource sustainability, ensuring long-term water security for North Texas communities.

The 2021 Region C Water Plan is the most recently adopted, but the 2026 Draft Region C Water Plan (Initially Prepared Plan) was released at the time of this publication.[6] TRWD continues to play an important role in Region C planning, and while the IWSP Update is more detailed and comprehensive, it complements the Region C analysis and reports. For some strategies and where noted, Region C planning information provided the foundation for the strategy evaluation.

[5] TRWD. 2022. Hydrologic Risk Review. Prepared by Brown and Caldwell.
[6] See https://regioncwater.org/wp-content/uploads/2025/03/2026_Region_C_Initially_Prepared_Plan_Volume_I.pdf

1.3 Key Terms and Definitions

Key terms and definitions relevant to the IWSP Update are provided in Table 1.1.

Table 1.1 Key Terms and Definitions

Term	Definition
Baseline Water Supply System	The existing and future planned water supply system against which water supply gaps are assessed, including definition of water right holdings, water supply reservoirs, and conveyance infrastructure.
Curtailed Demands	Reduced demands achieved by enacting TRWD's Drought Contingency Plan.
Demands	The amount of water requested at all locations within TRWD's service area without curtailment reductions.
Drought of Record	The period of time when natural hydrological conditions, based on historically observed records, provided the least amount of water supply.
Evaluation Criteria	Key components of an objective used to differentiate between portfolios and help identify preferred portfolios.
Firm Yield	The maximum amount of water that can be reliably supplied during a repeat of the drought of record, regardless of how much water is permitted.
Gap Analysis	Performed to quantify the amount of additional supply needed to meet growing demands and to determine when and where the supply is needed within the TRWD system.
No Action Alternative	Represents the "do nothing" scenario from which system reliability metrics are compared.
Objective	Big picture IWSP goals, defined in broad, understandable terms.
Performance Measure	Quantitative or qualitative standardized metric for each evaluation criterion.
Portfolio	Combinations of strategies, including the decadal timing of when those strategies are needed to be online, designed to meet the stated water supply objectives.
Reliability	Ensuring water supply is delivered to TRWD customers when and where they need it.
Resilience	The ability of a water system to anticipate, absorb, adapt to, and recover from disturbances while maintaining a reliable and safe water supply.
Risk	The chance that TRWD will be adversely impacted by its efforts to deliver water to customers reliably and economically.
Safe Yield	The maximum amount of water that can be reliably supplied during a repeat of the drought of record, while retaining a minimum supply in reserve; for TRWD, the minimum reserved supply is enough to meet demand for 1 year.
Scenario	A simulated future with defined conditions for the water supply system, hydrology, demands, and other key factors.
WMS (also referred to as strategy)	A discrete water supply option (i.e., a project or other solution) that could be developed or implemented in the future to increase water supply capacity or reliability, such as a new reservoir, additional reuse, or a change in policy or operations.
Weight	Relative importance of objectives and evaluation criteria.

1.4 Report Organization

This report is organized as follows:

- **Chapter 1 – Introduction and Background** presents the need for an IWSP Update, background from the 2014 IWSP, work conducted since, the scope of the IWSP Update, key terminology definitions, and organization of the report.
- **Chapter 2 – Project Approach** includes details about the project approach, modeling framework and tools used for analyses throughout the IWSP update project, and the project's decision-making assumptions.
- **Chapter 3 – Baseline Water Supply System** describes TRWD's baseline water system, including water sources, water rights, transmission, and pumping; then presents planned sources and transmission that are incorporated into the analysis.
- **Chapter 4 – Water Demands** discusses historical, current, and future water demands within TRWD's service area.
- **Chapter 5 – Future Supply Needs** reviews TRWD baseline system reliability and future water supply needs.
- **Chapter 6 – Water Management Strategies** presents the identification, screening, and evaluation of strategies.
- **Chapter 7 – Water Supply Portfolios** describes strategy scoring and water supply portfolio creation by theme. Descriptions of portfolios, analysis, and comparison are included.
- **Chapter 8 – Adaptive Implementation** presents implementation planning for strategies included in selected portfolios, discussion, as well as timelines, triggers, and other considerations.
- **Chapter 9 – Recommendations** summarizes recommendations based on the IWSP Update analysis results.

CHAPTER 2 PROJECT APPROACH

The IWSP Update identifies water supply strategies and combinations of those strategies that provide a reliable and resilient water supply to meet future demands while minimizing costs. To achieve this goal, the project team developed an objective evaluation framework supported by robust analytical tools, as detailed in this chapter.

2.1 Planning Timestep and Horizon

The IWSP Update analyzes supplies against projected demands from 2030 to 2080 in 10-year increments (i.e., 2030, 2040, 2050, 2060, 2070, and 2080). For those planning years, detailed modeling occurs at the monthly timestep. Interpolation between decades is applied as needed.

2.2 Strategies, Portfolios, and Scenarios

Strategies (also referred to as a WMS) are independent, discrett water supply options. Examples of a WMS include the development and conveyance of a new water supply source, purchase and delivery of water from an existing source, operational changes, permit changes, or expanded infrastructure capacity within the TRWD system to utilize sources. Information associated with a strategy includes capital cost, operation and maintenance (O&M) cost, firm yield, safe yield, and partnership potential.

A portfolio represents combinations of strategies. Portfolio evaluation is a core component of the IWSP Update. Typically, portfolios are developed based on themes (such as low cost, high reliability, or supply diversity) and are simulated against various conditions and assumptions, such as different demand scenarios or cost or energy assumptions.

A scenario is a portfolio simulated under a set of specific conditions and assumptions. Multiple scenarios are generated and compared to explore uncertainty in future conditions, assess risk and resilience, and inform decision making. For illustration purposes only, Table 2.1 provides examples of how strategies, portfolios, and assumptions are combined to create a scenario. In the example, the portfolio of strategies for scenario HNP1 is a new reuse project and a new northern reservoir, simulated with the highest demand projections and existing infrastructure system, with average inflation and energy cost assumptions.

Table 2.1 Scenario Definition Illustration

Scenario	Demands	Supplies	System Infrastructure	Other
HPP1	High	Existing and Planned	Existing and Planned	Average inflation and energy costs
MPP1	Mid	Existing and Planned	Existing and Planned	Average inflation and energy costs
HNP1	High	Existing and Planned, New Reuse Project in 2050, New Northern Reservoir in 2060	Existing and Planned	Average inflation and energy costs
HNP2	High	Existing and Planned, New Reuse Project in 2050, New Northern Reservoir in 2060	Existing and Planned	Higher inflation and energy costs
HEE1	High	Existing and Planned, Groundwater in 2050, New East Texas Reservoir in 2060	Existing and Planned, Expanded Intrasystem Conveyance	Average inflation and energy costs

2.3 Water Supply Reliability and Supply Gaps

A critical component of water supply planning is identifying when demands are projected to exceed available supply at any given point in the system, referred to as a gap. While simple in definition, the application of a gap analysis is more complex and ties directly to risk tolerance and level of service reliability.

When looking to the future, a gap can be projected due to insufficient supply, permit limitations, or insufficient infrastructure capacity to deliver the water where it is needed. The gap analysis approach adopted for the IWSP Update incorporates these elements in a system model to identify when and where a gap exists and, thus, how much additional supply, permits, or conveyance needs to be added to improve reliability.

With Carollo Engineers' (Carollo) guidance, TRWD established this minimum threshold for reliability for the IWSP Update: a gap exists if more than 5 percent of system demands cannot be met during the critical year of the historical drought of record (1956). The target, thus, is meeting 95 percent of demands or more during the critical drought year. This threshold guided the development of portfolios and was used to calculate the timing of when additional strategies must be implemented and how much water supply strategies must deliver.

Minimum Reliability Threshold:

At least 95% of system demands met during the critical year of the drought of record.

Per TRWD's Drought Contingency Plan, Stage 3 reservoir storage conditions correspond to restrictions that, when implemented by all customers, would result in approximately a 20 percent demand curtailment.[1] Thus, the 95 percent minimum reliability threshold represents a balance between water use reduction actions by consumers under extreme conditions and the high cost of meeting 100 percent demand during these extreme conditions.

TRWD has established a planning rule that targets having a new operational supply before demands are projected to exceed 90 percent of the combined safe yield of TRWD's reservoir system. Safe yield is defined as the maximum annual diversion that can be met during a repeat of the drought of record while leaving an equal amount of water in storage. The 90 percent safe yield rule provides system resilience against future droughts that could be more severe in intensity and extent than the drought of record.

The criterion threshold and reliability-based approach differs from the 90 percent safe yield planning rule. However, the tools utilized in this IWSP track the firm yield, safe yield, and 90 percent safe yield of the system across the planning horizon for each portfolio. Sensitivity analysis is presented around the gap analysis and portfolios, exploring the tradeoffs between improving reliability and maintaining the 90 percent safe yield rule (Chapter 5 and Chapter 7). Once the timing for new supplies becomes more in-focus as demands unfold, TRWD can determine if the risk tolerance of delaying infrastructure and supply development is acceptable.

2.4 Probabilistic System Analysis

For each simulated future year, the modeling framework was designed to generate 82 years of potential outcomes for each month based on hydrologic records from 1941 through 2022. The simulation includes historical hydrologic inflows superimposed against conditions for demands at TRWD delivery nodes, supplies, permits, operational rules, reservoir conditions (e.g., evaporation and storage), and infrastructure limitations. This process is repeated in 10-year increments for a forecast horizon from 2030 to 2080.

[1] TRWD Drought Contingency and Emergency Water Management Plan May 2024

The decadal water demand projection represents average weather conditions. Within the modeling, demands are adjusted up or down for each hydrologic inflow month based on the weather associated with the inflow. For example, a dry hydrologic year is associated with higher water demands.

With the results, statistics are calculated to determine the probability that demand exceeds supply. Results are calculated for the entire system, by source, and by customer. For each supply node, the average and maximum shortage over the hydrologic traces is calculated by month (984 months in total) and for each hydrologic year (82 years). Assuming the hydrologic traces represent the probability of future weather conditions producing a paired supply and demand outcome, the outputs can be converted into statistics on the likelihood that supply shortfalls will occur and the magnitude of such shortfalls. Several metrics are calculated from the outputs.

2.5 Water Supply Objectives

Portfolios are evaluated using a multi-criteria decision analysis (MCDA) framework established specifically for TRWD to provide a systematic, objective approach for comparison and selection of portfolios. MCDA is a well-known technique and mathematical framework that weighs alternatives against multiple qualitative and quantitative criteria with varying levels of importance. When used in the context of water resource management, the MCDA framework allows for the integration of physical, financial, environmental, and social considerations for portfolio evaluation.

The IWSP Update framework was developed during a workshop with TRWD. Best practice guidance states that objectives should be:

- **Discrete**—to distinguish portfolios.
- **Measurable**—to determine if objectives are achieved. This can be quantitative or qualitative.
- **Non-redundant**—to avoid overlapping and unexpected results.
- **Understandable**—to be easily understood by a broad audience.
- **Concise**—to focus on the most important considerations.

TRWD's water supply objectives are to ensure supply reliability, select implementable projects, maintain affordability, and align solutions with the community, as provided in Table 2.2. As with any decision-making process, primary objectives are generally not of equal importance. Thus, a weighting exercise using pairwise comparison was conducted with TRWD to quantify the relative importance of each objective. The resulting weights are provided in Table 2.2.

Table 2.2 Water Supply Objectives and Relative Weights

Objective	Description	Weight
Reliability	Ensuring that the water supply is delivered to TRWD's customers when and where they need it.	45%
Implementation	Selecting the long-term water supply options that can be successfully built and operated.	25%
Affordability	Providing cost-effective solutions for TRWD's customers, examining today's costs and what the future may hold.	20%
Community Alignment	Developing water supply solutions that will be accepted by stakeholders and end users.	10%

Evaluation criteria were defined for each objective to capture its key components. The evaluation criteria are associated with a sub-weight, and TRWD project staff members provided direction on sub-weights. Performance measures were specified for each evaluation criterion to define how criteria are quantified. The evaluation criteria and performance measures are provided in Table 2.3 and Figure 2.1.

Overall, the performance of a portfolio is scored by assessing the frequency and magnitude of shortages, how uncertain and complex the permitting process is expected to be, the number of strategies in a portfolio, the expected cost of supply, public acceptance, and the amount of energy used for pumping. Sources of information for the calculations include a system model and cost estimate (both tools are described in the next section), as well as a scorecard for qualitative metrics.

Several additional criteria were identified as important to TRWD's water supply mission, but after detailed evaluation, the criteria were found not to be a differentiator in scoring portfolios. Removing these criteria from the scoring framework allowed for the criteria that make the most difference to have more weight (due to fewer criteria in total). These important but non-differentiating criteria are identified in Table 2.3.

Table 2.3 Water Supply Evaluation Criteria

Evaluation Criteria	Sub-Weight	Performance Measures	Unit	Better: Low or High?	Source
Reliability (R): 45%					
R1. Frequency of shortages.	25%	Percent of months across the historical hydrologic traces (984) in which the 2080 total system demand can be met without implementing water use restrictions.	Percent	High	System Model
R2. Magnitude of shortage during extreme drought.	75%	Percent of 2080 total system demand that can be met during the critical year (1956) of the drought of record without implementing water use restrictions.	Percent	High	System Model
Implementation (I): 25%					
I1. Permit uncertainty and complexity.	50%	Weighted[1] qualitative score assessing permit uncertainty and complexity.	Qualitative Score	High	Scorecard
I2. Number of strategies.	50%	The number of strategies included in a portfolio.	Number	Low	System Model
Affordability (A): 20%					
A1. Unit cost of supplies.	100%	Weighted unit cost (capital and O&M) of supplies expressed in 2023 dollars (reflecting 30 years with debt service, 20 years without, and considering maximum available yield).	Cost/AF	Low	Cost Estimate
Community Alignment (C): 10%					
C1. Landowner, political, and public acceptance.	50%	Weighted[1] qualitative score defining the degree of acceptability by various members of the community.	Qualitative Score	High	Scorecard
C2. Energy footprint.	50%	Net change in average energy consumption (related to pumping) in 2080 relative to 2023.	kWh/AF	Low	Cost Estimate + System Model

Evaluation Criteria	Sub-Weight	Performance Measures	Unit	Better: Low or High?	Source
Other Evaluated Criteria Identified as Important but Not Included in Scoring					
O1. Individual customer reliability.	N/A	Ratio of the lowest customer delivery point reliability to the total systemwide reliability in 2080.	Ratio	High	System Model
O2. System risks and resilience.	N/A	Weighted(1) qualitative risk score for potential system vulnerabilities.	Qualitative Score	High	Scorecard
O3. Collaboration potential.	N/A	Weighted(1) qualitative score assessing beneficial regional partnerships and/or lower collaboration obstacles.	Qualitative Score	High	Scorecard
04. Operational simplicity.	N/A	Weighted(1) qualitative score assessing the relative ease of operating the future system.	Qualitative Score	High	Scorecard
O5. Phasing potential.	N/A	Weighted(1) qualitative score characterizing the potential to defer capital and expand the system as required to meet demand.	Qualitative Score	High	Scorecard
O6. Multi-benefit projects.	N/A	Weighted(1) qualitative score identifying the potential for recreation, flood control, and environmental co-benefits.	Qualitative Score	High	Scorecard
O7. Levelized cost of delivered water.	N/A	Net present value of the total cost (capital and O&M) for the system expressed as dollars per thousand gallons of delivered water.	Cost/kgal	Low	Cost Estimate + System Model

Notes:
kgal - thousand gallons; kWh - kilowatt-hour; kWh/AF - kilowatt-hour per acre-foot
(1) Scored for water management strategies and then weighted for portfolios by volume of included strategies.

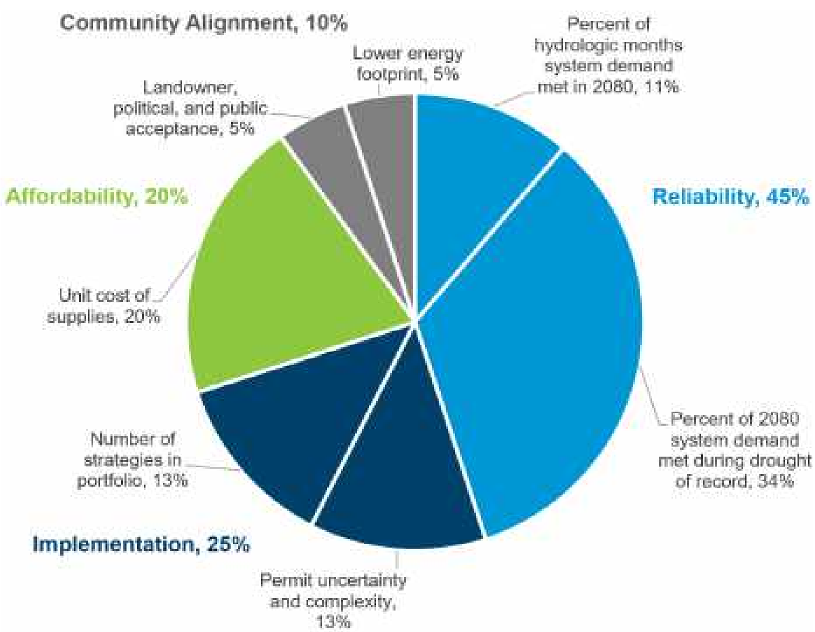


Figure 2.1 Water Supply Objectives and Evaluation Criteria Importance

2.6 Project Workflow and Tools

The project workflow is presented schematically in Figure 2.2. At a high level, the workflow included assessing the water supply gap under existing and planned system conditions and future demands; identifying and independently evaluating strategies; compiling strategies into portfolios to fill the gap; iteratively exploring and testing portfolios; and identifying preferred portfolios. Three tools make up the bulk of the analysis and workflow, each described in detail in the following sections. TRWD's RiverWare model performs system analysis. The Costing Tool, adapted specifically for the IWSP Update, serves as the platform for producing comparable cost estimates for the water management strategies. Following the development of those cost estimates, Carollo's Blue Plan-it, a customized application, serves as the data and decision-making integration hub.

Where available, other reports and studies were relied on to develop information for strategies. For example, the Water Availability Model (WAM), used by the Texas Commission on Environmental Quality (TCEQ) to predict the amount of water available in a river or stream, was used to estimate the yield potential for some strategies.

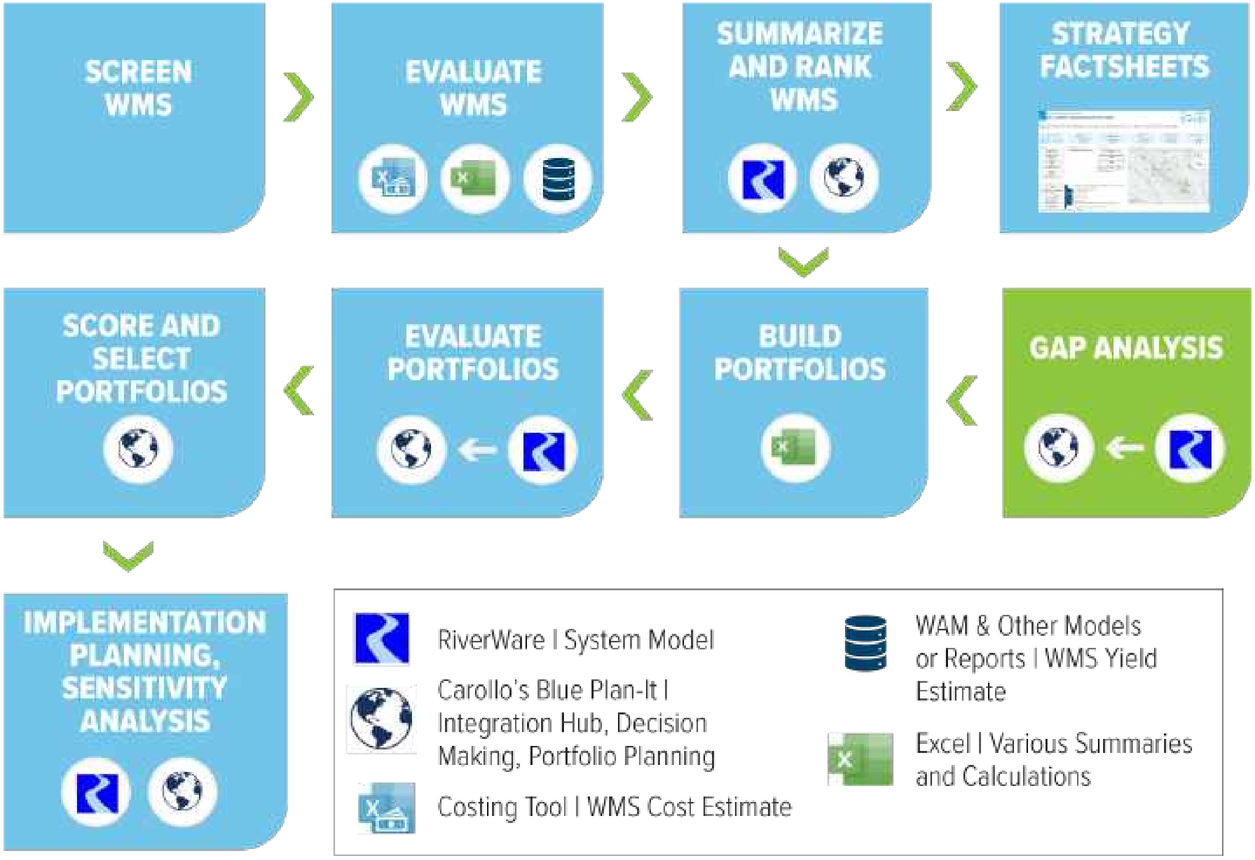


Figure 2.2 Project Workflow

2.6.1 RiverWare

TRWD has developed and relied on a RiverWare model for over two decades to support operations and long-term planning. The RiverWare model performs probabilistic simulations by incorporating hydrologic input (from 1941 through 2022) and defined conditions for demands, supplies, permits, operational rules and procedures, reservoir conditions (e.g., evaporation and storage), and infrastructure limitations. At a monthly timestep, the model superimposes the historical hydrologic inputs over any single decade of forecasted demand.

The existing long-term RiverWare model was adapted for the IWSP Update to include needed output fields (referred to as slots), incorporate current and planned infrastructure, and capture reservoir sedimentation impacts likely to occur over the 50-year planning horizon. For the IWSP, TRWD's Drought Contingency Plan and curtailment triggers were turned off in the simulations. The IWSP version of RiverWare was modified to produce an output file that feeds into Blue Plan-it for further analysis.

With this framework, RiverWare can assess system reliability and evaluate benefits from the addition of the water management strategies and portfolios. Shortages are identified at the customer delivery locations and are further summarized by the source of supply. The cause of the shortage is identified as insufficient water available for diversion in the system, lack of permit capacity, and/or conveyance capacity deficits. Together, these modeling outputs provide direction on what must be implemented to improve system reliability.

Appendix A – RiverWare Model includes details on the adapted IWSP RiverWare model. Extensive modifications were made to adapt the operational model for long-term planning and to reflect the baseline water supply system (detailed in Chapter 4). Appendix A documents these modifications.

2.6.2 Costing Tool

TWDB developed a Unified Costing Model (UCM) for use in the State's Regional Water Planning Process. The UCM provides consistency in cost estimates across each region. The UCM was constructed based on cost curves for infrastructure elements, references project-specific assumptions and is updated every few years to reflect inflationary impacts on construction services and materials. As part of the IWSP Update, a modified version of the UCM was developed and is herein referred to as the Costing Tool. The Costing Tool incorporates cost curves specific to recent infrastructure bids relevant to TRWD and was used to estimate planning level costs for water management strategies.

Note that some strategies required cost analysis outside of the Costing Tool, such as the construction of a new reservoir or strategies with recent planning level costs that need to be updated to current dollars. An independent Excel workbook with a summary tab identical to the Costing Tool was utilized in these instances.

Appendix B – Costing Tool includes details of the Costing Tool, including underlying assumptions, adaptation of cost curves based on recent projections, and the resulting cost curves.

2.6.3 Blue Plan-it

Carollo's Blue Plan-it serves as the data and analysis integration hub and decision-making support platform. The outputs from RiverWare, the Costing Tool, and Excel files are combined to evaluate strategies collectively into the defined portfolios. The key functionalities of the Blue Plan-it tool developed for TRWD include the following:

- Long-term system planning visualization (schematic).
- Visualization of outputs from RiverWare.

- Tracking of system firm and safe yields.
- Processing of outputs from RiverWare to assess gaps and key system performance metrics for a scenario.
- Incorporation of costs from the Costing Tool and other cost estimates via linked Excel files.
- Export of digital factsheets for strategies.
- Calculation of annualized costs for strategies based on timing of implementation and inflation factors.
- Combination of strategy costs for portfolios.
- Ability to perform portfolio sensitivity analysis based on changes to energy cost and inflation assumptions.
- Combination of strategy raw and weighted scores to develop performance measures for portfolios.
- MCDA for comparison of portfolios.
- Capital improvement plan (CIP) planning tool.

2.7 Project Assumptions

Key project assumptions are described below. Appendix C – Project Assumptions provides a detailed matrix of relevant project assumptions and the relative impact on results.

2.7.1 Water Demand Forecast

The demand projections were provided by TRWD, covering a period from 2020 to 2070 for average and dry conditions.[2] Demand assumptions were adopted from TRWD's 2020 Demand Study with a few minor adjustments to account for areas that have grown quicker than projected, adding a new user group in Wise County, and linearly extending to 2080. The following two scenarios from the demand study are utilized:

1. The **Baseline** (BL) demand scenario is the status quo based on current demographics and economic and water conservation projections in the TRWD service area.
2. The **Suburban Sprawl with Stressors** (S3) demand scenario assumes greater suburban growth (e.g., lower density, larger family size, higher income), hot/dry climate, increasing water rates, and the phasing out of local groundwater use.

The selection of a demand scenario for comparison of supplies affects the timing of strategy implementation. The S3 scenario provides the most aggressive timeline in terms of capital investments because it will require water management strategies to be online sooner. Planning is primarily conducted around the S3 demand scenario, with uncertainty and sensitivity analysis using the BL demand conditions. Portfolios are explored and developed using the S3 demands.

These projected demands are mapped to RiverWare delivery nodes. Within RiverWare, the average annual, decadal demands are allocated to the delivery nodes and multiplied by a monthly factor according to TRWD's historical delivery pattern (i.e., demands are higher during summer months and lower during winter months). Generally, each winter month accounts for 6 to 7 percent of annual demand, while each summer month peaks at 12 percent of annual demand. Average demands are further increased or decreased based on the weather observations from the 82 hydrologic years. Periods of dry and hot weather increase demand, while periods of wet and cool weather decrease demand. Appendix C details the actual to average assumptions.

The sections below provide the assumptions inherent to the two selected demand scenarios.

[2] TRWD. 2020. TRWD Service Area Demand Update: Water Demand Forecast Report. Prepared by CDM Smith.

2.7.1.1 Baseline Demand Forecast

The BL forecast assumes historical average weather conditions, planned growth and trends in demographics (as projected by the North Central Texas Council of Governments), and conservation achievements that are likely to occur. The BL forecast represents the most likely future conditions based on demographic projections and the known information.

The following are conservation assumptions inherent to the BL demand scenario:

- All average indoor residential use reduces to 62 gallons per capita per day (gpcd), per Texas plumbing code, by 2040.
- Non-residential passive savings estimated at 25 percent of the residential reduction in gpcd. Passive savings are those that occur over time from plumbing fixture efficiency gains.
- Outdoor water use is reduced by 10 percent by 2050 due to conservation efforts.
- Water rates increase annually to 2040.
- Non-revenue water reduces over time to 10 percent of the total demand (if currently higher than 10 percent).

2.7.1.2 Suburban Sprawl with Stressors Demand Forecast

The S3 forecast assumes that future climate, demographic growth, and low-density development all have a significantly higher impact on demand compared to the BL forecast, with moderate adaptation assumed from water conservation. Mathematically, these changes in demand are expressed relative to the BL by changing the specific factors affecting demand: increasing the rate of population growth, altering the spatial growth pattern, increasing household family size, increasing residential lot size, and decreasing the ratio of multifamily to single-family homes. Most of these variables are also distinguished between "urban" and "suburban" areas.

The following assumptions are inherent to the S3 demand forecast:

- The 2070 population is 10 percent higher than in the BL scenario.
- An expanded TRWD service area covers the extra-territorial jurisdictions of Fort Worth, Mansfield, Grand Prairie, and Waxahachie.
- Household family size is higher in this scenario compared to the BL.
- In suburban areas, residential lot size is 12 percent larger, and the ratio of multifamily to single-family homes decreases by 10 percent compared to the BL forecast.
- Climate is projected to be hotter and drier than the BL, increasing steadily through 2070. This causes a 19 percent demand increase by 2070.
- Adjustments were applied for the year 2070 and interpolated for all interim decades.

In contrast to all other demand forecasts, per capita water demand increases after 2040 in this scenario due to stressors such as climate change.

All conservation assumptions are equal to the BL forecast, except for water rate increases. Water rates are assumed to increase annually by 1.3 percent to 2040 (compared to 0.7 percent in the BL scenario). With this adjustment, conservation in the S3 scenario reduces residential and non-residential water demand by 16 percent, compared to 12 percent in the BL scenario.

2.7.2 RiverWare

The following outlines the general assumptions implemented within the RiverWare modeling specific to the IWSP Update.

- Historical hydrology is used. No attempt was made to adjust the historical hydrology for more extreme events or climate change. Climate change adjustments are included in the S3 demand projections.
- Reservoirs are full at the beginning of the simulation.
- Capacities and constraints are modeled based on current and near-term planned infrastructure improvements.
- Water treatment plant (WTP) capacities at local delivery points are increased to accommodate customers' ability to receive enough water to meet future demands. No cost was assumed for WTP expansions since these costs are borne by the receiving entity and not TRWD.
- Current water use permits are adhered to unless the strategy considered revised the permit.
- Area-capacity relationships for TRWD's major reservoirs are adopted from Region C. The "current conditions" are assumed for 2020, and the 2070 values are assumed for 2080, with interpolation for the intermediate decades.
- TRWD's current reservoir operational rules are implemented. Minor adjustments were made, as needed, to remove operational constraints specific to the current delivery system.
- TRWD's Drought Contingency Plan is turned off, and full demand is modeled.

2.7.3 Cost Estimates

Assumptions specific to TRWD for the Costing Tool are provided in Table 2.4. These assumptions are specific to water management strategies. All strategy costs are in September 2023 dollars.

Table 2.4 Costing Tool Assumptions

	2026 Regional Water Plan(1)	TRWD's Costing Tool
Date for Cost Estimates	September 2023	September 2023
Annual Interest Rate		
Reservoir	3.5%	4.0%
Non-Reservoir	3.5%	4.0%
IDC		
IDC Rate	3.5%	0%(2)
Rate of Return	0.5%	0%(2)
Engineering, Legal, and Contingencies (Pipes)		
Contingency	-	-
Engineering	-	-
Total	30%	30%
Engineering, Legal, and Contingencies (Other)		
Contingency	-	-
Engineering	-	-
Total	35%	35%

	2026 Regional Water Plan[1]	TRWD's Costing Tool
Debt Service Period		
Reservoir	40 years	30 years
Non-Reservoir	20 years	30 years
Power Costs		
Cost per kWh	$0.09	$0.06
Power connection costs for pump stations (per hp)	$150	$5M per pump station if within 2 miles of power grid; if >2 miles from power grid, $5M plus $0.5M/mile of transmission line.
Pipeline Length	Straight line + 10%	Straight line +10%

Notes:
hp - horsepower; IDC - interest during construction
(1) From regioncwater.org/wp-content/uploads/2025/03/2026_Region_C_Initially_Prepared_Plan_Volume_II.pdf, Appendix H.
(2) TRWD begins making payments on borrowed funds immediately (at the beginning of construction), so the Costing Tool does not include additional interest accrued during construction.

When assessing portfolio level costs, the value of money over time is incorporated. Strategies can be brought online during different periods across the 50-year planning horizon, with investments made as needed to meet the water supply gap. Additional portfolio level assumptions are needed to calculate the net present value of a portfolio. Annual inflation is assumed at 4 percent per year, and the discount rate is assumed at 5 percent. When assessing energy costs across the 50-year planning horizon, the cost of energy is assumed at $0.06 per kWh from 2030 through 2059, and then $0.08 per kWh from 2060 through 2080.

CHAPTER 3 BASELINE WATER SUPPLY SYSTEM

This chapter defines the key characteristics and elements of TRWD's baseline water supply system, including the service area extent, water right holdings, water supply reservoirs, and infrastructure to move water from the reservoirs to the customer delivery points, as well as the yield of the reservoirs. Each of these characteristics and elements are foundational to determining the future water supply gaps and needs. The baseline system definition includes current and future planned water supply and conveyance elements.

The extent and components of TRWD's baseline water supply system are shown in Figure 3.1. The TRWD service area includes all or part of Ellis, Navarro, Tarrant, Wise, Denton, Freestone, Henderson, Jack, Johnson, Kaufman, and Parker Counties. Water supply is captured in TRWD's water supply reservoirs and delivered to 95 customer take points along these reservoirs and TRWD's pipelines. Water supply sources, water rights, transmission and pumping capacity, and planned expansions are described in the following sections.

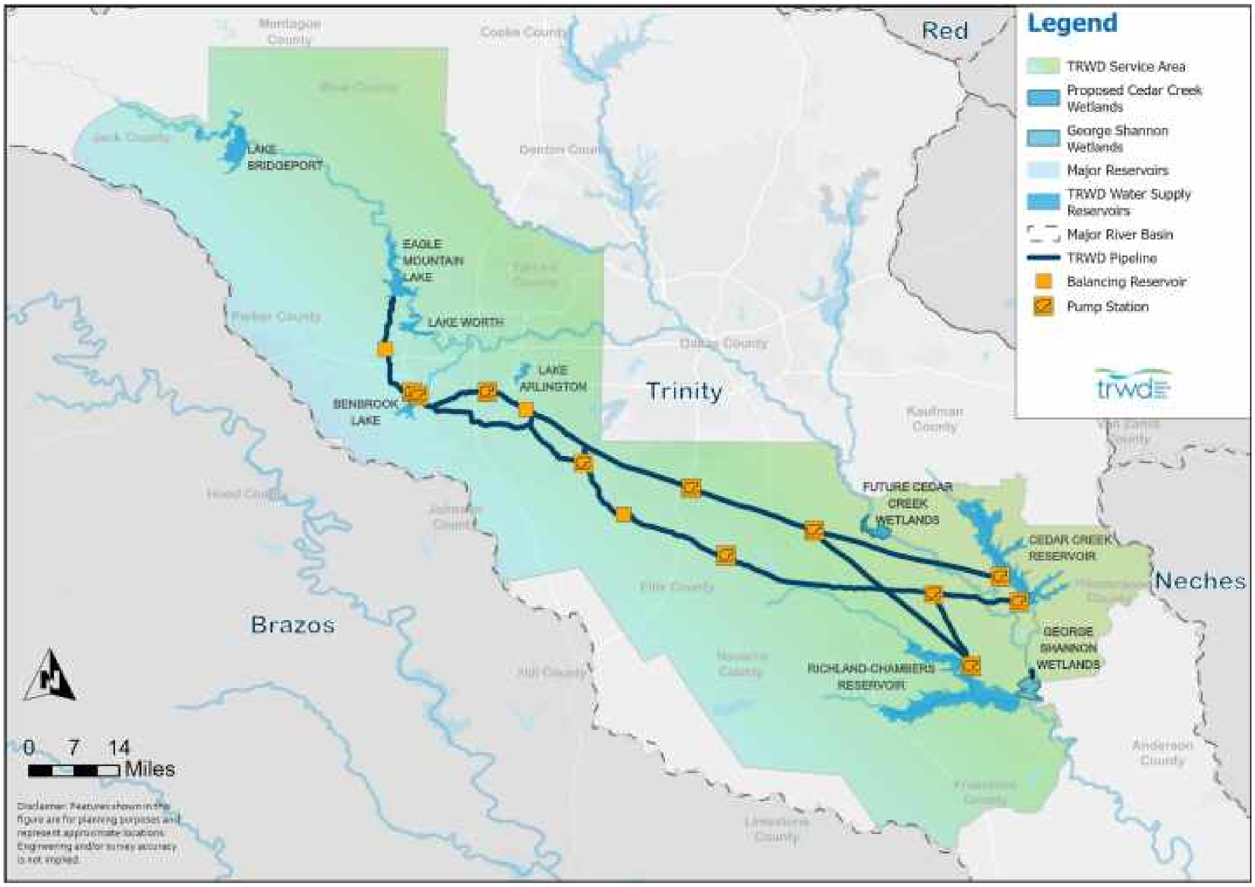


Figure 3.1 TRWD Baseline Water Supply System

3.1 Supply Sources

Supply sources within the TRWD system are characterized into component systems based on permitted surface water rights and TRWD's system configuration. Components of the TRWD water supply system include:

- TRWD East Texas water supply reservoirs.
  - Cedar Creek Reservoir.
  - Richland-Chambers Reservoir.
- TRWD West Fork water supply reservoirs.
  - Lake Bridgeport.
  - Eagle Mountain Lake.
- Terminal storage reservoirs utilized but not owned by TRWD.
  - Lake Arlington.
  - Benbrook Lake (provides some additional yield).
  - Lake Worth.
- Permitted return flow reuse projects.
  - George W. Shannon Wetlands, also referred to as the Richland-Chambers Wetlands.
  - Marty Leonard Wetlands, also referred to as the Cedar Creek Wetlands (to be constructed in the future but assumed to be part of the baseline TRWD supply system).
- ExFlo permits.
  - Benbrook Lake.
  - Eagle Mountain Lake.
  - Richland-Chambers Reservoir.
  - Cedar Creek Reservoir.
- Other sources.
  - Bed and banks authorizations.
  - Minor permits.

3.2 Water Rights

Table 3.1 provides a summary of TRWD water rights with authorized storage amounts, annual diversions, and corresponding priority dates. TRWD's existing water rights are all within the Trinity River Basin, and annual water rights total just over 810,000 AF. About 71 percent of the water rights are in the East Texas reservoirs. In addition to the water rights shown in Table 3.1, TRWD also administers some water rights held by others, including at Lakes Arlington and Worth.

Table 3.1 Water Rights Summary

Source	Certificate of Adjudication No.	Authorized Use (AFY)	Authorized Storage (AF)	Priority Date(s)
Cedar Creek Reservoir	08-4976E	263,059	678,900	May 28, 1956 September 7, 2000
Richland-Chambers Reservoir	08-5035E	310,465	1,135,000	October 18, 1954 September 7, 2000
Cedar Creek Wetlands	08-4976D	88,059(1)	2,700	September 7, 2000

Source	Certificate of Adjudication No.	Authorized Use (AFY)	Authorized Storage (AF)	Priority Date(s)
Richland-Chambers Wetlands	05-5035D	100,465(1)	3,000	September 7, 2000
Cedar Creek Reservoir ExFlo	13233	36,403 44,093, subject to maximum authorized for wetlands	Same as Cedar Creek Reservoir (08-4976E)	October 3, 2016 March 21, 2019
Richland-Chambers Reservoir ExFlo	13234	31,320 55,080, subject to maximum authorized for wetlands	Same as Richland-Chambers Reservoir (08-5035E)	October 3, 2016 March 21, 2019
Eagle Mountain Lake	08-3809C	159,600(2)	210,000	July 13, 1925
Lake Bridgeport	08-3808C	93,000 (78,000 maximum release to Eagle Mountain, 12,000 of which can be held for local use).	387,000	July 6, 1926
Benbrook ExFlo-1	12805	78,653	Same as Benbrook Lake (5157A)	February 20, 2014
Eagle Mountain ExFlo-1	12806	63,899	Same as Eagle Mountain Lake (08-3809)	February 20, 2014
Benbrook Lake	5157A	72,500(3)	72,500	Various: May 18, 1959–July 1, 1987
Clear Fork Bed & Banks	5806	N/A	N/A	N/A
Village Creek Bed & Banks	12735	N/A	N/A	August 14, 2012
Nutt Dam	08-3375	1,121	673	June 29, 1914
Bahan	08-3379	N/A	64	April 30, 1931
Marine Creek Lake	08-3812	0	15,366	April 2, 1956
Cement Creek Lake	08-3813	0	3,952	April 2, 1956
Greek Farmers	08-3813	130	5	December 31, 1922

Notes:
AF - acre-feet; AFY - acre-feet per year
(1) Wetlands amount is also included in authorized use of the reservoir. Should not be added to the total water rights calculation to avoid double counting.
(2) Storage volume may be used for terminal storage of water from East Texas supply reservoirs.
(3) As authorized under permit 5157A, the combined total annual diversion from Benbrook Lake, including re-diversion of water originating in other reservoirs, is limited to 72,500 AF.

3.2.1 East Texas Water Supply Reservoirs

The TRWD East Texas water supply reservoirs include Cedar Creek and Richland-Chambers Reservoirs, with a combined authorized use of 573,524 AFY, excluding TRWD's ExFlo permits, which are not fully available every year. TRWD is authorized to impound 1,135,000 AF of water in Richland-Chambers

Reservoir and 678,900 AF in Cedar Creek Reservoir. There are 310,465 AFY of diversions permitted from Richland-Chambers Reservoir, of which 210,000 AFY have a 1954 priority date and the remaining 100,465 AFY have a 2000 priority date. There are 263,059 AFY of diversions permitted from Cedar Creek Reservoir, of which 175,000 AFY have a 1956 priority date and the remaining 88,059 AFY have a 2000 priority date.

The 1954 and 1956 authorizations were based on the concept of safe yield, defined as the maximum annual diversion that can be met during a repeat of the drought of record while leaving an equal amount of water in storage at the end of the critical dry period. The safe yield concept recognizes the possibility of a drought that is more severe than the drought of record and attempts to mitigate the impact by reserving additional water in storage.

In 2005, the water rights for Richland-Chambers and Cedar Creek Reservoirs were amended to include constructed wetlands. These amendments allowed TRWD to divert return flows from the Trinity River into off-channel constructed wetlands to improve water quality, before being delivered to the reservoirs to supplement natural inflow. The amendment adding the Richland-Chambers Wetlands included a separate off-channel 3,000 AF impoundment for storing and treating return flows and increased the authorized diversion amount from the lake by 100,465 AFY. The amendment adding the Cedar Creek Wetlands included a separate 2,700 AF impoundment to receive return flows and increased the authorized diversion amount from the reservoir by 88,059 AFY.

TRWD manages deliveries from the East Texas reservoirs to meet customer demands and to supplement lake levels at Eagle Mountain Lake, Lake Arlington, and Lake Benbrook during off-peak periods. During normal operating conditions, TRWD diverts water in excess of demands into Lakes Arlington and Benbrook. Supplementing these reservoirs with the East Texas supplies in conjunction with natural hydrologic inflow maximizes storage to meet peak demands during the summer.

3.2.2 West Fork Water Supply Reservoirs

The West Fork system is comprised of Lake Bridgeport and Eagle Mountain Lake. The Lake Bridgeport permit provides TRWD with the right to impound 387,000 AF, use up to 15,000 AFY locally in Jack and Wise Counties, and to release up to 78,000 AFY to Eagle Mountain Lake for use in Tarrant County. Of the 78,000 AFY permitted for release to Eagle Mountain Lake, 12,000 AFY may be retained for local use at Lake Bridgeport in addition to the 15,000 AFY authorized for local use.

The Eagle Mountain Lake permit provides TRWD the right to impound 210,000 AF and use up to 159,600 AFY. TRWD is authorized to use the permitted storage volume in Eagle Mountain Lake as a terminal storage reservoir for water diverted from its East Texas reservoirs via the "Eagle Mountain Connection" pipeline. TRWD is authorized to divert and use the full amount of water placed into storage (less evaporative losses).

The West Fork reservoirs are evaluated as a system because Eagle Mountain Lake's yield depends on the water release from Lake Bridgeport. The authorized diversions from Eagle Mountain Lake and Lake Bridgeport are greater than the firm yield of the two lakes.

3.2.3 Benbrook Lake

Benbrook Lake is a United States Army Corps of Engineers (USACE) reservoir on the Clear Fork of the Trinity River. It was originally constructed to provide flood control and navigation. TRWD's Permit No. 5157, granted in 1987 and amended in 1998, provides the right to impound 72,500 AF of water between elevations 665 feet above mean sea level (msl) and 694 feet msl, divert and use up to 6,833 AFY from the reservoir, and utilize the storage volume of 72,500 AF for terminal storage of water diverted from Cedar Creek and Richland-Chambers Reservoirs. TRWD is also authorized via the permit to overdraft the lake when the lake elevation is at or above 694 feet msl or overdraft the lake under special conditions when the lake elevation is below 694 feet msl; however, TRWD is not authorized to divert more than 72,500 AFY in a given year.

3.2.4 Other Rights

TRWD holds three "bed and banks" authorizations (i.e., Clear Fork Bed & Banks, Village Creek Bed & Banks, and Nutt Dam) that provide the right to utilize the specified watercourses and impoundments to convey water to TRWD's customers. The Nutt Dam permit also authorizes diversion of 11,210 AFY, with 1,121 AFY authorized for industrial consumptive use and the remaining 10,089 AFY authorized for non-consumptive use that must be returned to the West Fork of the Trinity River. Marine Creek Lake and Cement Creek Lake impound water for recreation and flood control purposes, with no right of diversion. The remaining permits are small irrigation permits that have been acquired by TRWD.

3.2.5 ExFlo

Table 3.1 also reflects that TRWD holds ExFlo-1 permits on Benbrook Lake (Permit No. 12805) and Eagle Mountain Lake (Permit No. 12806). The ExFlo-1 permits provide TRWD with a supplemental water supply during high-flow periods when excess and unappropriated flows are available. These permits allow diversions of excess flows from Benbrook and Eagle Mountain Lakes when the water surface elevation of these reservoirs is above their respective conservation pool levels (694.0 feet msl for Benbrook Lake and 649.1 feet msl for Eagle Mountain) and when the water surface elevation of Lake Livingston is at or above its conservation pool level (131.0 feet msl). Otherwise, diversions from these reservoirs are accounted for within the respective reservoir's other water rights. Due to their junior priority dates, ExFlo1 diversions from the reservoirs are also subject to the Senate Bill 3 environmental flow standards at the Grand Prairie streamflow gage on the West Fork of the Trinity River. While these permits do not provide an additional firm water supply, they facilitate greater efficiencies in TRWD operations by reducing the amount of water pumped from TRWD's more distant East Texas water supply reservoirs when local surplus flows are available.

ExFlo permits were recently obtained for Cedar Creek and Richland-Chambers Reservoirs. As with the West Fork reservoirs, these permits do not provide additional firm water supply. However, it allows TWRD to make use of that authorization sooner and offer more operational flexibility.

3.2.6 Subordination of Lake Livingston

TRWD is a member of the class entitled to exercise the subordination provisions contained in Special Conditions 5. F, G, and H. in CoA 08-4248, owned by TRA, and in Special Condition 5. H, I, and J. in CoA 08-4261, owned by the City of Houston, for Lake Livingston. These conditions state that the water rights associated with Lake Livingston are subordinate to any claim on waters imported and/or originating in the Trinity River Basin above Lake Livingston that could be impounded by existing reservoirs; permitted reservoirs; reservoirs for which applications were pending as of the date of the permits for Lake Livingston; and a specific list of proposed reservoirs identified in the 1958 Master Plan Report of TRA.

All TRWD reservoirs listed in Table 3.2 are beneficiaries of the subordination provisions. Additionally, the provisions state that the Lake Livingston water rights are further subordinate to the present and future use, reuse, and consumptive use of any return flows from waters impounded in the designated upstream reservoirs.

3.3 Reservoir Yields

While TRWD's annual water rights exceed 800,000 AF, a water right is not a guarantee of available supply. Hydrologic conditions vary significantly from year to year in North Texas. Wet years bring excess water and flooding, while drought years put pressure on water supplies. Reservoir yield typically refers to the quantity of water from a reservoir projected to be available reliably during a critically dry period. Firm yield, specifically, is the maximum amount of water that can reliably be supplied during a repeat of the drought of record, regardless of how much water is permitted. Safe yield is defined as the maximum annual diversion that can be met while leaving an amount of water in storage. For TRWD, this specified minimum amount is defined as 1 year of supply.

Region C provides TRWD with firm and safe yield supply estimates for TRWD's major water supply reservoirs, as summarized in Table 3.2. Generally, Region C firm and safe yield estimates reflect modeled sedimentation impacts that have likely occurred since reservoir construction. TRWD's total firm yield is currently estimated at approximately 665,000 AF. With the addition and anticipated buildout of Cedar Creek Wetlands, and including sedimentation impacts, the firm yield is projected to increase to just under 739,000 AF by 2080. Safe yield is significantly lower, at a current estimate of 555,000 AF, increasing to 625,000 AF by 2080.

Table 3.2 Firm and Safe Yield of Reservoirs in AFY

	2030	2040	2050	2060	2070	2080
Firm Yield						
Richland Chambers Reservoir	224,650	223,205	221,760	220,357	218,953	217,550
Richland Chambers Wetlands	100,465	100,465	100,465	100,465	100,465	100,465
Cedar Creek Reservoir	207,350	206,105	204,860	203,640	202,420	201,200
Cedar Creek Wetlands(1)	0	40,856	58,273	74,191	90,974	90,974
West Fork System	118,961	118,361	117,761	117,078	116,394	115,711
Benbrook Lake	4,271	4,271	4,271	4,271	4,271	4,271
Lake Arlington	9,500	9,350	9,200	9,067	8,933	8,800
Total Firm Yield	**665,197**	**702,613**	**716,590**	**729,069**	**742,410**	**738,971**
Safe Yield						
Richland Chambers Reservoir	190,000	188,266	186,531	184,781	183,030	181,280
Richland Chambers Wetlands	100,465	100,465	100,465	100,465	100,465	100,465
Cedar Creek Reservoir	157,150	155,340	153,530	151,797	150,063	148,330
Cedar Creek Wetlands(1)	0	40,856	58,273	74,191	90,974	90,974
West Fork System	96,161	95,561	94,961	94,428	93,894	93,361
Benbrook Lake	3,371	3,371	3,371	3,371	3,371	3,371
Lake Arlington	7,500	7,385	7,270	7,157	7,043	6,930
Total Safe Yield	**554,647**	**591,244**	**604,401**	**616,190**	**628,840**	**624,711**
90% Safe Yield	**499,182**	**532,120**	**543,961**	**554,571**	**565,956**	**562,240**

Notes:
Source: 2026 Region C Initially Prepared Plan, Volume II. Available at https://regioncwater.org/wp-content/uploads/2025/03/2026_Region_C_Initially_Prepared_Plan_Volume_II.pdf.
(1) The yield at Cedar Creek Wetlands ramps up over time to the full permitted value based on projected available return flows.

3.4 Transmission

The baseline TRWD water supply system also includes the pumping and transmission facilities, including the "legacy pipelines" from Cedar Creek and Richland-Chambers Reservoirs and the IPL. The IPL is an intrasystem conveyance project constructed in partnership with DWU. The first phases of the IPL construction were completed in 2018, and based on TRWD's currently effective CIP, all portions of the IPL are anticipated to be complete around 2037. The IPL provides additional conveyance capacity from the existing East Texas reservoirs. Additional pipelines include the Eagle Mountain Connection between Benbrook Lake, Eagle Mountain Lake, and Fort Worth's Westside WTP; and a pipeline from Benbrook Lake to Rolling Hills WTP. Conveyance pipeline size, length, and maximum capacity are shown in Table 3.3.

Table 3.3 TRWD Baseline Raw Water Conveyance Capacity

Pipeline	Diameter (inches)	Length (miles)	Maximum Capacity(2) (mgd)
Cedar Creek Legacy Pipeline	72 to 84	74	127
Richland-Chambers Legacy Pipeline	90 to 108	78	247
IPL(1)	84 to 120	150	350 (200 to TRWD)
Benbrook Connection	90	11.2	230
Eagle Mountain Connection	84 or 96	20	350

Notes:
(1) IPL information obtained from the Integrated Pipeline Project Quarterly Executive Update, September 2024.
(2) Max capacity shown is accepted de-rated line capacity. The maximum capacity shown is the system capacity as limited by other parts of the system. For example, the actual capacity of the pipelines from Kennedale Balancing Reservoir to Lake Arlington and on to Rolling Hills WTP can be as high as 430 mgd if the Rolling Hills Booster Pump Station is used to pump into the Rolling Hills WTP and if the pipelines upstream of Kennedale Balancing Reservoir were able to transmit 430 mgd to Kennedale Balancing Reservoir.

TRWD's system also includes three balancing reservoirs: Eagle Mountain Balancing Reservoir, Kennedale Balancing Reservoir, and Midlothian Balancing Reservoir. The balancing reservoirs do not provide a source of supply but rather facilitate transmission operations. To date, they have not been represented within the official TCEQ WAM for the Trinity River Basin, which models permitted supply.

Outlet structures connect transmission lines to reservoirs. The outlet names and maximum capacities are listed in Table 3.4. Outlet capacity ranges from 118 to 280 mgd.

Table 3.4 Outlet Capacity

Outlet	Maximum Capacity (mgd)
Arlington Outlet	225
Benbrook Outlet	200
Eagle Mountain Outlet	280
Clear Fork Outlet	118

3.5 Pumping

TRWD's pump stations are shown in Figure 3.1 and summarized in Table 3.5. Pump station abbreviations (typically two or three letters and a number) are provided in Table 3.5.

Table 3.5 Pump Station Capacity

Pump Station	Maximum Capacity (mgd)
Cedar Creek Intake Pump Station (CC1)	240
Joint Cedar Creek Intake Pump Station (JCC1)	270
Richland-Chambers Intake Pump Station (RC1)	240
Joint Richland-Chambers Intake Pump Station (JRC1)	250
Booster Pump Station at Ennis, Cedar Creek side (CC2)	120
Booster Pump Station at Ennis, Richland-Chambers side (RC2)	240
Booster Pump Station at Waxahachie, Cedar Creek side (CC3)	120
Booster Pump Station at Waxahachie, Richland-Chambers side (RC3)	240
JB2 Booster Pump Station (JB2)	350
JB3 Booster Pump Station (JB3)	350
JB4 Booster Pump Station (JB4)	200
Benbrook Lake Intake Pump Station (BB1)	200
Rolling Hills Booster Pump Station (RH2)	230 mgd West and 400 mgd to WTP
Benbrook Booster Pump Station (BB2)	350
Palestine Pump Station, LP1 (used by DWU for IPL)	150

3.6 Water Treatment Plants

TRWD customers operate WTPs that rely upon TRWD's supply. Table 3.6 provides details about the capacities of the largest treatment plants and planned expansions. Future water supply deliveries in the modeling are not constrained by WTP design capacity, assuming customers will expand capacity as demands grow at their own cost.

Table 3.6 Major Water Treatment Plants in TRWD Service Area

Customer	WTP	Current Capacity, (mgd)	Planned Expansion Date	Future Planned Capacity (mgd)
City of Fort Worth	Holly	190	N/A	190
	Rolling Hills	190	2034	240
	Eagle Mountain	105	2039	170
	Westside WTP(1)	18	2032	36
City of Arlington	Pierce-Burch	75	N/A	95
	John F. Kubala	97.5	N/A	97.5
City of Mansfield	Bud Ervin	45.5	2027	63
	Mansfield II (future)	-	2032	Initial = 20; Buildout = 50-75

Customer	WTP	Current Capacity, (mgd)	Planned Expansion Date	Future Planned Capacity (mgd)
TRA	TCWSP	79.7	2026 2041	82.1 85.6
TRA	Ennis	9.1	before 2030	17.1
Misc.	Midlothian - Tayman	12	N/A	12
	Midlothian - Auger	24	N/A	24
	Sokoll WTP	20	unknown date	80

Notes:
TCWSP - Tarrant County Water Supply Project
(1) The Westside WTP received conditional approval to expand from 18 mgd to 21 mgd.

The City of Fort Worth's WTPs receive water from Lake Worth, Benbrook Lake, pipeline sources, and Eagle Mountain Lake. The Holly WTP is primarily supplied from Lake Worth but may be supplemented with Benbrook Lake water pumped from the Clear Fork of the Trinity River. TRWD's Benbrook Connection allows water from East Texas to flow to Benbrook Lake, and the blended water can be pumped back to the Rolling Hills or Holly WTPs. TRWD can also deliver water to the Clear Fork from the Eagle Mountain Connection Pipeline through the Clear Fork Outlet Structure. Rolling Hills WTP draws water from the legacy pipeline. The Westside WTP receives flow from the Eagle Mountain Connection Pipeline. The Eagle Mountain WTP draws water from Eagle Mountain Lake.

The City of Arlington's WTPs receive flows from Lake Arlington and the pipeline. The Pierce-Burch WTP has an intake on Lake Arlington, which receives runoff from Village Creek and is supplied from Cedar Creek and Richland-Chambers Reservoirs via the Arlington Outlet when needed. The John F. Kubala WTP receives water from the pipeline.

The City of Mansfield's WTP, Midlothian Auger WTP, and Waxahachie's Sokoll WTP receive flows from the legacy pipeline. The Midlothian Tayman WTP receives flows from Joe Pool Lake, which is not TRWD water, and TRA's TCWSP has an intake on Lake Arlington.

Customer WTPs and other customer delivery points are depicted in Figure 3.2.

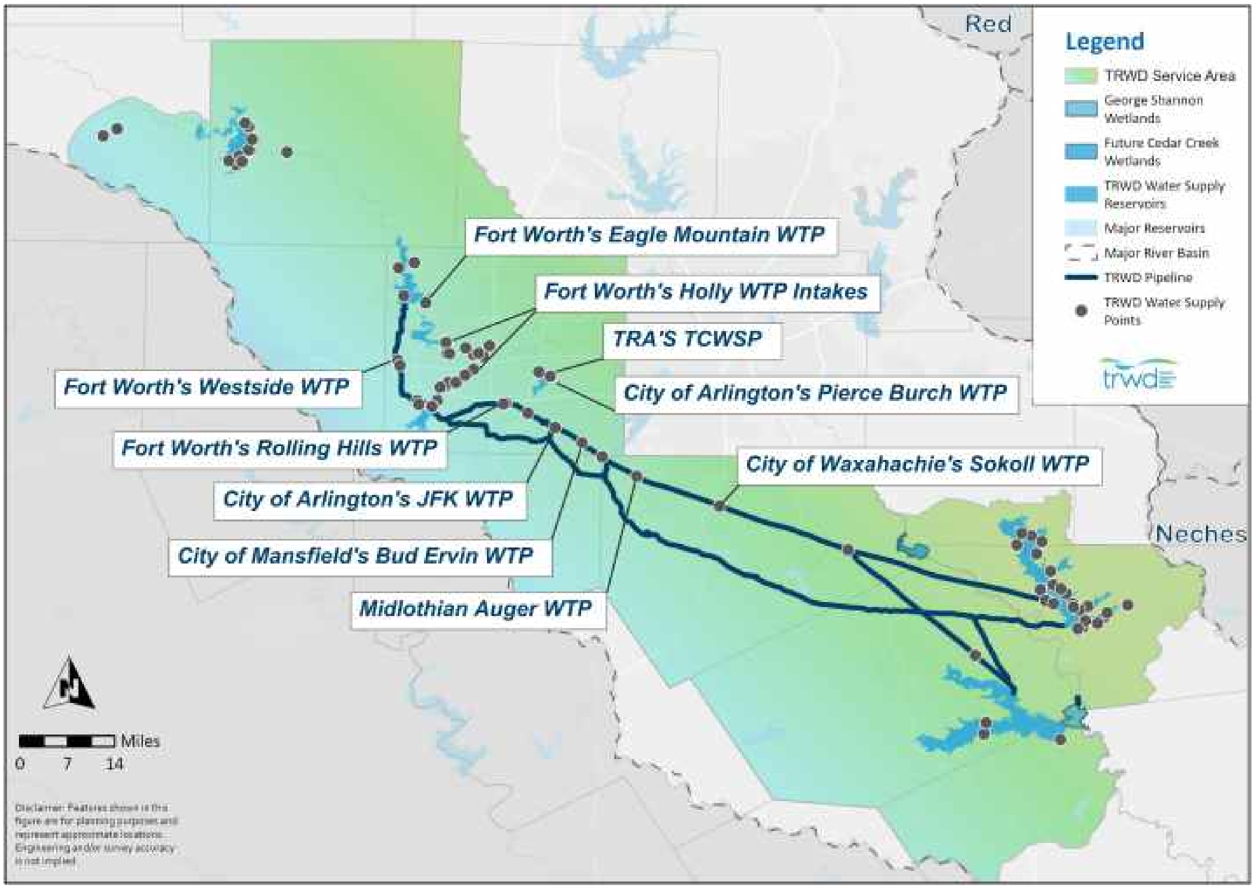


Figure 3.2 Water Supply Delivery Locations and Major Water Treatment Plants

CHAPTER 4 WATER DEMANDS

The IWSP Update builds on water demand projections prepared by TRWD in 2020 with minor revisions and an extension to 2080. This chapter includes an overview of historical TRWD deliveries and presents scenario-based future demand projections that serve as a critical input to the IWSP Update. For information on the assumptions, data, and approach for the water demands, see Chapter 2.7.1.

4.1 Historical and Current Demands

TRWD service area annual deliveries grew from 217,000 AF in 1992 to 418,000 AF in 2024, as shown in Figure 4.1. On average, demand grew by about 2 percent per year across the 32-year period. In 2022, after a very hot summer, TRWD recorded its highest demand to date, with annual deliveries reaching 428,600 AF. The demand record was surpassed the next year when TRWD's demands were 438,700 AF. In 2024, with weather closer to average, demands totaled 418,000 AF.

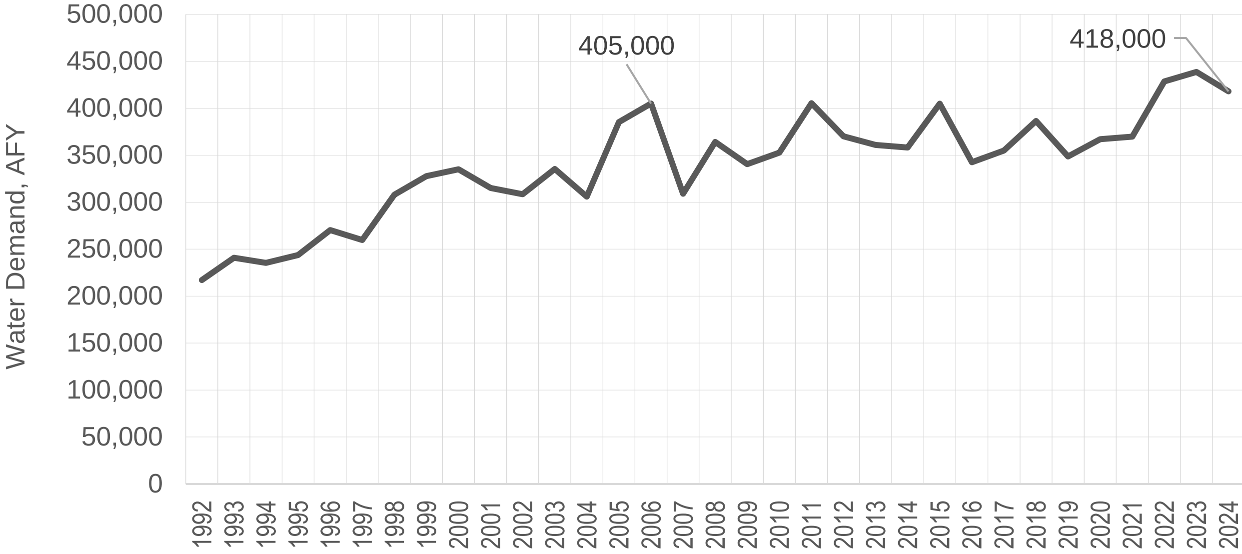
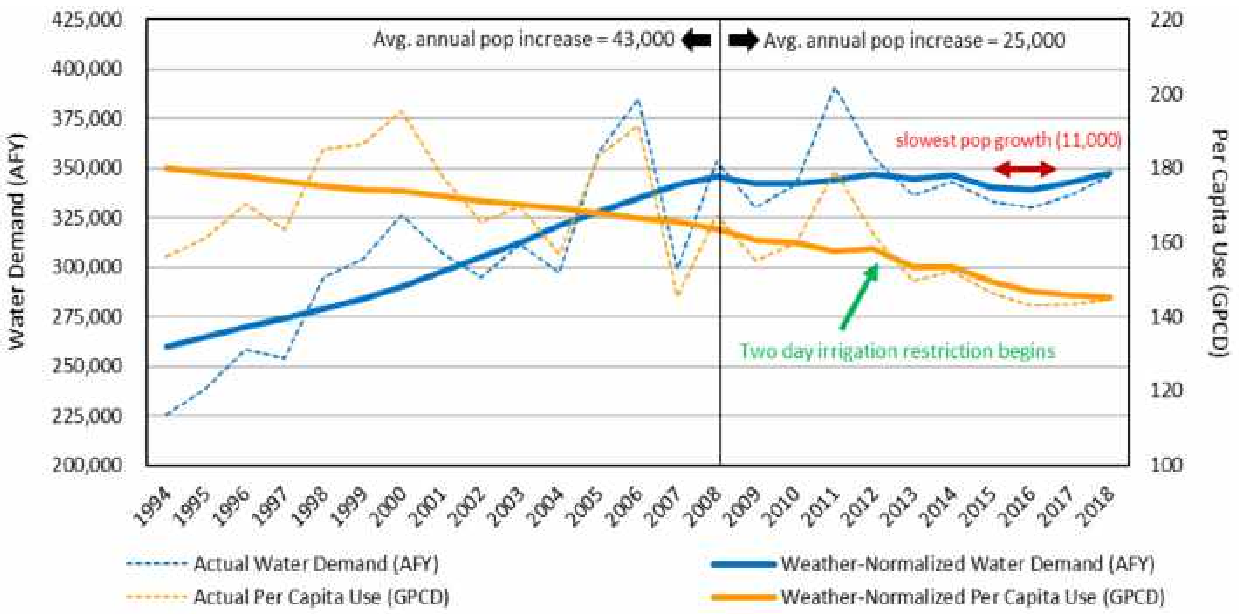


Figure 4.1 TRWD Historical Water Deliveries from 1992 to 2024

As shown in Figure 4.2, the most rapid growth in water demand occurred between 1992 and 2008, coinciding with a year-over-year population increase of 43,000 more people per year on average over the 16-year period.[1] Annual population growth slowed to an average rate of 25,000 more people per year from 2008 to 2018. TRWD's 2007 conservation program started in the mid-2000s combined with the U.S. Energy Policy Act of 1992 and the 2010 Texas Plumbing Fixtures Act contributed to lower per capita water use due to a combination of behavioral changes and plumbing fixture efficiency changes. Demands fluctuated widely from 2006 to 2024 depending on weather conditions, economic conditions, growth, and enactment of drought restrictions.

[1] TRWD. 2020. TRWD Service Area Demand Update: Water Demand Forecast Report. Prepared by CDM Smith.



Source: TRWD Service Area Demand Update: Water Demand Forecast Report, 2020

Figure 4.2 TRWD Municipal Water Demand and Per Capita Water Use Historical Analysis

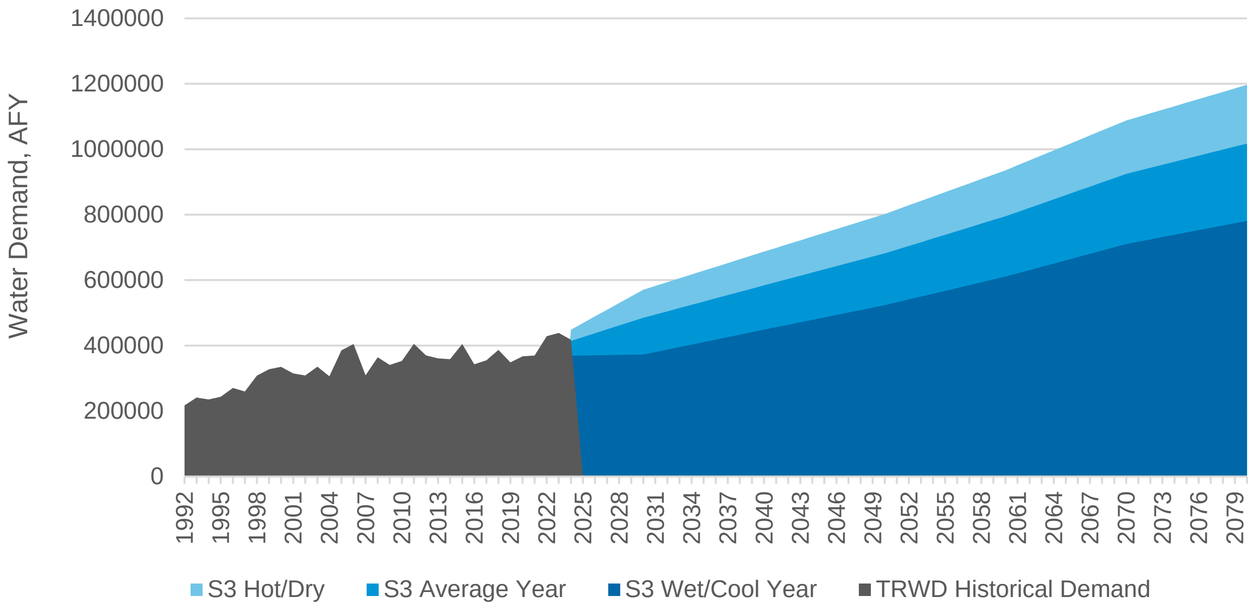
4.2 System Demand Projections

Water demand projections under cool/wet, average, and hot/dry conditions are provided in Table 4.1 and Figure 4.3. Under the range of historical weather conditions, current demand could range between 370,000 and 450,000 AFY. Given the S3 growth conditions and other assumptions on climate and conservation, the 2080 range of water demand is between 781,000 and 1,200,000 AFY, representing demand growth of up to 750,000 AFY during hot and dry conditions. The projected growth is an increase of 167 percent over the next 50 years and represents continued population and economic growth across TRWD's 11-county service area.

Table 4.1 System Demand Projections from 2030 to 2080

Year	S3 Demands Under Cool/Wet Conditions (AFY)(1)	S3 Demands Under Average Conditions (AFY)(1)	S3 Demands Under Hot/Dry Conditions (AFY)(1)
2030	372,430	484,870	570,540
2040	448,520	583,930	687,090
2050	523,530	681,600	802,000
2060	610,740	795,150	935,600
2070	710,120	924,540	1,087,840
2080	781,270	1,017,170	1,196,830

Notes:
(1) Developed from RiverWare outputs which are derived from average-to-actual ratios for each hydrologic year. The cool/wet hydrologic year resulting in the lowest demands is from 1978 weather conditions. The "average conditions" was calculated by averaging demands across the 82 hydrologic years. The hot/dry hydrologic year resulting in the highest demands is from 2006 weather conditions.



Notes: S3 = Suburban Sprawl with Stressors demand scenario.

Figure 4.3 System Demand Projections to 2080

4.3 Demands by Municipal Customer

The municipal customer demand projections for the S3 hot and dry condition are provided in Table 4.2. Customer demands are geographically dispersed across the TRWD system and are supplied from various sources. The largest of TRWD's customer deliveries are to Rolling Hills WTP, Eagle Mountain WTP, Holly WTP, John F. Kubala WTP, the Westside WTP, and Mansfield WTP. Many of TRWD's customers treat the raw water and then wholesale treated supply to other municipalities and water users. Some customer nodes have relatively constant demand over the planning horizon, while others are projected to experience sharp increases. This geographic variability of demands impacts the supplies needed and infrastructure to convey the supply, forming the basis for strategy selection, portfolio creation, and implementation planning.

Table 4.2 Demand Projections by Municipal Customer Delivery Point

Municipal Customer Delivery Point	Supply Source	S3 Demands Under Hot/Dry Conditions (AFY)					
		2030	2040	2050	2060	2070	2080
Lake Arlington Local Use	Lake Arlington	190	190	190	190	190	190
Benbrook Lake Local Use	Lake Benbrook	1,410	1,410	1,410	1,410	1,410	1,410
Bridgeport Lake Local Use	Lake Bridgeport	25,480	26,320	27,830	29,430	31,380	32,650
Benbrook Water Authority	Lake Benbrook	4,040	4,250	4,860	5,490	5,980	6,400
Cedar Creek Reservoir Local Use	Cedar Creek Reservoir	6,740	7,210	8,470	9,680	11,010	11,680
Eagle Mountain Local Use	Eagle Mountain Lake	8,050	12,180	24,480	33,930	42,220	49,350
Eagle Mountain WTP	Eagle Mountain Lake	86,650	114,690	138,410	170,720	208,510	232,110
Constellation	Lake Arlington	1,190	1,190	1,190	1,190	1,190	1,190

Municipal Customer Delivery Point	Supply Source	S3 Demands Under Hot/Dry Conditions (AFY)					
		2030	2040	2050	2060	2070	2080
Holly WTP	Lake Worth	78,010	86,230	90,500	93,890	99,880	108,200
John F. Kubala WTP	Pipeline	58,380	65,260	67,010	71,610	77,980	83,670
Mansfield WTP	Pipeline	24,350	30,570	36,800	45,640	56,460	61,530
Midlothian	Pipeline	8,470	13,200	18,980	27,310	35,110	39,450
Pierce Burch WTP	Lake Arlington	27,510	29,700	32,160	34,040	36,870	39,460
Richland-Chambers Reservoir Local Use	Richland-Chambers Reservoir	7,340	7,360	7,410	7,470	7,570	7,770
Rolling Hills WTP	Pipeline	158,790	186,770	210,030	238,740	273,510	299,930
Tierra Verde	Pipeline	230	230	230	230	230	230
TRA TCWSP	Lake Arlington	44,000	45,330	50,200	53,710	57,940	61,070
Waxahachie Rockett	Pipeline	8,500	11,510	15,930	22,030	28,850	31,670
Weatherford(1)	Lake Benbrook	3,100	5,780	8,640	11,610	14,680	17,850
Westside WTP	Pipeline	14,730	34,320	53,870	73,850	93,400	107,530
Lake Worth Local Use	Lake Worth	3,370	3,380	3,400	3,420	3,470	3,480

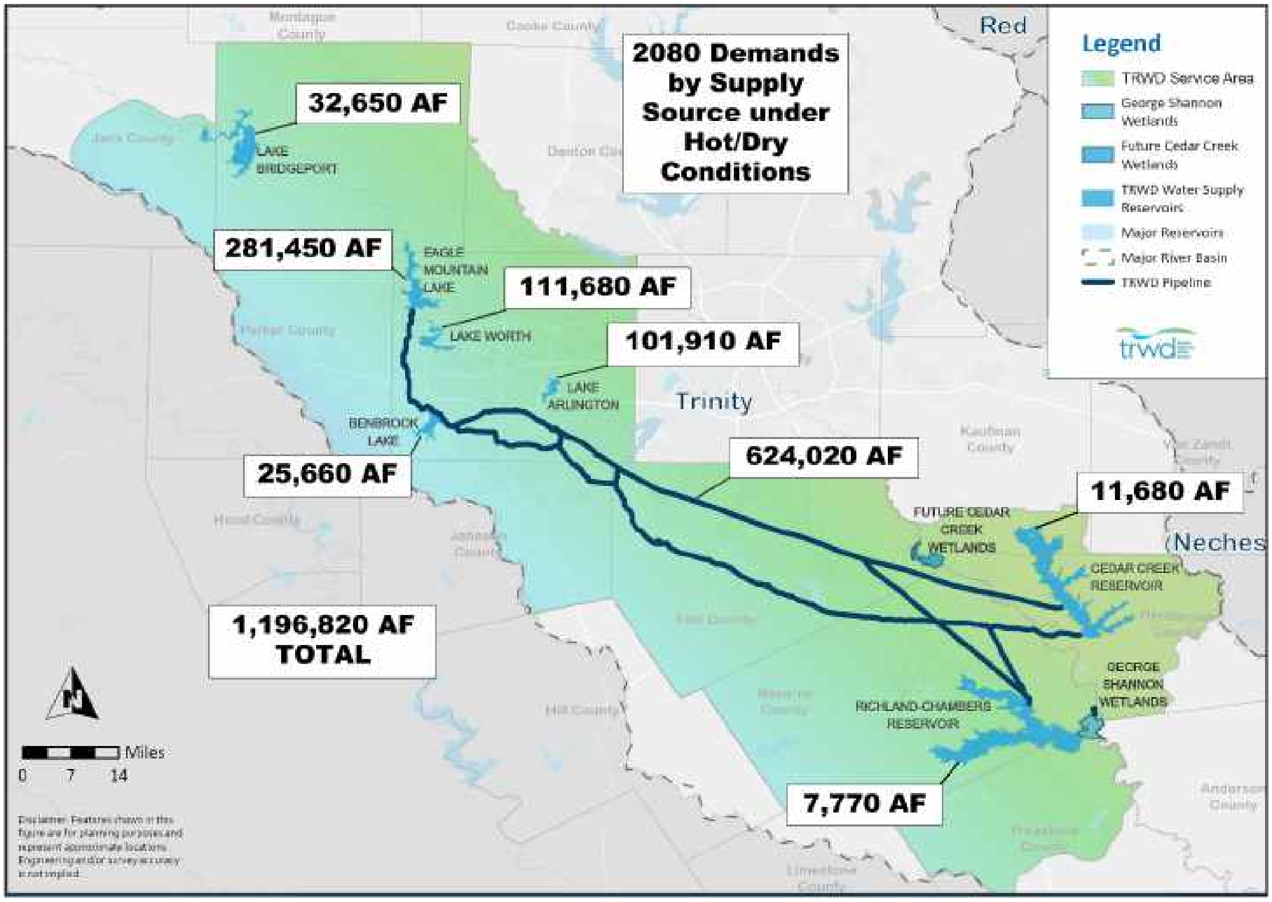
Notes:
(1) Weatherford demand is adjusted by 4,800 AF each year to account for local supply.
(2) Additional minor demands are included for industrial and irrigation customers but not included in the summary.

4.4 Demands by Supply Source

Water demands by customer delivery point are mapped to supply source, as provided in Table 4.3, and shown visually for 2080 in Figure 4.4. The largest system demands in 2080 are expected to be along the Pipeline (including legacy pipelines and the IPL) at more than 50 percent of demand. Eagle Mountain Lake demands make up another 24 percent of demand. When combined with Lake Worth demands, this region is one-third of total demands. As with demand by customer, demand by delivery point grows at different rates depending on projected population growth in each area of the system.

Table 4.3 S3 Hot/Dry Year Demand Projections by Delivery Point

Source	S3 Demands Under Hot/Dry Conditions (AFY)						2080 % of Total
	2030	2040	2050	2060	2070	2080	
Cedar Creek Reservoir	6,740	7,210	8,470	9,680	11,010	11,680	1%
Richland Chambers Reservoir	7,340	7,360	7,410	7,470	7,570	7,770	1%
Pipeline	273,460	341,870	402,860	479,420	565,540	624,020	52%
Lake Arlington	72,890	76,410	83,740	89,130	96,190	101,910	9%
Lake Benbrook	8,550	11,440	14,920	18,520	22,070	25,660	2%
Lake Worth	81,380	89,600	93,900	97,310	103,350	111,680	9%
Lake Bridgeport	25,480	26,320	27,830	29,430	31,380	32,650	3%
Eagle Mountain Lake	94,700	126,870	162,890	204,650	250,730	281,450	24%
TOTAL	**570,540**	**687,080**	**802,020**	**935,610**	**1,087,840**	**1,196,820**	

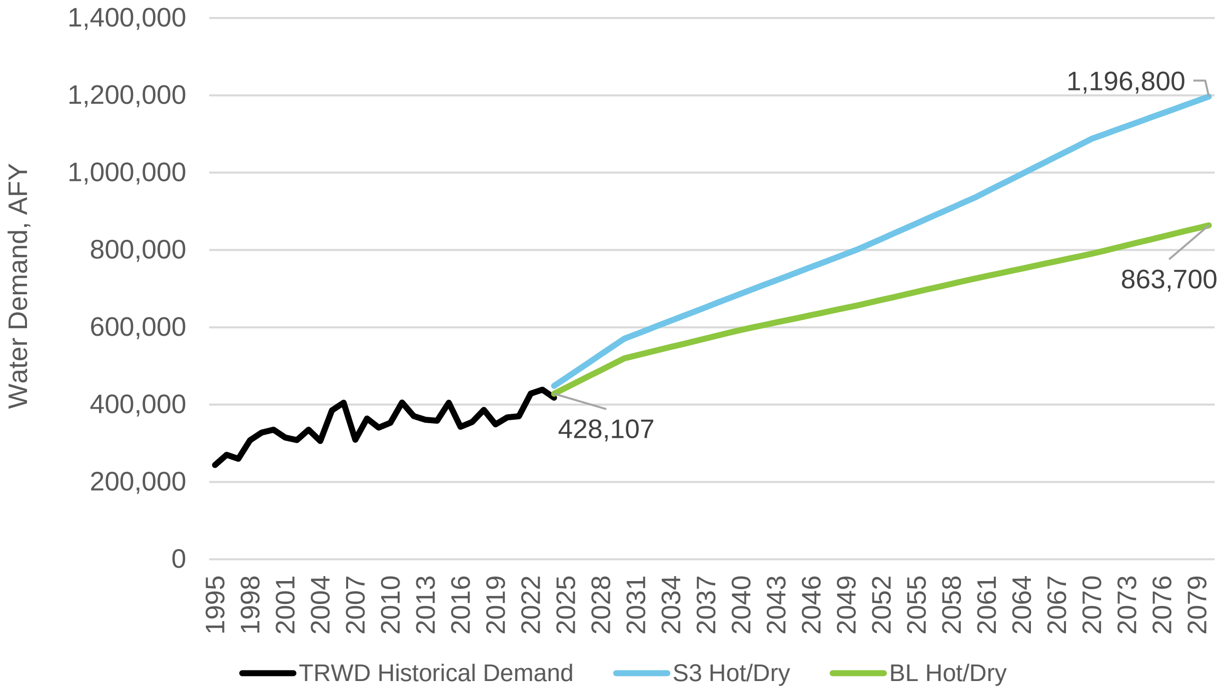


Notes: Projections represent the S3 (Suburban Sprawl with Stressors) demand scenario under hot and dry conditions.

Figure 4.4 TRWD Projected Demands by Source in 2080

4.5 Demand Uncertainty

The pace of growth over the next 50 years will significantly drive future demands. Other drivers include the efficiency of that use and climate trends. Under lower growth projections and without climate change, future demands could be 333,000 AFY less in 2080, as shown in Figure 4.5. The Baseline demand projections reach 860,000 AF by 2080 under hot and dry conditions, which is 28 percent lower than the S3 projections. The IWSP Update makes supply timing and quantity decisions based on the S3 scenario and examines the impact annual weather variability has on meeting supply reliability goals. Exploration of future needs based on the demand uncertainty is provided in Chapter 5.



Notes: Projections represent hot and dry conditions. S3 = Suburban Sprawl with Stressors; BL = Baseline.

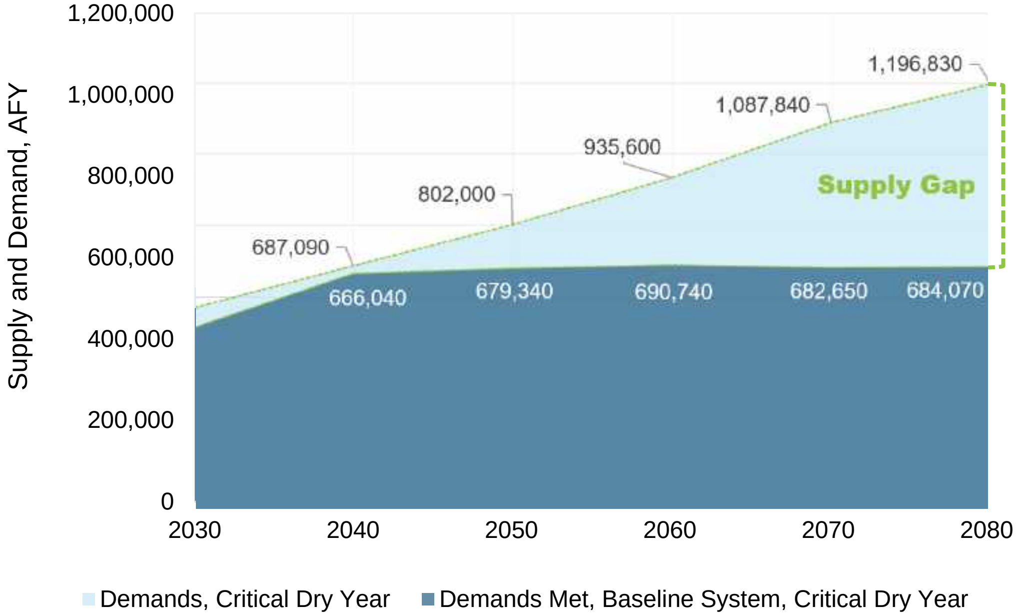
Figure 4.5 TRWD Demand Forecast Range of Uncertainty

CHAPTER 5 FUTURE SUPPLY NEEDS

The TRWD RiverWare model was used to analyze future water supply system reliability and to quantify supply gaps, or shortages, without new water supply strategies and infrastructure beyond the near-term planned projects. Gaps are presented as the maximum volume of supply shortage that occurs during a repeat of the drought of record when demands are high due to hot and dry conditions, and supplies are lowest due to reduced surface water flows. The drought of record for TRWD water supply reservoirs occurred between 1949 and 1956. The critical drought year with the highest total system gap occurs at the end of that drought period in 1956. Furthermore, gaps are presented from a probabilistic perspective by calculating the number of hydrologic years with a projected gap in future supply. Water supply gaps are presented for TRWD's system as a whole and by supply source. Results in this chapter were generated using RiverWare and are against the baseline water supply system, unless otherwise noted. The baseline water supply system is the current and planned water supply sources, conveyance, and operational rules.

5.1 System Water Supply Needs

The quantity of demand that can be met by the baseline water supply system varies over time. The demand that can be met is a function of RiverWare assumptions around permit constraints, reservoir inflows, reservoir sedimentation, conveyance and pumping capacity, and operational rules and policies. The demand that can be met is further a function of where the demands are located within the system and the monthly peaking of demands. Given the future conditions assumed in the modeling, the critical dry year supply gap begins to increase starting in 2040 and continues along that trend through 2080, as shown in Figure 5.1. The gap magnitude is the difference between the met demand and the system demand. The supply gap is just over 120,000 AF in 2050 and reaches 513,000 AF by 2080.



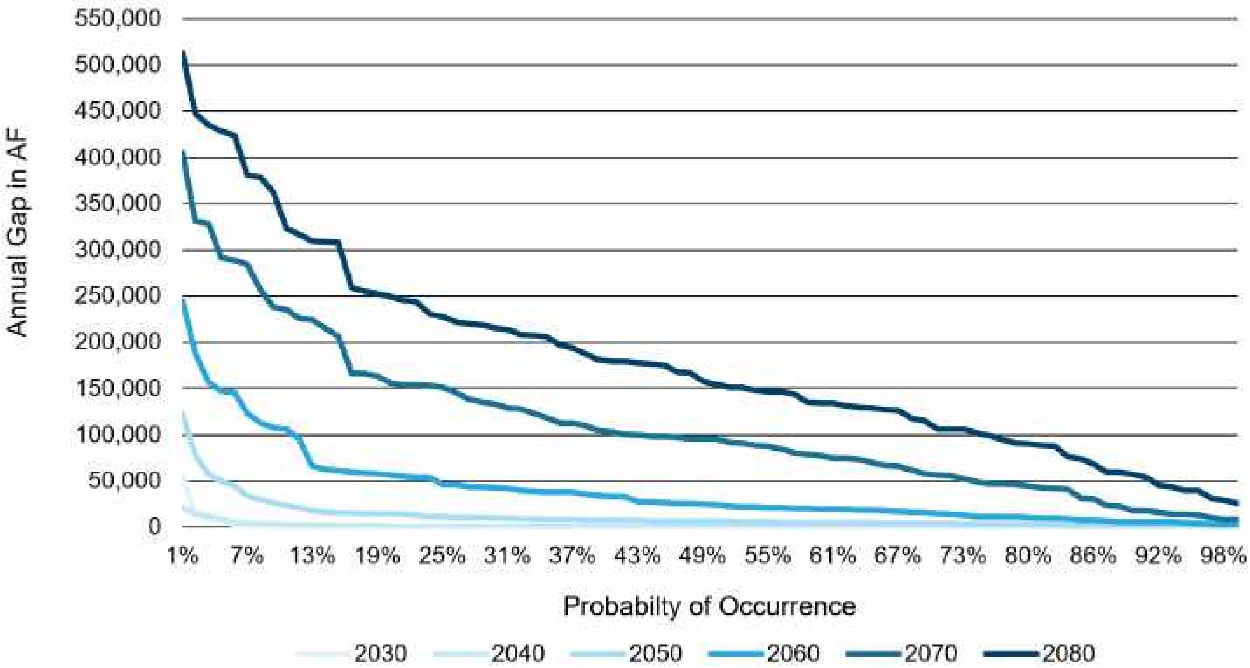
Notes: Calculated based on the critical year of the drought of record (1956) from the S3 demand scenario. The increase in demands met from 2030 to 2040 reflects the planned completion of the Cedar Creek Wetlands and the IPL. Results generated from RiverWare.

Figure 5.1 TRWD Critical Dry Year Supply Gap from RiverWare Analysis

Comparing the 684,070 AFY of demands met from RiverWare analysis of the baseline water supply system to the available firm yield reveals that not all of TRWD's system firm yield is being utilized under the planned future system. TRWD's firm yield grows to 738,971 AFY by 2080 (see Table 3.2). However, under the modeling conditions of the future system and without unplanned expansions or new supplies, only 684,070 AF of that supply is used (i.e., demands met in Figure 5.1). The difference of approximately 55,000 AF could be a result of conveyance capacity assumptions and/or operational rules, specifically the operational rule that triggers pumping when metroplex reservoirs are down one foot.

5.2 System Frequency of Gaps

Based on the 82 hydrologic traces, the probability of a gap by magnitude is presented in Figure 5.2. In 2030 and 2040, the probability of a gap larger than 15,000 AF is less than 2 percent. By 2050, the probability of a gap larger than 15,000 AF is 17 percent, and a gap larger than 50,000 AF is 4 percent. The gap probability of occurrence and the magnitude of the gaps greatly increase in 2060, with a probability of gap greater than 25,000 AF around 50 percent, and gaps greater than 100,000 AF have an 11 percent probability. With growing demands, by 2070, there is a 100 percent probability of a supply gap occurring, although the gaps range in magnitude. In 2080, without additional supply development, large magnitude gaps are projected to occur often, with the probability of a gap larger than 150,00 AF having a 50 percent chance of occurrence.



Note: Calculated based on 82 years of hydrologic inflow, the S3 demand scenario, and baseline water supply system.

Figure 5.2 TRWD Gap Magnitude Probability by Planning Decade

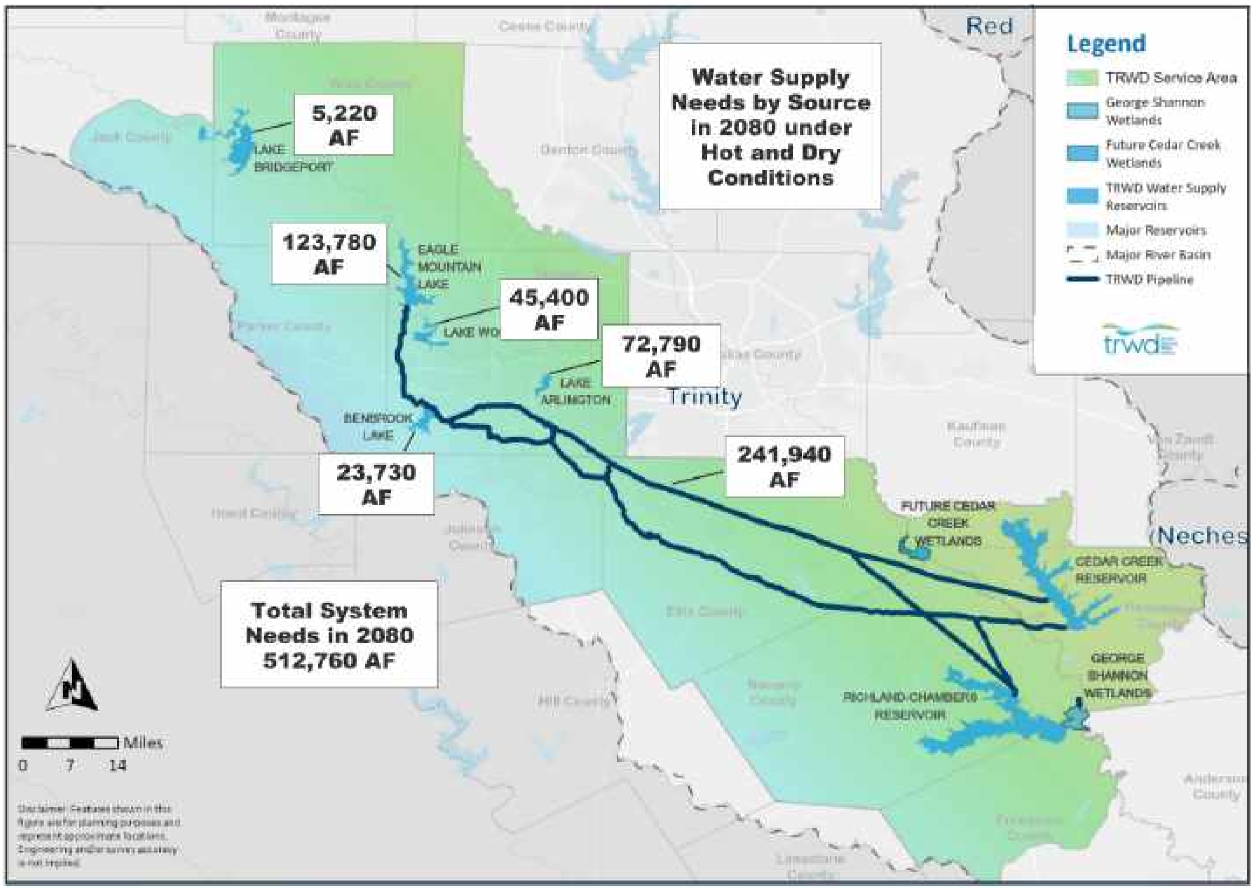
5.3 Needs by Supply Source

To understand where additional supply is needed and how much, the supply needs by source were evaluated, as provided in Table 5.1, and shown visually in Figure 5.3. Over the decades, the pipeline users have the largest water supply needs, followed by Eagle Mountain Lake users. By 2080, the pipeline users have a gap of approximately 242,000 AF. Lake Arlington has an ultimate supply need of 73,000 AF by 2080. Lake Benbrook has a slightly larger percentage of the gap in 2030 and 2040 but ultimately makes up 5 percent of the supply needs by 2080. Lake Worth has a water supply need of 45,400 AF by 2080. Lake Bridgeport has a relatively small supply need in 2080 of 5,220 AF.

Table 5.1 Water Supply Needs by TRWD Supply Source in AFY

Supply Source	2030	2040	2050	2060	2070	2080
Pipeline	26,870 (48%)	6,770 (32%)	51,540 (42%)	101,800 (42%)	183,470 (45%)	241,940 (47%)
Lake Arlington	10,710 (19%)	5,810 (28%)	19,260 (16%)	43,680 (18%)	66,230 (16%)	72,790 (14%)
Lake Benbrook	8,440 (15%)	6,110 (29%)	11,170 (9%)	16,180 (7%)	20,330 (5%)	23,640 (5%)
Lake Worth	7,600 (14%)	2,360 (11%)	13,700 (11%)	22,750 (9%)	35,500 (9%)	45,400 (9%)
Lake Bridgeport	0 (0%)	0 (0%)	460 (<1%)	2,050 (1%)	3,970 (1%)	5,220 (1%)
Eagle Mountain Lake	2,040 (4%)	0 (0%)	26,530 (22%)	58,390 (24%)	95,690 (24%)	123,760 (24%)
Total TRWD	**55,670**	**21,050**	**122,660**	**244,860**	**405,190**	**512,760**

Notes:
(1) Values are rounded to the nearest tenth and may impact totals.
(2) Value in parentheses is the percentage of the supply source water needs of the total TRWD water needs.
(3) Supply needs are calculated based on the critical year of the drought of record (1956) from the S3 demand scenario.
(4) The gap decreases from 2030 to 2040 based on the planned completion of the Cedar Creek Wetlands and IPL in 2040.
(5) TRWD supplies local users at Cedar Creek and Richland-Chambers Reservoirs. The gap in supply is zero for these users.



Notes: Calculated based on the critical year of the drought of record (1956) from the S3 demand scenario.

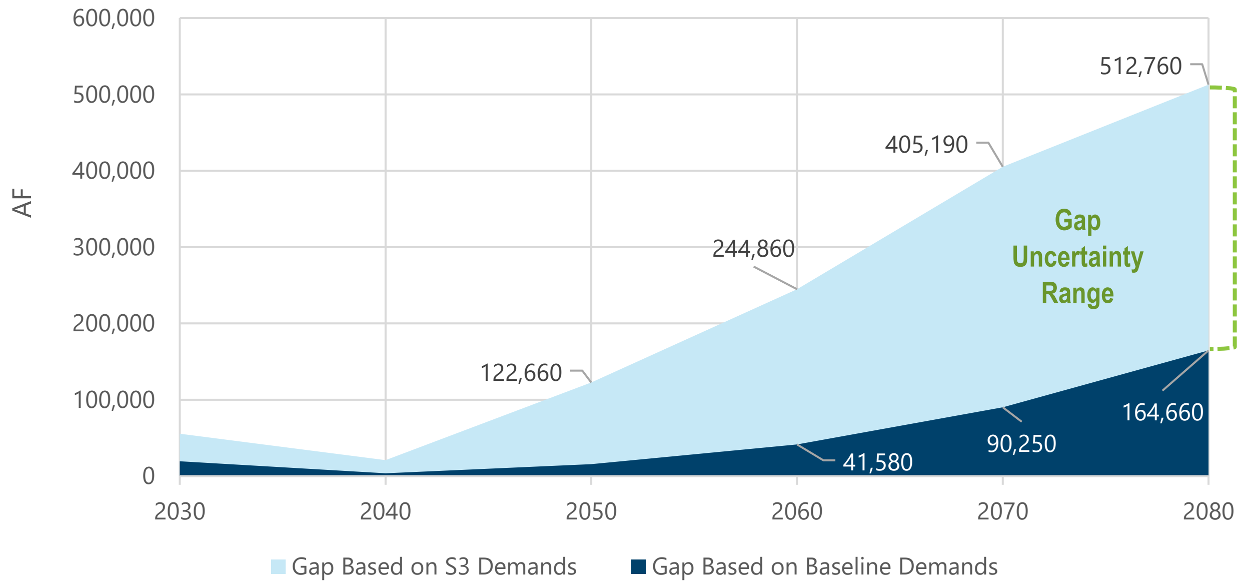
Figure 5.3 TRWD Water Supply Needs by Source in 2080

5.4 Supply Needs Uncertainty and Sensitivity Analysis

The timing of when new supplies are needed can shift based on how quickly demand is expected to grow and how much risk is acceptable to TRWD and its customers. This section discusses the uncertainty around the water supply needs assessment, based on alternative demand projections and risk tolerance in supply planning.

5.4.1 Supply Needs with Lower Demands

Future water demands for customers and the pace of growth in the region pose significant uncertainty in the analysis. The water supply gap was explored under the BL water demand scenario described in Chapter 4. For the BL demand scenario, nearly all demands are met through 2040 with the first supply gap occurring in 2050, as shown in Figure 5.4. By 2080, additional water supply needs are projected to reach 165,000 AF during a repeat of the drought of record if BL demands occur. The range in supply needs is large in 2080, from as high as 513,000 AF to as low as 165,000 AF.

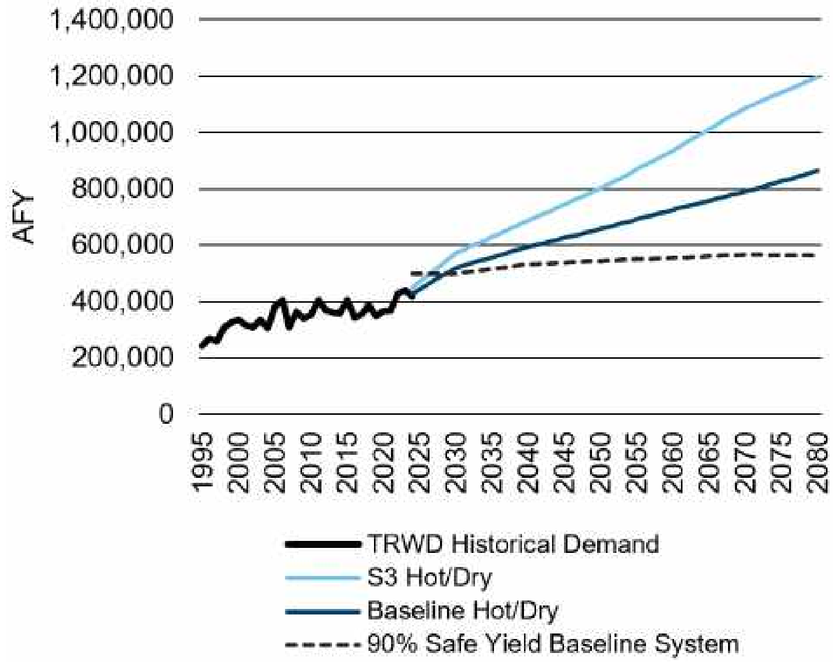


Notes: Calculated based on the critical year of the drought of record (1956). The gap decreases from 2030 to 2040 based on the planned completion of the Cedar Creek Wetlands and the IPL.

Figure 5.4 Comparison of Water Supply Needs Under Lower Demand Scenario

5.4.2 Supply Needs Using Safe Yield Planning Rule

TRWD's planning policy to have new supplies online before projected demands exceed 90 percent of the system's safe yield is a conservative approach adopted to create a supply buffer in case a drought worse than the drought of record occurs in the future. The IWSP Update adopts a probabilistic approach that allows for exploration of tradeoffs between reliability and cost. The sensitivity of how much supply is needed and when is presented in Figure 5.5. To keep supplies ahead of demands and adhere to the 90 percent rule, an additional 79,000 AF of safe yield is needed to be online by 2030, growing significantly to just over 700,000 AF by 2080. Compared to the analysis presented in Chapter 5.1, the 2080 difference is nearly 200,000 AF. This is because of the 90 percent safe yield approach factors in an additional water supply buffer and safety factors.



	Supply Needs Based on IWSP Update	Safe Yield Needs to Meet 90% Threshold
2030	55,670	79,000
2040	21,050	172,000
2050	122,660	287,000
2060	244,860	423,000
2070	405,190	580,000
2080	512,760	705,000

Notes: Based on Hot/Dry S3 demands.
Units = AFY

Notes: S3 = Suburban Sprawl with Stressors. The 90 percent safe yield increases gradually based on the planned completion of the Cedar Creek Wetlands and the growing return flow supplied to the wetlands.

Figure 5.5 Sensitivity Analysis of Water Supply Needs Compared to Safe Yield Rule

CHAPTER 6 WATER MANAGEMENT STRATEGIES

WMS, or simply strategies, are independent water supply options. This chapter describes how strategies were identified and screened and then presents the results of the detailed evaluation of each strategy. A summary of strategy implementation timing and comparison of strategy key metrics are included in Chapters 6.11 and 6.12, respectively. Strategies that were screened out but may be considered in future water supply planning at TRWD are described in Chapter 6.13. Strategies become the building blocks of water supply portfolios, which are described in Chapter 7.

6.1 Identification and Screening Process

Two workshops were held in November 2023 to identify potential strategies, the first with TRWD staff and another with TRWD and their customer stakeholders. In total, 73 potential strategies were identified during these workshops. Some of these strategies have been previously identified, studied, and/or conceptualized. Others were entirely new and surfaced via brainstorming and through a review of innovative ideas across the world.

Strategies are grouped into themes: Conservation, Reuse, Operational Change, Groundwater, Existing Reservoir, Proposed Reservoir, Transfer of Out-of-State Supply, and Transmission. The full list of strategies identified is provided in Appendix D – Strategy Screening. Initial screening was conducted qualitatively through discussions with TRWD staff, management, and regional stakeholders. Reasons for ruling out a strategy included:

- Anticipated fatal flaw due to permitting, partnerships, public opposition, or land acquisition.
- The strategy is already being implemented by others, or conflicts with a strategy being implemented by others.
- Lack of sufficient prior study or sufficient information for evaluation, or strategy is better for future evaluation beyond 2080.

Strategies that did not move forward but may be worth future evaluation and tracking are described in Chapter 6.14.

6.2 Evaluated Strategies

Eighteen strategies plus two intrasystem, infrastructure-only projects were evaluated, as shown in Figure 6.1. The types of strategies include:

- Conservation (1).
- Reuse (2).
- Operational Change (2).
- Groundwater (4).
- Existing Reservoir (3).
- Proposed New Reservoirs (5).
- Out-of-State Transfer (1).
- Intrasystem Transmission (2).

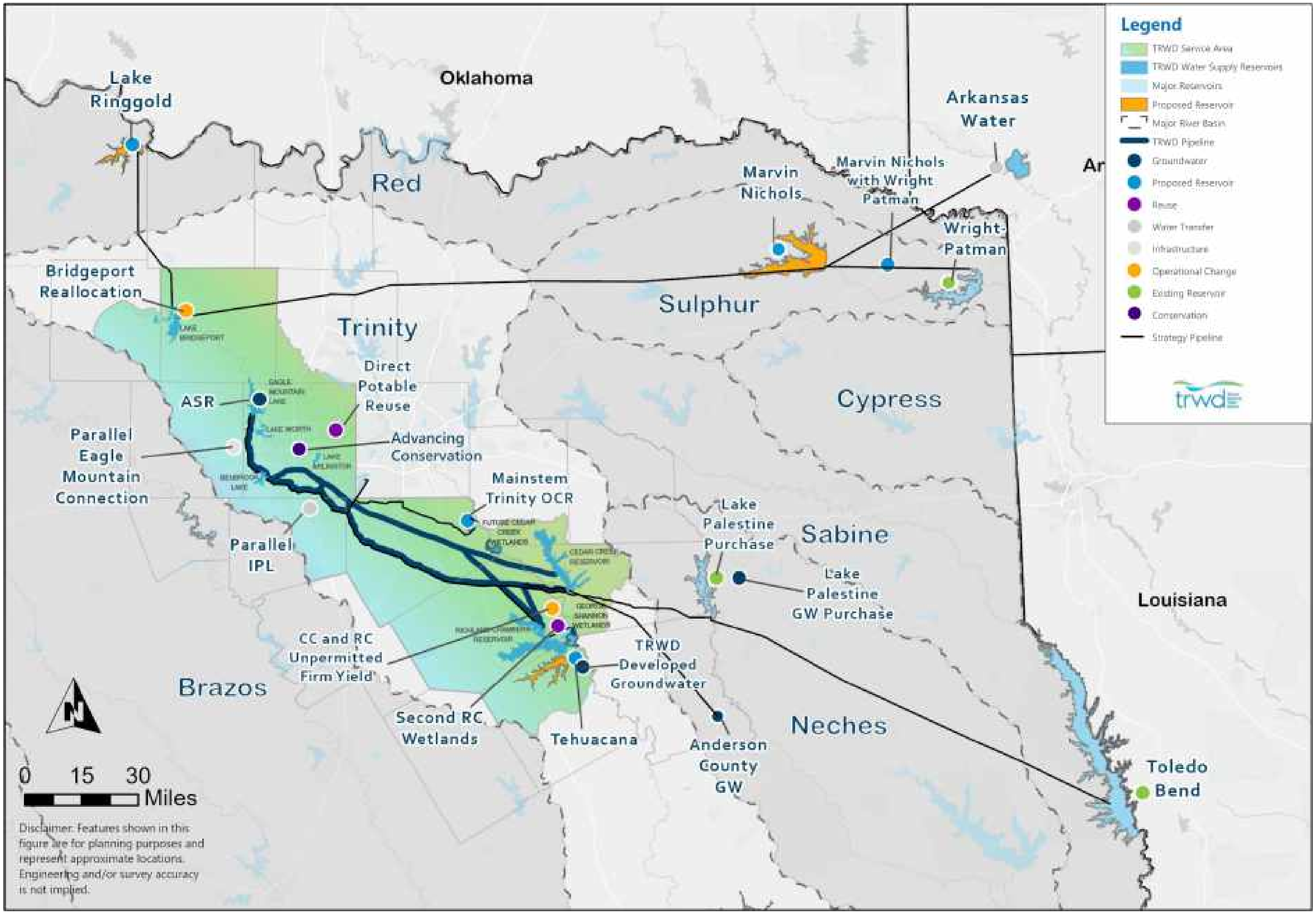


Figure 6.1 TRWD Water Management Strategy Locations

The strategies are described below in terms of location, yield, cost, partnership opportunities, infrastructure needs, phasing potential, implementation timing, and qualitative scores. Strategies are organized by type. Appendix E – Strategy Factsheets provides detailed numeric information for the 18 evaluated strategies (excluding the two intrasystem transmission strategies). Appendix F – Strategy Detailed Cost Estimate provides cost information for applicable strategies.

6.3 Conservation

Strategy Type: Conservation

Theme: One Water, No Regrets

Water Savings (2080 Average): 90,500 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $750/AF

Unit Cost after Debt Service: $750/AF

In planning and developing new water supplies to meet growing demands, water conservation plays a vital role in meeting TRWD's projected water needs. Water conservation is the most cost-effective alternative for meeting new water demands. Therefore, it is important that we use the water we already have more efficiently. Over time, conserving water daily:

- Extends the life of existing supplies to meet new water demands.
- Slows the drain on reservoirs, making more water available during times of drought.
- Reduces peak supply requirements, which reduces wear and tear on existing infrastructure.
- Defers increases in capital and operating costs for existing systems.
- Delays the need for developing expensive, new water supplies.

As a wholesale raw water supplier, TRWD does not directly control the water use of its customers, nor does it have a direct relationship with retail customers who are the consumers of the water. Nonetheless, TRWD has actively led the region in water conservation for almost two decades through municipal customer support, education and public awareness campaigns, efficiency, and accurate accounting in TRWD operations, and offerings of classes, programs, and landscape efficiency initiatives. TRWD's 2024 Water Conservation Plan documents the historical and current programs and establishes a per capita reduction goal of 7 percent over the next 10 years.[1]

The water conservation strategy included as an alternative in the IWSP Update goes beyond the current TRWD conservation efforts. Several ways of assessing conservation potential were considered. Ultimately, a single strategy was included that will result in lower demands and infrastructure investment delays beyond the savings inherent to the S3 demand projections (see Chapter 2.7.1).

6.3.1 Advancing Conservation

The Advancing Conservation strategy involves developing and implementing a robust, cost-effective regional water conservation program in coordination with customer cities to offer direct-to-customer rebates, utility cost-share measures, expanded education, and assistance in passing key ordinances, all aimed at reducing demand, improving efficiency, and ultimately delaying the need for CIPs.

[1]Available at TRWD Plans | Save Tarrant Water.

Partnerships. The Advancing Conservation strategy involves partnerships with customer cities to assist with educational and incentive programs encouraging water-saving practices and fixture installation. Conservation can also involve information-sharing and partnership with other regional water suppliers, though this is not required for implementation of an effective conservation program within TRWD's service area.

Annual Yield. Water conservation does not create a new water supply. It is measured in water savings rather than firm and safe yield. Water savings assumptions are broadly based on conservation savings assumptions from TRWD's 2020 Demand Study.[2] Additional conservation savings represent the S3 demand scenario with an additional 10 percent reduction in water use by 2070. The conservation scenario assumes an overall target of 55 gpcd for indoor residential water use, which is a reduction from the underlying forecast assumption of 62 gpcd. Further, the strategy assumes an additional 10 percent reduction in outdoor residential water use and 12 percent savings in nonresidential use. This results in the targeted additional 10 percent reduction. Savings, which will be referred to as "yield" when compared to other strategies, were calculated annually from 2030 to 2080. The water savings from 2030 to 2080 totals 81 mgd or 90,500 AFY during an average year, while the maximum savings in 2080 during a hot and dry year are estimated to be around 108 mgd or 121,000 AFY.

Cost. The cost of the conservation strategy is based on a selection of pre-defined conservation measures from the TWDB 2018 Municipal Water Conservation Planning Tool. The selected measures include a mix of rebates, retrofits, distributions, site visits, and customer assistance programs for indoor and outdoor uses in the residential and nonresidential sectors. The average unit cost (adjusted for inflation) of the tool is approximately $750 per AF of water saved. This WMS assumes annual programmatic costs funded through an O&M budget (or similar) to achieve the savings each year. Program costs grow over time, with increased demands and new saving targets. The total cost of the strategy over the 50 years is estimated at $750.1 million.

Key Infrastructure. Advancing Conservation does not require new infrastructure but rather can stretch existing infrastructure capacity further in time.

Phasing Potential. Advancing Conservation is highly flexible and works well when phased.

Current Status. Conservation is part of TRWD's existing programs, although expanding its conservation program to the level associated with this Advancing Conservation Strategy will require more investment.

Implementation Time. Advancing Conservation will be implemented on an ongoing basis, with implementation planning continuing through 2080. No permitting, design, or construction is needed for the Advancing Conservation strategy.

Qualitative Scores. Advancing Conservation scores a maximum score (5) for nearly all qualitative criteria except Collaboration Potential and Multi-Benefit Project. Collaboration with customers cannot be fully controlled by TRWD and requires voluntary, willing participation. The Multi-Benefit Project criterion scored in the middle, as leaving water in surface water bodies benefits the environment, but there are few other multi-benefits compared to other strategies. Qualitative scores are provided in Table 6.1.

[2] TRWD. 2020. TRWD Service Area Demand Update: Water Demand Forecast Report. Prepared by CDM Smith.

Table 6.1 Advancing Conservation Strategy Qualitative Scores

Category	Score	Description
System Risk	5	Minimal risks, although less ability for demand cutback during drought.
Permit Uncertainty and Complexity	5	No permitting required.
Collaboration Potential	4	Requires voluntary, willing partnerships with customers.
Operational Simplicity	5	Conservation planning and implementation are relatively simple.
Phasing Potential	5	Conservation program can grow and adapt with demands and conditions.
Public Acceptance	5	Generally, voluntary conservation is widely accepted.
Multi-Benefit Project	3	Environmental benefits of leaving more water in rivers, streams, and lakes.

6.4 Reuse

Indirect and/or direct reuse is an important component of future water supply plans across North Texas. TRWD is taking a lead role in water reuse by recycling return flows in the Trinity River. Return flows are a renewable resource as they are made up of water discharged by area wastewater treatment plants. A large portion of those flows originated from reservoirs managed by TRWD. TRWD's current reuse projects include the George Shannon Wetlands at Richland-Chambers Reservoir and the future Marty Leonard Wetlands at Cedar Creek Reservoir. New reuse strategies evaluated include direct potable reuse (DPR) and Second Richland-Chambers Wetlands.

6.4.1 Direct Potable Reuse

The DPR strategy would enhance water efficiency, optimize local supplies, and reduce pumping needs from TRWD's East Texas reservoirs to the Fort Worth metroplex by using purified recycled water to augment drinking water supplies. The strategy involves the construction of an advanced water purification facility (AWPF) to treat a portion of the tertiary-treated flow produced at the Village Creek Water Reclamation Facility (VCWRF) to create advanced purified recycled water that will augment the existing raw water supply sources of TRA's Tarrant County Water Supply Project (WSP). This strategy would require contractual agreements between multiple parties. Relative to the Cedar Creek and Richland-Chambers Wetlands reuse systems, this strategy would reduce the amount of conveyance infrastructure and energy needed to recycle water in the TRWD service area.

Strategy Type: Reuse

Theme: Resilience, One Water

Firm Yield: 20,500 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $1,917/AF

Unit Cost after Debt Service: $804/AF

This DPR strategy has been conceptualized as similar to a DPR project currently under development in El Paso, Texas. El Paso Water's Pure Water Center will be the first direct-to-potable facility in the nation, providing proof that DPR has advanced in the United States (U.S.) and specifically in Texas to be more than a concept. El Paso's AWPF will use a treatment train of membrane filtration, reverse osmosis, advanced oxidation with ultraviolet light and hydrogen peroxide, granular activated carbon for peroxide quenching, and chlorine disinfection. The facility will treat up to 10 mgd of secondary effluent from the Roberto R. Bustamante Wastewater Treatment Plant to produce high-quality purified water, which will be introduced directly into the potable water distribution system via conveyance infrastructure.

A conceptual process flow diagram for a DPR treatment train is shown in Figure 6.2. This diagram represents a carbon-based treatment train.

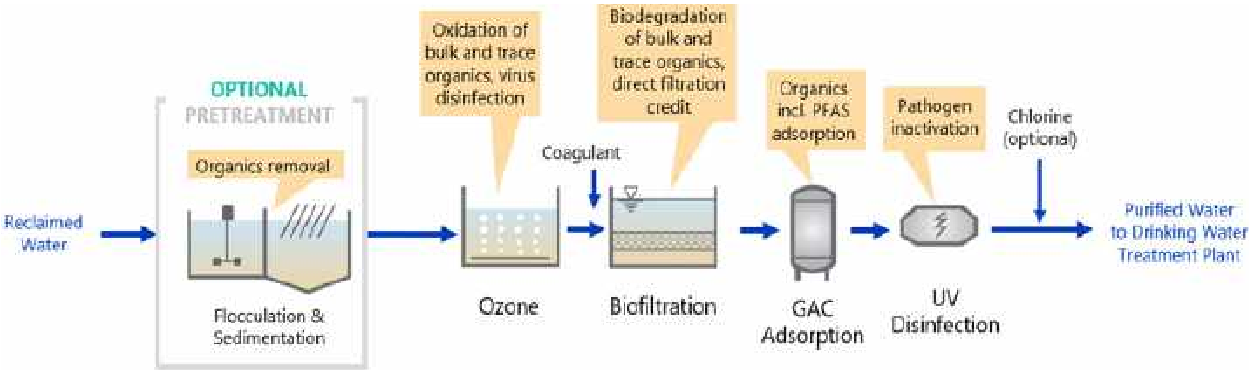


Figure 6.2 Carbon-based AWPF Treatment Train Flow Diagram

Figure 6.3 demonstrates a DPR project concept for TRWD designed to receive VCWRF source water and send purified water to the WTP at TRA's WSP. With this conceptual project, the AWTF is located along the raw water line that conveys supply from Lake Arlington to the WTP. The treated effluent is added through an intertie along the raw water line.

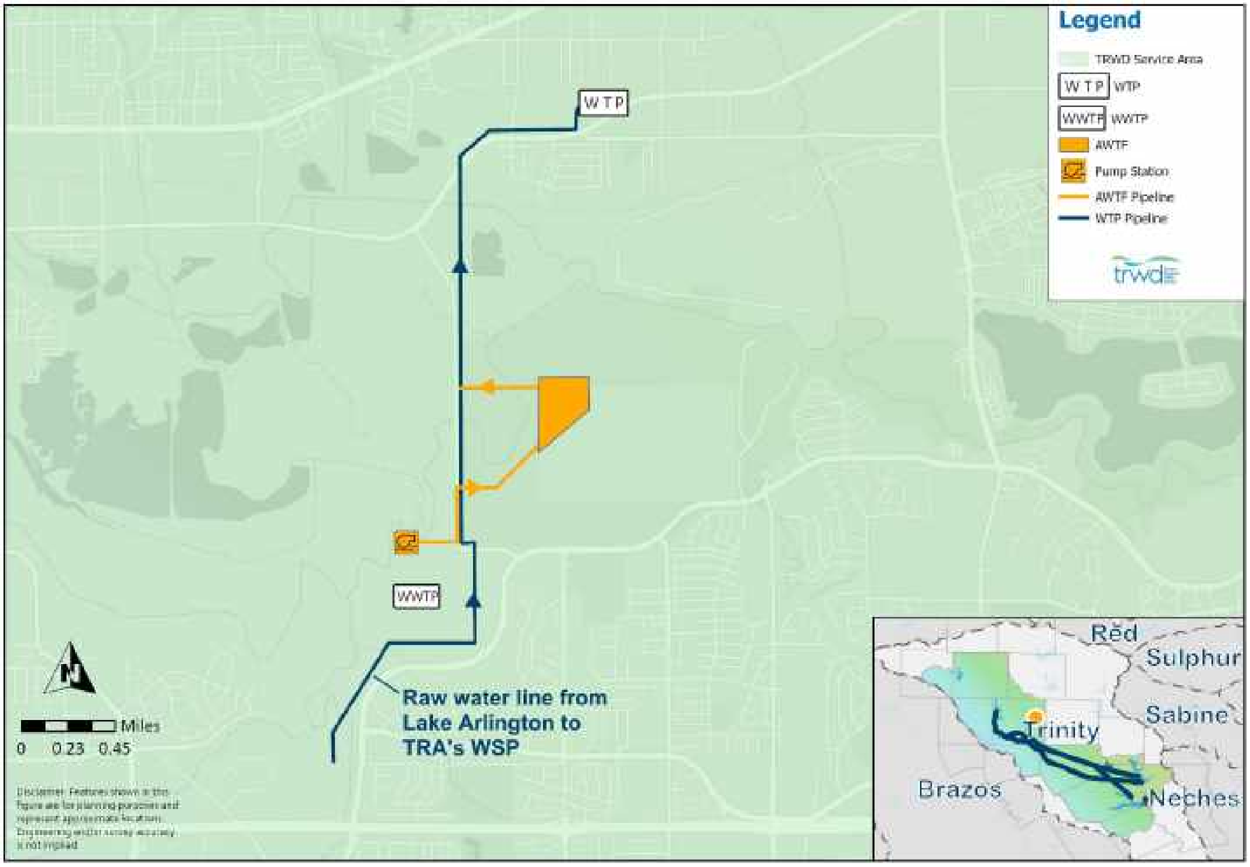


Figure 6.3 DPR Strategy Infrastructure and Location

Partnerships. As envisioned, a DPR project using VCWRF source water would require partnerships between TRWD, TRA, and the City of Fort Worth. Other possible projects could be planned using other source water with different partnerships.

Annual Yield. Yield potential for this strategy was estimated by assessing 2040 TRA WSP demand projections. Winter demand was assessed at a minimum of 18.6 mgd, with potential peaks as high as 67 mgd. As AWPFs are typically designed for base flow with little peaking, a yield of 20 mgd (targeted finished water capacity) was assumed, with a slightly lower winter yield of 18.3 mgd.

- Firm yield: 18.3 mgd or 20,500 AFY.
- Safe yield: 18.3 mgd or 20,500 AFY.

Cost. Capital and O&M costs were estimated using Carollo's DPR Costing Tool (for the facility and treatment). Those costs were incorporated into the IWSP Costing Tool to capture the additional costs for pipelines and the pump station. Treatment at the AWPF can either be based on a reverse osmosis (RO) based treatment train or a carbon-based treatment train. There are pros and cons of each treatment train, but both are feasible options. The cost estimate is based on the carbon treatment train because it does not create an RO brine that requires handling and disposal. However, since carbon-based AWPFs do not remove salinity, a system-level salinity management assessment would be needed.

- Total Strategy Cost: $394.6 million.
- External Development Cost: $394.6 million.
- Intrasystem Transmission Cost: $0.0 million.

Key Infrastructure. Table 6.2 lists the pipelines, pump stations, and treatment facility needed for DPR.

Table 6.2 Infrastructure for DPR Project

Infrastructure Type	Number (unit)	Size (unit)
Source Water Pipeline	1 mile	36-inch diameter
Purified Water Pipeline	0.5 miles	30-inch diameter
Purified Water Pump Station	1	25 mgd
Advanced Water Purification Facility	80% efficiency assumed	20 mgd AWPF (25 mgd VCWWTP flow)

Phasing Potential. DPR can potentially be phased, but phasing needs to be considered during the design of all infrastructure – pipelines, pump stations, and treatment. For example, a plant could be installed to produce 10 mgd at first, leaving space for sufficient additional treatment units to expand plant capacity to provide for future demand growth. Pipelines may need to be installed with extra capacity to accommodate expansion, and pump stations may need to hold space to add more pumps or electrical equipment. If phasing/expansion is not accounted for during design, expanding a facility can be expensive and time-consuming.

Current Status. This specific project is conceptual and will require significant planning, including feasibility analyses and preliminary design, before entering the design phase.

Implementation Time. Implementation of a DPR Project is estimated to take 18 years. For reference, the El Paso DPR project started planning in 2012 with 5 years for planning and piloting. Construction completion is estimated to be in 2027, meaning the entire El Paso DPR project timeline is around 15 years. For the IWSP Update DPR strategy, a 3-year timeline buffer was added to the El Paso precedent timeline, due to a lack of certainty around public support and inter-agency coordination. The 18-year timeline assumes 5 years for planning, 5 years for permitting, and 8 years for design and construction.

Strategy Qualitative Scores. DPR scores highest in system risk (it offers a drought-resistant supply) and in phasing potential, as its capacity can grow as demand grows. DPR scores lowest in permit uncertainty/complexity and operational simplicity. Qualitative scores are provided in Table 6.3.

Table 6.3 DPR Strategy Qualitative Scores

Category	Score	Description
System Risk	5	If water quality parameters are triggered at the AWTF, it could result in flow diversion; drought-resistant supply.
Permit Uncertainty and Complexity	1	DPR permitting required.
Collaboration Potential	2	Complex agreements between multiple parties required.
Operational Simplicity	1	Advanced treatment operations required.
Phasing Potential	5	Capacity can be expanded over time and grow as wastewater and water demands grow.
Public Acceptance	2	Acceptance of DPR as a reliable, efficient, and safe water supply is increasing, but still uncertain.
Multi-Benefit Project	2	Some environmental benefits from reduced energy consumption from pumping the supply.

6.4.2 Second Richland-Chambers Wetlands

This strategy involves creating a second Richland-Chambers Wetlands to treat return flow in excess of TRWD's currently permitted reuse, now or in the future, or purchased from a regional partner. There are multiple avenues by which the wetlands could be sourced, including purchase of supply from a regional partner, new reuse opportunities from interbasin transfers, negotiation on the Lake Livingston agreement, or a SysOps permit, for examples. Richland-Chambers Reservoir can assimilate and estimated 90 mgd of additional reuse supply, so the wetlands would be sized at approximately 2,000 acres, similar in size to the existing George Shannon Wetlands. The strategy assumes that a second IPL would be needed to transmit the supply from Richland-Chambers Reservoir to Benbrook Lake.

Strategy Type: Reuse

Theme: Resilience, One Water, Trinity River Priority

Firm Yield: 100,890 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost w/ Debt Service: $1,143/AF

Unit Cost after Debt Service: $254/AF

Figure 6.4 depicts the Second Richland-Chambers Wetlands strategy location and necessary infrastructure. The wetlands were envisioned at a point along the Trinity River where TRWD can maximize collection of return flows.

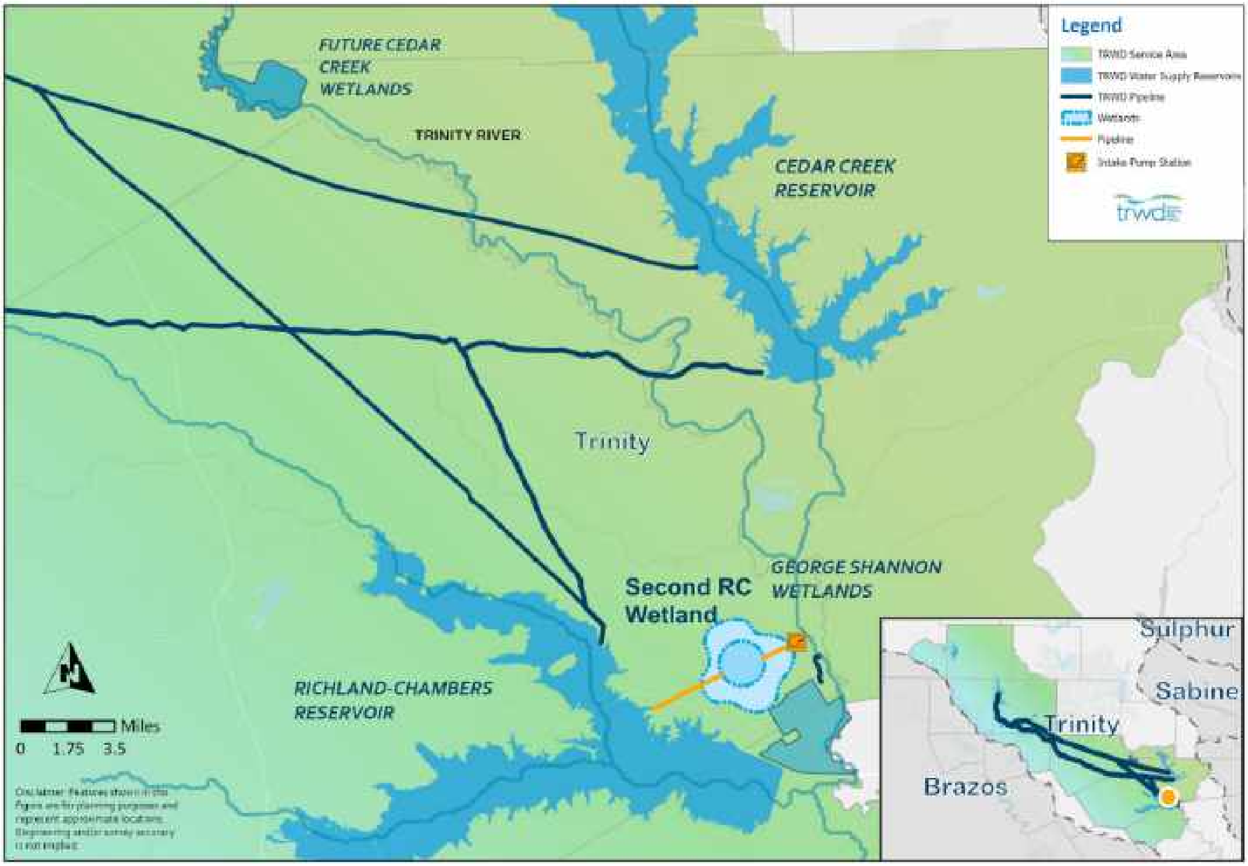


Figure 6.4 Second Richland-Chambers Wetlands Strategy Location

Partnerships. The Second Richland-Chambers Wetlands could require partnerships with TRA and/or NTMWD and could involve other regional partners in the future. The strategy offers environmental benefits and recreational opportunities for trails surrounding the wetland, which may entice partner participation beyond water suppliers.

Current Status. The Second Richland-Chambers Wetlands strategy is still in the conceptual stage.

Annual Yield. The yield estimate for this strategy assumes 90 mgd is achievable on an average annual basis. This could be fully or partially supplied by TRWD return flows or from return flows purchased from a regional partner. The yield will likely start smaller and grow over time, as return flows in the Trinity River increase.

The yield potential for this strategy was determined by TRWD through analysis of reservoir assimilation capacity. The 90 mgd could be assimilated in addition to the wetlands and reuse already in place.

- Firm Yield: 90 mgd or 100,890 AFY.
- Safe Yield: 90 mgd or 100,890 AFY.

Cost. The cost estimate for this strategy assumed 2,000 acres for the wetlands at $7,238 per acre. The cost of wetlands was indexed up from the Cedar Creek Wetlands cost per acre. The new intake on the Trinity River was sized for a peak day capacity of 135 mgd, using a 1.5 peaking factor and 90 mgd. The cost estimate does not include channel dam cost, as those infrastructure components are site-specific and were not needed at TRWD's Richland-Chambers nor Cedar Creek Wetlands, or the purchase cost of return flows.

- Total Strategy Cost: $1,545 million.
- External Development Cost: $337 million.
- Intrasystem Transmission Cost: $1,207 million.
- Purchase Cost of Water: $0.00 $/kgal.

Key Infrastructure. Figure 6.4 depicts the potential strategy location and suggested infrastructure.

- **Pipelines:** 19.2 miles of 90-inch pipeline from the Trinity River to the wetland, and from the wetland to the Richland-Chambers reservoir. Assumes a 100 pounds per square inch pressure class pipe. The second IPL will be needed to convey the supply.
- **Pump Stations:** 135 mgd intake pump station.
- **Wetland Facility:** 2,000 wetland acres.

Phasing Potential. The Second Richland-Chambers Wetlands strategy has the potential to be phased, with the wetland cells implemented increasing over time as return flow volume increases or as supply is needed.

Implementation Time. The existing Richland-Chambers Wetlands project took approximately 24 years to implement but included around 8 years of alternatives analysis, pilot testing, and negotiations to arrive at an agreement between TRWD and the Texas Parks and Wildlife Department. For a Second Richland-Chambers Wetlands project, a pilot wetland is likely not needed due to the success of the existing full-scale Richland-Chambers Wetlands project. A 20-year implementation timeline is assumed, including 6 years for planning, 5 years for permitting, and 9 years for design and construction.

Strategy Qualitative Scores. The Second Richland-Chambers Wetlands project scored well in all qualitative scoring categories, with a five for Collaboration Potential and Multi-Benefit Project, and four in the remaining categories. Qualitative scores are provided in Table 6.4.

Table 6.4 Second Richland-Chambers Wetlands Strategy Qualitative Scores

Category	Score	Description
System Risk	4	Moderately resilient to drought; more susceptible to wildfire and contamination.
Permit Uncertainty and Complexity	4	Existing precedent for wetlands permitting.
Collaboration Potential	5	Partnership could be required.
Operational Simplicity	4	TRWD has extensive knowledge of operating wetlands.
Phasing Potential	4	Build capacity over time as the reuse volume increases.
Public Acceptance	4	Requires acquisition of land for wetlands; generally, high political and public support.
Multi-Benefit Project	5	Provides water quality and recreation benefits.

6.5 Operational Change

While changing operations does not create new supplies, it can allow TRWD flexibility to maximize use of existing supplies or the ability to use reservoir water during times of extreme shortages. Two operational change strategies include: (1) Cedar Creek and Richland-Chambers Unpermitted Firm Yield and (2) Bridgeport Reallocation. Both require permit modifications and represent cost-effective ways of moving or accessing supplies when and where they are needed. Both strategies were identified as having no regrets and are included in all portfolios.

6.5.1 Cedar Creek and Richland-Chambers Unpermitted Firm Yield

TRWD's original water rights for Cedar Creek and Richland-Chambers Reservoirs authorize annual diversions that are based on the safe yield of the reservoirs. This strategy is to obtain a permit for the additional yield associated with the firm yield of the reservoir, referred to as the safe-to-firm amount. The additional permitted supply would then be available to TRWD during periods of drought. The strategy assumes that a second IPL will be needed to transmit the additional supply to Benbrook Lake and includes a proportional cost.

The Cedar Creek and Richland-Chambers Unpermitted Firm Yield strategy uses reservoir storage from Cedar Creek and Richland-Chambers Reservoirs, as depicted in Figure 6.5.

Strategy Type: Operational Change

Theme: Resilience, No Regrets

Firm Yield: 21,920 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $864/AF

Unit Cost after Debt Service: $76/AF

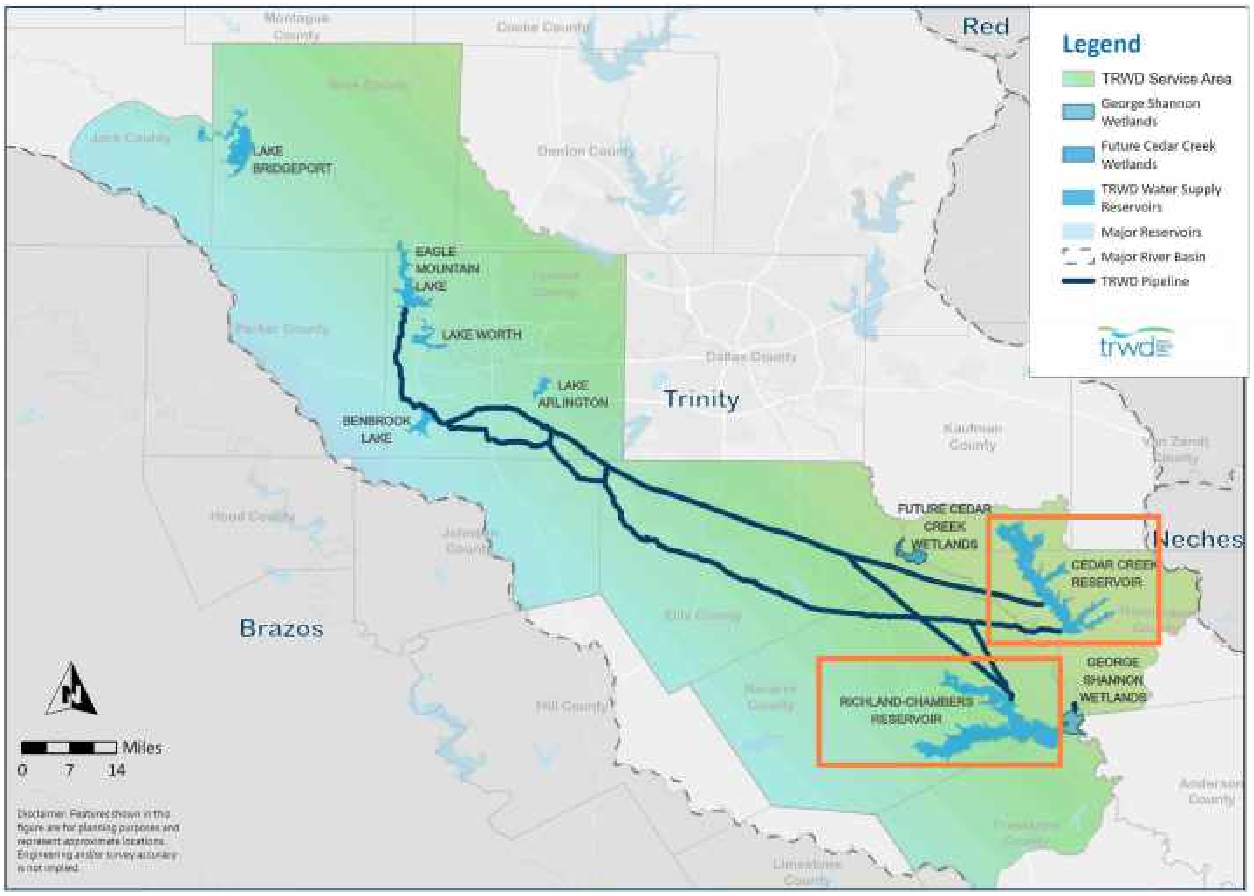


Figure 6.5 Cedar Creek and Richland-Chambers Unpermitted Firm Yield Strategy Location

Partnerships. Cedar Creek and Richland-Chambers Unpermitted Firm Yield does not require partnerships, though regional partners could benefit from the strategy.

Current Status. Cedar Creek and Richland-Chambers Unpermitted Firm Yield has been previously studied.

Annual Yield. The yield for this strategy was estimated in a separate study conducted by TRWD.[3] Since the time that the Richland-Chambers and Cedar Creek Reservoirs were originally permitted, additional water rights have been granted within the Trinity River Basin. The additional authorizations for the increased amount of water to be stored, taken, or diverted would be junior to other existing, senior water rights in the basin, which limits the amount of additional yield to be realized. Additionally, authorized wetlands at Richland-Chambers and Cedar Creek Reservoirs utilize some of the available storage in the reservoirs. The amount of additional firm yield that could be realized from each reservoir is reduced when the wetlands are being utilized. The determination of the safe-to-firm amounts included an analysis of wetland operations and was evaluated using the modified WAM Run 3 and presented in Table 6.5. The strategy yield would not be used during normal operations but rather only during extreme drought.

Table 6.5 Yield Calculations for Cedar Creek and Richland-Chambers Unpermitted Firm Yield Strategy

Reservoir	TRWD Authorizations (AFY)		Firm Yield (AFY)		Unpermitted Safe-to-Firm Yield (AFY)	
	Original	Amended	Original	Amended	Original	Amended
West Fork Water Supply Reservoirs						
Eagle Mountain(1)	159,600		90,500		-	
Bridgeport(2)	27,000		27,000		-	
Total	**159,600**		**117,500**		**-**	
East Texas Water Supply Reservoirs						
Richland-Chambers	210,000	310,465	229,450	319,535	19,450	9,070
Cedar Creek	175,000	263,059	213,060	275,909	38,060	12,850
Total	**385,000**	**573,524**	**442,510**	**595,444**	**57,510**	**21,920**
TRWD Total	**544,600**	**733,124**	**560,010**	**712,944**	**57,510**	**21,920**

Notes:
(1) Firm yield of Eagle Mountain Lake is based on the release of up to 66,000 AFY from Lake Bridgeport diverted from Eagle Mountain in accordance with Certificate of Adjudication 08-3808C.
(2) Lake Bridgeport yield based on satisfying local demand of 27,000 AFY (Certificate of Adjudication 08-3808C 1.b. and 1.c.). Remaining releases contribute to the estimated yield of Eagle Mountain Lake.

Cost. This strategy will require an amended water right permit, which is assumed to cost $250,000. Additional infrastructure could be needed to have transmission capacity to convey the additional yield. Intrasystem transmission assumes 3.5 percent of the costs of the second IPL from Richland-Chambers to JB2, 4.9 percent of the costs from Cedar Creek to JB2, and 8.4 percent of the costs from JB2 to Benbrook Lake.

- Total Strategy Cost: $252.3 million.
- External Development Cost: $0.25 million for permit revision.
- Intrasystem Transmission Cost: $252.1 million.

[3] TRWD. 2023. SysOps Existing System Evaluation. Prepared by Carollo Engineers.

Key Infrastructure. Figure 6.5 depicts the project location. Though no new dedicated infrastructure is part of the strategy, the second IPL could be needed to transmit the supply.

Phasing Potential. There is no need to phase the Cedar Creek and Richland-Chambers Unpermitted Firm Yield. Once the permit is approved, the supply will be available.

Implementation Time. Cedar Creek and Richland-Chambers Unpermitted Firm Yield is estimated to take 3 years, including 1 year of planning and 2 years for negotiating an amended water right permit. Although an uncontested application may be processed within a year, inter-agency coordination, public notices, and environmental impact assessments may push timelines to 2 years. For Cedar Creek and Richland-Chambers Unpermitted Firm Yield, it is assumed that the application will not be contested, but the implementation timeline builds in time for extra coordination.

Strategy Qualitative Scores. Cedar Creek and Richland-Chambers Unpermitted Firm Yield received the maximum score of five in all but two categories: System Risk and Multi-Benefit Projects. System risk scores low because the supply may not be available under extreme drought conditions, and it may be impacted by wildfire. It is not a Multi-Benefit Project and is only focused on water supply. The project does not require partnerships, requires no operation (just water rights accounting), is publicly acceptable, and would not need phasing. Qualitative scores are provided in Table 6.6.

Table 6.6 Cedar Creek and Richland-Chambers Unpermitted Firm Yield Qualitative Scores

Category	Score	Description
System Risk	2	Reliance on surface water, which can be impacted by wildfires; safe-to-firm supply may not be available under a drought worse than drought of record.
Permit Uncertainty and Complexity	5	Low complexity permitting required.
Collaboration Potential	5	Partnership not required.
Operational Simplicity	5	Water rights accounting.
Phasing Potential	5	No phasing required.
Public Acceptance	5	Generally acceptable across landowners, political entities, and the general public.
Multi-Benefit Project	1	Not considered to have project benefits beyond water supply.

6.5.2 Bridgeport Reallocation

Currently, the majority of Lake Bridgeport water rights are released downstream and captured in Eagle Mountain Lake to supply the higher demands in that area. The Bridgeport Reallocation strategy reallocates additional Lake Bridgeport supplies for users at Lake Bridgeport and releases less water to Eagle Mountain Lake. The strategy does not create new supplies and represents an operational change only. When implemented, it would be paired with other strategies that bring new supply to Eagle Mountain Lake.

The Bridgeport Reallocation strategy focuses on flows from Lake Bridgeport, depicted in Figure 6.6. Additional flow would be released downstream approximately 25 miles to Eagle Mountain Lake.

Strategy Type: Operational Change

Theme: Resilience, No Regrets

Firm Yield: 0 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $0/AF

Unit Cost after Debt Service: $0/AF

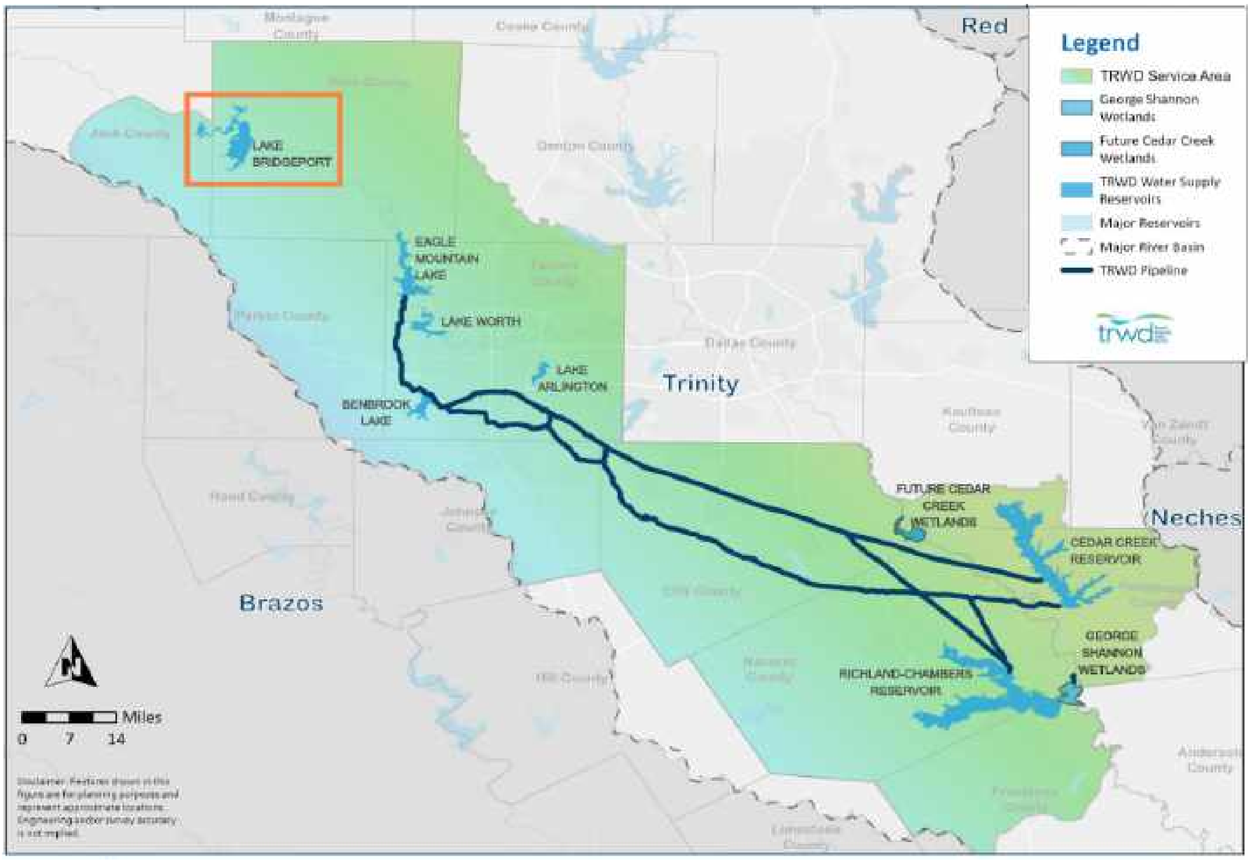


Figure 6.6 Bridgeport Reallocation Strategy Location

Partnerships. Bridgeport Reallocation does not require partnerships, but if one is desired, it could benefit regional partners.

Current Status. Bridgeport Reallocation is in the planning phase.

Annual Yield. Alone, this strategy does not have a new supply yield associated with it. Rather, this strategy involves an operational change in how TRWD manages Lake Bridgeport. Specifically, this conceptual strategy includes reallocating 40,000 AF of permitted use from the "Bridgeport to Eagle Mountain" authorization to the "Bridgeport Local Use" authorization. The reallocation amount was estimated based on potential build-out demands at Bridgeport. This strategy would likely occur in combination with other strategies that develop new supplies for Eagle Mountain, such as Lake Ringgold, or Marvin Nichols, for example. WAM modeling was assessed to confirm that the reallocation did not impact the joint system yield beyond negligible amounts.

Cost. The only cost associated with this strategy is the cost to revise the water rights permits, which is assumed to be $250,000 (one-time cost).

- Total Strategy Cost: $0.25 million for permit revision.

Key Infrastructure. No infrastructure is required for Bridgeport Reallocation.

Implementation Time. As in Cedar Creek and Richland-Chambers Unpermitted Firm Yield, Bridgeport Reallocation requires an amended water use permit application. It is assumed that the application will not be contested, but a 2-year timeline allows some lag due to inter-agency coordination. A total implementation timeline of 3 years is assumed, including 1 year for planning and two for permitting.

Strategy Qualitative Scores. Bridgeport Reallocation has maximum scores for Permit Uncertainty and Complexity, Collaboration Potential, Phasing Potential, and Public Acceptance, because the project would be simple to permit, likely receive public support, and not require either collaboration or phasing. It scored four for Operational Simplicity because some operational changes are needed to implement the strategy. System Risk and Multi-Benefit Project scored three. For risk, the strategy depends on surface water, which could be impacted by wildfire, drought, or contamination. For multi-benefit, the strategy has few benefits outside of water supply, although higher lake levels could improve recreation. Qualitative scores are provided in Table 6.7.

Table 6.7 Bridgeport Reallocation Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	5	Low complexity permitting required.
Collaboration Potential	5	Partnership not required.
Operational Simplicity	4	Requires accounting and operational changes.
Phasing Potential	5	No phasing required.
Public Acceptance	5	Support from Bridgeport landowners and water users.
Multi-Benefit Project	3	Maintain higher lake levels for improved recreation.

6.6 Groundwater

Groundwater strategies offer supply diversity and resilience for TRWD's surface water-reliant system. Concerns associated with groundwater supplies include contamination potential and over-pumping, particularly during drought. Strategies evaluated include ASR, TRWD Developed Groundwater, Lake Palestine Groundwater, and Anderson County Groundwater. TRWD has studied groundwater potential, and these four strategies build upon that work.

6.6.1 Aquifer Storage and Recovery

ASR is the storage of water in an underground aquifer with the intent of later recovering that water for beneficial use. For the IWSP Update, ASR was considered as a conceptual strategy evaluated to better understand the potential for ASR to improve system reliability. Currently, TRWD has an ASR pilot project underway with TRA.

There may be other partnership opportunities to develop ASR schemes across TRWD's service area. This strategy includes a 10 mgd conceptual ASR project around Eagle Mountain Lake using ExFlo water supply as the source of water to be injected and stored underground, as depicted in Figure 6.7. The 2020 TWDB study on ASR suitability shows the Eagle Mountain Lake area as suitable for ASR, per Figure 6.8.

Strategy Type: Groundwater

Theme: Resilience, One Water

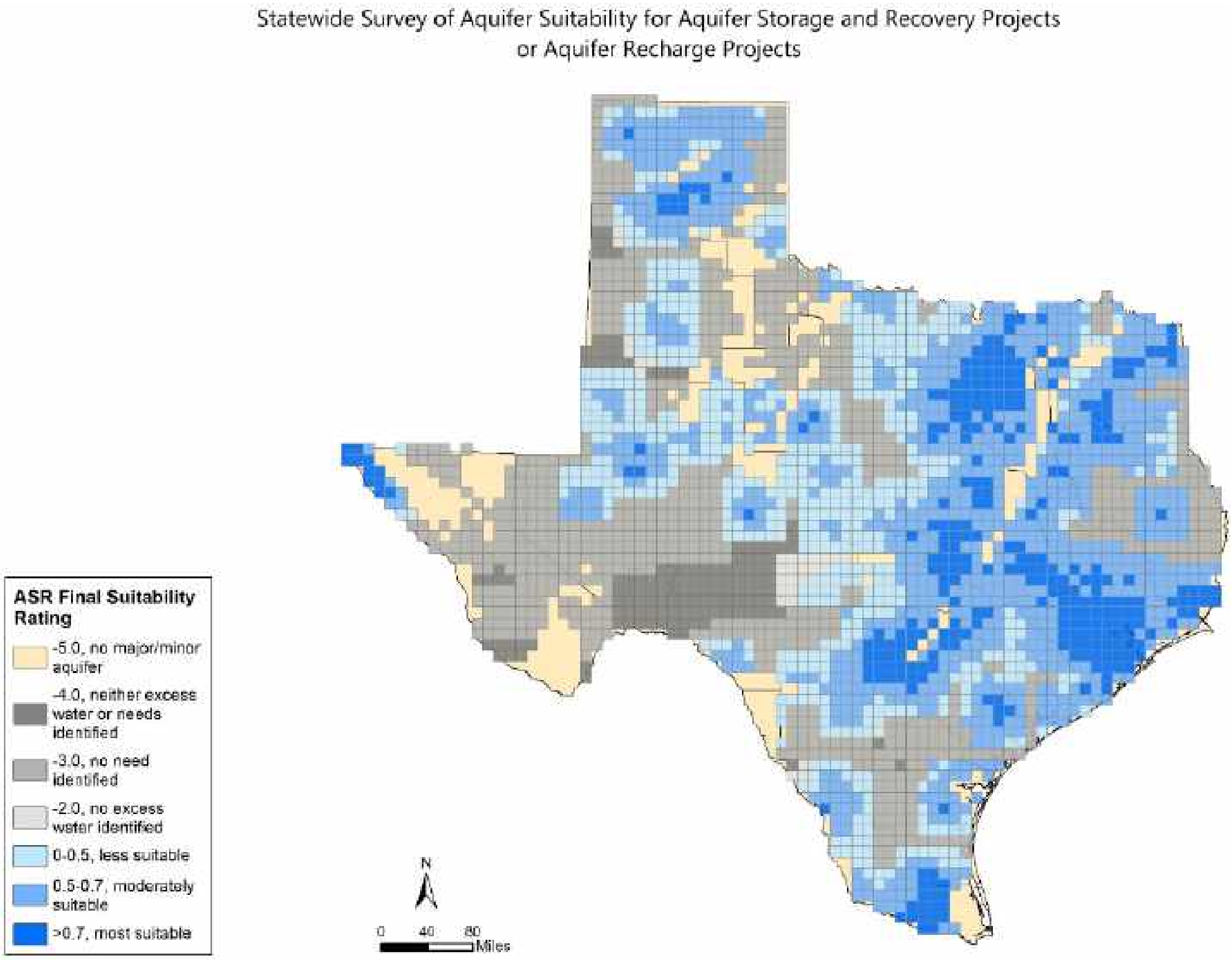
Firm Yield: 11,209 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $1,313/AF

Unit Cost after Debt Service: $218/AF

Figure 6.7 Aquifer Storage and Recovery Strategy Locations



Source: TWDB. 2020.Statewide Survey of Aquifer Suitability for Aquifer Storage and Recovery Projects or Aquifer Recharge Projects. Prepared by HDR. Figure 26.

Figure 6.8 Aquifer Storage and Recharge Suitability Rating by Grid

Partnerships. TRWD currently has a pilot project for ASR with TRA using treated water as the ASR source of supply. Other partnership opportunities are likely in TRWD's service area.

Current Status. ASR has been studied and is in the pilot project stage for TRWD. This conceptual strategy would need to be studied in detail to understand the specific aquifer composition and suitability, since the proposed location is not close to the pilot project location.

Annual Yield. The supply goal for the ASR strategy is 10 mgd. The source of water is assumed to be TRWD's ExFlo permit at Eagle Mountain Lake. Supply is added to the 56,000 AF storage capacity "bubble" during periods when ExFlo is available and then recovered and pumped back to the lake. It is assumed that the aquifer formation can store the required "bubble." The TRWD pilot project with TRA was permitted for 88 percent recovery, which is assumed to be the recovery for additional ASR strategies.

- Firm yield: 10.0 mgd, or 11,209 AFY.
- Safe yield: 10.0 mgd, or 11,209 AFY.

Cost. This cost estimate is a rough-order-of-magnitude estimate, assuming $5 million per well plus costs for a pipeline and intake pump station. Water may need to be treated prior to injection and may only require disinfection after extraction. The ASR wellfield is operated continuously, whether injecting or extracting, and is not left idle for months or years on end. Operating the wellfield with long periods of downtime would change the assumptions about annual O&M costs. TRWD may consider purchasing additional property around the wellfield to protect the groundwater bubble, but no more land than required by the Costing Tool was assumed.

- Total Strategy Cost: $285.4 million.
- External Development Cost: $285.4 million.
- Intrasystem Transmission Cost: $0.0 million.

Key Infrastructure:

- **Pipelines:** 5.5 miles of 30-inch pipeline to the lake, 8-inch well pipelines.
- **Pump Stations:** 11 mgd intake pump station.
- **Wellfields:** 20 wells at 0.5 mgd capacity.

Phasing Potential. ASR wells could be implemented over time with increasing intensity.

Implementation Time. This strategy is already being piloted by TRWD together with TRA. Total Implementation time is estimated at 11 years. This includes 3 years of planning. Permits will be needed from the TCEQ under the Underground Injection Control program (Class V injection wells), and 4 years is assumed for permitting. Based on San Antonio's ASR project of 5 years for planning/ permitting and 3 years for construction, and Austin's ASR project of 7 years for piloting and 7 years for planning/permitting/construction, 4 years were assumed for design and construction.

Strategy Qualitative Scores. ASR scored well for System Risk as a relatively drought-proof supply. Collaboration Potential scores high as there are several beneficial and likely willing partners. Phasing potential scores high, as wells and pipelines can be added as they are needed. Public acceptance is high because there has been political support for developing this type of supply, even though some land acquisition would be required. The strategy scored poorly for Permit Uncertainty and Complexity, as a TCEQ permit is required. Operational Simplicity scores low because it requires the operation of many wells. There are no additional benefits beyond water supply. Qualitative scores are provided in Table 6.8.

Table 6.8 ASR Strategy Qualitative Scores

Category	Score	Description
System Risk	4	Slight risk of leaching from chemical interaction; not fully drought-proof as multi-year droughts are possible.
Permit Uncertainty and Complexity	2	TCEQ permit required.
Collaboration Potential	4	Beneficial, willing partnerships.
Operational Simplicity	2	Requires the operation and treatment of many wells.
Phasing Potential	4	Can add ASR wells over time.
Public Acceptance	4	Some land acquisition is required; political support for alternative supply development.
Multi-Benefit Project	1	Not considered to have project benefits beyond water supply.

6.6.2 TRWD Developed Groundwater

This conceptual groundwater strategy is included to improve understanding of the potential of groundwater to improve system reliability and resilience, especially during droughts. Groundwater wells and the cost to pump supplies were assessed on land owned by TRWD in Freestone County. Water would be pumped to Richland-Chambers Reservoir. The strategy assumes that a second IPL will be needed to transmit the supply from Richland-Chambers to Benbrook Lake and includes a proportional cost, although there is potential for the groundwater to be conveyed using the existing IPL through operational optimization. The TRWD Developed Groundwater strategy location is depicted in Figure 6.9.

Strategy Type: Groundwater

Theme: Resilience

Firm Yield: 7,000 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $1,585/AF

Unit Cost after Debt Service: $337/AF

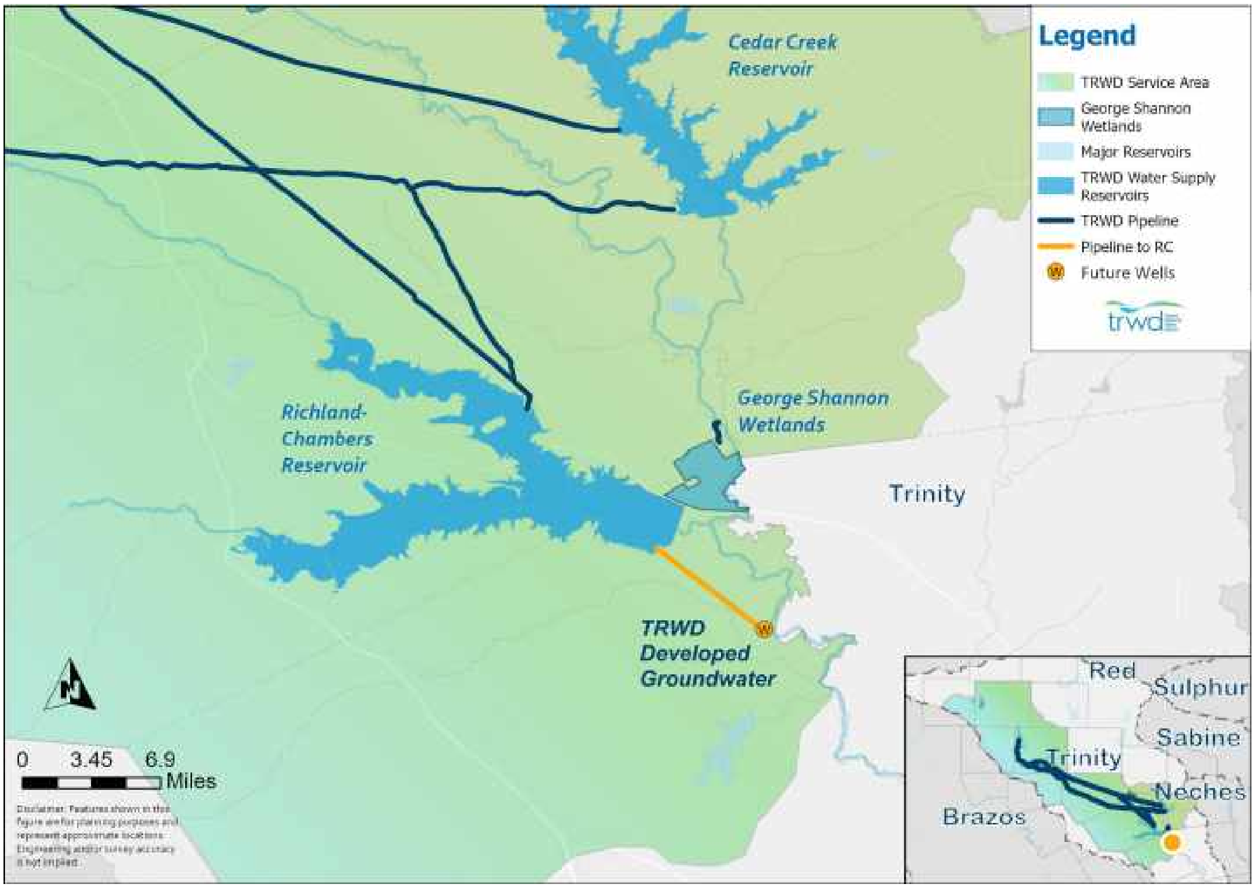


Figure 6.9 TRWD Developed Groundwater Strategy Location

Partnerships. Partnerships are not required for the TRWD Developed Groundwater strategy.

Current Status. This project has been studied and concepts have been developed.

Annual Yield. In 2016, TRWD commissioned an Impaired Groundwater Study, which indicated that a well field consisting of 11 to 15 wells on the Amerada property in Freestone County would be capable of producing 7,000 to 8,000 AFY of water from the Carrizo-Wilcox Aquifer.[4] The aquifer extent is shown in Figure 6.10. The amount of modeled available groundwater (MAG) for 2070 from the Carrizo-Wilcox Aquifer in Freestone County was set by the Mid-East Groundwater Conservation District (GCD) at 11,304 AFY. After subtracting out the maximum historical pumping from 2002 to 2021 (3,639 AFY) as a reserve for current users, 7,665 AFY would be available in 2070. This is approximately equivalent to the yield assumed for the proposed strategy. The firm and safe yield were assumed at 7,000 AFY.

Cost. The cost estimate for this strategy assumed a 1.5 peaking factor, resulting in a 9.4 mgd peak day capacity. This includes 15 wells at 675 gallons per minute (gpm) maximum pumping, with a 300-foot depth. The well field may be placed or partially placed on TRWD-owned property, but the exact location was not determined. As a conservative assumption, land acquisition of 0.5 acres per well site is included. The well field was assumed to include collection piping, a 9.4 mgd pump station, and a small transmission pipeline from the well field to Richland-Chambers Reservoir. The strategy assumes a 50-foot right-of-way (ROW) for the pipeline. Intrasystem transmission assumes 3 percent of the costs of the second IPL from Richland-Chambers to JB2, and 3 percent of the costs from JB2 to Benbrook Lake.

- Total Strategy Cost: $151.7 million.
- External Development Cost: $67.9 million.
- Intrasystem Transmission Cost: $83.8 million.

Key Infrastructure:

- **Pipelines:** 6.7 miles of 24-inch.
- **Pump Stations:** 10 mgd pump station.
- **Facility:** 15 wells with 675 gpm maximum pumping at 300-foot depth.

Phasing Potential. TRWD Developed Groundwater project implementation could be phased.

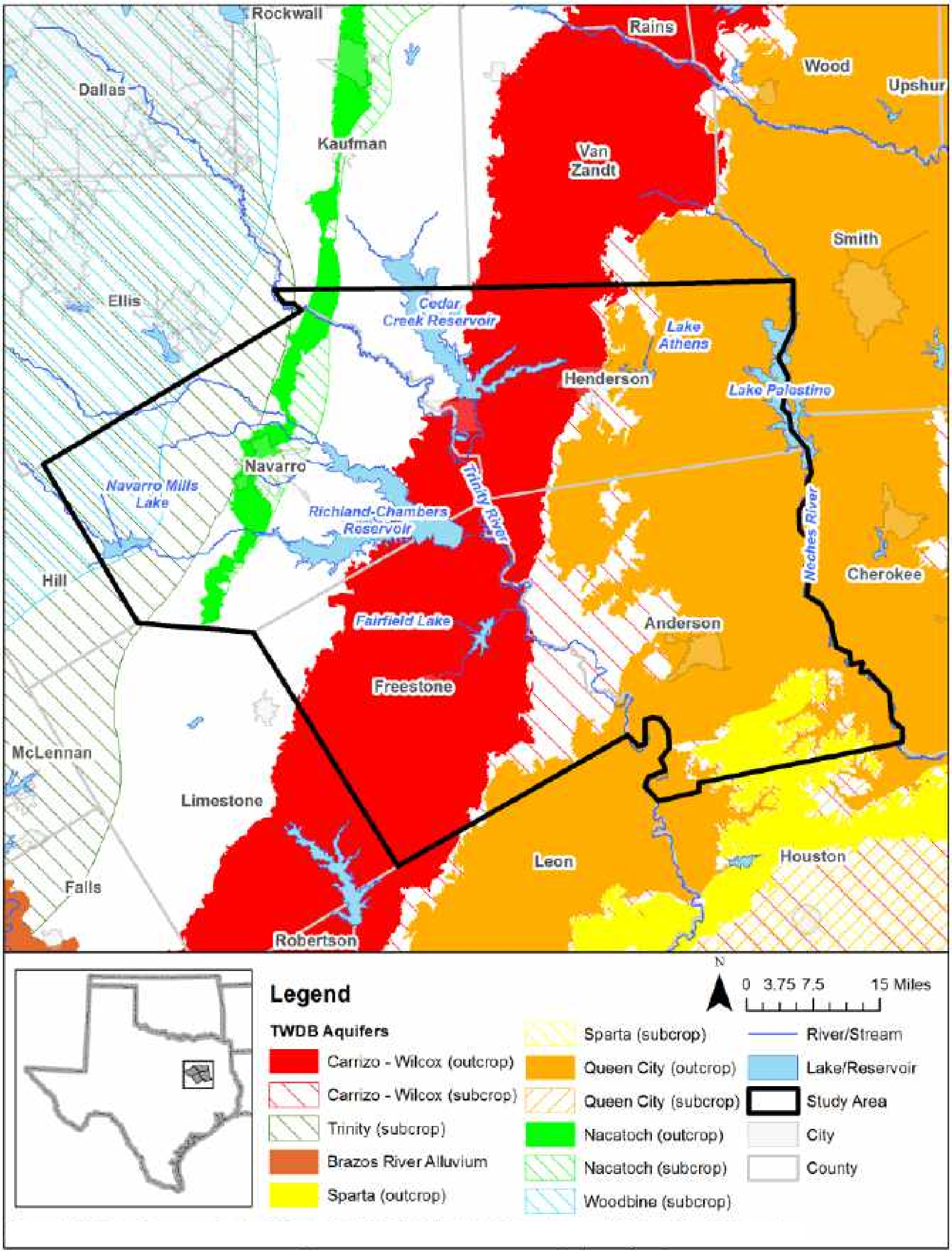
Implementation Time. Implementation timing is assumed to be 10 years, with 3 years of planning and feasibility studies, including more detailed hydrogeological studies and site selection. An additional 4 years of environmental permitting and land acquisition, along with regulatory approvals from TCEQ and local groundwater conservation districts, are assumed. Design and construction, including drilling and pipeline/pump station design and construction, are assumed to take approximately 3 years.

Strategy Qualitative Scores. TRWD Developed Groundwater scores well (four or five) for all categories except the Multi-Benefit Project category, as the only benefit is water supply. Qualitative scores are provided in Table 6.9.

Table 6.9 TRWD Developed Groundwater Strategy Qualitative Scores

Category	Score	Description
System Risk	5	Resistant to droughts and wildfires; slight contamination risk.
Permit Uncertainty and Complexity	4	Permitting groundwater with relatively low complexity.
Collaboration Potential	5	Partnership not required.
Operational Simplicity	4	Groundwater wells close proximity to TRWD's existing infrastructure.
Phasing Potential	4	Can add wells over time.
Public Acceptance	4	Developed on TRWD property; low opposition likely.
Multi-Benefit Project	1	Not considered to have project benefits beyond water supply.

[4] TRWD and Wichita Falls. 2016. Study of Impaired Groundwater Availability and Quality. Prepared by Intera and Freese and Nichols.



Source: TRWD and Wichita Falls. 2016. Study of Impaired Groundwater Availability and Quality. Prepared by Intera and Freese and Nichols.

Figure 6.10 Groundwater Aquifers in East Texas Region

6.6.3 Lake Palestine Groundwater Purchase

This strategy involves purchasing groundwater in Henderson County from a water marketer with a point of transfer in Lake Palestine. To convey the supply, this strategy assumes that DWU would be willing to allow TRWD to utilize a portion of DWU's IPL between Lake Palestine and the existing IPL for a fee. The strategy also assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake and includes a proportional cost. The Lake Palestine Groundwater Purchase strategy location is depicted in Figure 6.11.

Strategy Type: Groundwater

Theme: Resilience

Firm Yield: 15,000 AFY

Purchase Cost of Water: $1.46/kgal

Unit Cost with Debt Service: $1,917/AF

Unit Cost after Debt Service: $762/AF

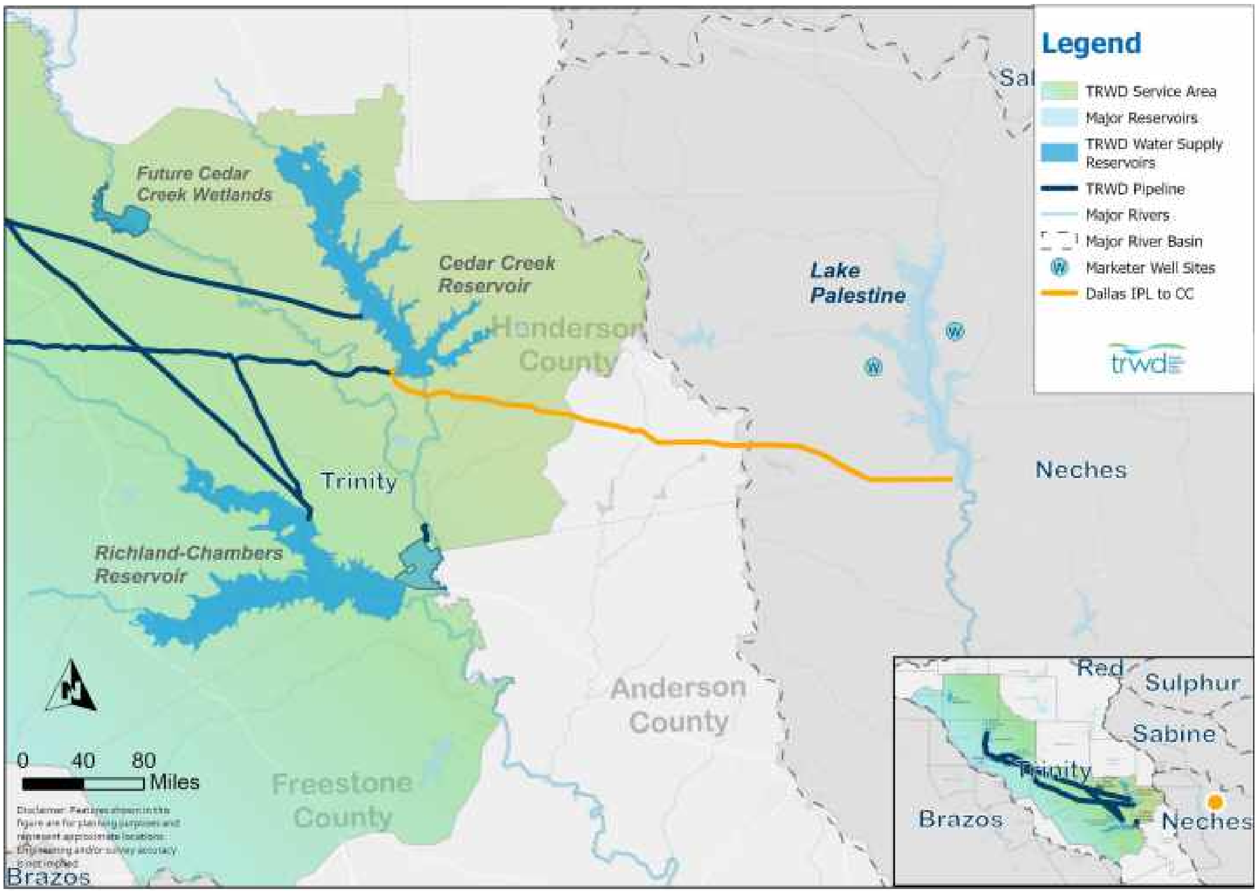


Figure 6.11 Lake Palestine Groundwater Purchase Strategy Location

Partnerships. Partnership would be needed with DWU for use of the IPL from Lake Palestine to Cedar Creek Reservoir.

Current Status. A confidential marketer ("Marketer") has studied the groundwater and proposed a volume and cost, but this project is conceptual.

Annual Yield. Yield estimates were obtained from a confidential water Marketer developing the project. The Marketer provided two scenarios: one for 11,000 AFY and one for 27,500 AFY. Based on direction from TRWD, the yield was calculated using the average of the two yield scenarios, leading to a yield of 15,000 AFY taken to Lake Palestine by the Marketer. Based on maximum historical pumping and the 2070 MAGs, around 9,400 AFY to 9,800 AFY may be available to permit without increasing the MAG; however, the majority of that would have to come from the Queen City Aquifer. The Marketer proposed pumping between 5,256 AFY and 6,348 AFY from the Queen City Aquifer. Extracting additional water from the Carrizo-Wilcox may involve proving that the MAG is not violated or increasing the MAG.

- Firm yield: 13.4 mgd, or 15,000 AFY.
- Safe yield: 13.4 mgd, or 15,000 AFY.

Cost. Costs from the Marketer include the infrastructure to develop the groundwater and deliver it to Lake Palestine. The Marketer proposal also included an option to deliver the supply directly to the IPL, but this option was not considered in the final analysis but may be studied in more detail if the strategy advances. The cost of water and transportation to Lake Palestine is assumed to be $475/AF, which is the midpoint from the Marketer price ranges for water calls. The cost of transporting water from Lake Palestine to Cedar Creek assumes the percentage of DWU's IPL portion (19-2 and 19-1) actual cost and Dallas' LP1 cost estimate. This assumes that DWU would be willing to allow TRWD to utilize a portion of the line for a fee. The cost estimate included prorating DWU's pipeline and intake costs per the percentage of the pipeline that would be needed to convey the supply. Cost estimates were indexed up to September 2023 dollars. Intrasystem transmission assumes 7 percent of the costs of the second IPL from Cedar Creek to JB2 and 6 percent of the costs from JB2 to Benbrook Lake.

- Total Strategy Cost: $286 million.
- External Development Cost: $107.3 million.
- Intrasystem Transmission Cost: $178.7 million.
- Purchase Cost of Water: $1.46 $/kgal.

Key Infrastructure:

- **Pipelines:** Prorated use of DWU's IPL from Lake Palestine to Cedar Creek Reservoir.
- **Pump Stations:** Prorated use of DWU's intake pump station at Lake Palestine.
- **Facility:** 15 wells with 675 GPM max pumping at 300-foot depth (owned and operated by the Marketer).

Phasing Potential. Lake Palestine Groundwater Purchase project implementation could be phased.

Implementation Time. Overall implementation timing is assumed to be 10 years. This assumes 3 years of planning and feasibility studies are still needed, including more detailed hydrogeological studies and site selection. An additional 4 years of environmental permitting and land acquisition, along with regulatory approvals from TCEQ and local groundwater conservation districts, are assumed. Design and construction, including drilling and pipeline/pump station design and construction, are assumed to take approximately 3 years.

Strategy Qualitative Scores. Lake Palestine Groundwater Purchase scores well (three or higher) for all categories except the Multi-Benefit Project category, as the only benefit is water supply. It performs lower than TRWD Developed Groundwater because phasing potential is reduced (the land acquisition goes through the Marketer), and public acceptance is also lower due to the need for land acquisition and potential impacts on local groundwater users. Qualitative scores are provided in Table 6.10.

Table 6.10 Lake Palestine Groundwater Purchase Strategy Qualitative Scores

Category	Score	Description
System Risk	5	Resistant to droughts and wildfires; slight contamination risk.
Permit Uncertainty and Complexity	4	Permitting groundwater with relatively low complexity.
Collaboration Potential	4	Beneficial willing partnership through the seller.
Operational Simplicity	4	Utilize DWU's infrastructure.
Phasing Potential	3	The marketer may allow some phasing.
Public Acceptance	3	Requires acquisition of land by the marketer; may be perceived poorly by local landowners and groundwater users.
Multi-Benefit Project	1	Not considered to have project benefits beyond water supply.

6.6.4 Anderson County Groundwater

The Anderson County Groundwater Strategy involves purchasing groundwater from a holding in Anderson County and conveying the supply to the IPL via a pipeline. This supply falls within the Neches and Trinity Valley GCD. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake and includes a proportional cost. The Anderson County Groundwater strategy location and infrastructure are depicted in Figure 6.12.

Strategy Type: Groundwater

Theme: Resilience

Firm Yield: 42,000 AFY

Purchase Cost of Water: $0.20/kgal

Unit Cost with Debt Service: $2,359/AF

Unit Cost after Debt Service: $542/AF

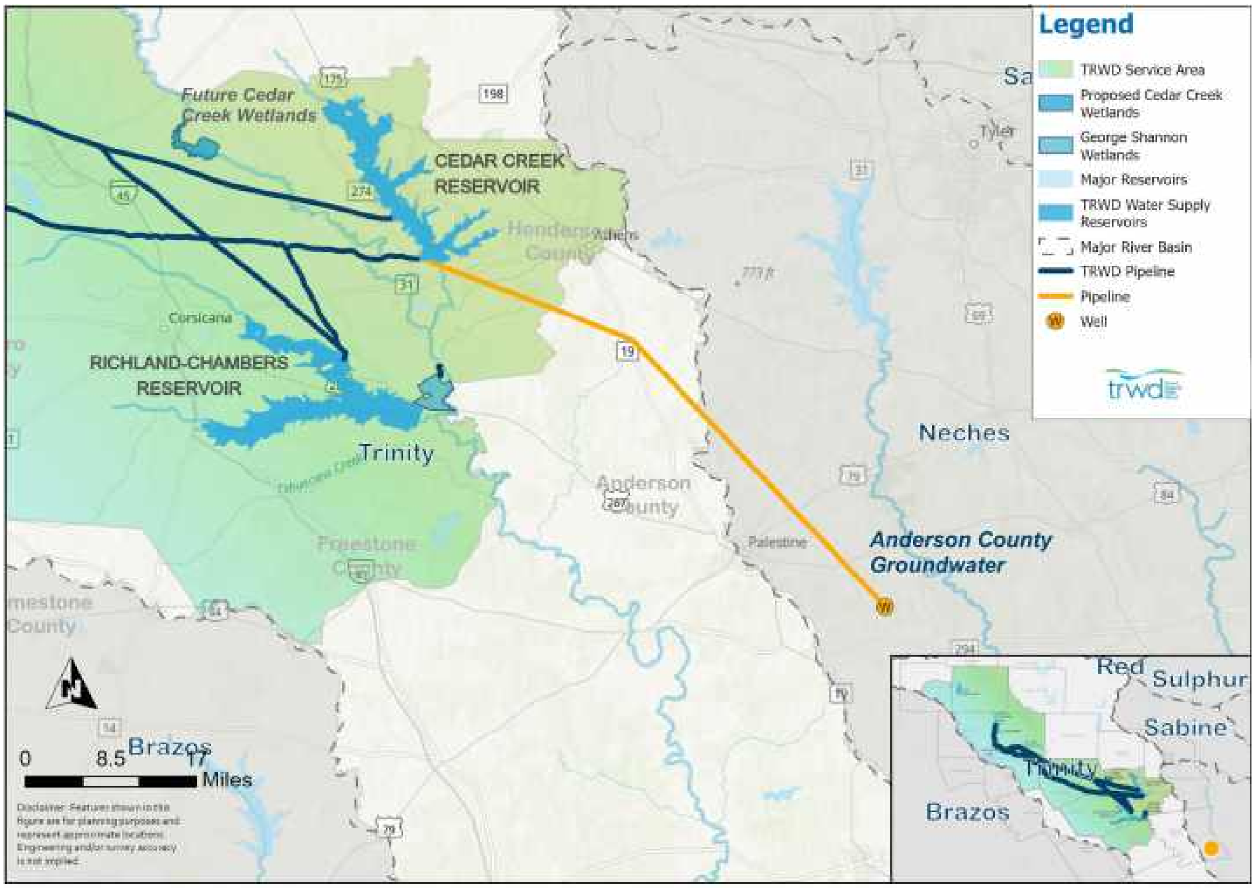


Figure 6.12 Anderson County Groundwater Strategy Location

Partnerships. Anderson County Groundwater does not require, but could involve, a partnership.

Current Status. Anderson County Groundwater has been developed as a project concept to date.

Annual Yield. The yield estimate for this strategy assumes 42,000 AF from both the Carrizo and Upper Wilcox formations, which are shown in Figure 6.10. This volume exceeds the current MAG in Anderson County. If the MAG is not adjusted, it may preclude TRWD from accessing SWIFT funding for this project. Anderson County falls within the Neches and Trinity Valley GCD.

- Firm yield: 37.5 mgd, or 42,000 AFY.
- Safe yield: 37.5 mgd, or 42,000 AFY.

Cost. The cost estimate for this strategy assumed a peak well capacity of 850 gpm. This includes 46 wells at an average depth of 1,160 feet depth. The well field and initial pump station are assumed to share a power connection. A pipeline spanning 58 miles is needed to convey the supply along rural soil to Cedar Creek Reservoir. Water Solutions, LLC, has existing production (but not export) permits from the GCD for approximately half of this volume. The permits were granted in 2020 and have 5-year renewal periods. TRWD is assumed to purchase the raw water at a cost consistent with IWSP assumptions.

- Total Strategy Cost: $1,324 million.
- External Development Cost: $823.4 million.
- Intrasystem Transmission Cost: $500.5 million.
- Purchase Cost of Water: $0.20/kgal ($65/AF).

Key Infrastructure:

- **Pipelines:** 58 miles of 54-inch.
- **Pump Stations:** 56 mgd intake pump station, booster pump station with storage tanks.
- **Wells:** 46 wells at 1,050 feet of depth.

Phasing Potential. This project is unlikely to be phased.

Implementation Time. Anderson County Groundwater has an assumed 10-year implementation timeline for planning, permitting, and construction. This assumes 3 years of planning and feasibility studies, including more detailed hydrogeological studies and site selection. An additional 4 years are assumed for environmental permitting and land acquisition, along with regulatory approvals from TCEQ and local groundwater conservation districts. Design and construction, including drilling and pipeline/pump station design and construction, are assumed to take approximately 3 years.

Strategy Qualitative Scores. Anderson County Groundwater Purchase scores are slightly lower than the other groundwater projects but are still relatively good. Transferring the large supply from Anderson County may be met with low public acceptance. Qualitative scores are provided in Table 6.11.

Table 6.11 Anderson County Groundwater Strategy Qualitative Scores

Category	Score	Description
System Risk	5	Resistant to droughts and wildfires; slight contamination risk.
Permit Uncertainty and Complexity	4	Permitting groundwater relatively low complexity, permits already held by outside entity.
Collaboration Potential	5	Partnership not required.
Operational Simplicity	4	Groundwater wells reasonable proximity to TRWD's existing infrastructure.
Phasing Potential	2	Low phasing potential.
Public Acceptance	3	Requires ROW acquisition for pipeline; some local opposition possible against transferring groundwater.
Multi-Benefit Project	1	Not considered to have project benefits beyond water supply.

6.7 Existing Reservoir

Utilizing supply from an existing reservoir is an attractive option for TRWD. The water supply is more certain, and the difficult steps of land acquisition and permitting are completed. However, there is not a significant volume of available supplies from an existing reservoir close to TRWD's existing water supply system that would fulfill the water supply gap, which implies that securing supplies from an existing reservoir will require TRWD to convey supplies from long distances. Three projects related to existing reservoirs were evaluated, including a purchase from Lake Palestine and Toledo Bend, and obtaining a permit for supply from Wright Patman following a reallocation. These three projects fall within a basin other than the Trinity River Basin and will require interbasin transfer permits. Because these surface water reservoirs are to the east of Trinity River Basin, these regions receive more rainfall and have a different hydrologic risk profile. Procurement of these supplies would improve the resilience of TRWD's system.

6.7.1 Lake Palestine Purchase

Strategy Type: Existing Reservoir

Theme: Regionalization, Resilience

Firm Yield: 30,000 AFY

Purchase Cost of Water: $0.20/kgal

Unit Cost with Debt Service: $1,507/AF

Unit Cost after Debt Service: $352/AF

Lake Palestine is located in the Neches River Basin, 60 miles east of Cedar Creek Reservoir. UNRMWA owns and operates the reservoir and has municipal supply contracts with multiple cities. TRWD would purchase unused yield from one or more entities with contracts for Lake Palestine supply. To convey the supply, this strategy assumes that DWU would be willing to allow TRWD to utilize a portion of DWU's IPL between Lake Palestine and Cedar Creek for a fee. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake and includes a proportional cost. This strategy could require an interbasin transfer permit, depending on whom the supply is purchased from, to transfer water from the Neches to the Trinity (to the extent applicable from Texas Water Code (TWC) §11.085). Additional detailed studies for the receiving and the source basins would be required as part of the permitting process for new interbasin transfers. Section 11.085 of the TWC includes permitting requirements for interbasin transfers. The Lake Palestine Purchase location and infrastructure are shown on Figure 6.13.

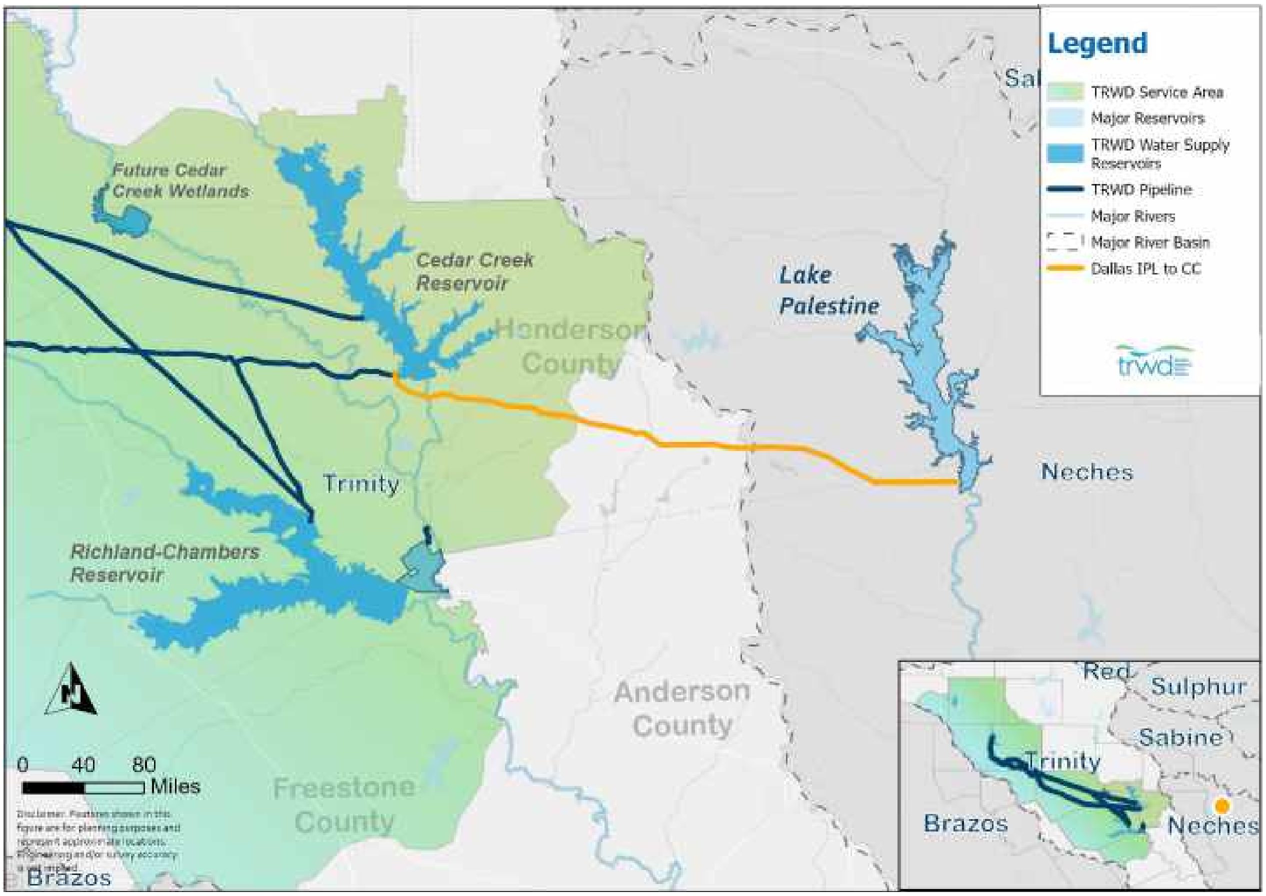


Figure 6.13 Lake Palestine Purchase Strategy Location

Partnerships. Partnership would be required with a willing contract holder such as DWU or City of Tyler for negotiation of the purchase or lease of 30,000 AFY from Lake Palestine.

Current Status. The Lake Palestine Purchase strategy is conceptual.

Annual Yield. Permitted diversions total 238,110 AF from Lake Palestine. However, firm supply is lower due to sedimentation impacts in the reservoir. City of Tyler is contracted for 67,200 AF. City of Dallas is contracted for 114,337 AF. City of Palestine is contracted for 28,000 AF. Additional contracts are for domestic, irrigation, and industrial uses. This strategy would require TRWD to negotiate the purchase of 30,000 AF of Lake Palestine water from a willing contract holder.

Cost. The cost of transporting water from Lake Palestine to the IPL at Cedar Creek is based on the percentage of DWU's LP1 used for the TRWD supply and the cost of 'DWU's LP1, using 'DWU's design cost estimate. The strategy assumes that DWU would be willing to allow TRWD to utilize a portion of the line for a fee. The cost estimate includes prorating DWU's pipeline and intake costs per the percentage of the pipeline that would be needed to convey the supply. Cost estimates were indexed to align with IWSP costing tool assumptions. The purchase cost of raw water from a Lake Palestine contract holder would be subject to negotiations. In the absence of data, the Region C wholesale raw water cost of $0.20/kgal was assumed. Intrasystem transmission assumes 11 percent of the costs of the second IPL from Cedar Creek to JB2 and 15 percent of the costs from JB2 to Benbrook Lake.

- Total Strategy Cost: $572.1 million.
- External Development Cost: $214.6 million.
- Intrasystem Transmission Cost: $357.5 million.
- Purchase Cost of Water: $0.20 $/kgal.

Key Infrastructure:

- **Pipelines:** Prorated use of DWU's IPL from Lake Palestine to Cedar Creek Reservoir.
- **Pump Stations:** Prorated use of DWU's intake pump station at Lake Palestine.

Phasing Potential. Lake Palestine Purchase pipeline/pump station infrastructure could be phased, as could the amount of water purchased from partners. This strategy could also be explored as a temporary contract to fill the water supply gap in the short and mid-term.

Implementation Time. The Lake Palestine Purchase strategy does not require new infrastructure beyond the parallel IPL and predominantly consists of interagency negotiations. It is reliant on the construction of DWU's portion of the IPL completion. It is assumed that 3 years are needed for project planning to conduct additional modeling and studies, and 6 years to obtain an interbasin transfer permit and possible environmental studies.

Strategy Qualitative Scores. The purchase of Lake Palestine supply scores relatively well for most categories. As this supply does not create any new multi-benefits beyond water supply, it scores lowest for that category. Qualitative scores are provided in Table 6.12.

Table 6.12 Lake Palestine Purchase Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; the Neches River is less drought-prone; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	4	Permitting for pipelines, pump stations, and intakes; out-of-basin transfer.
Collaboration Potential	3	Unclear if willing partnership.
Operational Simplicity	4	Utilize DWU's infrastructure.
Phasing Potential	4	Can phase if the water seller is willing.
Public Acceptance	4	May garner public support by using the existing reservoir and pipelines.
Multi-Benefit Project	1	Not considered to have benefits beyond water supply.

6.7.2 Toledo Bend

Strategy Type: Existing Reservoir

Theme: Diversification, Large Supply

Firm Yield: 240,000 AFY

Purchase Cost of Water: $0.20/kgal

Unit Cost with Debt Service: $2,268/AF

Unit Cost after Debt Service: $522/AF

The Toledo Bend Strategy involves conveying available supplies from Toledo Bend, an existing reservoir in the Sabine River Basin (located on the Texas and Louisiana border), to TRWD's service area. The Sabine River Authority in Texas (SRA) holds the water right permit for the Texas portion of the reservoir yield. This strategy assumes that TRWD and one regional partner would purchase and convey half of SRA's available supply, 480,000 AF. The infrastructure was assumed to be phased with dual pipelines. The strategy assumes that a second IPL will be needed to transmit the supply to Benbrook Lake and includes a proportional cost. This strategy would require an interbasin transfer permit to transfer water from the Sabine to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins would be required as part of the permitting process for new interbasin transfers. Section 11.085 of the TWC includes permitting requirements for interbasin transfers. Toledo Bend Reservoir, along with pipeline and pump stations, are shown on Figure 6.14.

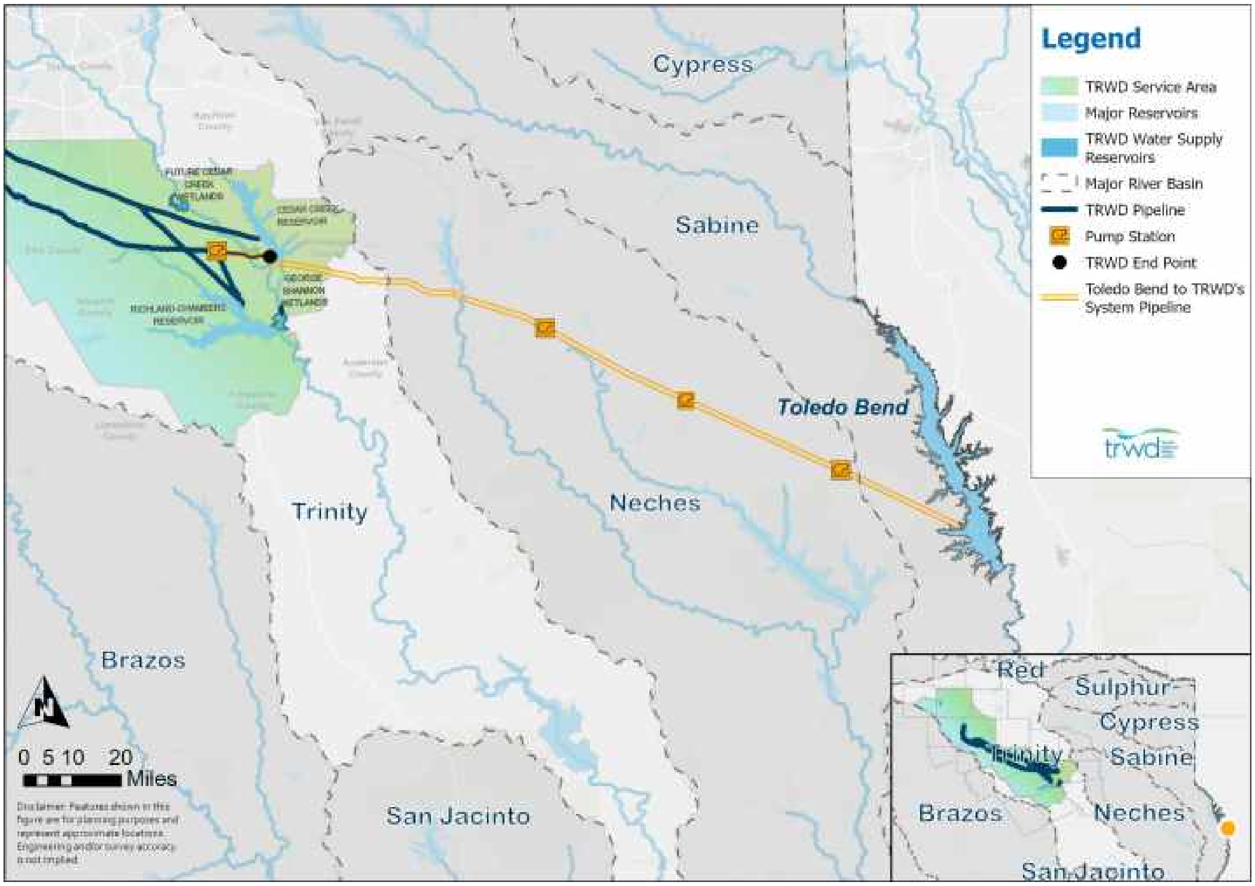


Figure 6.14 Toledo Bend Strategy Location

Partnerships. A partnership is assumed with one regional partner which could include NTMWD, DWU, or others. Many configurations of partnerships for this strategy could be considered.

Current Status. Toledo Bend is referred to in prior studies as a TRWD strategy.

Annual Yield. Toledo Bend is jointly owned and operated by the SRA and the Sabine River Authority in Louisiana (SRA LA). The yield of the reservoir is 2.1 million AF, split equally between the two authorities. SRA has approximately 970,000 AF permitted, with current use of 6,000 AF. The TRWD yield estimate of 480,000 AF represents a purchase agreement from SRA for half of their remaining yield. This strategy assumes TRWD would procure and convey the supply with a 50/50 regional partner, resulting in a 240,000 AFY firm yield for TRWD.

Cost. The estimated total strategy costs are assumed to be shared 50/50 between one regional partner and TRWD. The purchase price of water was assumed at $0.20 per kgal; however, the actual purchase price would be subject to negotiation between parties. The conveyance of supply was assumed to occur in two phases. Phase I includes a 120-inch pipeline from Toledo Bend to JB2, an intake pump station sized for 401 mgd, and three booster stations. Phase II includes a 108-inch pipeline from Toledo Bend to JB2, an intake pump station, and two booster pump stations. A terminal storage reservoir was assumed at each Phase I booster pump station, sized at 2,630 AF of storage capacity and 198 acres. The intrasystem transmission for Phase I assumed 73 percent of the costs of the second IPL from Cedar Creek to JB2 and 57 percent of the costs from JB2 to Benbrook Lake. The intrasystem transmission for

Phase II assumed an additional 44 percent of the costs of the second IPL from Cedar Creek to JB2 and 34 percent of the costs from JB2 to Benbrook Lake.

- Total Strategy Cost: $7,278.6 million.
- External Development Cost: $4,418.4 million.
- Intrasystem Transmission Cost: $2,860.1 million.
- Purchase Cost of Water: $0.20 $/kgal or $65 $/AF.

Key Infrastructure: Figure 6.14 depicts the suggested infrastructure.

- **Pipelines.** 173 miles of 108-inch, 173 miles of 120-inch.
- **Pump Stations.** Two intake pump stations (402 and 241 mgd), three booster pump stations in Phase I, and two booster pump stations in Phase II.
- **Facility.** Three terminal storage facilities for 2,630 AF.

Phasing Potential. Toledo Bend pipeline/pump station infrastructure could be phased.

Implementation Time. Considerations for the implementation of Toledo Bend include regional partnerships, interbasin transfer permitting, and significant infrastructure design and construction. As an existing reservoir project, environmental permitting will be less than that of an existing reservoir, and land acquisition will be limited to piping and pump station easements, leases, or acquisitions. The overall implementation timeline is assumed to be 18 years, including 3 years for planning and detailed studies, 5 years for permitting (including environmental impact assessment and an interbasin transfer permit), and 10 years for design and construction. For comparison, the Luce Bayou Interbasin Transfer Project was planned and permitted between 2005 and 2014, with a permit application for the project submitted in 2005 and USACE approving the permit in 2014 (9 years). The design and construction of pipelines for the Luce Bayou project was from 2014 to 2020 for a 500-mgd pump station, 3 miles of 96-inch dual pipelines, and 24 miles of earthen canal.

Strategy Qualitative Scores. Toledo Bend scores well for permit uncertainty and complexity since the primary activities include an interbasin transfer and pipeline construction. The strategy would be operationally difficult, as Toledo Bend includes nearly 175 miles of pipeline that extends eastward beyond 'Cedar Creek Reservoir. Qualitative scores are provided in Table 6.13.

Table 6.13 Toledo Bend Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; the Sabine River Basin is less drought-prone; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	4	Permitting for pipelines, pump stations, and intakes; out-of-basin transfer.
Collaboration Potential	3	Partnership required but not yet identified.
Operational Simplicity	2	Infrastructure and operations stretch nearly 175 miles beyond the current end point of TRWD's system at Cedar Creek Reservoir.
Phasing Potential	3	Can construct two pipelines, one and then another, to phase supply and capital investment.
Public Acceptance	3	Potential opposition due to perception around costs; requires ROW acquisition. Public support due to use of existing reservoir over construction of a new one.
Multi-Benefit Project	1	No new multi-project benefits.

6.7.3 Wright Patman Reallocation

Strategy Type: Existing Reservoir

Theme: Regionalization, Large Northern Supply

Firm Yield: 65,067 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $2,545/AF

Unit Cost after Debt Service: $488/AF

This strategy includes reallocating flood storage to water supply in Wright Patman Lake, a USACE reservoir in the Sulphur River Basin. Six sponsors, including TRWD, are involved in this joint regional strategy. Reallocation at Wright Patman Lake is a change in the use of storage in an existing reservoir project from its present use as flood control to municipal and industrial use and includes a pool raise. Reallocation requires approval by the U.S. Congress. Water from Wright Patman Lake would be conveyed to Lake Bridgeport and then released for downstream TRWD customers. This strategy requires an interbasin transfer permit to transfer water from the Sulphur to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for interbasin transfers. Section 11.085 of the TWC includes permitting requirements for interbasin transfers. Wright Patman Lake and the pipeline and pump station locations are shown on Figure 6.15.

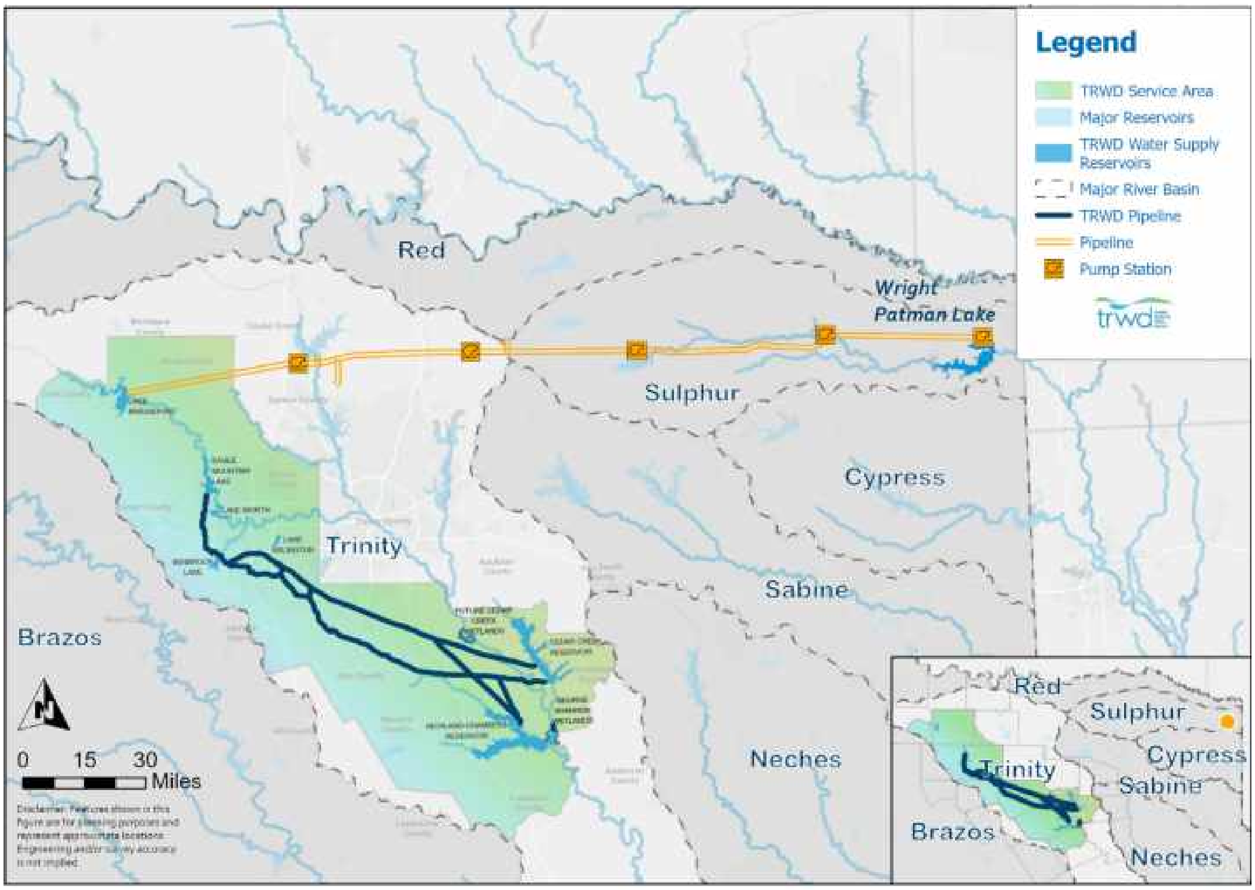


Figure 6.15 Wright Patman Reallocation Strategy Location

Partnerships. This strategy includes regional partnerships with North Texas Municipal Water District (NTMWD), DWU, Upper Trinity Regional Water District (UTRWD), Irving, and a local partnership with Sulphur River Basin Authority (SRBA). The local sponsor for the project is SRBA.

Current Status. Wright Patman Lake reallocation has been studied previously and USACE is currently preparing a Draft Feasibility Report and Draft Environmental Impact Statement.[5]

Annual Yield. The firm and safe yields for this strategy were based on the WPR-4b scenario from the 2024 Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update (Yield Update Report).[6] This report was the first major update since 2014 and reflects recent drought impacts and a new design storm for the Marvin Nichols dam. The drought of record for Marvin Nichols is the 2006 timeframe, which was worse than the drought of the 1950s.

Scenario WRP-4b assumes that the Texarkana water rights application in Wright Patman Lake is not granted, that the Wright Patman Lake minimum elevation is 220.0 feet, and that the Lyons Method environmental flows from the Sulphur River Basin Feasibility Study are used. Under this strategy, which is Wright Patman Lake alone, the yield assumes Wright Patman Lake reallocation is senior to Marvin Nichols. The reallocation results in a new total firm yield of 202,070 AFY. TRWD's portion of the yield is 32.2 percent.

- Firm yield: 58.1 mgd, or 65,067 AFY.
- Safe yield: 35.6 mgd, or 39,896 AFY.

Cost. Costs for Wright Patman Lake reallocation came from the 2021 Region C Regional Water Plan[7] and were escalated from September 2018 dollars to September 2023 dollars. Costs include a total of 28,744 acres for land mitigation. The delivery location for TRWD is Lake Bridgeport. Costs include reversal of the Eagle Mountain connection. The updated costs were estimated for TRWD's share only.

- Total Strategy Cost: $2,456 million.
- External Development Cost: $2,456 million.
- Intrasystem Transmission Cost: $0.

Key Infrastructure:

- **Pipelines:** Five segments from Wright Patman Lake to Lake Bridgeport for a total of 240 miles, ranging in size from 72- to 102-inch.
- **Pump Stations:** Reservoir intake pump station at Wright Patman Lake of 265 mgd, four booster pump stations with storage.
- **Reservoir:** Raise storage pool (i.e., storage reallocation) and dam modification.
- **Other:** Reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

Phasing Potential. Phasing is not included in this strategy.

Implementation Time. An overall timeline of 22 years is assumed for Wright Patman Lake, with 6 years of planning, 11 years of permitting, and 5 years of design and construction. As an existing reservoir project, environmental permitting will be less than that of a new reservoir, and land acquisition will be less than for a new reservoir but not insignificant, as 28,744 acres will be needed for mitigation. The planning timeline of 6 years and 11 years of permitting reflects the need to reallocate Wright Patman's use from flood control to municipal and industrial use, requiring approval by Congress. An interbasin transfer permit

[5] See Fort Worth District > Missions > Civil Works > Wright Patman.
[6] NTMWD. 2024. Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update. Prepared by Freese and Nichols in association with Rivulous, LLC.
[7] See https://www.twdb.texas.gov/waterplanning/rwp/plans/2021/C/RegionC_2021RWP_V1.pdf. Table H.24.

will be required, along with environmental permits to reallocate flood storage. Significant coordination and interagency planning are also needed, along with ROW acquisition to raise the storage pool.

Strategy Qualitative Scores. Wright Patman Reallocation scores low for an existing reservoir because it requires environmental permits, including an out of basin transfer, for reallocation of storage; remote reservoir operations are challenging; local collaboration is needed but willingness of partners is not confirmed; phasing is unsure; and public acceptance may be low due to the increase in inundated area due to raising the conservation pool elevation. Qualitative scores are provided in Table 6.14.

Table 6.14 Wright Patman Reallocation Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	1	Environmental permits required for reallocation; out-of-basin transfer.
Collaboration Potential	2	Mixed benefits from multiple partnerships; local collaboration needed.
Operational Simplicity	2	Remote reservoir operations required; remote pipelines and infrastructure.
Phasing Potential	2	Reallocation cannot be easily phased.
Public Acceptance	2	Requires flooding of areas to raise the dam; strong local opposition; requires ROW acquisition.
Multi-Benefit Project	3	Recreation benefits exist, which would create some environmental offsets.

6.8 Proposed Reservoir

Building new water supply reservoirs is feasible but increasingly uncertain and challenging due to environmental, financial, and regulatory hurdles, and because there are few viable sites remaining for a new reservoir. However, reservoirs provide large amounts of storage that can meet the needs of urban growth, expand recreational opportunities, and boost economic development around the new reservoir. Constructing new water supply reservoirs will continue to be an important strategy for TRWD and other North Texas water suppliers.

Most reservoirs in Texas were constructed between the 1940s and 1980s, with a boom in water supply reservoir construction occurring after the 1950s mega drought.[8] Bois d'Arc Lake is a notable new development, marking the state's first major reservoir constructed in 30 years. Located in Fannin County, the lake was developed by NTMWD as a critical water source for more than 2 million people in 80 growing communities. Bois d'Arc Lake permitting and planning had a duration of 18 years, and construction of the reservoir was complete after 6 years.

The IWSP Update includes five strategies that involve construction of a new reservoir: Marvin Nichols, Marvin Nichols with Wright Patman, Lake Ringgold, Tehuacana, and Mainstem Trinity Off-Channel Reservoir (OCR). Of these, Marvin Nichols, Lake Ringgold, and Tehuacana have been designated as unique reservoir sites by the Texas Legislature. The designation offers some protection by precluding state agencies or political subdivisions of the state to obtain fee titles or easements that would significantly prevent the construction of the reservoir. The codified authority aligns with the state's policy to encourage optimum development of the limited number of feasible sites available for construction of large dams and reservoirs for water supply. Siting potential new reservoirs that have not yet been identified was beyond the scope of the IWSP Update.

[8] TWDB. History of Reservoir Construction in Texas. https://www.twdb.texas.gov/surfacewater/rivers/reservoirs/

Marvin Nichols and Lake Ringgold fall within a basin other than the Trinity River Basin and will require interbasin transfer permits. Both reservoirs have a different hydrologic risk profile compared to each other and to the Trinity River Basin and would improve system resilience. Tehuacana and the Mainstem Trinity OCR fall within the Trinity River Basin. Tehuacana would be permitted with native runoff, while the OCR would be permitted with return flows.

6.8.1 Marvin Nichols

Marvin Nichols is a proposed water supply reservoir in the Sulphur River Basin, located 115 miles from Dallas-Fort Worth. The reservoir would store 1.5 million AF of water and inundate approximately 71,440 acres. This joint regional strategy includes six sponsors, including TRWD. Water from Marvin Nichols would be conveyed to Lake Bridgeport and then released for downstream TRWD customers. This strategy would require an interbasin transfer permit to transfer water from the Sulphur to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the TWC includes permitting requirements for interbasin transfers. The Marvin Nichols reservoir and needed infrastructure to convey supply to Lake Bridgeport are shown in Figure 6.16.

Strategy Type: Proposed Reservoir

Theme: Regionalization, Large Northern Supply, Resilience

Firm Yield: 110,237 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $1,907/AF

Unit Cost after Debt Service: $371/AF

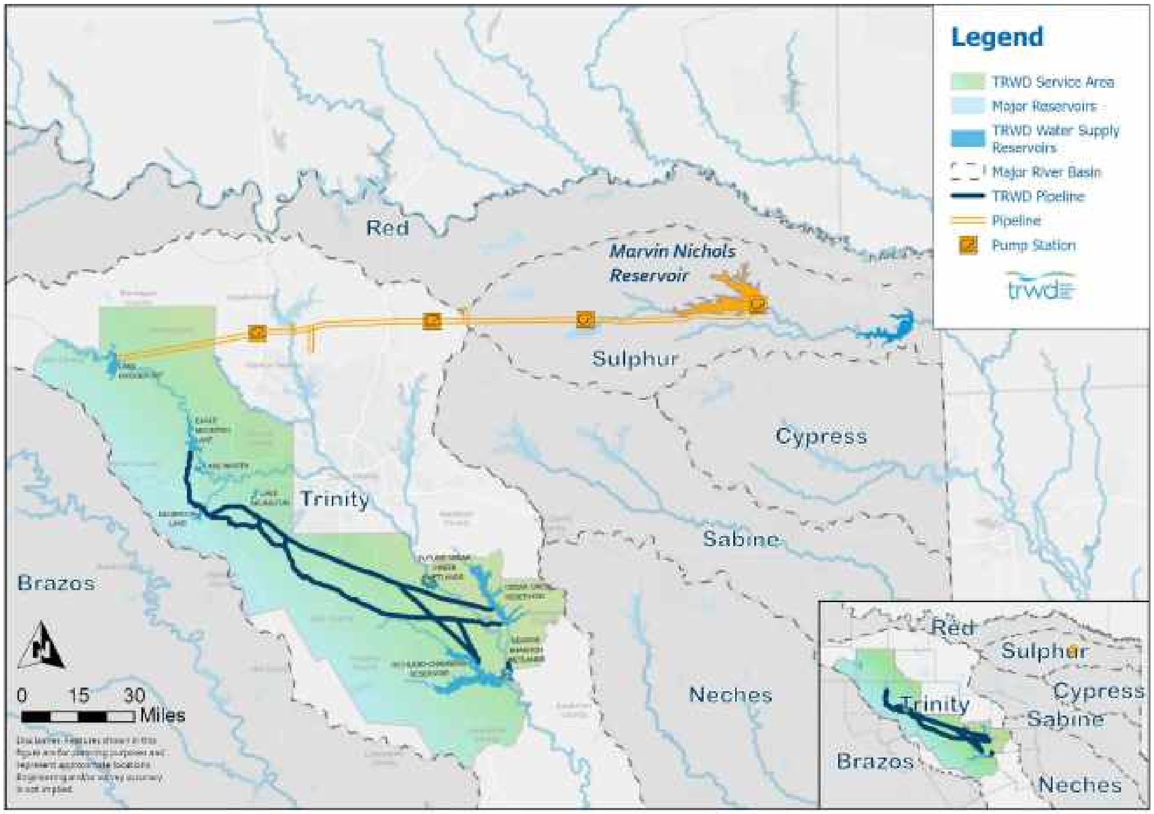


Figure 6.16 Marvin Nichols Strategy Location

Partnerships. This strategy includes regional partnerships with NTMWD, DWU, UTRWD, Irving, and a local partnership with SRBA.

Current Status. Marvin Nichols was first proposed in the 1968 Texas State Water Plan. It has been studied extensively over the decades, including a 2024 study to update the Marvin Nichols firm yield.

Annual Yield. The firm and safe yields for this strategy were based on a High Yield Scenario (C-3) from the Yield Update.[9] The Yield Update is the first major update since 2014 and reflects recent drought impacts and a new design storm for the dam. The drought of record for Marvin Nichols is the 2006 timeframe, which was worse than the drought of the 1950s. Scenario C-3 assumes the Texarkana water rights application in Wright Patman is not granted, the Wright Patman minimum elevation of 220.0 feet, the Lyons Method environmental flows from the Sulphur River Basin Feasibility Study, and that Wright Patman is junior to Marvin Nichols. Total firm yield available to TRWD is estimated at 110,237 AFY, which assumes TRWD's portion of the total firm yield at 25.76 percent.

- Firm yield: 98.4 mgd, or 110,237 AFY.
- Safe yield: 79.3 mgd, or 88,810 AFY.

Cost. Project costs for Marvin Nichols are based on the Conceptual Cost Assumptions from the 2024 report Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update but were updated to reflect IWSP assumptions. This assures comparable costs to other strategies.

Conceptual costs for the dam and spillway (from Table C-1 of the Yield Update) were assumed and indexed to September 2023 dollars. This assumption considers the level of uncertainty at the current stage of design, along with increases in interest rates and other costs. The pipeline, terminal storage, and pump station curves from the Yield Update report were converted to the TRWD cost curves. All other costs were indexed to September 2023 dollars. The pumping energy costs were adjusted to reflect IWSP assumptions of 0.06 $/kWh, and assumptions for debt service and contingencies were updated. Land acquisition of 72,192 acres is needed. The cost estimate per acre was updated from the Yield Update report assumption of $4,502/acre to $6,099/acre based on Land Management Assistance (LMA) 29 and includes 72,192 total acres acquired. Environmental and archeology studies and mitigation were assumed at 3 times the land costs. The updated costs were estimated for TRWD's share only.

The delivery location for TRWD is Lake Bridgeport. Costs include reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

- Total Strategy Cost: $3,062 million.
- External Development Cost: $2,927.1 million.
- Intrasystem Transmission Cost: $135.4 (Eagle Mountain connection reversal).

Key Infrastructure:

- **Pipelines:** Seven segments from Marvin Nichols Reservoir to Bridgeport totally 192 miles, ranging in size from 78- to 120-inch.
- **Pump Stations:** Reservoir intake pump station (450 mgd), three booster pump stations.
- **Reservoir:** 71,440 surface acres.
- **Other:** Reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

Phasing Potential. Phasing is assumed to be infeasible for a new reservoir project.

[9] NTMWD. 2024. Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update. Prepared by Freese and Nichols in association with Rivulous, LLC.

Implementation Time. Considerations for the implementation of Marvin Nichols include regional partnerships, environmental permitting, interbasin transfer permitting, political opposition, and extensive land acquisition. Implementation is assumed to take approximately 30 years, with 5 years for planning, 15 years for permitting, and 10 years for design/construction. Design and construction are assumed to take longer for Marvin Nichols due to the significantly larger reservoir area, more complex dam, and larger pipelines needed for the project. Planning and permitting timelines are difficult to predict for new reservoirs due to environmental permitting hurdles, and political and legal factors. The 2026 Region C Water Plan estimates Marvin Nichols could be brought online by 2060.

Strategy Qualitative Scores. Marvin Nichols scores well for system risk, as the new reservoir in an eastern basin beyond the Trinity River Basin provides resilience. All surface water is susceptible to wildfires, drought, and contamination. The new reservoir also scores high for recreational impacts that could offset environmental impacts. Marvin Nichols does not score well for collaboration, operational simplicity, nor public acceptance. Qualitative scores are provided in Table 6.15.

Table 6.15 Marvin Nichols Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	1	Environmental permits required for new reservoir; out-of-basin transfer.
Collaboration Potential	2	Mixed benefits from multiple partnerships; local collaboration needed.
Operational Simplicity	2	Remote reservoir operations required; remote pipelines and infrastructure.
Phasing Potential	1	Construction of a new reservoir cannot be easily phased.
Public Acceptance	2	Requires acquisition of land for reservoir footprint; strong local opposition; requires ROW acquisition.
Multi-Benefit Project	4	High recreation opportunities are partially offset by environmental impacts.

6.8.2 Marvin Nichols with Wright Patman

Strategy Type: Proposed Reservoir

Theme: Regionalization, Large Northern Supply, Resilience

Firm Yield: 141,800 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $2,262/AF

Unit Cost after Debt Service: $365/AF

Marvin Nichols Reservoir is a proposed water supply reservoir in the Sulphur River Basin, located 115 miles from Dallas-Fort Worth. The reservoir would store 1.5 million AF of water and inundate approximately 71,440 acres. This strategy pairs construction of Marvin Nichols with reallocation of and supply from Wright Patman Lake, a USACE reservoir just to the east of the proposed Marvin Nichols, whose conservation pool raising to 235 feet would inundate approximately 14,372 acres. This joint, regional strategy, includes six sponsors, including TRWD. Water from Marvin Nichols and Wright Patman would be conveyed to Lake Bridgeport and then released for downstream TRWD customers. This strategy would require an interbasin transfer permit to transfer water from the Sulphur to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the TWC includes permitting requirements for interbasin transfers.

The location of Marvin Nichols and Wright Patman reservoirs and the required strategy infrastructure are depicted in Figure 6.17.

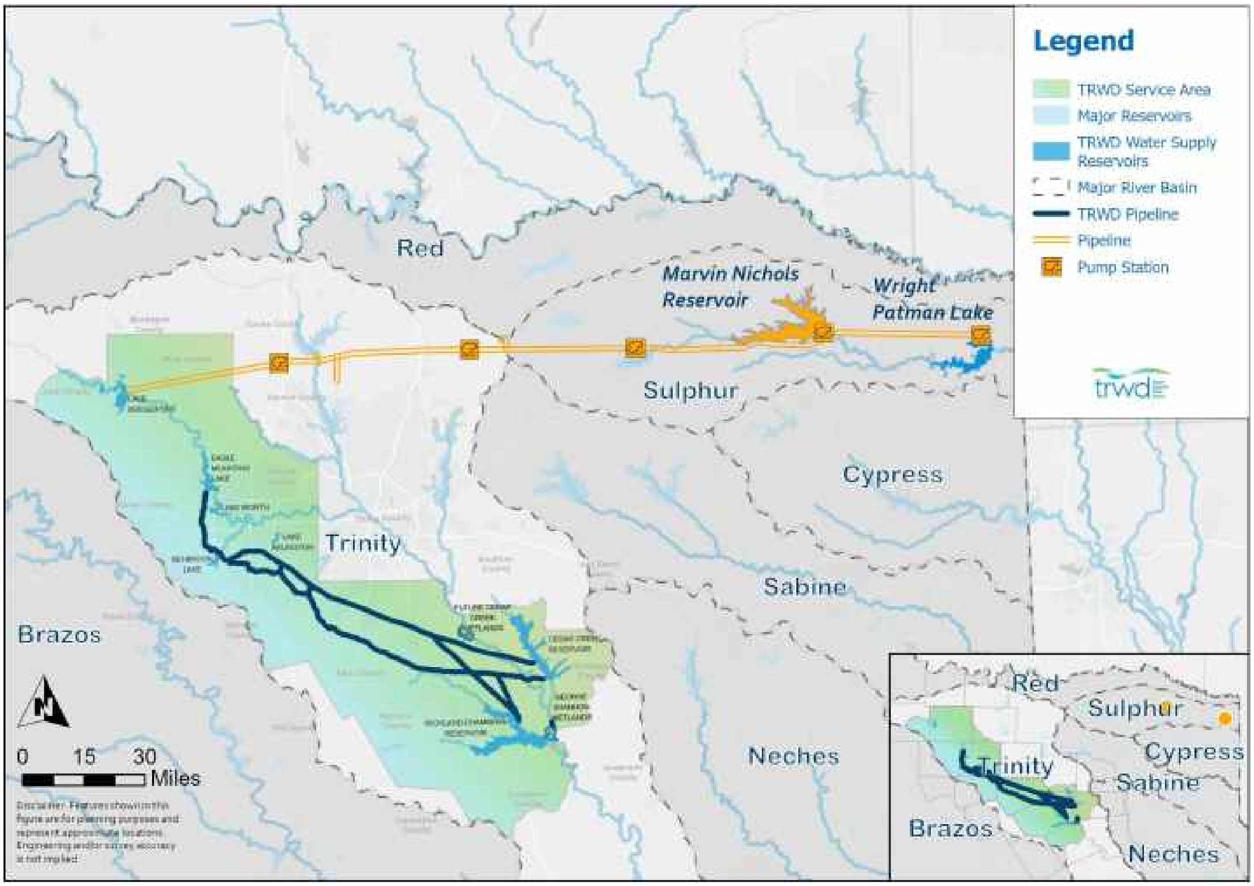


Figure 6.17 Marvin Nichols with Wright Patman Infrastructure and Location

Partnerships. This large reservoir is a joint strategy to be implemented together with NTMWD, DWU, UTRWD, Irving, and SRBA.

Current Status. Procurement of supplies from Marvin Nichols and Wright Patman as a joint strategy has been studied extensively over the decades, including a 2024 study to update the Marvin Nichols firm yield.

Annual Yield. The firm and safe yields for this strategy were based on a High Yield Scenario (C-3) from the February 1, 2024, report, *Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update* (Yield Update).[10] The Yield Update is the first major update since 2014 and reflects recent drought impacts and a new design storm for the dam. The drought of record for Marvin Nichols is the 2006 timeframe, which was worse than the drought of the 1950s. Scenario C-3 assumes the Texarkana water rights application in Wright Patman is not granted, the Wright Patman minimum elevation of 220.0 feet, the Lyons Method environmental flows from the Sulphur River Basin Feasibility Study, and that Wright Patman is junior to Marvin Nichols. Total firm yield is estimated at 141,800 AFY, which reflects

[10] NTMWD. 2024. Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update. Prepared by Freese and Nichols in association with Rivulous, LLC.

TRWD's portion of 25.76 percent. TRWD's portion of the yield at Marvin Nichols is 25.76 percent and 32.2 percent at Wright Patman.

- Firm Yield: 126.6 mgd or 141,800 AFY.
- Safe Yield: 100.3 mgd or 112,371 AFY.

Cost. Project costs for Marvin Nichols are based on the Conceptual Cost Assumptions from the 2024 report *Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update* but were updated to reflect IWSP assumptions. This assures comparable costs to other strategies.

Conceptual costs for the Marvin Nichols dam and spillway (from Table C-1 of the Yield Update) were assumed and indexed to September 2023 dollars. This assumption considers the level of uncertainty at the current stage of design, along with increases in interest rates and other costs. Costs for Wright Patman Lake reallocation came from the 2021 Region C Regional Water Plan and were escalated from September 2018 dollars to September 2023 dollars.[11] Costs include a total of 28,744 acres for land mitigation at Wright Patman.

The pipeline, terminal storage, and pump station curves were updated to reflect the needed capacity to convey both supplies and were converted to the TRWD cost curves. All other costs were indexed to September 2023 dollars. The pumping energy costs were adjusted to reflect IWSP assumptions of 0.06 $/kWh, and assumptions for debt service and contingencies were updated. Land acquisition is needed for Marvin Nichols totaling 72,192 acres. The cost estimate per acre was updated from the Yield Update report assumption of $4,502/acre to $6,099/acre based on LMA 29. Environmental and archeology studies and mitigation were assumed at 3 times the land costs. The updated costs were estimated for TRWD's share only.

The delivery location for TRWD is Lake Bridgeport. Costs include reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

- Total Strategy Cost: $4,796 million.
- External Development Cost: $4,661 million.
- Intrasystem Transmission Cost: $135 million for Eagle Mountain connection reversal.

Key Infrastructure:

- **Pipelines:** Eight segments from Wright Patman to Lake Bridgeport for a total of 240 miles, ranging in size from 84- to 144-inch.
- **Pump Stations:** Reservoir intake pump stations, three booster pump stations.
- **Reservoir:** 71,440 surface acre reservoir.
- **Other:** Reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

Phasing Potential. Although a new reservoir cannot be phased, the construction of a second pipeline for the project could be phased.

Implementation Time. The total implementation timeline is assumed to be 30 years. This reservoir has been studied for years, so some of the planning timeline is condensed. Planning activities are assumed to take 5 years and include stakeholder engagement, legal discussions, and interagency coordination on cost-sharing and water rights. If other geological or hydrologic studies are needed, planning could take longer, but it is likely these studies could be completed in tandem with legal/agency planning and permitting. Permitting is assumed to take 15 years, in line with permitting for Marvin Nichols. A design/construction timeline of 10 years is assumed due to the reservoir's large size and significant infrastructure implementation needed.

[11] See https://www.twdb.texas.gov/waterplanning/rwp/plans/2021/C/RegionC_2021RWP_V1.pdf. Table H.24.

Strategy Qualitative Scores. Marvin Nichols with Wright Patman scores well for system risk, as the new reservoir in an eastern basin beyond the Trinity River Basin provides resilience. All surface water is susceptible to wildfires, drought, and contamination. The new reservoir also scores high for recreational impacts that could offset environmental impacts. The combination project does not score well for collaboration, operational simplicity, nor public acceptance. Qualitative scores are provided Table 6.16.

Table 6.16 Marvin Nichols with Wright Patman Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	1	Environmental permits required for new reservoir; out-of-basin transfer.
Collaboration Potential	2	Mixed benefits from multiple partnerships; local collaboration needed.
Operational Simplicity	2	Remote reservoir operations required; remote pipelines and infrastructure.
Phasing Potential	2	Construction of a new reservoir cannot be easily phased.
Public Acceptance	2	Requires acquisition of land for reservoir footprint; strong local opposition; requires ROW acquisition.
Multi-Benefit Project	4	High recreation opportunities are partially offset by environmental impacts.

6.8.3 Lake Ringgold

Strategy Type: Proposed Reservoir

Theme: Northern Supply

Firm Yield: 28,000 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $2,497/AF

Unit Cost after Debt Service: $356/AF

Lake Ringgold, a new reservoir on the Little Wichita River just upstream of the confluence of the Red River, would be constructed and supply conveyed to TRWD's system. Lake Ringgold would have a storage capacity of 275,000 AF of water with an approximate surface area of 15,500 acres. Because the yield of Lake Ringgold is relatively small compared to other Northern supplies, TRWD would likely need to procure the full supply for the strategy to have a meaningful and worthwhile impact on TRWD's system yield. Thus, although the City of Wichita Falls has obtained the permit for Lake Ringgold from TCEQ, this strategy assumes TRWD would be fully responsible for future permitting, planning, design, construction, and O&M. The next step for this strategy is to obtain a Section 404 permit under the Clean Water Act from the USACE, which authorizes construction of the reservoir. Additionally, this strategy would require an interbasin transfer permit to transfer water from the Red River Basin to the Trinity River Basin, to the extent applicable from the TWC §11.085. Additional detailed studies for the receiving and the source basins would be required as part of the permitting process for new interbasin transfers. The proposed Lake Ringgold location and associated infrastructure are depicted in Figure 6.18.

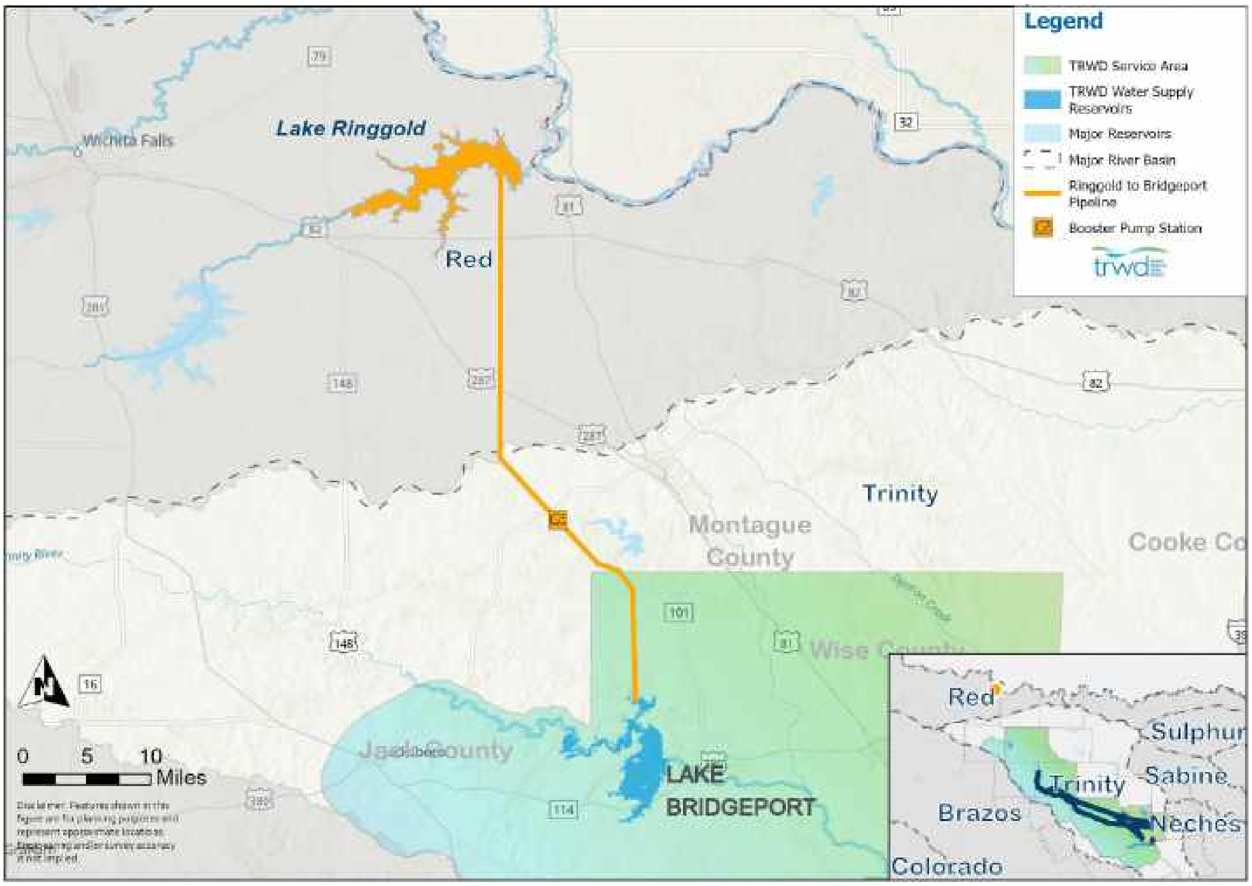


Figure 6.18 Lake Ringgold Strategy Location

Partnerships. This strategy does not assume partnerships, although a partnership with the City of Wichita Falls could be considered.

Current Status. Lake Ringgold was first proposed as a reservoir in the 1950s and has been extensively studied.

Annual Yield. The reservoir would inundate 17,280 acres. Firm yield for Lake Ringgold was estimated at 30,115 AFY based on Region B's most recently updated firm yield. TRWD is assumed to have water rights to 28,000 AFY. TRWD would begin pumping from Lake Ringgold when Lake Bridgeport is one below the conservation pool elevation.

Cost. The reservoir and dam costs, along with environmental mitigation and relocation costs, were indexed from the 2021 Region B Regional Water Plan to September 2023 dollars. The intake pump station was sized for TRWD's yield using a 1.5 peaking factor. Costs include construction of the intake pump station and the pipeline to convey supply from Lake Ringgold to Lake Bridgeport and were estimated using the IWSP Costing Tool. Costs include reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

- Total Strategy Cost: $1,037.8 million.
- External Development Cost: $902.8 million.
- Intrasystem Transmission Cost: $135.0 million for Eagle Mountain connection reversal.
- Purchase Cost of Water: $0.00 $/kgal.

Key Infrastructure: Figure 6.18 depicts the infrastructure layout.

- **Pipelines:** 50 miles of 48-inch.
- **Pump Stations:** One 38 mgd intake pump station, and one booster pump.
- **Reservoir:** 17,280 surface acres, 82 AF of terminal storage.
- **Other:** Reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

Phasing Potential: Phasing is assumed to be infeasible for any new reservoir project.

Implementation Time: The assumed implementation timeline for Lake Ringgold is 25 years. The City of Wichita Falls has already received a water rights permit for Lake Ringgold from TCEQ, but the reservoir still needs environmental permitting, land acquisition, and agreements between TRWD and the City of Wichita Falls. Based on Bois d'Arc's timeline, a planning timeline of 4 years, a permitting timeline of 14 years, and a design plus construction timeline of 7 years are assumed. The construction timeline is slightly longer than Bois d'Arc as Ringgold assumed additional time for design.

Strategy Qualitative Scores: Lake Ringgold scores in the low to moderate range for most categories, but with a high score for recreational impacts that could offset environmental impacts. The reservoir project does not score well for collaboration, operational simplicity, nor public acceptance. System Risk scores a two, slightly lower than other reservoirs because the Red River Basin is more vulnerable to drought when compared to other strategy locations. Qualitative scores are provided in Table 6.17.

Table 6.17 Lake Ringgold Strategy Qualitative Scores

Category	Score	Description
System Risk	2	Reliance on surface water; the Red River Basin is more drought-prone.
Permit Uncertainty and Complexity	2	Environmental permits required for new reservoir; water rights approved.
Collaboration Potential	3	Unclear if willing partnership.
Operational Simplicity	3	Reservoir operations required.
Phasing Potential	1	Construction of a new reservoir cannot be easily phased.
Public Acceptance	3	Requires acquisition of land for reservoir footprint; potential environmental opposition; requires ROW acquisition.
Multi-Benefit Project	4	High recreation opportunities are partially offset by environmental impacts.

6.8.4 Tehuacana

Tehuacana involves the construction of a new reservoir on Tehuacana Creek, a tributary to the Trinity River in Freestone County, located south of the Richland-Chambers Reservoir. Tehuacana would be hydraulically connected to Richland-Chambers with a small channel. Water from Tehuacana would be transported from Richland-Chambers and then into TRWD's transmission system. The strategy assumes that a second IPL will be needed to transmit the supply from Richland-Chambers to Benbrook Lake and includes a proportional cost. The proposed location of the Tehuacana reservoir, adjacent to Richland-Chambers, is shown in Figure 6.19.

Strategy Type: Proposed Reservoir

Theme: Large Supply, Trinity River Priority

Firm Yield: 27,514 AFY

Purchase Cost of Water: $0.00/kgal

Unit Cost with Debt Service: $2,875/AF

Unit Cost after Debt Service: $409/AF

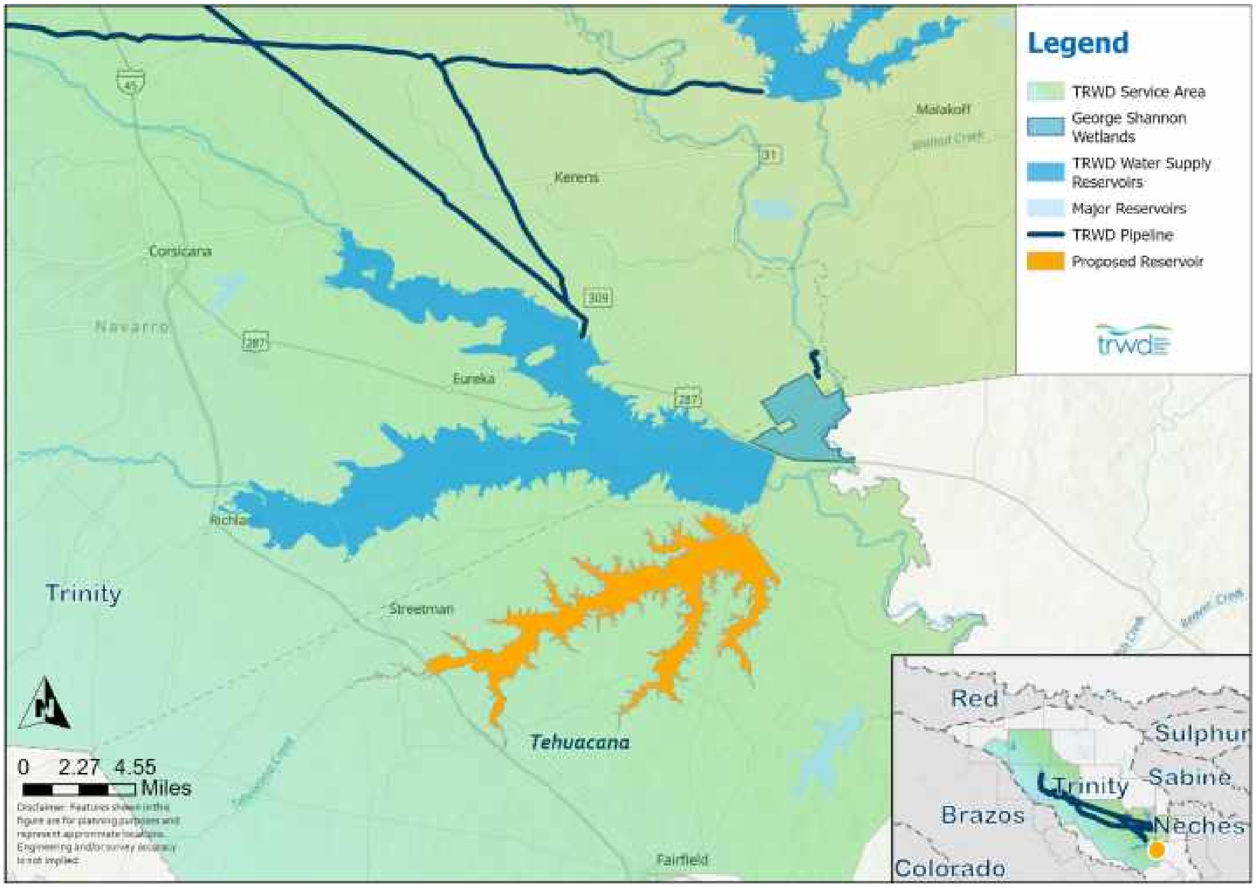


Figure 6.19 Tehuacana Strategy Location

Partnerships. No partnerships are assumed for implementation.

Current Status. Tehuacana was first identified as a potential water supply project in the late 1950s and has been a part of TRWD's long-term planning since.

Annual Yield. Tehuacana will inundate approximately 15,000 acres, and the reservoir will hold 338,000 AF. Based on the assumptions reflected in the October 2023 TCEQ WAM, the firm yield of Tehuacana is estimated to be 27,514 AFY. If the unpermitted yield in Richland-Chambers and Cedar Creek Reservoirs is permitted before the yield of Lake Tehuacana, then the yield of Tehuacana is estimated to decrease to 26,000 AFY. If the WAM includes local environmental flows at Tehuacana, consistent with yields previously reported for Region C, the firm yield decreases further to 25,225 AFY. The safe yield of Tehuacana is estimated to be 21,963 AFY, assuming local environmental flows and a diversion junior to the unpermitted yield of Richland-Chambers and Cedar Creek Reservoirs.

Cost. Cost estimates for this strategy assumed that Tehuacana would be hydraulically connected to Richland-Chambers Reservoir via a small channel. TRWD already owns the land for the channel connection. It is unknown whether structural components may be needed for the connection, so the cost estimate assumed none are needed, to be consistent with the previous estimates from the 2014 IWSP. The 2014 TRWD IWSP dam assumptions were also used and indexed to September 2023 dollars.

Extensive information has been collected over the years on the oil/gas deposits and current operations/wells within the footprint of Tehuacana. This information is included in the land acquisition cost estimate, so there is no need to include additional factors for oil/gas. The cost of land was assumed at $10,000 per acre, with additional costs added for parcels with residential structures (19 total).

The existing spillway for the Richland-Chambers Reservoir was designed to provide enough discharge capacity to accommodate the increased flood flows from the Tehuacana Reservoir for the probable maximum flood (PMF) event. Previous studies indicated that the dam for the Tehuacana Reservoir can be constructed without a spillway. If this strategy is moved forward, TRWD should confirm whether the current sizing of the Richland-Chambers spillway is adequate given a new PMF.

Intrasystem transmission assumes 13 percent of the costs of the second IPL from Richland-Chambers to JB2 and 11 percent of the costs from JB2 to Benbrook Lake.

- Total Strategy Cost: $1,175.4 million.
- External Development Cost: $846.2 million.
- Intrasystem Transmission Cost: $329.2 million.

Key Infrastructure: Figure 6.19 depicts the infrastructure layout.

- **Pipelines:** Second IPL to transmit supply.
- **Pump Stations:** One intake pump station.
- **Reservoir:** Zoned earthen embankment with a maximum height of 81 feet, 9,000 feet channel, and 337,947 AF reservoir.

Phasing Potential: Phasing is assumed to be infeasible for any new reservoir project.

Implementation Time. Tehuacana is a new reservoir and will require land acquisition, water rights permitting, and environmental impact studies. Based on Bois d'Arc's timeline, a planning timeline of 4 years (including some of the land acquisition), a permitting timeline of 15 years (like Bois d'Arc, including the majority of land acquisition), and a design plus construction timeline of 5 years are assumed for Tehuacana. Construction was assumed to take a year more than the Bois d'Arc construction timeline since Tehuacana uses an earthen dam and requires construction of a new pump station, plus 2 years of design time. A total implementation timeline of 25 years is assumed, aligned with assumptions in the Initially Prepared Region C 2026.[12]

First steps for this strategy would include TRWD submitting a water rights permit application to TCEQ for Tehuacana, which would give TRWD the right to use and impound the water. If granted, the next step would be to obtain a Section 404 permit under the Clean Water Act from the USACE, which provides authorization to construct the reservoir.

Strategy Qualitative Scores. Tehuacana scores well for Collaboration Potential, as no partnerships are needed, and for Operational Simplicity, and Multi-Benefit Project. Consistent with other reservoir strategies, Tehuacana scores a three for system risk and public acceptance. Qualitative scores are provided in Table 6.18.

[12] See https://regioncwater.org/wp-content/uploads/2025/03/2026_Region_C_Initially_Prepared_Plan_Volume_I.pdf

Table 6.18 Tehuacana Strategy Qualitative Scores

Category	Score	Description
System Risk	3	Reliance on surface water, which can be impacted by wildfires and drought; reservoirs are susceptible to contamination.
Permit Uncertainty and Complexity	1	Environmental permits are required for a new reservoir.
Collaboration Potential	4	No partnership required.
Operational Simplicity	4	Operating a large reservoir, but located in close proximity to TRWD's existing infrastructure.
Phasing Potential	1	Construction of a new reservoir cannot be easily phased.
Public Acceptance	3	Requires acquisition of land for reservoir footprint; potential environmental opposition.
Multi-Benefit Project	4	High recreation opportunities are partially offset by environmental impacts.

6.8.5 Mainstem Trinity OCR

The Mainstem Trinity OCR strategy involves an OCR located near the main stem of the Trinity River. The OCR could store approximately 300,000 AF of supply from DWU return flows, stormwater runoff originating in the upstream Trinity River watershed, or reuse water from other partners. Water would be diverted to the OCR and then conveyed via pipeline to Joe Pool. TRWD would then convey the supply from Joe Pool to JB4. This strategy assumes a 50/50 cost share with DWU for the construction of the OCR and pipeline to Joe Pool. Given the volume of supply, return flows in the Trinity will need to be mitigated to maintain TRWD raw water quality standards. A map indicating the location of the OCR and related infrastructure are included in Figure 6.20.

Strategy Type: Proposed Reservoir

Theme: Regionalization, One Water, Trinity River Priority

Firm Yield: 57,169 AFY

Purchase Cost of Water: $0.20/kgal

Unit Cost with Debt Service: $1,260/AF

Unit Cost after Debt Service: $385/AF

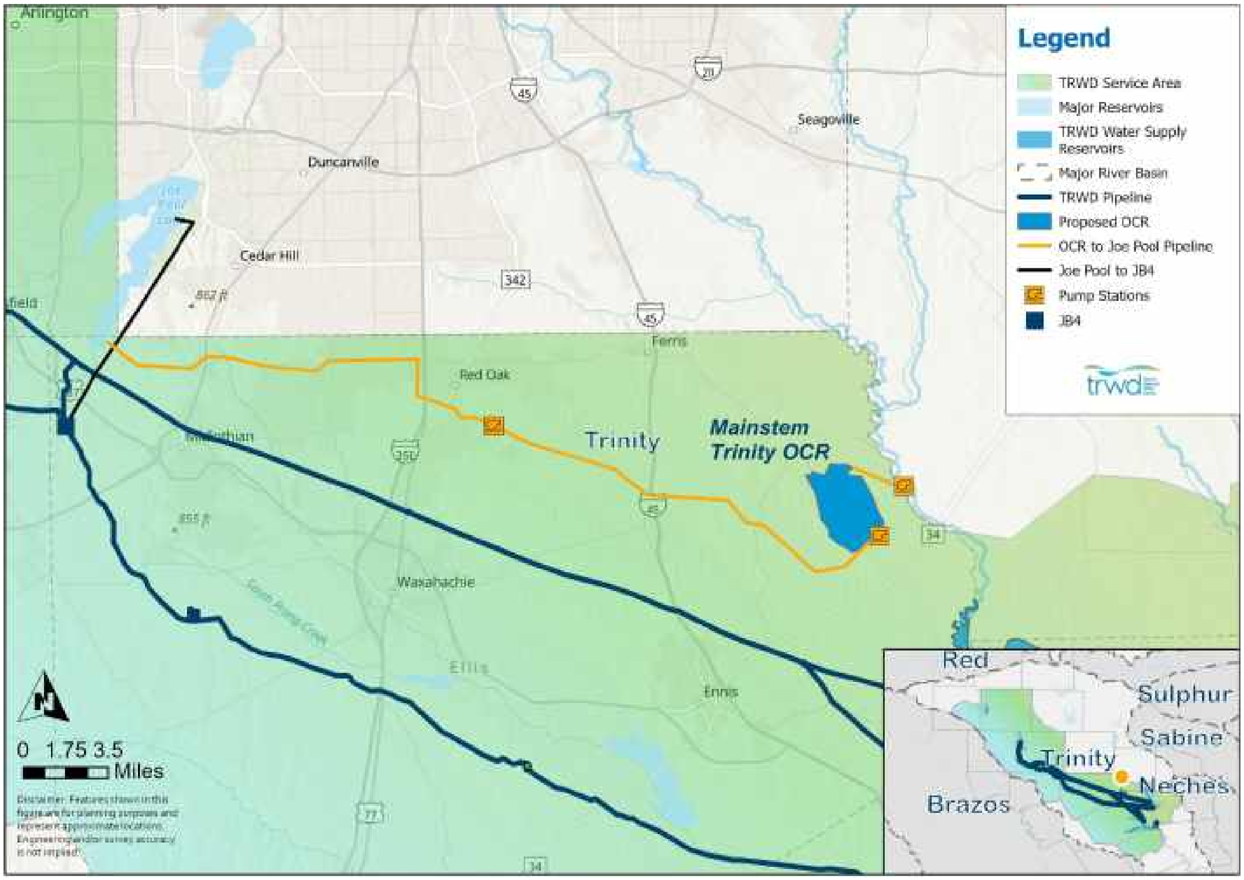


Figure 6.20 Mainstem Trinity Strategy Location Infrastructure

Annual Yield: The DWU project was proposed in the 2014 DWU Long Range Water Supply Plan to 2070 and Beyond (LRWSP) for a large OCR near the main stem of the Trinity River to capture DWU return flows (and possibly other flows). The strategy assumes the OCR can store approximately 300,000 AF with 114,337 AFY (102 mgd) of yield, based on the 2014 DWU LRWSP. No modeling was conducted to confirm the firm yield. Additionally, the strategy assumes that TRWD could purchase half of the firm yield, or 51 mgd per year from DWU.

- Firm yield: 51.0 mgd, or 57,169 AFY.
- Safe yield: 51.0 mgd, or 57,169 AFY.

Cost: The purchase cost of DWU return flows is unknown for this strategy. Consistent with other strategies, a unit cost of $0.20 per 1,000 gallon was assumed. All prices would be subject to negotiation between the parties.

The costs for constructing the OCR, intake pump station, and conveyance to Joel Pool were estimated by escalating the assumptions from the LRWSP from 2013 dollars to September 2023 dollars. Intake and pipeline costs are included. Intrasystem conveyance is 22 percent of the costs from JB4 to Benbrook. While not included in the costs, TRWD would likely require some form of water quality mitigation.

- Total Strategy Cost: $867.5 million.
- External Development Cost: $641.1 million.

- Intrasystem Transmission Cost: $226.5 million.
- Purchase Cost of Water: $0.20 $/kgal.

Key Infrastructure:

- **Pipelines:** Portion of second IPL to transmit supply; 40 miles of 66-inch from OCR to Joe Pool; 12 miles of 66-inch from Joe Pool to JB4.
- **Pump Stations:** 77 mgd intake pump station at Joe Pool and one booster pump station.
- **Reservoir:** 4,337 surface area.

Phasing Potential: Phasing is assumed to be infeasible for a new reservoir project.

Implementation Time. This proposed OCR is assumed to have a 20-year implementation timeline. It would require environmental permitting and land acquisition, but these are expected to be less than a typical reservoir. The project also requires ROW acquisition for a new pipeline. The Mainstem Trinity OCR has not been extensively studied, so a planning timeline of 5 years is assumed to account for modeling and technical studies related to project impacts, including water quality. Environmental permitting/land acquisition time is assumed to take about 9 years since it likely will not encounter as much opposition as a full reservoir project. Construction is assumed to take 6 years to account for major pipelines and pump stations along with the reservoir.

Strategy Qualitative Scores. The OCR scores well across most categories. System risk is low, since reuse supply is fairly drought proof. Permitting is less uncertain and complex compared to a new reservoir. Qualitative scores are shown in Table 6.19.

Table 6.19 Mainstem Trinity OCR Strategy Qualitative Scores

Category	Score	Description
System Risk	4	Less likely to be contaminated or impacted by wildfire; reuse supply available during drought, but not ExFlo.
Permit Uncertainty and Complexity	3	Environmental permits required for new reservoir; off-channel, less environmental impacts.
Collaboration Potential	3	Partnership required.
Operational Simplicity	3	Operations require filling and release; located in close proximity to TRWD's existing infrastructure.
Phasing Potential	1	No phasing potential.
Public Acceptance	3	Requires acquisition of land for reservoir footprint; requires ROW acquisition for pipeline; potential environmental opposition.
Multi-Benefit Project	2	Some opportunities for recreation benefits via trails.

6.9 Out-of-State Transfer

TRWD's northernmost water supply reservoir, Lake Bridgeport, is 40 miles from Oklahoma's southern border. TRWD and other North Texas suppliers have looked towards Oklahoma for water for decades. In the early 2000s, TRWD submitted a permit to purchase water from Oklahoma's Kiamichi River. The Oklahoma Legislature, in response, established a moratorium on the export of water from the state, which has prevented the out-of-state transfer for any entity to date. TRWD pursued a case in Federal Court to determine whether this moratorium could be overturned, and the Supreme Court ruled in favor of Oklahoma. In 2024, Texas and Oklahoma reached a significant agreement to resolve a longstanding water access issue involving Lake Texoma, a major water source for NTMWD. Should political opposition and viewpoints in Oklahoma change, a purchase from Oklahoma could become a viable opportunity.

While a longer distance at 200 miles, there is potential to purchase out-of-state water from Arkansas. TWDB studied this option in 1976.[13] Arkansas Law Title 3-1, Section VI, does outline the application process for Interstate Transfers.[14] The IWSP Update includes a strategy to secure water rights from Arkansas just north of Lake Millwood and convey supplies to Lake Bridgeport.

As of the date of this report, the Texas Legislature is actively considering legislation that could enable state funding for out-of-state water transfers. The 2025 SB7 from the 89th Legislature, currently under review, proposes amendments to the TWC to allow the TWDB to purchase and transfer water rights, including those from outside the state. This bill aims to expand the state's capacity to secure water resources to meet growing demand. Should the bill pass, and depending on the outcome, an out-of-state transfer of supply could be subject to additional funding and wider political support.

6.9.1 Arkansas Water

Strategy Type: Water Transfer

Theme: Diversification, Large Northern Supply

Firm Yield: 260,000 AFY

Purchase Cost of Water: $0.20/kgal

Unit Cost with Debt Service: $2,761/AF

Unit Cost after Debt Service: $488/AF

The Arkansas Water strategy would involve submitting a legislative request for an out-of-state transfer of 260,000 AF of supply annually from Arkansas. The diversion would be just above Millwood Lake on the Little River in Arkansas, and the supply would be conveyed to Lake Bridgeport. This strategy assumes an OCR could further improve reliability and reduce costs. The location and needed infrastructure are presented in Figure 6.21. A more optimal diversion point or pipeline layout may be identified with additional study.

While Arkansas has a legislative process established for an out-of-state transfer, there is no precedent for such a transfer. This strategy may require an interbasin transfer permit to transfer water from the Red River Basin to the Trinity River Basin (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the TWC includes permitting requirements for interbasin transfers.

[13] TWDB. 1976. An Assessment of Surface Water Supplies of Arkansas. Available at An Assessment of Surface Water Supplies of Arkansas.
[14] See Rules for the Utilization of Surface Water.

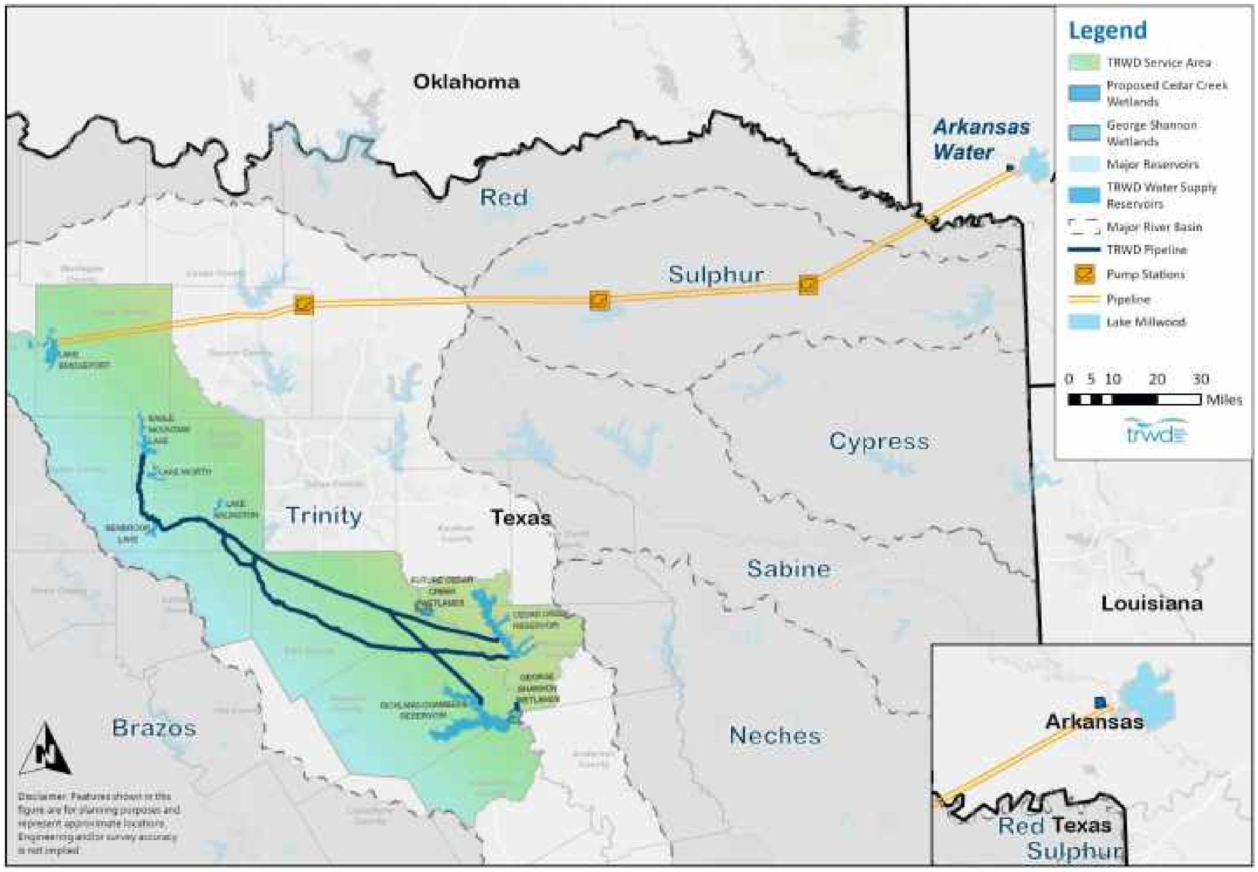


Figure 6.21 Arkansas Water Strategy Location

Annual Yield. Supply available for permitted use was determined from the 2014 Arkansas State Plan.[15] The Red River has an "excess" supply available of 1,220,000 AF, with 378,000 AF originating in the Little River just above Millwood Lake. The 378,000 AF is not a firm supply, as the excess calculation in Arkansas is based on the 50th percentile for annual streamflow and would not be available in all years. As of this report, Arkansas is updating their state plan, so these numbers may change.

An assessment was made to determine the approximation of reliable supply. While this will require detailed study, 260,000 AFY of firm yield was assumed. This annual excess flow is available approximately 68 percent of the time and is fully available during years that coincide with the TRWD drought of record.

- Firm yield: 232.1 mgd, or 260,000 AFY.
- Safe yield: 232.1 mgd, or 260,000 AFY.

Cost: Capital and O&M costs were estimated using the IWSP Costing Tool. The purchase price of water was assumed at $0.20/kgal. The path of the pipeline from just north of Lake Millwood in Arkansas to Lake Bridgeport in Texas was assumed to follow the same route as the Marvin Nichols transmission system. To be conservative, the cost of an OCR was added to firm up run-of-river supplies.

[15] Arkansas Natural Resources Commission. 2014. Water Availability Report. Appendix C of the Arkansas State Water Plan Update. Table 3-2. agriculture.arkansas.gov/wp-content/uploads/App-C_Water-Availability-Report_Final_11.24.14-1.pdf

The delivery location for TRWD is Lake Bridgeport. Costs include reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

- Total Strategy Cost: $10,239.8 million.
- External Development Cost: $10,104.8 million.
- Intrasystem Transmission Cost: $135.0 million for Eagle Mountain connection reversal.
- Purchase Cost of Water: $0.20 $/kgal or $65 $/AF.

Key Infrastructure:

- **Pipelines:** Two parallel 102-inch pipelines at 248 miles each.
- **Pump Stations:** Two intake pump stations at 174 mgd each, and six booster pump stations.
- **Transmission and Facility Footprint:** 2,778 acres of land acquisition.
- **Other:** Reversal of the Eagle Mountain connection so supply can be conveyed to Benbrook Lake.

Phasing Potential. Arkansas Water could be phased, although there are some efficiencies in building out the full-size pipeline initially. Sizing pumps for the volume needed initially makes sense, and these could be changed out as pumping needs increase.

Implementation Time. The Arkansas Water concept will require significant planning, permitting, and construction time. There is no existing precedent for out-of-state water transfers, and to be conservative, lengthy negotiations are possible at a state-to-state level and possibly at a federal level. Local opposition to the transfer, plus environmental opposition is possible. A timeline of 25 years is assumed, with 10 years for planning, including acquisition of almost 2,800 acres of land; 5 years for permitting; and 10 years for design and construction of the nearly 500 miles of pipelines and 10 pump stations.

Strategy Qualitative Scores. Arkansas Water has high permit uncertainty considering the out-of-state transfer, complex operations, and minimal benefits outside of water supply. The strategy scores relatively low in system risk given the river flow susceptibility to contamination, wildfires, and reductions in supply during drought. Collaboration potential is high. TRWD could implement this alone or with partnerships. The project has medium phasing potential, as two pipelines could be constructed during different phases. Arkansas water has a medium public acceptance score assuming support of the Texas legislature offset by potential environmental and local opposition. Qualitative scores are shown in Table 6.20.

Table 6.20 Arkansas Water Strategy Qualitative Scores

Category	Score	Description
System Risk	2	Reliance on surface water which can be impacted by wildfires; run-of-river supply reliability without an OCR; river flow susceptible to contamination.
Permit Uncertainty and Complexity	1	Although the state has outlined procedures, no precedent for out-of-state water transfers.
Collaboration Potential	5	Partnership not required.
Operational Simplicity	1	Infrastructure and operations stretch 250 miles beyond TRWD's existing system.
Phasing Potential	3	Could phase two pipelines.
Public Acceptance	3	Requires ROW acquisition for pipeline; environmental opposition possible; strong local Arkansas opposition possible; Texas legislative support for out-of-state supplies.
Multi-Benefit Project	1	Not considered to have project benefits beyond water supply.

6.10 Intrasystem Transmission

Two large transmission projects are included as strategies in the IWSP update. Although they do not create a new water supply or have an associated yield, they are needed for water sources to be distributed between storage locations, or from storage locations to customer use points. As TRWD water demands increase in the coming decades, the capacity of the IPL could be exceeded, depending on the portfolio of supplies compiled. Hence, a new Parallel Integrated Pipeline (IPL2) was costed, as well as a Parallel Eagle Mountain Connection (EM2).

6.10.1 Parallel IPL

TRWD and DWU partnered to build the IPL, which transports water from East Texas reservoirs (Palestine, Cedar Creek, and Richland-Chambers) to metroplex reservoirs (Benbrook and Joe Pool and onto other places within each entity's system). DWU solely owns segments 19-1 and 19-2 from Palestine to Cedar Creek. TRWD solely owns segment 16 from Richland-Chambers to Joint Booster Pump Station 2 (JB2).

The IPL2 would run parallel to the IPL, as TRWD purchased a large enough ROW for two pipelines. The IPL2 is shown in Figure 6.22.

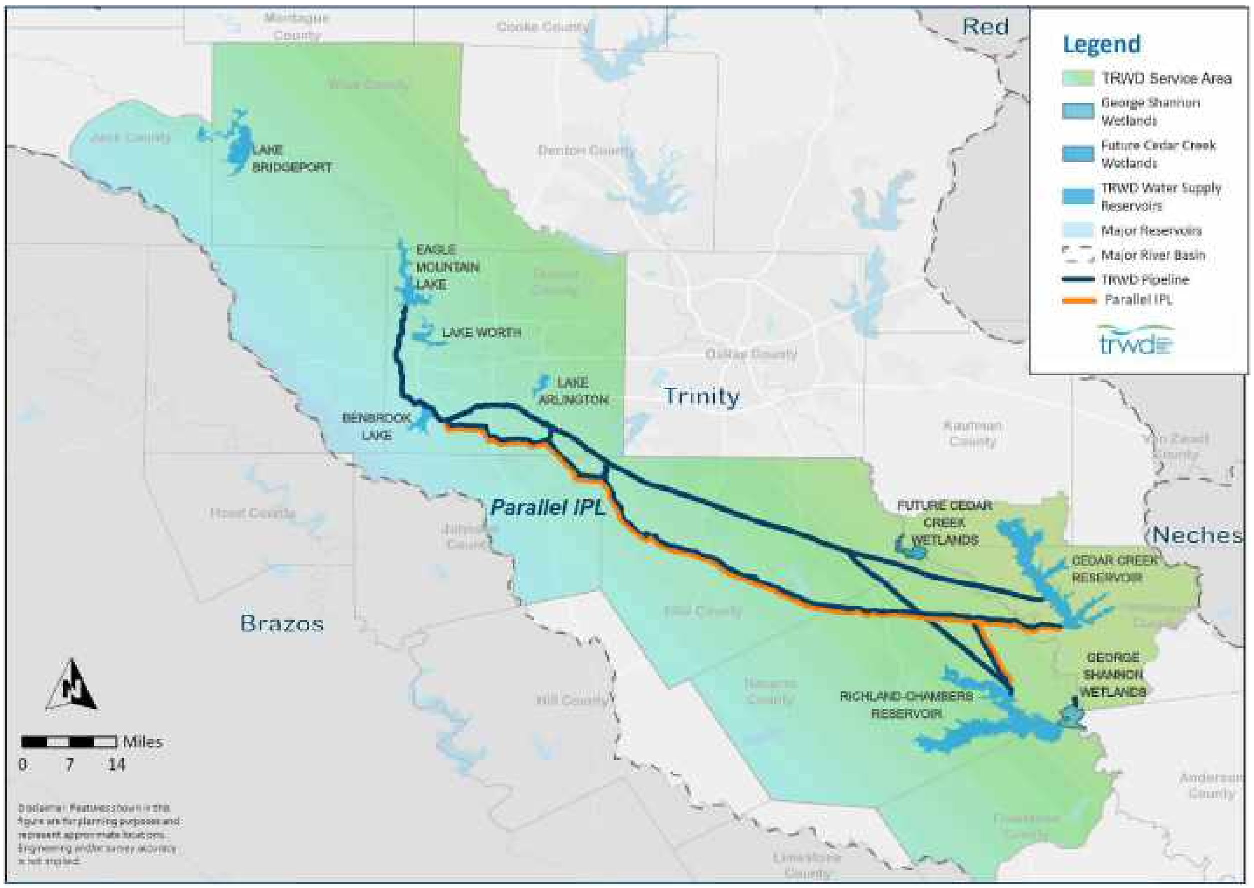


Figure 6.22 Parallel IPL Sections

Cost. The capacity and infrastructure of the IPL2 was assumed to generally match the existing IPL capacities, and a prorated percentage of the cost was assigned to each strategy cost based on the volume of the capacity it takes up within the IPL2. The IPL2 is assumed to be fully owned and developed by TRWD (not shared with DWU or others), and segments 19-1 and 19-2 from Palestine to Cedar Creek are not considered part of IPL2. TRWD already owns the ROW for IPL2, so no ROW costs are included except for land acquisition for intake pump stations. Power connection costs are included, as well as costs for new balancing reservoirs: one new 475-million-gallon (MG) Kennedale Balancing Reservoir and a new 450-MG Midlothian Balancing Reservoir.

- Total Strategy Cost: $3,424.3 million.

Key Infrastructure: Figure 6.22 depicts the infrastructure layout for the IPL, which will be the same alignment used for the IPL2.

- **Pipelines:** Richland Chambers to JB2, 14 miles of 96-inch; Cedar Creek to JB2, 13 miles of 108-inch; JB2 to Benbrook, 90 miles of 108-inch. Pipeline capacity is 350 mgd. Peaking factors of 1.5 or greater were used for pipeline sizing.
- **Pump Stations:** Two new 275 mgd intake pump stations at Cedar Creek and Richland-Chambers Reservoirs, three 350 mgd joint booster pump stations (JB2, JB3, and JB4).
- **Balancing Reservoirs:** New Kennedale Balancing Reservoir with 475 MG capacity, and new Midlothian Balancing Reservoir with 450 MG capacity.

Phasing Potential. Phasing is likely to be useful in implementing the IPL2 project as supply is needed in the north and west of the system.

Implementation Time. The implementation timing of the IPL2 is assumed to closely follow the timeline of the original IPL project, with 4 years for planning, 8 years for permitting (including land acquisition), and 6 years for construction.

6.10.2 Parallel Eagle Mountain Connection

The IWSP Update includes the IPL2 project to bring supplies from East Texas reservoirs to metroplex reservoirs (Benbrook Lake and Joe Pool). Depending on the combination of strategies and their assumed endpoint, TRWD may have further need to transport the supplies from Benbrook Lake to Eagle Mountain Lake. This anticipated need would require the EM2 strategy. Costs of EM2 are not assigned to each individual water management strategy but may be needed at the portfolio level (combination of strategies) if the capacity of the existing Benbrook to Eagle Mountain Connection pipeline is not adequate. The strategy adds capital cost but also flexibility and reliability within a portfolio. Figure 6.23 shows the alignment of EM2, parallel to the existing Eagle Mountain Connection.

Figure 6.23 Parallel Eagle Mountain Connection Pipeline and Benbrook Booster Pump Station Location

Cost. The cost of the EM2 includes a pipeline from Rolling Hills PS to a new Benbrook Booster Pump Station (BB2), and from BB2 to the Eagle Mountain Outlet. The capacity of EM2 is assumed to be 350 mgd. The existing Eagle Mountain Balancing Reservoir is currently being expanded, and it is assumed that the new capacity will be sufficient for use by the existing EM connection and EM2. TRWD already owns the ROW for a second EM connection, so no ROW costs are included except for land acquisition for the new BB2.

- Total Strategy Cost: $645.2 million.

Key Infrastructure:

- **Pipelines:** 22 miles of 96-inch pipeline with a capacity of 350 mgd. Peaking factors of 1.5 or greater were used for pipeline sizing.
- **Pump Stations:** One new 350 mgd booster pump station, BB2 is included.

Phasing Potential. Phasing is not likely for the EM2 strategy.

Implementation Time. The implementation timeline for the EM2 strategy is assumed to closely follow the timeline of the original IPL project, with about 4 years for planning, 8 years for permitting (including land acquisition), and 6 years for construction.

6.11 Implementation Schedules

The implementation timing for each strategy is summarized visually in Table 6.21. In general, timeline assumptions are based on similar projects that have already been implemented nearby or using typical permit process approval timelines.

Table 6.21 Strategy Implementation Time Visualization

Strategy Name	Years	Planning	Permitting	Design and Construction
Conservation	1	Ongoing		
DPR	18	5	5	8
Second Richland-Chambers Wetlands	20	6	5	9
Cedar Creek/Richland-Chambers Unpermitted Firm Yield	3	1	2	
Bridgeport Reallocation	3	1	2	
ASR	11	3	4	4
TRWD Groundwater	10	3	4	3
Lake Palestine Groundwater	6	3	3	
Anderson County Groundwater	10	3	4	3
Lake Palestine Purchase	9	3	6	
Toledo Bend	18	3	5	10
Wright Patman Reallocation	22	6	11	5
Marvin Nichols	30	5	15	10
Marvin Nichols with Wright Patman	30	5	15	10
Lake Ringgold	25	4	14	7
Tehuacana	25	4	15	6
Mainstem Trinity OCR	20	5	9	6
Arkansas Water	25	10	5	10
Second IPL	18	4	8	6
Parallel Eagle Mountain Connection	18	4	8	6

Legend

Planning   Permitting   Design and Construction

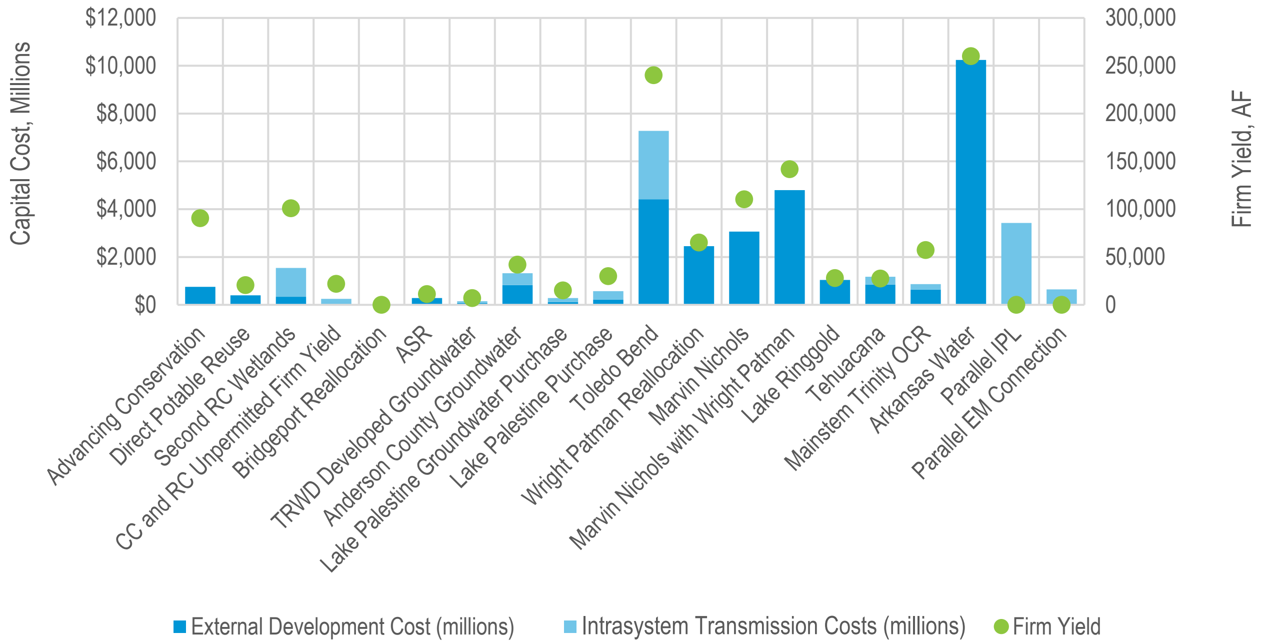
6.12 Strategy Comparison

Table 6.22 summarizes key strategy metrics and costs. The capital investment costs and fixed costs do not include the Parallel IPL costs for those strategies that would require it because, when looked at collectively, the costs would not be additive. The unit costs and variable costs; however, include the proportion of the Parallel IPL as these are yield-based calculations. Capital costs are compared in Figure 6.24 and unit costs in Figure 6.25.

Table 6.22 Summary of Water Management Strategies and Infrastructure

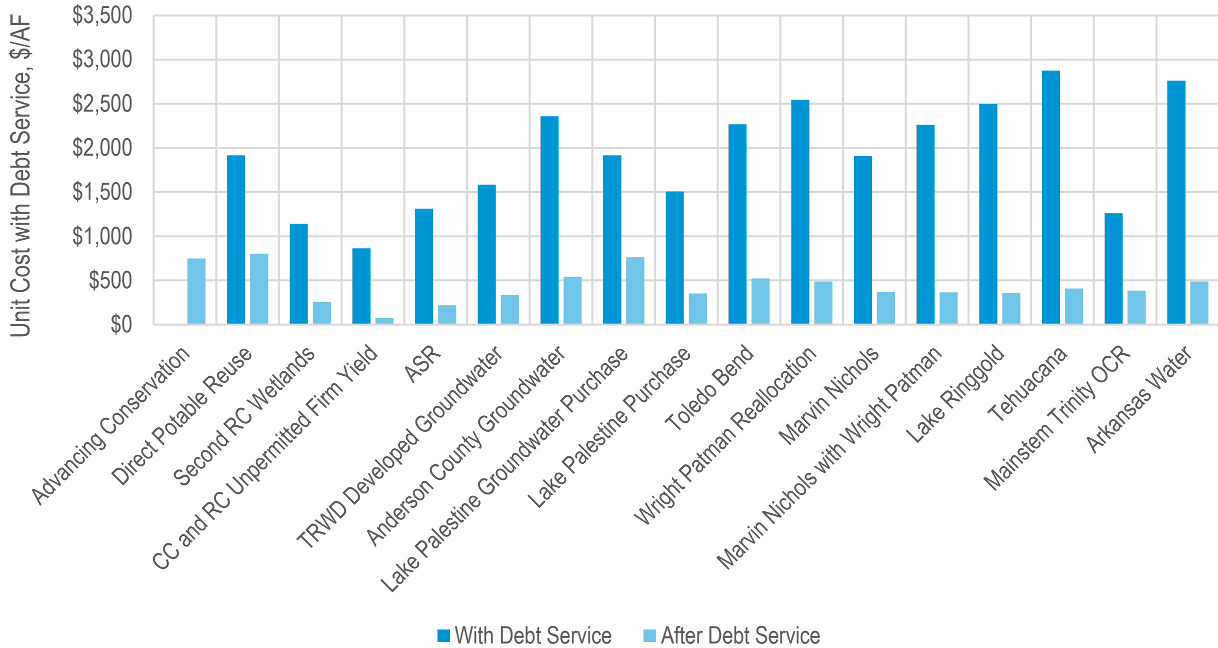
Strategy Type	No.	Strategy Name	Requires IPL2 for Intrasystem Conveyance and Additional Capital Investment(1)	Capital Investment and Fixed Costs(2)						Variable and Unit Costs(3)					
				Total Cost of Facilities(2)	Non-Construction Capital Cost(2,5)	Total Cost of Project(2)	Annual Debt Service(2)	O&M Fixed(2)	Available Project Yield	O&M Variable Pumping Energy Needs(3)	Energy to Pump Project Yield(3)	O&M Variable Purchase Cost of Water	Unit Cost with Debt Service(3)	Unit Cost after Debt Service(3)	Unit Cost, 50-year Average(3)
				Sept 2023$	Sept 2023$	Sept 2023$	Sept 2023$	Sept 2023$	AFY	KWH/Kgal	KWh	$/KGal	$/AF	$/AF	$/AF
Conservation	1	Advancing Conservation(4)	No	0	0	0	0	$14,708,230	90,500	0.00	0	$0.00	$0	$750	$750
Reuse	2	DPR	No	$290,887,000	$103,671,000	$394,558,000	$22,802,000	$16,237,000	20,500	0.63	4,216,491	$0.00	$1,917	$804	$1,472
	3	Second Richland-Chambers Wetlands	**Yes**	$229,212,000	$108,036,000	$337,248,000	$19,503,000	$4,522,000	100,890	4.28	140,700,000	$0.00	$1,143	$254	$788
Operational Change	5	Cedar Creek and Richland-Chambers Unpermitted Firm Yield	**Yes**	$0	$0	$250,000	$0	$0	21,920	4.22	30,150,901	$0.00	$864	$76	$548
	6	Bridgeport Reallocation	No	$0	$0	$250,000	$0	$0	0	0.00	0	$0.00	$0	$0	$0
Groundwater	7	ASR	No	$211,136,000	$74,397,000	$285,533,000	$12,265,000	$2,110,000	11,209	1.55	5,650,000	$0.00	$1,313	$218	$875
	8	TRWD Developed Groundwater	**Yes**	$49,602,000	$18,293,000	$67,895,000	$3,920,000	$779,000	7,000	4.70	10,716,667	$0.00	$1,585	$337	$1,086
	9	Lake Palestine Groundwater Purchase	**Yes**	$93,305,000	$13,995,000	$107,300,000	$7,056,000	$1,148,000	15,000	3.98	19,457,394	$1.46	$1,917	$762	$1,455
	10	Anderson County Groundwater	**Yes**	$614,260,000	$209,179,000	$823,439,000	$47,556,000	$8,068,000	42,000	7.78	106,450,000	$0.20	$2,359	$542	$1,632
Existing Reservoir	11	Lake Palestine Purchase	**Yes**	$186,624,000	$27,993,000	$214,617,000	$14,113,000	$2,295,000	30,000	3.98	38,914,788	$0.20	$1,507	$352	$1,045
	12	Toledo Bend	**Yes**	$3,353,030,000	$1,065,410,500	$4,418,440,500	$254,581,000	$43,214,000	240,000	7.38	577,408,333	$0.20	$2,268	$522	$1,570
	14	Wright Patman Reallocation	No	$1,770,533,000	$685,476,000	$2,456,009,000	$133,806,000	$23,163,000	65,067	5.18	109,882,500	$0.00	$2,545	$488	$1,722
Proposed Reservoir	15	Marvin Nichols	No	$2,403,333,000	$659,132,000	$3,062,465,000	$169,273,000	$27,943,000	110,237	6.00	215,666,667	$0.00	$1,907	$371	$1,293
	16	Marvin Nichols with Wright Patman	No	$3,152,317,000	$1,643,604,000	$4,795,921,000	$268,926,000	$38,354,000	141,800	4.86	224,345,516	$0.00	$2,262	$365	$1,503
	17	Lake Ringgold	No	$656,460,000	$381,305,000	$1,037,765,000	$59,953,000	$8,929,000	28,000	1.88	17,150,000	$0.00	$2,497	$356	$1,640
	18	Tehuacana	**Yes**	$371,592,000	$474,631,000	$846,223,000	$48,938,000	$5,448,000	27,514	3.95	35,400,000	$0.00	$2,875	$409	$1,889
	19	Mainstem Trinity OCR	**Yes**	$464,760,000	$176,303,000	$641,063,000	$37,038,000	$7,094,000	57,169	7.83	145,833,333	$0.20	$1,260	$385	$910
Transfer	20	Arkansas Water	No	$7,806,687,000	$2,433,154,000	$10,239,841,000	$591,007,000	$90,218,000	260,000	3.90	330,166,667	$0.20	$2,761	$488	$1,852
Transmission	21	Parallel IPL (IPL2)	N/A	$2,587,391,000	$836,875,000	$3,424,266,000	$196,758,000	$38,961,000	0	N/A	N/A	N/A	$984	$231	$683
	22	Parallel EM Connection	N/A	$488,770,000	$156,398,000	$645,168,000	$36,958,000	$7,487,000	0	N/A	N/A	N/A	$193	$52	$136

Notes:
Values in constant September 2023 dollars to align with Region C Planning.
(1) Indicates whether the IPL2 could be needed to move the strategy supply to where it is needed.
(2) If the IPL2 is required and indicated as **"Yes"**, the cost of Strategy number 21, Parallel IPL, should be added to understand the full investment cost associated with the strategy. The cost was not added in this portion of the table to allow for straightforward calculations of total investment if multiple strategies requiring the IPL2 are explored.
(3) For the per unit calculations, includes the proportional cost of intrasystem transmission for the IPL2 for comparative analysis.
(4) 2080 yield reaches 114,000 AF during a critical dry year.
(5) Non-Construction Capital Costs include: Planning, Design, Engineering, Permitting, Environmental, Land, and Contingency.



Note: Values in constant September 2023 dollars to align with Region C Planning.

Figure 6.24 Strategy Capital Cost Comparison



Note: Excludes BP Reallocation, IPL2, and EM2 because those strategies have no associated yield. Values in constant September 2023 dollars to align with Region C Planning.

Figure 6.25 Strategy Unit Costs Comparison

6.13 Other Strategies Considered

Regional Optimization. Water sharing through regional partnerships could improve resilience across North Texas, where supplies from areas with temporary excess can be conveyed to areas of need, or geographic connections to improve resilience and efficiency are constructed. This strategy includes looking at the operations of Dallas, NTMWD, and TRWD to determine what benefit there is to water trading, interconnects, and redistribution. There are likely to be institutional barriers to solutions that include full integration of systems if that were to be explored. Additional partnering opportunities are possible, including with TRA, Fort Worth, and others to facilitate mutual benefits, especially when it comes to reuse and downstream requirements. This strategy was not evaluated because it was conceptual at the time and not quantifiable. TRWD, DWU, and NTMWD are currently studying opportunities for regional optimization.

One Water Concept. The One Water Concept is under consideration in many regions of the U.S. and refers to holistic, integrated water resource planning. The Water Research Foundation's Self-Assessment Framework for One Water Cities (4969) defines One Water as, *"a collaborative planning and implementation approach that fosters integrated and equitable management of water resources for long-term resilience and reliability, meeting both community and ecosystem needs."*[16]

In many ways TRWD has practiced One Water for decades, viewing return flows as valuable water resources, creating ecosystem health and recreation opportunities, and managing the system for times of stormwater excess. This approach would further TRWD's efforts and could include an enhanced stakeholder engagement platform. As a step further, TRWD could expand its offerings for holistic service, for example, by implementing a One Water approach in growing areas where TRWD could be involved in management of water at all points in the water cycle across the region. From a practical perspective, this idea expands to include the additional services of wastewater treatment and direct reuse and stormwater collection.

One Water did not carry forth in the form of a strategy, but it did become a theme around which certain strategies are organized. TRWD should consider how an elevated One Water framework and vision would look from a management and organizational perspective and could study this in the future.

Brackish Groundwater. Water that is slightly to moderately saline is referred to as brackish groundwater. Significant quantities of brackish groundwater are present in the aquifers underlying parts of TRWD's service area. Pumping and treating brackish groundwater reduces the use of freshwater. Brackish groundwater pumping and treatment is energy intensive and generally has higher operational costs. Desalination is required, which is the process of removing dissolved solids and other minerals.

As of 2024, there were 43 desalination facilities in Texas that treat brackish groundwater, most of which are along or west of the Brazos River.[17] Data are still somewhat limited regarding the true potential for brackish groundwater production, as the depth, quantity, and salinity levels need to be known with reasonable precision to quantify the yield potential and costs. Per an impaired groundwater study conducted by TRWD in 2016, which encompassed Anderson, Freestone, Henderson, and Navarro counties, approximately 38,000 AFY of brackish groundwater could be developed.[18] Per a 2019 TWDB report, the Northern Trinity Aquifer in the Glen Rose hydrostratigraphic unit, which falls partly in Ellis and Navaro counties, has significant amounts of moderately saline groundwater (about 64 million AF), but the

[16] See Advances in Water Research - Issue Library.
[17] The Future of Desalination in Texas 2024 Biennial Report on Seawater and Brackish Groundwater Desalination in Texas.
[18] *TRWD and Wichita Falls. 2016. Study of Impaired Groundwater Availability and Quality. Prepared by Intera and Freese and Nichols.*

depth to water is over 1,000 feet.[19] This strategy was not evaluated in detail as a part of the IWSP Update because other strategies with lower unit costs were selected. As more study and monitoring occurs, or as technology advances to make this a cost-effective strategy, TRWD should continue to consider the development of brackish groundwater supplies.

Other Sulphur River Basin Supplies. Several other potential new reservoirs are located within the Sulphur River Basin, including Lake Ralph Hall, Parkhouse I, and/or Parkhouse II. Lake Ralph Hall, sponsored by UTRWD, is currently under construction on the North Fork of the Sulphur River. UTRWD has a water right to divert 45,000 AFY. TRWD could collaborate with UTRWD to receive flows from the project or return flows, but the likelihood that UTRWD does not have the need to fully utilize the supply is low.

The George Parkhouse Lake I is a new reservoir strategy located on the Sulphur River downstream from Jim Chapman Lake and has an estimated yield of 114,960 AFY, though the yield depends on whether other downstream projects are permitted. Yield reductions from downstream projects may decrease yields by as much as 60 percent.[20] The lake would inundate approximately 28,900 acres, and over 50 percent of the land impacted would be bottomland hardwood forest or marsh. The project would require significant mitigation. Project costs listed in the 2026 Region C Water Plan are $1.9 to $2 billion. It is currently considered a potential strategy for NTMWD and UTRWD.[20] Given the extent of mitigation and risk around yield, this strategy was not evaluated in detail.

The George Parkhouse Lake II is a new reservoir strategy located on the North Sulphur River 15 miles southeast of the City of Paris and has an estimated yield of 94,460 AFY, though the yield depends on whether other downstream projects are permitted. Yield reductions from downstream projects may decrease yields by as much as 70 percent.[20] The lake would inundate approximately 14,400 acres, of which about 20 percent is bottomland hardwood forest or marsh. The project cost listed in the 2026 Region C Water Plan is $1.8 billion. It is currently considered a potential strategy for NTMWD and UTRWD.[20] Given the extent of mitigation and risk around yield, this strategy was not evaluated in detail.

Other Reservoirs and Alignments. TRWD considered Lake Columbia, Lake O' The Pines, a larger Toledo Bend option, and a transfer from Lake Granbury. Each were evaluated at a varying level of detail but were not carried forward into the IWSP Update.

Lake Granbury is owned and operated by the Brazos River Authority who indicated there was no supply available for transfer, so this strategy was not further considered.

Lake Columbia is a proposed new reservoir on Mud Creek in the Neches River Basin, currently sponsored by Angelina and Neches River Authority (ANRA), which received a water right permit to divert 85,507 AFY for municipal and industrial purposes. DWU is planning to assist in developing the project and contract for approximately 56,000 AFY of supplies from ANRA.[20] Lack of activity and funds from ANRA, USACE 404 permitting, and competing with DWU are all reasons the strategy was not carried forward for this IWSP. DWU's 2014 LRWSP notes, *"A pipeline to convey only Lake Columbia is assumed to be cost prohibitive."* Further, the strategy is recommended for implementation after 2080 in the 2026 Initially Prepared Region C Water Plan. TRWD could participate in the project instead of DWU; however, infrastructure costs would need to be further evaluated for this option. Given the lack of certainty around the project, it was not carried forth for evaluation.

Lake O' The Pines is owned and operated by USACE and was constructed in 1955 as part of the flood control plan for the Red River Basin below Denison Dam in Oklahoma. The lake provides storage for the Northeast Texas Municipal Water District, which serves the cities of Jefferson, Ore City, Lone Star,

---

[19] TWDB. 2019. Identification of Potential Brackish Groundwater Production Areas – Northern Trinity Aquifer. Prepared by Intera.
[20] See https://regioncwater.org/wp-content/uploads/2025/03/2026_Region_C_Initially_Prepared_Plan_Volume_I.pdf

Avinger, Hughes Springs, Daingerfield, and, most recently, Longview. The 2026 Region C Plan recommended NTMWD purchase excess supply from Lake O' The Pines. As of mid-April 2025, NTMWD has not yet negotiated the sale or lease of Lake O' The Pines water from NETWMD but is interested in doing so. Given this strategy is considered for NTMWD, and that regional partnerships with NTMWD are possible, Lake O' Pines as a strategy for TRWD was not further considered.

A larger Toledo Bend strategy was considered that conveyed the full 480,000 AF of supply from Toledo Bend, rather than with a partner. As the water supply gap can be supplied with more cost-efficient solutions, where Toledo Bend makes up only a portion of the future portfolio, this strategy was not further evaluated. Many configurations of the Toledo Bend strategy, with various numbers of partnerships and scaled supply are possible.

Reservoir and Watershed Management. TRWD considered several reservoir and watershed management options, including sedimentation management through enhanced watershed programs, reservoir dredging, and evaporative loss reduction. While these strategies may be worth pursuing in the future, each were eliminated for further evaluation as major sources of additional water supply.

Sedimentation management is a current program at TRWD. The program could be expanded to provide additional emphasis on sedimentation control for the purpose of preserving supply capacity in reservoirs. This could be achieved through landowner incentive programs, channel stabilization, upstream trapping, wetland development, or pass through, for example. Given the lower, uncertain yield, this strategy was not further evaluated.

Reservoir dredging to reclaim reservoir capacity and supply yield is an alternative often considered by suppliers with large reservoirs. Cost is highly variable and largely impacted by the type of dredging, disposal options, and sediment quality. The 2026 Region C Water Plan considers the idea by analyzing costs and water supply benefits of dredging four lakes in the greater Metroplex area and found the amount of reliable supply gained through dredging ranged from 1,700 to 3,360 AFY from the lakes evaluated. Costs were estimated at $134 per 1,000 gallons of supply, which would not be economically viable compared to other strategy costs per AF.

A significant amount of water is evaporated each day in North Texas from reservoir surfaces. Evaporative loss reduction measures could be pursued. Emerging strategies include biofilm, plastic balls, or floating solar panels, although many are not acceptable by the community. TRWD may opt to further study this potential at balancing reservoirs.

Lower Trinity Negotiations. In the early 2000s, the "Big 5" water suppliers (TRA, TRWD, Houston, Dallas, and NTMWD) in the Trinity River Basin entered into formal and informal agreements around the reuse of supplies and the respective impacts of Lake Livingston (Lake Livingston agreement is described in Chapter 3.2.6). In practice and as a result, TRWD agreed to reuse only 70 percent of return flows, less carriage loss, of TRWD's return flows. The "70/30" agreement is reflected in TRWD's reuse amendments for Cedar Creek and Richland-Chambers Reservoirs. Even small changes in the agreement could yield worthwhile supply for TRWD.

Under this strategy, TRWD could support the funding of alternative water supplies in the lower Trinity in exchange for access to the 30 percent return flows that are currently released to the lower basin. This strategy would yield a reuse supply and would need to be paired with other strategies such a wetland. This may be a worthwhile concept to pursue, but it was not carried forth due to uncertainties in outcome.

Denton Partnerships. A partnership with Denton could involve purchasing or leasing excess supply from Lake Ray Roberts, Denton's primary source of water supply. This strategy was not evaluated but could provide partnership opportunities in the future.

Out of State. As described in Chapter 6.9, TRWD options in Oklahoma are not viable at this time due to the Oklahoma Legislature moratorium on out-of-state sales. If this were to change, TRWD options include a diversion from the Kiamichi River to off channel storage and then conveyance to Lake Bridgeport. Also, Cable Mountain Lake, or Navajo Reservoir, is a proposed new reservoir in Oklahoma on the border of Jackson and Kiowa Counties. While extensive treatment or implementation of chloride controls is needed to be viable for supply, this could be an option.

When assessing the Arkansas Water transfer potential, other supplies were considered such as purchasing from a Millwood Lake permit holder or obtaining a water supply contract from one or more of the Tri Lakes (Gillham, DeQeeen, Dierks). There is about 70,000 AF of uncommitted supply in the Tri Lakes.[21] These strategies could be pursued parallel to the Arkansas Water strategy.

OCRs. Two additional OCRs were considered. The Red River OCR project is a proposed water supply strategy DWU has been evaluating to divert Texas's share of Red River flows downstream of Lake Texoma for storage and use. The project features an intake and pump station near Arthur City, Texas, which would convey water approximately two miles to a system of three OCRs designed for sediment removal, water quality improvement, and extended storage. These reservoirs, totaling 803 acres and 39,800 AF of capacity, would supply up to 114,000 AF annually, with water ultimately conveyed to Lake Ray Roberts for use by DWU. While the project offers a significant new water supply, challenges include riverbank stability, water quality, sediment control, invasive species, permitting, and potential upstream development, particularly in Oklahoma's Blue and Muddy Boggy River watersheds. TRWD did not pursue evaluation of the strategy at this time but could consider it as a regional partnership.

Through the IWSP Update, constructing an OCR on the soon-to-be retired mining ground immediately north of the future Cedar Creek Wetlands was evaluated. The OCR would store flow during periods of excess streamflow and/or reuse water to be used during periods of low streamflow. The OCR would have an estimated surface area of 7,512 acres. After evaluation of the sizing potential, the ability for Cedar Creek Reservoir to assimilate the return flows was determined to be a limiting factor. Should conditions change, or more modeling or treatment opportunities reveal a configuration that is beneficial, TRWD could reconsider this strategy.

[21] Per personal communication with USACE staff from the Little Rock office.

CHAPTER 7 WATER SUPPLY PORTFOLIOS

A portfolio represents combinations of strategies designed to meet TRWD's water supply objectives. Evaluation and compilation of portfolios is a core component of the IWSP Update. Given the significant future water supply needs and the geographic span of TRWD's system, and with the inherent uncertainty in several of the larger supply volume strategies, there are numerous portfolios that could be possible, each with unique risk, cost, and yield profiles. While Chapter 8 explores this uncertainty and risk through an adaptive planning lens, Chapter 7 presents five portfolios selected for evaluation compiled from the potential water supply strategies presented in Chapter 6. The process of arriving at these portfolios is described, as well as the key metrics and calculations for portfolios. Each portfolio is described in detail with information on yield, supply utilization, cost, and resulting reliability. Comparison of key metrics for the selected portfolios is provided as well. Scores from the MCDA framework are presented in Chapter 7.5.

While the reliability metrics are useful for a planning level study, the metrics should not be considered indicative of future conditions. The reliability of TRWD's system, both in a simulated environment and reality, is optimized with detailed study to meet individual and total customer demands.

7.1 Overview of Evaluation Metrics

With the detailed and nuanced analysis framework, an array of metrics are generated and available for presentation. The following key metrics were selected and are provided for each selected portfolio. The metrics are defined for reference when reviewing portfolio results.

7.1.1 Strategy Yield and Utilization

TRWD's RiverWare model serves as the simulation engine for evaluating portfolio performance in terms of reliability and supply additions. Most of the strategies are input into RiverWare with the firm yield as the available supply. The exception is Advancing Conservation, which reduces the demands at each planning node for each hydrologic trace. Infrastructure is sized to convey the firm yield with a 1.5 peaking factor and is included in the portfolio evaluations. In addition to the firm yield, RiverWare calculates the amount of supply utilized in a portfolio. Intuitively, this can vary from decade to decade, given the growth in demand. However, the supply utilization also varies by hydrologic year. In traces with wetter hydrologic conditions, less supply is needed from strategies. In traces with extreme dry hydrologic conditions (i.e., the drought of record), more supply is needed from strategies. In portfolio summaries, metrics are provided for both the supply utilized during a critical dry year and the firm and safe yield of the portfolio.

For a higher-level comparison, total portfolio supply utilization is calculated. This metric includes strategy supplies only. The calculation includes the average supply utilization (averaged across 82 years of hydrologic inflow), interpolated between decades, and summed for the entire 50-year period of analysis.

7.1.2 Reliability Metrics

From the RiverWare outputs, reliability metrics are calculated for both system and individual customer delivery performance. These statistics are available for single hydrologic years, and for the full sequence of inflows, which allows for numerous views into a portfolio's performance. Note that TRWD's Drought Contingency Plan is not activated during the simulations, so the goal is to meet at least 95 percent of 1956 demands without curtailment. The selected criteria from the array of outputs to characterize portfolio reliability are defined in Table 7.1.

Table 7.1 Reliability Metric Definitions

Metric	Description
1956 Remaining Gap Magnitude in AF	This unmet system demand during the critical year of the drought of record (1956) expressed as a volume. This is the remaining gap without enactment of TRWD's Drought Contingency Plan.
1956 Percent of Demands Met	This unmet system demand during the critical year of the drought of record (1956) expressed as a percentage of demands without curtailment. This is the reliability achievable without enactment of TRWD's Drought Contingency Plan.
Percent of Hydrologic Years with Gap	Across the 82 hydrologic years, the percent of years with a remaining water supply gap. Due to the complexity of TRWD's RiverWare model and operational rules, a threshold of 5 percent was set, where months with a gap of less than 5 percent was assumed to be model within the range of model error. The 5 percent threshold was selected based on review of the initial modelling results and engineering judgement. No years had gaps that exceeded 10% of system demand.
Maximum Annual Gap in AF	For each planning decade, the highest system gap in terms of volume for any hydrologic year. In all instances, the gap and hydrologic year is 1980, which varies from the 1956 critical year of the drought of record. Study of this modeled gap showed that it was a result of operational rules that could be further studied and optimized as the system changes and demand increase. While the 1980 maximum annual gap is reflective of the complexity of TRWD's operation rules, which are generally established around meeting demands during the drought of record for the existing system, the metric is useful and was included for a portfolio.

7.1.3 Cost Metrics

Carollo's Blue Plan-it integrated information for each portfolio to generate cost metrics for portfolios. Specific metrics are calculated to reflect both constant 2023 dollars and the net present value (NPV) of future dollars.

Presenting results in constant 2023 dollars provides a comparative portfolio investment if all strategies within the portfolio are constructed today. Further, constant 2023 dollars is the financial unit expressed in the 2026 Region C Initially Prepared Plan and provides an equivalent comparison.

Presenting costs in NPV demonstrates the difference between the present value of cash inflows and the present value of cash outflows over the 50-year period. This financial metric is commonly used to assess the true economic cost of an investment and reflects the money savings that result from delaying large investments. To calculate the NPV, an inflation rate of 4 percent and discount rate of 5 percent were assumed. Further, the cost of energy was escalated separately using the assumption of a net increase from the current rate of $0.06/kWh to a rate of $0.08/kWh by 2060.

Planning-level cost metrics are intended for conceptual evaluation and comparison only. The actual costs are subject to change as strategy and portfolio scope, design, and market conditions evolve.

Definitions for cost metrics presented for portfolios are included in Table 7.2. The metrics include a range of calculations for capital costs, O&M, and costs expressed on a per unit of supply basis.

Table 7.2 Cost Metric Definitions

Metric	Description
Total Capital Costs (2023$)	The sum of all capital investments in the portfolio expressed in constant September 2023 dollars. Capital costs include the cost to construct facilities plus 3% for preliminary engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Capital costs also include environmental and archaeology studies and mitigation, and land acquisition and surveying.
Debt-Covered Capital (2030-2080)	The sum of annual debt payments to cover capital costs in the portfolio. Costs are escalated and discounted. This metric considers the timing of strategy development and the value in delaying large infrastructure investments. The calculation extends to the 50-year period of analysis only.
Total O&M Costs (2030-2080)	Includes fixed O&M for pipeline, well, intake, pump station, and dam and reservoir maintenance. Variable costs are added including pumping costs and purchase cost of water. The calculation extends to the 50-year period of analysis only and is based on average annual strategy supply utilization. Costs are escalated and discounted. Energy costs are assumed at $0.06/kWh from 2030-2059 and then increase to $0.08/kWh from 2060 to 2080.
Total Portfolio Cost (2030-2080)	The sum of debt payments to cover capital costs in the portfolio plus O&M costs. Costs are escalated and discounted. The calculation considers the timing of strategy development and extends to the 50-year period of analysis only.
Weighted Unit Cost of Supplies (2023$/AF)[1]	The unit cost of supplies expressed in constant September 2023 dollars per AF of firm yield (or equivalent) in the portfolio. For the portfolio, the value is weighted to account for the volume of supplies relative to the total portfolio supply. A second weighting is applied assuming 30 years of unit cost with debt service and 20 years of unit cost after debt service, respectively.
Levelized Cost of Delivered Water ($/kgal)[(1)]	Analyzed at the portfolio scale against the 50-year period of analysis. The calculation captures both portfolio spending, as strategies come online within a portfolio, and portfolio supply utilization. Costs are escalated and discounted. The cost includes the initiated debt, assumed to start the year the strategy comes online, plus fixed and variable O&M. The costs are then divided by the total portfolio supply utilization over the 50-years. These costs do not include existing system costs.

Notes:
(1) While the weighted unit cost of supplies and levelized cost of delivered water both capture a cost per volume of water, the former is considering the supply potential (firm yield) whereas the latter considers how much of that potential supply will be delivered and sold (on average) during the 50-year period.

7.1.4 Other Metrics

Energy costs can represent a large annual operating expense, which continues long after the project debt is paid off. Further, climate and sustainability goals consider the amount of greenhouse gas emissions and look for strategies that meet the same water supply objective with a lower energy footprint. Thus, portfolios are analyzed to determine the amount of energy needed to convey supplies to TRWD's system. For each portfolio, the amount of energy required to pump portfolio water supplies from its source location to where it is needed is calculated. The metric includes average annual pumping for strategies only over 50 years, expressed as MWh.

7.2 Themes and Analysis Process

Multiple iterations of portfolios were generated to explore reliability, system performance, and to balance these against affordability objectives. In all, more than 50 portfolios were simulated. With each iteration, supply timing, infrastructure timing, and variations in certain supplies were tested and adjusted to achieve improved portfolio performance.

Certain strategies were beneficial for all portfolios and were identified as "No Regrets". These strategies include Advancing Conservation, Cedar Creek and Richland-Chambers Unpermitted Firm Yield, and Bridgeport Reallocation.

Initial themes were explored based around goals, types of supplies, or outcomes, such as full reliability, lowest unit costs, or maximizing regional partnership opportunities. However, results indicate that larger supplies are needed to meet objectives, generally defined as strategies that provide 100,000 AFY of supply or more. To simplify the portfolio naming, names were adopted to reflect the larger supply present in each portfolio. One portfolio was maintained that has a mix of many smaller supplies.

7.3 Selected Portfolios

To address the supply gap, some combination of strategies is needed to have new supply sources online and operational ahead of the projected gap. There are many combinations of supply strategies possible, but five supply portfolios were selected based on performance. All portfolios include three common strategies referred to as the No Regrets. One portfolio includes only smaller strategies, and four of the five portfolios include one large supply project that comes online in 2060 and multiple smaller capacity strategies, as presented in Table 7.3 and described below. Each portfolio is described in detail with tables and graphics for key metrics in the sub-sections that follow.

- **Mix of Smaller.** This portfolio is a combination of multiple smaller strategies selected to demonstrate system performance in the absence of a larger supply strategy (other than reuse). The portfolio does not have a significant supply coming from the North. Supplies include Tehuacana and the Second Richland-Chambers Wetlands in the East Texas region of TRWD's service area, and many other smaller supplies spread out across TRWD's service area and just beyond. There is a moderate amount of groundwater included.
- **Toledo Bend.** The large supply in this portfolio is Toledo Bend, coming online in 2060. This portfolio has a large amount of supply, but nearly all supplies are in the East and must be conveyed nearly 175 miles to Cedar Creek Reservoir and then another near 80 miles to the metroplex where the greatest concentration of demands are located.
- **Marvin Nichols.** This portfolio includes construction and conveyance of supply from the proposed Marvin Nichols Reservoir to Lake Bridgeport, conveyed by 192 miles of pipeline. Even with Marvin Nichols, several other strategies are needed to meet reliability metrics, including the Second Richland-Chambers Wetlands, ASR, and the Mainstem Trinity OCR. The portfolio is well balanced geographically, with a new supply coming into Lake Bridgeport from the North, supplies from East Texas (Lake Palestine Purchase), and other smaller supplies spread out across TRWD's service area and just beyond. The Second Richland-Chambers Wetlands are included to capture and utilize the return flows of the new supplies.
- **Marvin Nichols with Wright Patman.** This portfolio includes construction and conveyance of supply from Marvin Nichols with the addition of Wright Patman reallocation, to Lake Bridgeport, conveyed by 240 of miles of pipeline. The portfolio is a larger northern supply, but also includes several other supplies to meet reliability metrics. The Second Richland-Chambers Wetlands are included to capture and utilize the return flows of the new supplies.
- **Arkansas**. This portfolio includes conveyance of supply from Arkansas, just north of Millwood Lake to Lake Bridgeport, conveyed by 250 of miles of pipeline. The Arkansas strategy is the largest single supply analyzed and thus brings the largest supply into the northern portion of TRWD's service area. To meet reliability metrics, two additional supplies are included in 2050 until Arkansas Water is assumed online.

Table 7.3 Summary of Selected Portfolios with Strategies Included and Year Online

Mix of Smaller Portfolio		Toledo Bend Portfolio		Marvin Nichols Portfolio		Marvin Nichols with Wright Patman Portfolio		Arkansas Portfolio	
Strategies	Year Online	Strategies	Year Online	Strategies	Year Online	Strategies	Year Online	Strategies	Year Online
Advancing Conservation	2030	Advancing Conservation	2030	Advancing Conservation	2030	Advancing Conservation	2030	Advancing Conservation	2030
Cedar Creek and Richland-Chambers Unpermitted Firm Yield	2030	Cedar Creek and Richland-Chambers Unpermitted Firm Yield	2030	Cedar Creek and Richland-Chambers Unpermitted Firm Yield	2030	Cedar Creek and Richland-Chambers Unpermitted Firm Yield	2030	Cedar Creek and Richland-Chambers Unpermitted Firm Yield	2030
Bridgeport Reallocation	2030	Bridgeport Reallocation	2030	Bridgeport Reallocation	2030	Bridgeport Reallocation	2030	Bridgeport Reallocation	2030
ASR	2050	Direct Potable Reuse	2050	Lake Palestine Purchase	2030	Lake Palestine Purchase	2050	Lake Palestine Groundwater Purchase	2050
Lake Palestine Purchase	2050	TRWD Developed Groundwater	2050	ASR	2040	Mainstem Trinity OCR	2060	Anderson County Groundwater	2050
TRWD Developed Groundwater	2050	Lake Palestine Purchase	2050	Mainstem Trinity OCR	2040	Marvin Nichols with Wright Patman	2060	Arkansas Water	2060
Parallel EM Connection	2050	Toledo Bend	2060	TRWD Developed Groundwater	2050	Second Richland-Chambers Wetlands	2070		
Second Richland-Chambers Wetlands	2060	Parallel IPL	2060	Marvin Nichols	2060	Parallel IPL	2070		
Mainstem Trinity OCR	2060	Parallel EM Connection	2060	Parallel IPL	2060				
Direct Potable Reuse	2070			Second Richland-Chambers Wetlands	2070				
Anderson County Groundwater	2070								
Tehuacana	2070								
Parallel IPL	2070								

7.3.1 Mix of Smaller Portfolio

The Mix of Smaller Portfolio includes ten strategies with modeled inflow plus Bridgeport Reallocation, as summarized in Table 7.4. The portfolio requires both the Parallel IPL and Parallel EM Connection to convey new supplies to meet demands. If there were to be a repeat of the drought of record, during the critical year of shortages (i.e., 1956 for the drought of record), Advancing Conservation provides 121,000 AF of the needed supply. The Second Richland-Chambers Wetlands provides almost 98,000 AF of inflow into the system by 2080. In total, the portfolio supply utilization grows to nearly 415,000 AF by 2080. With the expansion of the system under this portfolio, new supply utilization when compared to the baseline system reaches 470,000 AF (see Figure 5.1 in Chapter 5), for a total of 1.15 million AF. The total portfolio supply is greater than the total of the supply from individual Strategies because additional reuse is made available by some strategies and because additional conveyance has been added to move both portfolio and existing supplies.

Table 7.4 Supply Utilized During Critical Dry Year for the Mix of Smaller Portfolio in AFY

Strategies	2030	2040	2050	2060	2070	2080
Advancing Conservation(1)	1,130	15,000	33,420	57,560	88,510	121,000
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)(2)	0	6,930	4,370	0	3,390	10,310
ASR(3)	0	0	9,880	9,880	7,940	0
Lake Palestine Purchase	0	0	30,000	30,000	30,000	30,000
TRWD Developed Groundwater	0	0	7,000	7,000	7,000	7,000
Second Richland-Chambers Wetlands	0	0	0	91,280	93,550	97,530
Mainstem Trinity OCR	0	0	0	57,170	57,170	57,170
Direct Potable Reuse	0	0	0	0	20,930	20,930
Anderson County Groundwater	0	0	0	0	42,000	42,000
Tehuacana	0	0	0	0	27,510	27,510
Total - Strategies	**1,130**	**21,930**	**84,670**	**252,890**	**378,000**	**413,450**
Total - Portfolio	**6,580**	**8,080**	**106,210**	**233,090**	**391,110**	**470,020**
Total - Portfolio Plus Baseline System	**521,450**	**674,120**	**785,550**	**923,830**	**1,073,760**	**1,154,090**
Bridgeport Reallocation(1)	**On**	**On**	**On**	**On**	**On**	**On**
Parallel IPL	Off	Off	Off	Off	**On**	**On**
Parallel EM Connection	Off	Off	**On**	**On**	**On**	**On**

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) While Cedar Creek and Richland-Chambers Unpermitted Firm Yield is turned on in all simulation years, the supply is not always used. In 2030, infrastructure is not present to convey the supply. In later years, the supply is not utilized if other supplies are available.
(3) ASR is only utilized during dry conditions when no other supplies are available, per the operation rules established for the portfolio analysis. Thus, the utilization of the supply varies by decade, depending on the availability of other supplies in the portfolio.
(4) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

By 2080, the firm and safe yield of the Mix of Smaller Portfolio reaches 408,000 AF and 372,000 AF, respectively, as provided in Table 7.5. The largest increase in firm yield occurs between 2050 and 2060. Combined with the firm and safe yield of the baseline system (Table 3.2 from Chapter 3), the firm yield reaches 1,147,670 AF by 2080, with safe yield estimated at 996,860 AF by 2080.

Table 7.5 Strategy Timing and Yield Analysis for the Mix of Smaller Portfolio

Strategies	Year Online	Portfolio Only (AFY)		Portfolio Plus Baseline System (AFY)	
		Firm Yield	Safe Yield	Firm Yield	Safe Yield
Advancing Conservation[1][2]	2030	90,500	81,450		
Cedar Creek and Richland-Chambers Unpermitted Firm Yield[1]	2030	21,920	0		
Bridgeport Reallocation[1]	2030	0	0		
ASR	2050	11,210	11,210		
Lake Palestine Purchase	2050	30,000	30,000		
TRWD Developed Groundwater	2050	7,000	7,000		
Second Richland-Chambers Wetlands	2060	100,890	100,890		
Mainstem Trinity OCR	2060	57,170	57,170		
Direct Potable Reuse	2070	20,500	20,500		
Anderson County Groundwater	2070	42,000	42,000		
Tehuacana	2070	27,510	21,940		
Firm and Safe Yield by Decade[2]	2030	22,890	870	688,090	555,520
	2040	34,820	11,610	737,430	602,850
	2050	98,880	74,090	815,470	678,490
	2060	276,310	249,580	1,005,380	865,770
	2070	392,460	357,540	1,134,870	986,380
	2080	408,700	372,150	1,147,670	996,860

(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) Advancing Conservation firm yield is assumed to be the average annual savings in 2080. Note that dry year savings are higher, as a 10% reduction is assumed for all demand years throughout the hydrologic traces. Safe yield is assumed at 90% of firm yield. For the summary by decade, Advancing Conservation ramps up.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

Reliability metrics were obtained from the RiverWare model by assessing demands and any remaining gaps for the 82 years of monthly hydrologic inflow. In 2080, the Mix of Smaller portfolio meets 98 percent of the uncurtailed water demands during the critical year of the drought of record, as shown in Table 7.6. Across the planning decades, the small remaining gap would be mitigated through the enactment of TRWD's Drought Contingency Plan. This portfolio does moderately well in terms of meeting demands during other hydrologic traces, with 9 percent of years having a small gap. Generally, this metric within the RiverWare model is an indicator of how well the new portfolio of supplies performs under the existing TRWD operational framework. The largest gap happens in the hydrological period replicated from 1980, as shown, and is a result of operational rules that would be reviewed and adjusted under new supply conditions.

Table 7.6 Reliability Metrics for the Mix of Smaller Portfolio

Metric[1]	2030[2]	2040	2050	2060	2070	2080
Demands, Average, AF[3]	483,690	570,720	652,420	745,090	847,740	912,290
Demands, 1956, AF[3]	563,500	678,590	792,100	924,070	1,074,450	1,182,080
Demands Met, 1956, AF	521,450	674,120	785,550	923,830	1,073,760	1,154,090
1956 Remaining Gap Magnitude, AF	42,050	4,470	6,550	230	690	28,000
1956 Percent of Demands Met	93%	99%	99%	100%	100%	98%
Percent of Hydrologic Years with Gap	1%	0%	0%	0%	1%	9%
Maximum Gap (1980), AF	42,000	4,500	20,200	42,300	83,600	120,700

Notes:
(1) See Table 7.1 for reliability metric definitions.
(2) Modeling shows that with the 2030 conditions, a gap of 7% remains during 1956 critical conditions. The modeling assumed that much of the planned infrastructure expansions (e.g., completion of the IPL) plus the Cedar Creek Wetlands are not online until 2040. See Chapter 9 for recommendations on meeting this gap.
(3) Results are from the S3 demand scenario. Average demands were calculated from the 82 hydrologic input years. Demands in 1956 are the annual demands related to the hot and dry conditions with that hydrologic year and were generated using the actual to average assumptions ratios described in Chapter 2 and provided in Appendix C.
(4) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

The Mix of Smaller portfolio requires a capital investment of $8.43 billion dollars if constructed today, as provided in Table 7.7. With the delay in timing to bring supplies on as demand grows, and with the quantified risk of meeting the reliability metrics, the 50-year portfolio costs total $4.93 billion, with 68 percent as debt-covered capital costs and the remaining O&M. The weighted unit cost of the portfolio is $704 per AF of supply.

Table 7.7 Cost Metrics for the Mix of Smaller Portfolio

Metric[2]	Value[2]	Unit[2]
Total Capital Costs	$8,430	Millions (Sept 2023$)
Debt-Covered Capital (2030-2080)	$3,363	Millions (NPV)
Total O&M Costs (2030-2080)	$1,568	Millions (NPV)
Total Portfolio Cost (2030-2080)	$4,930	Millions (NPV)
Weighted Unit Cost of Supply	$704	$/AF (Sept 2023$)
Portfolio Levelized Unit Cost of Delivered Water	$2.63	$/kgal

Notes:
(1) See Table 7.2 for cost metric definitions.
(2) All values are rounded to the nearest significant digit.

7.3.2 Toledo Bend Portfolio

The Toledo Bend portfolio includes six strategies with modeled inflow plus Bridgeport Reallocation, as summarized in Table 7.8. The portfolio requires both the Parallel IPL and Parallel EM Connection to convey new supplies to meet demands. If there were to be a repeat of the drought of record, during the critical year of shortages (i.e., 1956 for the drought of record), Advancing Conservation provides 121,000 AF of inflow. The largest supply is from Toledo Bend which provides almost 240,000 AF of inflow into the system by 2080. Interim supplies include Direct Potable Reuse, TRWD Developed Groundwater, and a purchase of surface water from Lake Palestine. In total, the portfolio supply utilization grows to nearly 438,000 AF by 2080. With the expansion of the system under this portfolio, new supply utilization when compared to the baseline system reaches 475,000 AF (see Figure 5.1 in Chapter 5), for a total of just under 1,160,000 AF. The total portfolio supply is greater than the total of the supply from individual Strategies because additional reuse is made available by some strategies and because additional conveyance has been added to move both portfolio and existing supplies. This portfolio does not include the Second Richland-Chambers Wetlands because it is not needed to meet demand; however, it could become a valuable strategy beyond the 2080 planning horizon to utilize the Toledo Bend return flows.

Table 7.8 Supply Utilized During Critical Dry Year for the Toledo Bend Portfolio in AFY

Strategies	2030	2040	2050	2060	2070	2080
Advancing Conservation(1)	1,130	15,000	33,420	57,560	88,510	121,000
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)(2)	0	0	0	0	15,070	19,120
Direct Potable Reuse	0	0	20,930	20,930	20,930	20,930
TRWD Developed Groundwater	0	0	7,000	7,000	7,000	7,000
Lake Palestine Purchase	0	0	30,000	30,000	30,000	30,000
Toledo Bend	0	0	0	239,810	239,810	239,810
Total – Strategies	**1,130**	**15,000**	**91,350**	**355,300**	**401,320**	**437,860**
Total – Portfolio	**6,580**	**980**	**95,160**	**233,330**	**387,080**	**475,380**
Total – Portfolio Plus Baseline System	**521,450**	**667,020**	**774,500**	**924,070**	**1,069,730**	**1,159,450**
Bridgeport Reallocation(2)	**On**	**On**	**On**	**On**	**On**	**On**
Parallel IPL	Off	Off	Off	**On**	**On**	**On**
Parallel EM Connection	Off	Off	Off	**On**	**On**	**On**

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) While Cedar Creek and Richland-Chambers Unpermitted Firm Yield is turned on in all simulation years, the supply is not always used. In 2030, infrastructure is not present to convey the supply. In later years, the supply is not utilized if other supplies are available.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

By 2080, the firm and safe yield of the Toledo Bend portfolio reaches 410,000 AF and 379,000 AF, respectively, as provided in Table 7.9. The largest increase in firm yield occurs between 2050 and 2060. Combined with the firm and safe yield of the baseline system (Table 3.2 from Chapter 3), the firm yield reaches 1,149,000 AF by 2080, with safe yield estimated at 1,004,000 AF by 2080.

Table 7.9 Strategy Timing and Yield Analysis for the Toledo Bend Portfolio

Strategies	Year Online	Portfolio Only (AFY)		Portfolio Plus Baseline System (AFY)	
		Firm Yield	Safe Yield	Firm Yield	Safe Yield
Advancing Conservation(1)(2)	2030	90,500	81,450		
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)	2030	21,920	0		
Bridgeport Reallocation1	2030	0	0		
Direct Potable Reuse	2050	20,500	20,500		
TRWD Developed Groundwater	2050	7,000	7,000		
Lake Palestine Purchase	2050	30,000	30,000		
Toledo Bend	2060	240,000	240,000		
Firm and Safe Yield by Decade(2)	2030	22,890	870	688,090	555,520
	2040	34,820	11,610	737,430	602,850
	2050	108,170	83,380	824,760	687,780
	2060	367,540	340,810	1,096,610	957,000
	2070	393,680	364,330	1,136,090	993,170
	2080	409,920	378,940	1,148,890	1,003,650

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) Advancing Conservation firm yield is assumed to be the average annual savings in 2080. Note that dry year savings are higher, as a 10% reduction is assumed for all demand years throughout the hydrologic traces. Safe yield is assumed at 90% of firm yield. For the summary by decade, Advancing Conservation ramps up.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

Reliability metrics were obtained from the RiverWare model by assessing demands and any remaining gaps for the 82 years of monthly hydrologic inflow. In 2080, the Toledo Bend portfolio meets 98 percent of the uncurtailed water demands during the critical year of the drought of record, as shown in Table 7.10. Across the planning decades, the small remaining gap would be mitigated through the enactment of TRWD's Drought Contingency Plan. This portfolio does not perform well in terms of meeting demands during other hydrologic traces, with 18 percent of years having a relatively small remaining gap. Generally, this metric within the RiverWare model is an indicator of how well the new portfolio of supplies performs under the existing TRWD operational framework. The Toledo Bend portfolio has the largest supply coming from East Texas and would require study to optimize operation rules to resolve these modeled gaps. Likewise, the largest gap happens in the hydrological period replicated from 1980, as shown, and is a result of operational rules that would be reviewed and adjusted under new supply conditions.

Table 7.10 Reliability Metrics for the Toledo Bend Portfolio

Metric(1)	2030(2)	2040	2050	2060	2070	2080
Demands, Average, AF(3)	483,690	570,720	652,420	745,090	847,740	912,290
Demands, 1956, AF(3)	563,500	678,590	792,100	924,070	1,074,450	1,182,080
Demands Met, 1956, AF	521,450	667,020	774,500	924,070	1,069,730	1,159,450
1956 Remaining Gap Magnitude, AF	42,050	11,570	17,600	0	4,720	22,640
1956 Percent of Demands Met	93%	98%	98%	100%	100%	98%
Percent of Hydrologic Years with Gap	1%	0%	0%	1%	5%	18%
Maximum Gap (1980), AF	42,000	11,600	26,400	44,100	69,100	104,200

Notes:
(1) See Table 7.1 for reliability metric definitions.
(2) Modeling shows that with the 2030 conditions, a gap of 7% remains during 1956 critical conditions. The modeling assumed that much of the planned infrastructure expansions (e.g., completion of the IPL) plus the Cedar Creek Wetlands are not online until 2040. See Chapter 9 for recommendations on meeting this gap.
(3) Results are from the S3 demand scenario. Average demands were calculated from the 82 hydrologic input years. Demands in 1956 are the annual demands related to the hot and dry conditions with that hydrologic year and were generated using the actual to average assumptions ratios described in Chapter 2 and provided in Appendix C.
(4) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

The Toledo Bend portfolio requires a capital investment of $9.92 billion dollars if constructed today, as provided in Table 7.11. With the delay in timing to bring supplies on as demand grows, and with the quantified risk of meeting the reliability metrics, the 50-year portfolio costs total $5.43 billion, with 70 percent of those debt-covered capital costs and the remaining O&M. The weighted unit cost of the portfolio is $759 per AF of supply.

Table 7.11 Cost Metrics for the Toledo Bend Portfolio

Metric(1)	Value(2)	Unit
Total Capital Costs	$9,915	Millions (Sept 2023$)
Debt-Covered Capital (2030-2080)	$5,429	Millions (NPV)
Total O&M Costs (2030-2080)	$2,369	Millions (NPV)
Total Portfolio Cost (2030-2080)	$7,798	Millions (NPV)
Weighted Unit Cost of Supply	$759	$/AF (Sept 2023$)
Portfolio Levelized Unit Cost of Delivered Water	$3.62	$/kgal

Notes:
(1) See Table 7.2 for cost metric definitions.
(2) All values are rounded to the nearest significant digit.

7.3.3 Marvin Nichols Portfolio

The Marvin Nichols portfolio includes eight strategies with modeled inflow plus Bridgeport Reallocation, as summarized in Table 7.12. The portfolio requires the Parallel IPL to convey East Texas supplies to meet demands. If there were to be a repeat of the drought of record, during the critical year of shortages (i.e., 1956 for the drought of record), Advancing Conservation provides 121,000 AF of inflow. The largest supply is from Marvin Nichols which provides over 110,000 AF of inflow into the northern part of the system by 2060. Interim supplies include the Mainstem Trinity OCR, ASR, TRWD Developed Groundwater, and a purchase of surface water from Lake Palestine. In total, the portfolio supply utilization grows to over 426,000 AF by 2080. With the expansion of the system under this portfolio, new supply utilization when compared to the baseline system reaches 460,000 AF (see Figure 5.1 in Chapter 5), for a total of just over 1,144,000 AF. The total portfolio supply is greater than the total of the supply from individual Strategies because additional reuse is made available by some strategies and because additional conveyance has been added to move both portfolio and existing supplies.

Of note, Lake Palestine Purchase is assumed to take 9 years to implement, and Mainstem Trinity OCR is assumed to take 20 years for implementation. In the Marvin Nichols portfolio, both are put on expedited timelines for implementation in 2030 for Lake Palestine Purchase and 2040 for Mainstem Trinity OCR.

Table 7.12 Supply Utilized During Critical Dry Year for the Marvin Nichols Portfolio in AFY

Strategies	2030	2040	2050	2060	2070	2080
Advancing Conservation(1)	1,130	15,000	33,420	57,560	88,510	121,000
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)(2)	0	0	0	0	0	0
Lake Palestine Purchase	30,000	30,000	30,000	30,000	30,000	30,000
Mainstem Trinity OCR	0	57,170	57,170	57,170	57,170	57,170
ASR	0	9,880	9,880	9,880	7,690	0
TRWD Developed Groundwater	0	0	7,000	7,000	7,000	7,000
Marvin Nichols	0	0	0	110,240	110,240	110,240
Second Richland-Chambers Wetlands	0	0	0	0	99,720	100,890
Total – Strategies	**31,130**	**112,050**	**137,470**	**271,850**	**400,330**	**426,300**
Total – Portfolio	**23,230**	**12,550**	**112,450**	**233,090**	**384,750**	**460,140**
Total – Portfolio Plus Baseline System	**538,100**	**678,590**	**791,790**	**923,830**	**1,067,400**	**1,144,210**
Bridgeport Reallocation(1)	**On**	**On**	**On**	**On**	**On**	**On**
Parallel IPL	Off	Off	Off	**On**	**On**	**On**
Parallel EM Connection	Off	Off	Off	Off	Off	Off

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) While Cedar Creek and Richland-Chambers Unpermitted Firm Yield is turned on in all simulation years, the supply is not always used. In 2030, infrastructure is not present to convey the supply. In later years, the supply is not utilized if other supplies are available.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

By 2080, the firm and safe yield of the Marvin Nichols portfolio reaches 429,000 AF and 377,000 AF, respectively, as provided in Table 7.13. The largest increase in firm yield occurs between 2060 and 2070. Combined with the firm and safe yield of the baseline system (Table 3.2 from Chapter 3), the firm yield reaches 1,168,000 AF by 2080, with safe yield estimated at 1,001,000 AF by 2080.

Table 7.13 Strategy Timing and Yield Analysis for the Marvin Nichols Portfolio

Strategies	Year Online	Portfolio Only (AFY)		Portfolio Plus Baseline System (AFY)	
		Firm Yield	Safe Yield	Firm Yield	Safe Yield
Advancing Conservation(1)(2)	2030	90,500	81,450		
Cedar Creek and Richland-Chambers Unpermitted Firm Yield1	2030	21,920	0		
Bridgeport Reallocation(1)	2030	0	0		
Lake Palestine Purchase	2030	30,000	30,000		
Mainstem Trinity OCR	2040	57,170	57,170		
ASR	2040	11,210	11,210		
TRWD Developed Groundwater	2050	7,000	7,000		
Marvin Nichols	2060	110,240	88,810		
Second Richland-Chambers Wetlands	2070	100,890	100,890		
Firm and Safe Yield by Decade(2)	2030	52,890	30,870	718,090	585,520
	2040	133,200	109,990	835,810	701,230
	2050	156,050	131,260	872,640	735,660
	2060	285,660	237,500	1,014,730	853,690
	2070	412,690	361,910	1,155,100	990,750
	2080	428,930	376,520	1,167,900	1,001,230

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) Advancing Conservation firm yield is assumed to be the average annual savings in 2080. Note that dry year savings are higher, as a 10% reduction is assumed for all demand years throughout the hydrologic traces. Safe yield is assumed at 90% of firm yield. For the summary by decade, Advancing Conservation ramps up.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

Reliability metrics were obtained from the RiverWare model by assessing demands and any remaining gaps for the 82 years of monthly hydrologic inflow. In 2080, the Marvin Nichols portfolio meets 97 percent of the uncurtailed water demands during the critical year of the drought of record, as shown in Table 7.14. Across the planning decades, the small remaining gap would be mitigated through the enactment of TRWD's Drought Contingency Plan. This portfolio performs well in terms of meeting demands during other hydrologic traces, with only 4 percent of years having a small gap. Generally, this metric within the RiverWare model is an indicator of how well the new portfolio of supplies performs under the existing TRWD operational framework. The Marvin Nichols portfolio has a large supply coming from the North and performs well under the existing operational framework. The largest gap happens in the hydrological period replicated from 1980, as shown, and is a result of operational rules that would be reviewed and adjusted under new supply conditions.

Table 7.14 Reliability Metrics for the Marvin Nichols Portfolio

Metric[1]	2030[2]	2040	2050	2060	2070	2080
Demands, Average, AF[3]	483,690	570,720	652,420	745,090	847,740	912,290
Demands, 1956, AF[3]	563,500	678,590	792,100	924,070	1,074,450	1,182,080
Demands Met, 1956, AF	538,100	678,590	791,790	923,830	1,067,400	1,144,210
1956 Remaining Gap Magnitude, AF	25,400	0	310	230	7,050	37,870
1956 Percent of Demands Met	96%	100%	100%	100%	99%	97%
Percent of Hydrologic Years with Gap	0%	0%	0%	0%	1%	4%
Maximum Gap (1980), AF	25,400	1,000	23,700	25,200	70,600	114,300

Notes:
(1) See Table 7.1 for reliability metric definitions.
(2) Modeling shows that with the 2030 conditions, a gap of 7% remains during 1956 critical conditions. The modeling assumed that much of the planned infrastructure expansions (e.g., completion of the IPL) plus the Cedar Creek Wetlands are not online until 2040. See Chapter 9 for recommendations on meeting this gap.
(3) Results are from the S3 demand scenario. Average demands were calculated from the 82 hydrologic input years. Demands in 1956 are the annual demands related to the hot and dry conditions with that hydrologic year and were generated using the actual to average assumptions ratios described in Chapter 2 and provided in Appendix C.
(4) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

The Marvin Nichols portfolio requires a capital investment of $8.78 billion dollars if constructed today, as provided in Table 7.15. With the delay in timing to bring supplies on as demand grows, and with the quantified risk to meet the reliability metrics, the 50-year portfolio costs total $4.37 billion, with 73 percent of those costs debt-covered capital and the remaining O&M. The weighted unit cost of the portfolio is $654 per AF of supply.

Table 7.15 Cost Metrics for the Marvin Nichols Portfolio

Metric[1]	Value[2]	Unit
Total Capital Costs	$8,783	Millions (Sept 2023$)
Debt-Covered Capital (2030-2080)	$4,898	Millions (NPV)
Total O&M Costs (2030-2080)	$2,078	Millions (NPV)
Total Portfolio Cost (2030-2080)	$6,975	Millions (NPV)
Weighted Unit Cost of Supply	$654	$/AF (Sept 2023$)
Portfolio Levelized Unit Cost of Delivered Water	$2.86	$/kgal

Notes:
(1) See Table 7.2 for cost metric definitions.
(2) All values are rounded to the nearest significant digit.

7.3.4 Marvin Nichols with Wright Patman Portfolio

The Marvin Nichols with Wright Patman portfolio includes six strategies with modeled inflow plus Bridgeport Reallocation, as summarized in Table 7.16. The portfolio requires the Parallel IPL to convey East Texas supplies to meet demands. If there were to be a repeat of the drought of record, during the critical year of shortages (i.e., 1956 for the drought of record), Advancing Conservation provides 121,000 AF of inflow. The largest supply is from Marvin Nichols with Wright Patman which provides nearly 142,000 AF of inflow into the northern part of the system by 2080. Interim supplies include the Mainstem Trinity OCR, the Second Richland-Chambers Wetlands, and a purchase of surface water from Lake Palestine. In total, the portfolio supply utilization grows to over 450,000 AF by 2080. With the expansion of the system under this portfolio, new supply utilization when compared to the baseline system reaches 458,000 AF (see Figure 5.1 in Chapter 5), for a total of just over 1,142,000 AF. The total portfolio supply is greater than the total of the supply from individual Strategies because additional reuse is made available by some strategies and because additional conveyance has been added to move both portfolio and existing supplies.

Table 7.16 Supply Utilized During Critical Dry Year for the Marvin Nichols with Wright Patman Portfolio in AFY

Strategies	2030	2040	2050	2060	2070	2080
Advancing Conservation(1)	1,130	15,000	33,420	57,560	88,510	121,000
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)(2)	0	6,930	5,670	0	0	0
Lake Palestine Purchase	0	0	30,000	30,000	30,000	30,000
Mainstem Trinity OCR	0	0	0	57,170	57,170	57,170
Marvin Nichols with Wright Patman	0	0	0	141,800	141,800	141,800
Second Richland-Chambers Wetlands	0	0	0	0	100,340	100,890
Total – Strategies	**1,130**	**21,930**	**69,090**	**286,530**	**417,820**	**450,860**
Total – Portfolio	**6,580**	**8,080**	**96,380**	**233,090**	**380,770**	**457,960**
Total – Portfolio Plus Baseline System	**521,450**	**674,120**	**775,720**	**923,830**	**1,063,420**	**1,142,030**
Bridgeport Reallocation(1)	On	On	On	On	On	On
Parallel IPL	Off	Off	Off	On	On	On
Parallel EM Connection	Off	Off	Off	Off	Off	Off

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) While Cedar Creek and Richland-Chambers Unpermitted Firm Yield is turned on in all simulation years, the supply is not always used. In 2030, infrastructure is not present to convey the supply. In later years, the supply is not utilized if other supplies are available.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

By 2080, the firm and safe yield of the Marvin Nichols with Wright Patman portfolio reaches 442,000 AF and 382,000 AF, respectively, as provided in Table 7.17. The largest increase in firm yield occurs between 2050 and 2060. Combined with the firm and safe yield of the baseline system (Table 3.2 from Chapter 3), the firm yield reaches 1,181,000 AF by 2080, with safe yield estimated at 1,007,000 AF by 2080.

Table 7.17 Strategy Timing and Yield Analysis for the Marvin Nichols with Wright Patman Portfolio

Strategies	Year Online	Portfolio Only (AFY)		Portfolio Plus Baseline System (AFY)	
		Firm Yield	Safe Yield	Firm Yield	Safe Yield
Advancing Conservation(1)(2)	2030	90,500	81,450		
Cedar Creek and Richland-Chambers Unpermitted Firm Yield1	2030	21,920	0		
Bridgeport Reallocation(1)	2030	0	0		
Lake Palestine Purchase	2050	30,000	30,000		
Mainstem Trinity OCR	2060	57,170	57,170		
Marvin Nichols with Wright Patman	2060	141,800	112,370		
Second Richland-Chambers Wetlands	2070	100,890	100,890		
Portfolio firm and safe yield by decade(2)	2030	22,890	870	688,090	555,520
	2040	34,820	11,610	737,430	602,850
	2050	80,670	55,880	797,260	660,280
	2060	299,010	242,850	1,028,080	859,040
	2070	426,040	367,260	1,168,450	996,100
	2080	442,280	381,870	1,181,250	1,006,580

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) Advancing Conservation firm yield is assumed to be the average annual savings in 2080. Note that dry year savings are higher, as a 10% reduction is assumed for all demand years throughout the hydrologic traces. Safe yield is assumed at 90% of firm yield. For the summary by decade, Advancing Conservation ramps up.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

Reliability metrics were obtained from the RiverWare model by assessing demands and any remaining gaps for the 82 years of monthly hydrologic inflow. In 2080, the Marvin Nichols with Wright Patman portfolio meets 97 percent of the uncurtailed water demands during the critical year of the drought of record, as shown in Table 7.18. Across the planning decades, the small remaining gap would be mitigated through the enactment of TRWD's Drought Contingency Plan. This portfolio performs well in terms of meeting demands during other hydrologic traces, with only 1 percent of years having a small gap. Generally, this metric within the RiverWare model is an indicator of how well the new portfolio of supplies performs under the existing TRWD operational framework. The Marvin Nichols with Wright Patman portfolio has a large supply coming from the North and performs well under the existing operational framework. The largest gap happens in the hydrological period replicated from 1980, as shown, and is a result of operational rules that would be reviewed and adjusted under new supply conditions.

Table 7.18 Reliability Metrics for the Marvin Nichols with Wright Patman Portfolio

Metric(1)	2030(2)	2040	2050	2060	2070	2080
Demands, Average, AF(3)	483,690	570,720	652,420	745,090	847,740	912,290
Demands, 1956, AF(3)	563,500	678,590	792,100	924,070	1,074,450	1,182,080
Demands Met, 1956, AF	521,450	674,120	775,720	923,830	1,063,420	1,142,030
1956 Remaining Gap Magnitude, AF	42,050	4,470	16,380	230	11,030	40,050
1956 Percent of Demands Met	93%	99%	98%	100%	99%	97%
Percent of Hydrologic Years with Gap	1%	0%	1%	0%	1%	1%
Maximum Gap (1980), AF	42,000	4,500	40,700	16,300	54,200	109,800

Notes:
(1) See Table 7.1 for reliability metric definitions.
(2) Modeling shows that with the 2030 conditions, a gap of 7% remains during 1956 critical conditions. The modeling assumed that much of the planned infrastructure expansions (e.g., completion of the IPL) plus the Cedar Creek Wetlands are not online until 2040. See Chapter 9 for recommendations on meeting this gap.
(3) Results are from the S3 demand scenario. Average demands were calculated from the 82 hydrologic input years. Demands in 1956 are the annual demands related to the hot and dry conditions with that hydrologic year and were generated using the actual to average assumptions ratios described in Chapter 2 and provided in Appendix C.
(4) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

The Marvin Nichols with Wright Patman portfolio requires a capital investment of $10.16 billion dollars if constructed today, as provided in Table 7.19. With the delay in timing to bring supplies on as demands grow, and with the quantified risk to meet the reliability metrics, the 50-year portfolio costs total $4.59 billion, with 73 percent of those costs debt-covered capital and the remaining O&M. The weighted unit cost of the portfolio is $715 per AF of supply.

Table 7.19 Cost Metrics for the Marvin Nichols with Wright Patman Portfolio

Metric(1)	Value(2)	Unit
Total Capital Costs	$10,163	Millions (Sept 2023$)
Debt-Covered Capital (2030-2080)	$4,592	Millions (NPV)
Total O&M Costs (2030-2080)	$1,661	Millions (NPV)
Total Portfolio Cost (2030-2080)	$6,253	Millions (NPV)
Weighted Unit Cost of Supply	$715	$/AF (Sept 2023$)
Portfolio Levelized Unit Cost of Delivered Water	$2.63	$/kgal

Notes:
(1) See Table 7.2 for cost metric definitions.
(2) All values are rounded to the nearest significant digit.

7.3.5 Arkansas Portfolio

The Arkansas portfolio includes five strategies with modeled inflow plus Bridgeport Reallocation, as summarized in Table 7.20. The portfolio does not require the Parallel IPL nor the Parallel EM Connection. If there were to be a repeat of the drought of record, during the critical year of shortages (i.e., 1956 for the drought of record), Advancing Conservation provides 121,000 AF of inflow. The largest supply is from the Arkansas Water strategy which provides 260,000 AF of inflow into the northern part of the system starting in 2060. Interim supplies include the Anderson County Groundwater and a purchase of groundwater from Lake Palestine. In total, the portfolio supply utilization grows to 438,000 AF by 2080. With the expansion of the system under this portfolio, new supply utilization when compared to the baseline system reaches nearly 500,000 AF (see Figure 5.1 in Chapter 5), for a total of just over 1,182,000 AF. The total portfolio supply is greater than the total of the supply from individual Strategies because additional reuse is made available by some strategies and because additional conveyance has been added to move both portfolio and existing supplies.

Table 7.20 Supply Utilized During Critical Dry Year for the Arkansas Portfolio in AFY

Strategies	2030	2040	2050	2060	2070	2080
Advancing Conservation(1)	1,130	15,000	33,420	57,560	88,510	121,000
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)(2)	0	0	0	0	0	0
Lake Palestine Groundwater Purchase	0	0	15,000	14,200	15,000	15,000
Anderson County Groundwater	0	0	42,000	38,660	42,000	42,000
Arkansas Water	0	0	0	260,000	260,000	260,000
Total – Strategies	**1,130**	**15,000**	**90,420**	**370,420**	**405,510**	**438,000**
Total – Portfolio	**6,580**	**980**	**97,360**	**233,330**	**391,800**	**498,010**
Total – Portfolio Plus Baseline System	**521,450**	**667,020**	**776,700**	**924,070**	**1,074,450**	**1,182,080**
Bridgeport Reallocation(1)	**On**	**On**	**On**	**On**	**On**	**On**
Parallel IPL	Off	Off	Off	Off	Off	Off
Parallel EM Connection	Off	Off	Off	Off	Off	Off

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) While Cedar Creek and Richland-Chambers Unpermitted Firm Yield is turned on in all simulation years, the supply is not always used. In 2030, infrastructure is not present to convey the supply. In later years, the supply is not utilized if other supplies are available.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

By 2080, the firm and safe yield of the Arkansas portfolio reaches 429,000 AF and 392,000 AF, respectively, as provided in Table 7.21. The largest increase in firm yield occurs between 2050 and 2060 with Arkansas Water coming online. Combined with the firm and safe yield of the baseline system (Table 3.2 from Chapter 3), the firm yield reaches 1,168,000 AF by 2080, with safe yield estimated at 1,023,000 AF by 2080.

Table 7.21 Strategy Timing and Yield Analysis for the Arkansas Portfolio

Strategies	Year Online	Portfolio Only (AFY)		Portfolio Plus Baseline System (AFY)	
		Firm Yield	Safe Yield	Firm Yield	Safe Yield
Advancing Conservation(1)(2)	2030	90,500	81,450		
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(1)	2030	21,920	0		
Bridgeport Reallocation(1)	2030	0	0		
Lake Palestine Groundwater Purchase	2050	15,000	15,000		
Anderson County Groundwater	2050	42,000	42,000		
Arkansas Water	2060	260,000	260,000		
Portfolio Firm and Safe Yield by Decade(2)	2030	22,890	870	688,090	555,520
	2040	34,820	11,610	737,430	602,850
	2050	107,670	82,880	824,260	687,280
	2060	387,040	360,310	1,116,110	976,500
	2070	413,180	383,830	1,155,590	1,012,670
	2080	429,420	398,440	1,168,390	1,023,150

Notes:
(1) No regrets strategy. Bridgeport Reallocation has no associated supply.
(2) Advancing Conservation firm yield is assumed to be the average annual savings in 2080. Note that dry year savings are higher, as a 10% reduction is assumed for all demand years throughout the hydrologic traces. Safe yield is assumed at 90% of firm yield. For the summary by decade, Advancing Conservation ramps up.
(3) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

Reliability metrics were obtained from the RiverWare model by assessing demands and any remaining gaps for the 82 years of monthly hydrologic inflow. In 2080, the Arkansas portfolio meets 100 percent of the uncurtailed water demands during the critical year of the drought of record, as shown in Table 7.22. This portfolio performs exceptionally well in terms of meeting demands during other hydrologic traces, with nearly zero hydrologic traces having a small gap. Generally, this metric within the RiverWare model is an indicator of how well the new portfolio of supplies performs under the existing TRWD operational framework. The Arkansas portfolio has the largest supply coming from the North and performs best under the existing operational framework. The largest gap happens in the hydrological period replicated from 1980, as shown, and is a result of operational rules that would be reviewed and adjusted under new supply conditions.

Table 7.22 Reliability Metrics for the Arkansas Portfolio

Metric(1)	2030(2)	2040	2050	2060	2070	2080
Demands, Average, AF(3)	483,690	570,720	652,420	745,090	847,740	912,290
Demands, 1956, AF(3)	563,500	678,590	792,100	924,070	1,074,450	1,182,080
Demands Met, 1956, AF	521,450	667,020	776,700	924,070	1,074,450	1,182,080
1956 Remaining Gap Magnitude, AF	42,050	11,570	15,400	0	0	0
1956 Percent of Demands Met	93%	98%	98%	100%	100%	100%
Percent of Hydrologic Years with Gap	1%	0%	0%	0%	0%	0%
Maximum Gap (1980), AF	42,000	11,600	34,300	9,500	19,400	30,000

Notes:
(1) See Table 7.1 for reliability metric definitions.
(2) Modeling shows that with the 2030 conditions, a gap of 7% remains during 1956 critical conditions. The modeling assumed that much of the planned infrastructure expansions (e.g., completion of the IPL) plus the Cedar Creek Wetlands are not online until 2040. See Chapter 9 for recommendations on meeting this gap.
(3) Results are from the S3 demand scenario. Average demands were calculated from the 82 hydrologic input years. Demands in 1956 are the annual demands related to the hot and dry conditions with that hydrologic year and were generated using the actual to average assumptions ratios described in Chapter 2 and provided in Appendix C.
(4) All values are rounded to the nearest ten. Totals may not sum exactly due to rounding.

The Arkansas portfolio requires a capital investment of $11.92 billion dollars if constructed today, as provided in Table 7.23. With the delay in timing to bring supplies on as demand grows, and with the quantified risk to meet the reliability metrics, the 50-year portfolio costs total $6.64 billion, with 75 percent of those costs debt-covered capital and the remaining O&M. The weighted unit cost of the portfolio is $833 per AF of supply.

Table 7.23 Cost Metrics for the Arkansas Portfolio

Metric[1]	Value[2]	Unit
Total Capital Costs	$11,921	Millions (Sept 2023$)
Debt-Covered Capital (2030-2080)	$6,637	Millions (NPV)
Total O&M Costs (2030-2080)	$2,187	Millions (NPV)
Total Portfolio Cost (2030-2080)	$8,824	Millions (NPV)
Weighted Unit Cost of Supply	$833	$/AF (Sept 2023$)
Portfolio Levelized Unit Cost of Delivered Water	$3.33	$/kgal

Notes:
(1) See Table 7.2 for cost metric definitions.
(2) All values are rounded to the nearest significant digit.

7.4 Portfolio Comparison

Key metrics for portfolios are provided in Table 7.24. These metrics focus on the 2080 modeling condition or the entire planning horizon and include additional metrics, such as those used in the scoring matrix (see Chapter 2.5 and Chapter 7.5). Results are a product of the detailed assumptions made under each portfolio, such as the timing of new strategies and the types and locations of strategies. All portfolios except Arkansas require the Parallel IPL. Two of the five portfolios require the Parallel EM Connection, with those that have northern supplies not needing that additional conveyance. Portfolio firm yield ranges from about 410,000 AF up to 442,000 AF. All portfolios meet the minimum reliability criteria during the critical drought of record, with percentage of demands met exceeding 95 percent. Capital costs if built today range from $8,430 million up to $11,920 million. This range of investment correlates with reliability and unit costs. The metrics shown in Table 7.24 provide general information about each portfolio that was used to guide discussions about the various possible combinations of strategies that could be implemented but were not used as the basis of the recommendations of this report.

Table 7.24 Portfolio Comparison of Key Metrics

Metric	Mix of Smaller	Toledo Bend	Marvin Nichols	Marvin Nichols with Wright Patman	Arkansas
Count of Strategies Included	12	7	10	8	6
Parallel IPL Included	Yes	Yes	Yes	Yes	No
Parallel EM Connection Included	Yes	Yes	No	No	No
Portfolio Firm Yield Potential (AFY)	408,700	409,920	428,930	442,280	429,420
Total Portfolio Inflow 2030-2080 (MG) (strategies only)	1,877,223	2,154,541	2,436,924	2,379,071	2,646,301
Percent of Hydrologic Years with Gap in 2080(2)	9%	18%	4%	1%	0%
Percent of Hydrologic Months System Demand Met in 2080	93%	92%	96%	96%	98%
Percent of 2080 System Demand Met During Drought of Record	98%	98%	97%	97%	100%
Lowest Customer Reliability in 2080	89%	89%	95%	96%	94%
Total Portfolio Pumping Energy Use 2030-2080 (MWh) (strategies only)	4,378,000	6,828,700	8,295,900	6,993,200	7,154,200
Portfolio Capital Cost (2023$) (millions)	$8,430	$9,915	$8,783	$10,163	$11,921
Total Portfolio Cost 2030-2080 (NPV) (millions)	$4,930	$7,798	$6,975	$6,253	$8,824
Portfolio Levelized Unit Cost of Delivered Water ($/kgal)	$2.63	$3.62	$2.86	$2.63	$3.33
Weighted Unit Cost of Supply (2023$/AF)	$704	$759	$654	$715	$833

Notes:
(1) See Tables 7.1 and 7.2 for definitions of reliability and cost metrics, respectively.
(2) Per the definition, these are gaps greater than 5% but less than 10% of total system demand. These gaps are most likely a result of operation rules that were designed around the existing water supply system. See Chapter 9 for recommendations related to these modeled gaps.

Figure 7.1 provides a graphical comparison of portfolio reliability in 2080. The Arkansas portfolio meets demands more often when looking across hydrologic years. This is a result of the largest northern supply that is conveyed to Lake Bridgeport, hydrologically passed downstream to Eagle Mountain Lake, and hydraulically pumped to Benbrook Lake for distribution to the east. The portfolios with northern supplies perform best due to this ability to meet demands around Eagle Mountain Lake and beyond. Given these portfolios are scored against the ability to meet uncurtailed demands and given the modeling noise inherent in RiverWare (or any simulation model), the reliability of these portfolios is within the acceptable range for planning level analyses. Many of the modeled gaps could be resolved through operational rule changes.

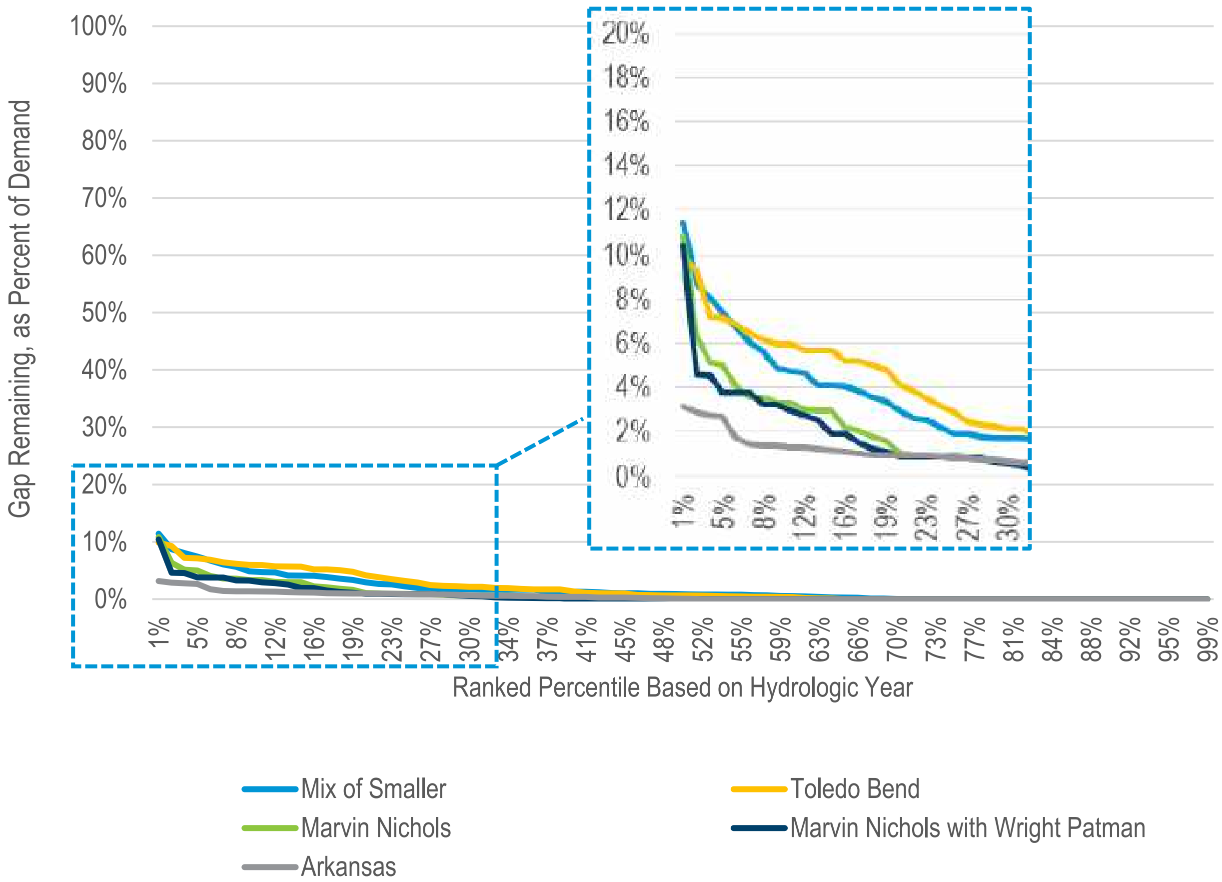


Figure 7.1 Comparison of 2080 Reliability by Portfolio

Unit costs and capital costs are generally correlated, as shown in Figure 7.2. The unit cost can be higher depending on fixed and variable O&M of the strategies included in each portfolio. In terms of unit costs, the Arkansas portfolio is the most expensive, followed by Toledo Bend. The Mix of Smaller and Marvin Nichols with Wright Patman portfolios have similar unit costs. Although the Mix of Smaller has a lower capital investment, the Marvin Nichols portfolio has the lowest unit costs.

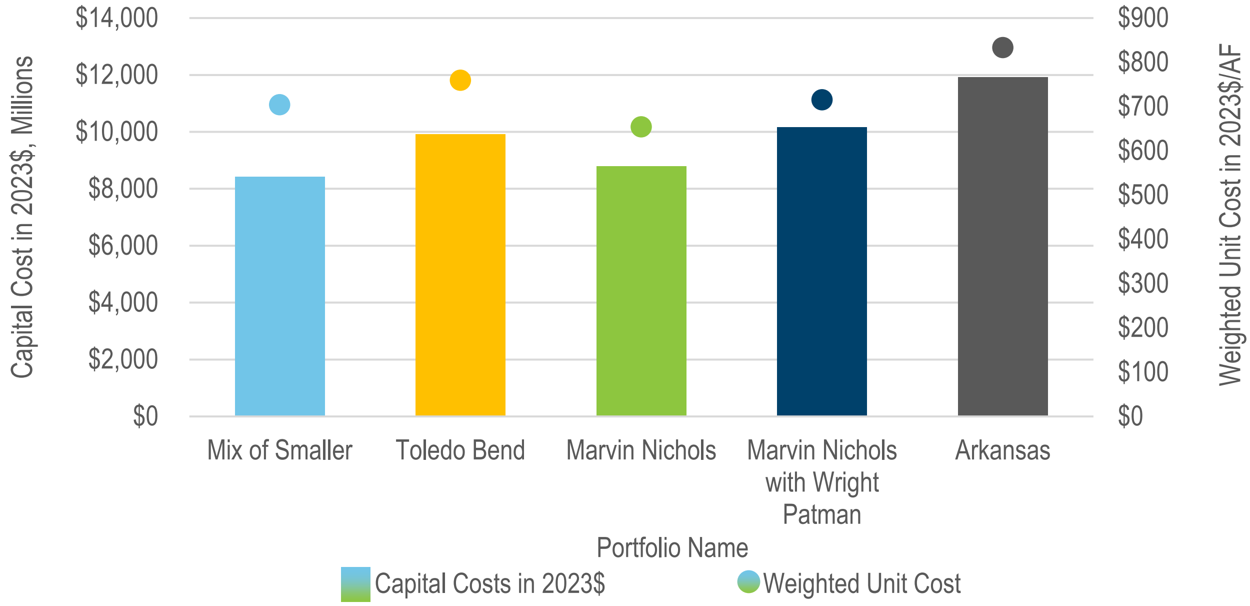


Figure 7.2 Comparison of Portfolio Cost Metrics

When comparing unit costs to supply, generally the largest supply at the lowest unit cost is desired. Figure 7.3 compares unit costs to firm yield represented. On a yield versus cost basis, the Marvin Nichols portfolio provides the greatest cost benefit. Incrementally, the Marvin Nichols with Wright Patman provides an additional 15,000 AFY of supply for about $50 per AF.

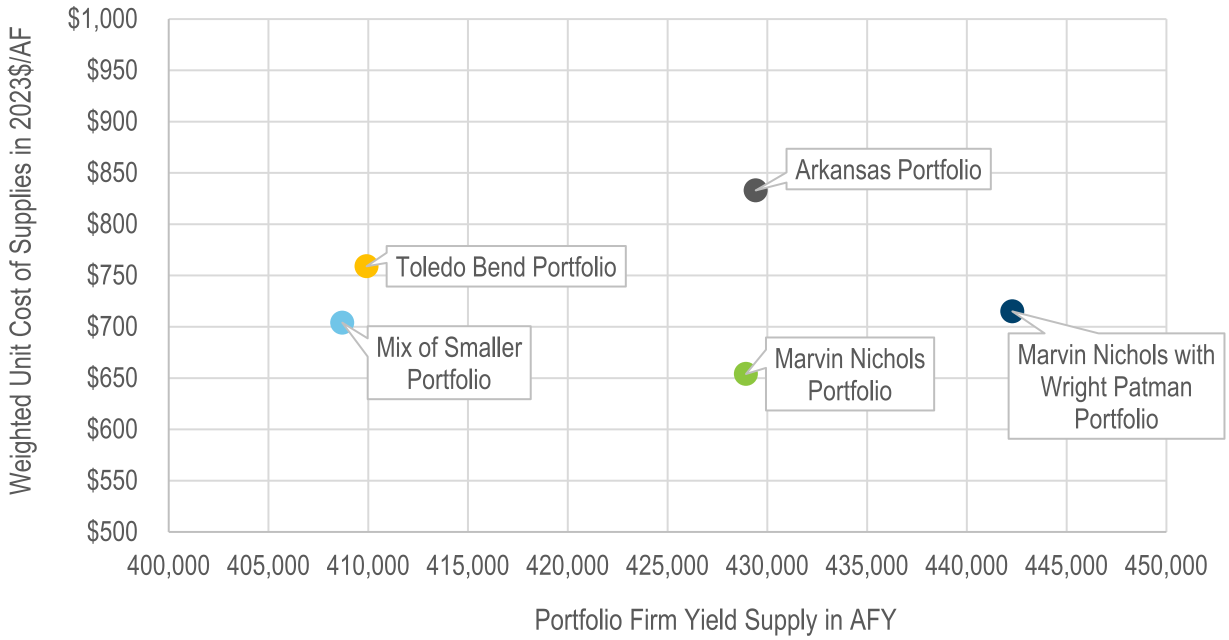


Figure 7.3 Comparison of Portfolio Unit Cost and Supply

7.5 Portfolio Scoring

The MCDA framework is described in Chapter 2.5. Using the metrics and key data on reliability, costs, and strategy scoring for qualitative metrics (Chapter 6), each portfolio was scored. A higher score indicates that a portfolio better meets that metric or set of metrics. Portfolio overall scores are relatively close, ranging from 70 to 72, as shown in Figure 7.4. The Arkansas Portfolio scores the best for reliability, but lowest for affordability. The Mix of Smaller portfolio scores best for community alignment, but lowest for implementation. The Marvin Nichols and Marvin Nichols with Wright Patman portfolios score best overall. The Toledo Bend portfolio scores well for implementation and community alignment.

MCDA results should inform, but not dictate, decisions regarding TRWD's future supply portfolio. Many of the supplies within each of these portfolios are inherently uncertain and require adaptive planning, as discussed in Chapter 8.

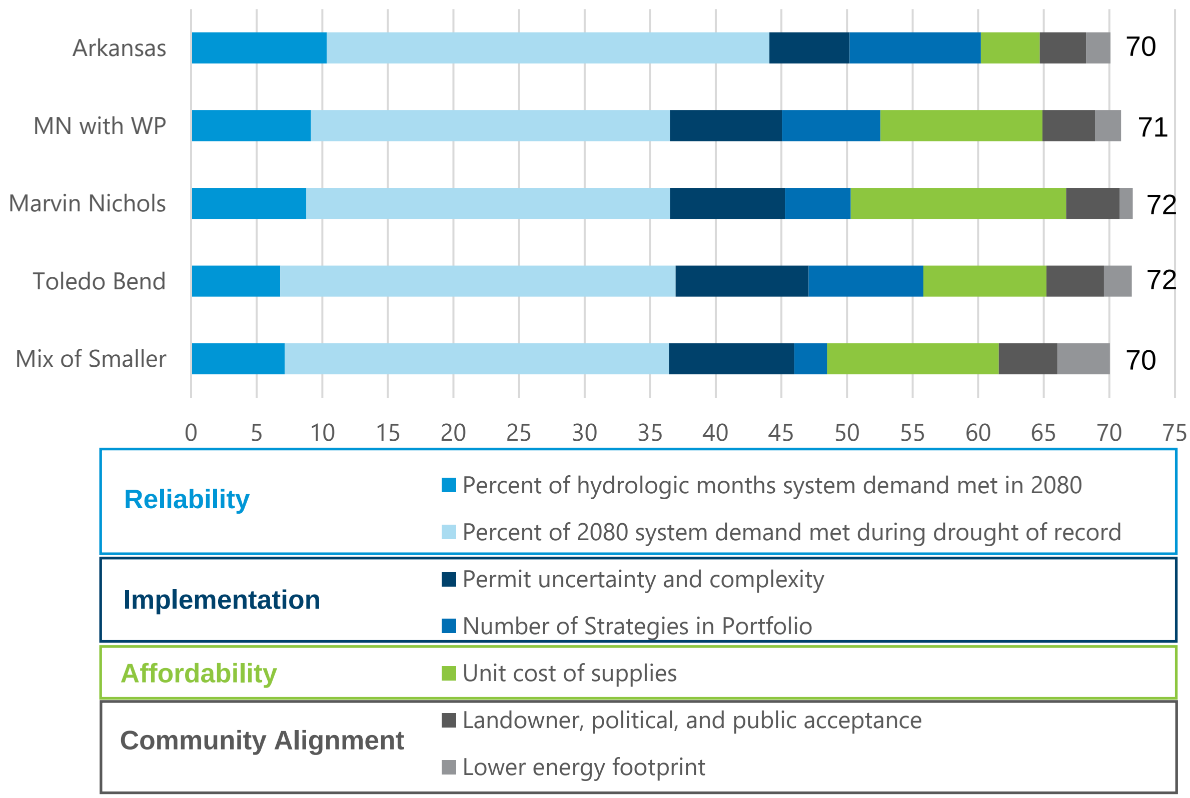


Figure 7.4 Portfolio MCDA Scores

CHAPTER 8 ADAPTIVE IMPLEMENTATION

Adaptive implementation refers to a flexible, responsive approach to executing long-term infrastructure investments where underlying planning assumptions, infrastructure sizing and timing decisions are continuously updated based on changing conditions and emerging priorities. For example, if the projected population growth and water demands accelerate at a faster pace than assumed in this IWSP Update, the proposed timing of new water supply strategies would also need to be moved forward. Similarly, the estimated yield or implementation timeline assumed for individual supply strategies could increase or decrease in the future when more information becomes available, resulting in adjustments of the proposed timelines presented in this chapter. Or if a strategy that is planned for implementation encounters a fatal flaw during planning or permitting, another strategy may be needed instead.

To provide flexibility in implementation, this chapter presents an adaptive and trigger-based implementation approach for each of the five portfolios described in Chapter 7. As each of these includes a few common supply strategies, such as the "No Regrets" strategies plus other smaller strategies, these are discussed first in Chapter 8.1. Subsequently, the proposed implementation timelines for each of the five portfolios are discussed in Chapter 8.2. In Chapter 8.3, trigger-based implementation is offered for big-picture planning and specific strategies that anchor the portfolios. Conclusions and recommendations are summarized at the end of this chapter.

In the context of this IWSP Update with a planning horizon of 2080, near-term is defined as supply strategies that are recommended to be operational by 2050, while long-term is defined as strategies that are phased to be completed sometime after 2050. To simplify and focus the discussion, only firm yield is discussed in this chapter. Full results and metrics for the portfolios can be found in Chapter 7.

8.1 Supply Strategies Grouped by Planning Horizon

Implementation of most water supply strategies includes four distinct phases: 1) planning, 2) permitting, 3) design, and 4) construction. The duration of each phase varies by strategy, but the total implementation period of all the strategies, except water conservation, is estimated to range from 6 to 30 years. Hence, the initial implementation steps for all near-term strategies need to begin significantly earlier than 2050.

This IWSP Update distinguishes between two types of near-term supply strategies: Planned Supplies and No Regrets strategies. Each category is described in more detail in the next two subsections.

8.1.1 Planned Supplies

TRWD's existing water supplies and planned supplies are described in detail in Chapter 3 and include completion of the Cedar Creek Wetlands and remaining segments of the IPL. The combined yield of the existing water supplies and the planned supplies is referred to as the baseline supply. As shown in Figure 8.1, the combined firm yield of existing and planned supplies is projected to increase from 665,200 AFY in 2030 to 738,970 AFY in 2080. The arrows represent the projected water supply gap in firm yield to meet the 95 percent target of S3 demands during a repeat of the critical year of the drought (1956). As shown, TRWD will have a 36,000 AF firm yield gap in 2050 without any additional supply strategies in place beyond the already planned projects. The firm yield supply gap is estimated to increase to nearly 384,000 AFY by the year 2080.

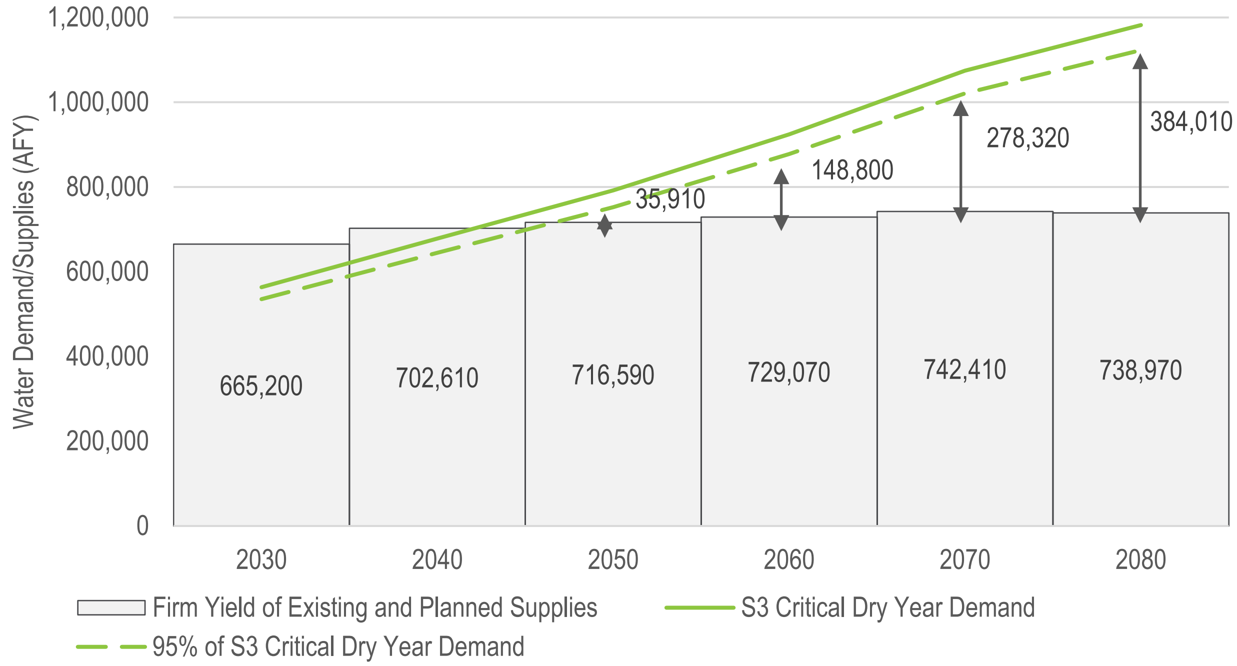


Figure 8.1 Projected Firm Yield Supply Gap with Existing and Already Planned New Supplies

8.1.2 No Regrets for Near-Term Implementation

As part of this IWSP Update, a total of 18 new water supply strategies were evaluated to supplement the planned supplies. The strategies are described in detail in Chapter 6. Three strategies were identified as No Regrets because of their supply reliability benefits, relatively low unit cost, and ease of implementation. Moreover, none of the No Regrets strategies involve construction of large infrastructure and can therefore be implemented independently of other strategies. The three No Regets strategies, including estimated firm yield, capital cost, and implementation timeline are summarized in Table 8.1. All portfolios described in Chapter 7 include these No Regrets strategies.

Table 8.1 No Regrets Strategies Summary

Project Name	Type	2080 Estimated Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost (2023 $M)
Advancing Conservation	Conservation	90,500 (average)	2029	2030	$750(1)
Cedar Creek and Richland-Chambers Unpermitted Firm Yield(2)	Operational Change	21,920	2027	2030	$252(2)
Bridgeport Reallocation	Operational Change	N/A	2027	2030	$0.25

Notes:
$M - million dollars; N/A - Not Applicable
(1) Conservation would be funded through TRWD's annual budget.
(2) The cost associated with the Cedar Creek and Richland-Chambers firm yield is the proportional cost of the second IPL to convey supply. Pumping optimization may allow for this supply to be conveyed without the need for the second IPL.

It should be noted that the No Regrets strategies may not provide the estimated firm yield in a consistent or predictable manner compared to most of the other strategies. However, all No Regrets strategies will help operationally to maximize efficient water use or provide water to where it is needed geographically. As shown in Table 8.1, all three No Regrets strategies are assumed to be online by 2030. By 2080, these No Regrets could collectively address approximately 29 percent of the supply gap, shown in Figure 8.1. Implementation of the No Regrets strategies should consider the following:

- **Advancing Conservation:**
  - This strategy is estimated to have the highest estimated yield of the No Regrets strategies with 90,500 AFY by the year 2080 (for average weather conditions), which represents a 10 percent reduction in water use. As water conservation measures would be implemented over time on an ongoing basis, it is assumed that the yield would gradually increase starting in 2030. As no permitting, design, or construction is needed for the Advancing Conservation strategy, the total implementation period is assumed to last throughout the 50-year period of analysis.
  - This strategy could be enhanced through regional partnerships by offering direct-to-consumer rebates, customer-to-city support, and education campaigns, for examples. A regional water conservation task force could offer a platform for ideas and programs and improve buy-in.
  - TRWD should focus on the lowest cost programs during early phases, such as targeting water loss and inefficiencies, conducting water use audits, and assuring metering practices are in place.
  - The next phase would be to offer infrastructure modernization and other incentives. This could include leak detection and repair programs, retrofits and rebates for appliances and fixtures, rebates and incentives for landscape efficiency improvements.
  - To further innovate in later phases, TRWD could offer grants for stormwater and greywater reuse projects, support AMI and other real-time customer incentives. Further, TRWD could work to improve local land use policies to institutionalize conservation metrics.
- **Cedar Creek and Richland-Chambers Unpermitted Firm Yield:**
  - This strategy involves an operational change by obtaining a permit for additional yield to increase permitted withdrawals from Cedar Creek and Richland-Chambers Reservoirs by a total of 22,000 AFY. This supply would only be used during extreme drought conditions. The implementation is estimated to take 1 year for planning and 2 years for permitting, for a combined implementation period of 3 years. Although no new dedicated infrastructure is part of the strategy, the second IPL could be needed to transmit the supply.
  - TRWD may opt to amend the Cedar Creek and Richland-Chambers water use permits as a part of a bigger strategy to improve system operations. Under this scenario, planning and permitting may take up to 10 years.
- **Bridgeport Reallocation:**
  - The strategy does not create new supplies and only represents an operational change that would leave more water in Lake Bridgeport for local users, where demand is anticipated to grow in coming years, by reducing releases to Eagle Mountain Lake. The implementation is estimated to take 1 year for planning and 2 years for permitting, for a combined implementation period of 3 years.
  - Through this study, no significant yield impact is anticipated from this change, so no additional study should be needed.

When the estimated firm yield associated with the three No Regrets strategies are added to the existing and already planned supplies, the projected supply gap is delayed from 2050 to 2060. Additionally, the supply gap in 2060 is reduced from roughly 150,000 AFY down to 80,000 AFY. As shown in Figure 8.2, the remaining supply gap in 2080 is approximately 272,000 AFY.

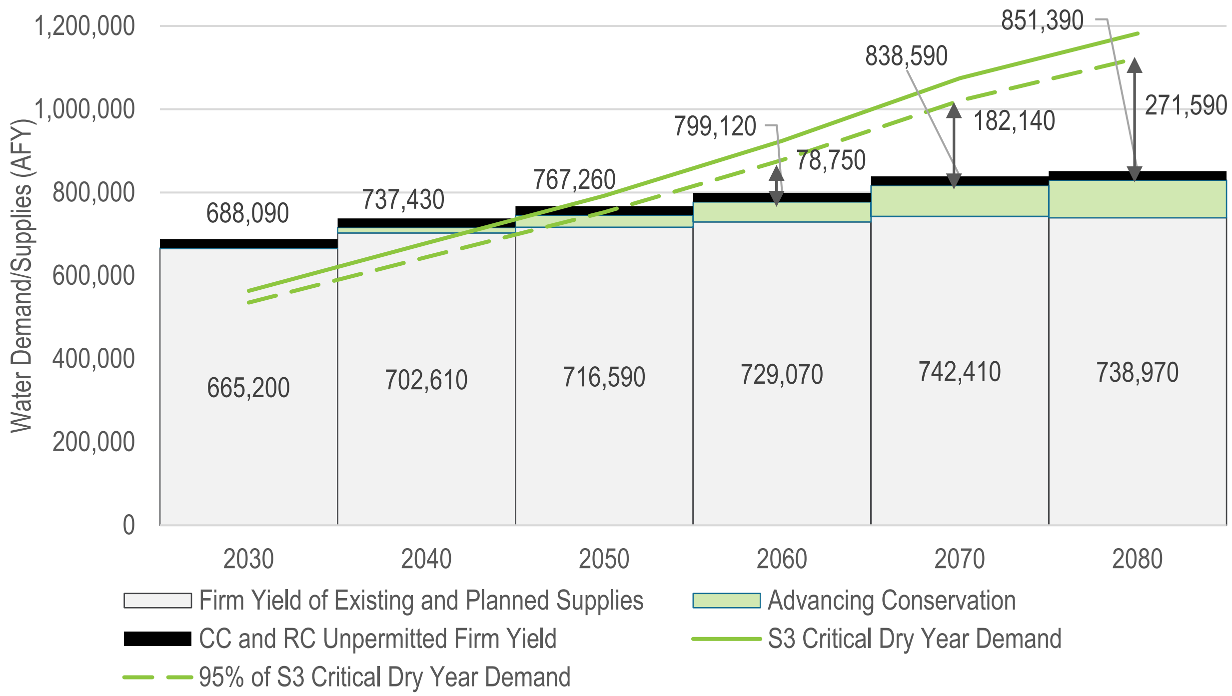


Figure 8.2 Projected Supply Gap with Existing, Planned, and No Regrets Strategies

8.1.3 Next Supply Development Phase

With both the baseline supplies and No Regrets strategies in place, additional new water supply is needed no later than 2060 to avoid a potential supply gap of 80,000 AFY, if demands reach the projected 2060 forecast of 924,000 AFY.

To address the 80,000 AFY supply gap prior to 2060, some combination of the other 15 supply strategies is needed years or decades earlier to have new supply sources online and operational by 2060. As there are many combinations of supply strategies possible, five supply portfolios were developed (see Chapter 7) after optimizing for supply, reliability, and cost using modeling tools. One portfolio includes only smaller strategies, and four of the five portfolios include one large supply project and multiple smaller capacity strategies. The following defines the categorization of small versus large strategies:

- **Large Supply Strategies:** Projects that have an estimated firm yield greater than 100,000 AFY and require major infrastructure, such as new reservoirs and long transmission pipelines (excluding intrasystem transmission needs).
- **Small Supply Strategies:** Projects that have an estimated firm yield of 100,000 AFY or less and do not require large water infrastructure to convey supplies to TRWD's existing system, which includes the Second Richland-Chambers Wetlands.

The large and small strategies are briefly summarized in the following sections to provide context for the discussion of the implementation by portfolio in Chapter 8.1.3.2. Figure 8.3 distinguishes between large and small strategies in pink and yellow, respectively, along with No Regrets strategies in grey and infrastructure only strategies in white. Of the 18 supply strategies evaluated, there are four large and 11 small supply strategies.

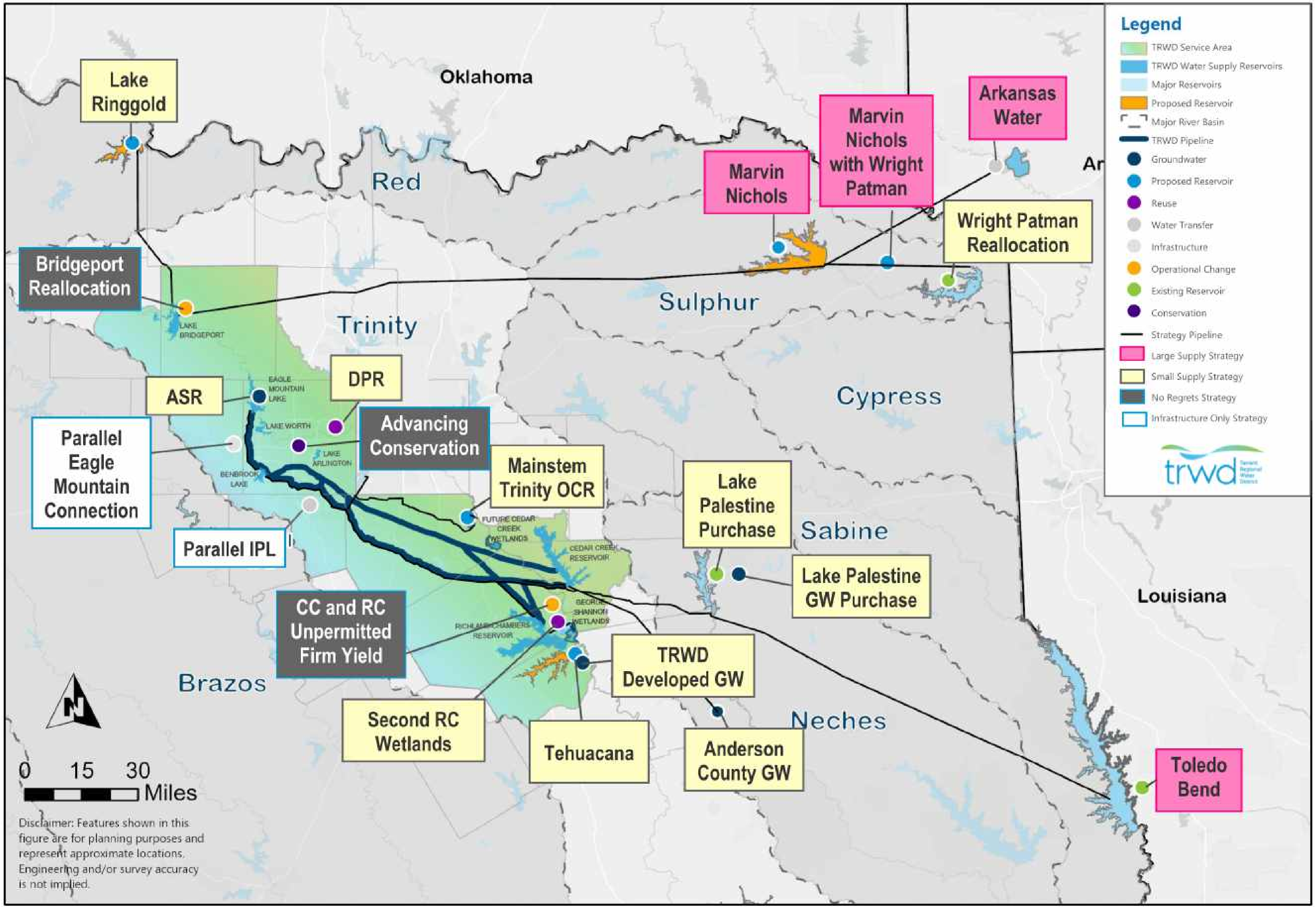


Figure 8.3 All Strategies Map Indicating No Regrets, Infrastructure Only, and Large and Small Supply Strategies

8.1.3.1 Small Supply Strategies for Mid-Term Implementation

The estimated firm yield, capital cost, unit cost with debt service, and implementation timeline of the eleven small supply strategies are listed in Table 8.2. As shown, all small supply strategies can theoretically be made operational before 2060 and would collectively add over 400,000 AFY of firm yield. Assuming implementation starts in 2026, all small strategies could theoretically be brought online between 2032 and 2051. The estimated unit costs vary significantly, ranging from $1,143 per AF (Second Richland-Chambers Wetlands) to $2,875 per AF (Tehuacana).

Table 8.2 Small Supply Strategies Summary

Supply Option	Firm Yield (AFY)	Implementation Timeline (years)	Earliest Year Operational(1)	General Service Area Location	Unit Cost with Debt Service ($/AF)	Capital Cost (2023 $M)
Lake Palestine Groundwater Purchase(2)	15,000	6	2032	East	$1,917	$286
Lake Palestine Purchase(2)(3)	30,000	9	2035	East	$1,507	$572
TRWD Developed Groundwater(2)	7,000	10	2036	East	$1,585	$152
Anderson County Groundwater(2)	42,000	10	2036	East	$2,359	$1,324
ASR	11,209	11	2037	North	$1,313	$285
Direct Potable Reuse	20,500	18	2044	Metro	$1,917	$395
Mainstem Trinity OCR(3)	57,169	20	2046	Metro	$1,260	$868
Second Richland-Chambers Wetlands(2)	100,890	20	2046	East	$1,143	$1,545
Wright Patman Reallocation	65,067	22	2048	North	$2,545	$2,456
Lake Ringgold	28,000	25	2051	North	$2,497	$1,038
Tehuacana(2)	27,514	25	2051	East	$2,875	$1,175

Notes:
(1) Earliest year operational assumes starting implementation steps in 2026.
(2) Costs include the proportional Parallel IPL to convey supply to the metroplex.
(3) Lake Palestine Purchase is assumed to take 9 years, and Mainstem Trinity OCR is assumed to take 20 years for implementation. In the Marvin Nichols portfolio, both are put on expedited timelines for implementation in 2030 for Lake Palestine Purchase and 2040 for Mainstem Trinity OCR.

The likelihood of all 11 small strategies being fully developed and brought online is very low and would not be ideal for future operations. Some of the smaller sources may be met with local resistance, permitting may not be successful, or TRWD may not be able to reach partnership agreements. Each new water source would require a separate permit and environmental review, increasing time and costs. Further, adding multiple small sources to the supply system would increase TRWD's operational complexity, as each small source would need its own monitoring, maintenance, permitting, accounting, and staffing.

8.1.3.2 Large Supply Strategies for Long-Term Implementation

The estimated firm yield, capital cost, unit cost with debt service, and implementation timeline of the four large supply strategies are listed in Table 8.3. The estimated firm yield of the large supply strategies ranges from approximately 110,000 to 260,000 AFY. All large supply strategies involve interbasin transfer permits, some level of regional partnerships, and the design and construction of major infrastructure and long-distance conveyance. The multiple steps required to plan, permit, design, and construct strategies in this category are expected to take decades, ranging from an estimated 18 years for Toledo Bend to up to 30 years for Marvin Nichols with and without Wright Patman.

Table 8.3 Large Supply Strategies Summary

Supply Option	Firm Yield (AFY)	Implementation Timeline (years)	Earliest Year Operational(1)	General Service Area Location	Unit Cost with Debt Service ($/AF)	Capital Cost (2023 $M)
Toledo Bend(2)	240,000	18	2044	East	$2,268	$7,279
Marvin Nichols	110,237	30	2056	North	$1,907	$3,062
Marvin Nichols with Wright Patman	141,800	30	2056	North	$2,262	$4,796
Arkansas Water	260,000	25	2051	North	$2,761	$10,240

Notes:
(1) Earliest year operational assumes starting implementation steps in 2026.
(2) Costs include the proportional Parallel IPL to convey supply to the metroplex.

The location of the supply strategy influences which other strategies are needed in a portfolio – if new supply strategies are implemented to the north of TRWD's system, the Parallel EM Connection is not needed over the period of analysis. If enough supply comes from the north such as with the Arkansas Water strategy, neither the Parallel EM Connection nor the Parallel IPL are needed. All other large supply strategies require a Parallel IPL to convey water supply, with the Toledo Bend strategy also needing the Parallel EM Connection.

Due to the complexity and scale of these large projects, the total capital cost of each strategy is significant, ranging from just over $3 billion to more than $10 billion. However, due to economies of scale, the unit cost of these options considering debt service is similar to most of the small strategies, ranging from $1,907 per AF (Marvin Nichols only) to almost $2,761 per AF (Arkansas Water). The larger strategies provide significant supply, and because each is located to the east of the Trinity Basin, these strategies offer TRWD more resilience to drought.

8.2 Implementation Planning by Portfolio

This IWSP Update includes five portfolios of water supply strategies for possible implementation. Each portfolio includes the planned supplies, No Regrets strategies, and combination of small supply strategies to meet reliability targets through 2050. One portfolio was compiled that includes a mix of smaller supply strategies. The other four portfolios include a single large supply strategy coming online in 2060. The large strategy functions as the "anchor" water supply in these portfolios.

The five portfolios are listed below with implementation considerations provided in the following sections.

- Mix of Smaller.
- Toledo Bend.
- Marvin Nichols.
- Marvin Nichols with Wright Patman.
- Arkansas.

8.2.1 Mix of Smaller Portfolio

The Mix of Smaller Portfolio includes eight strategies (excluding the No Regrets), which is the highest number of all portfolios. Based on the individual strategy information provided in Chapter 7, strategy firm yield, planning start year, operational start year, and capital cost are shown in Table 8.4. The Second Richland-Chambers Wetlands has the highest firm yield of just over 100,000 AFY. To convey this and other new supplies from the east to the north, both major transmission projects (the Parallel IPL and the Parallel EM Connection) are included in this portfolio. The Parallel IPL is needed to convey Second Richland-Chambers Wetlands supplies to Benbrook Lake, while the Parallel EM Connection is needed to bring supplies further north to Eagle Mountain Lake.

The Mix of Smaller Portfolio includes eight strategies plus the No Regrets. If even one of these strategies is unsuccessfully implemented, this would no longer be a viable portfolio.

Table 8.4 Mix of Smaller Supplies Portfolio Summary

Strategy Name	Type	Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost (2023 MM)(1)
No Regrets Strategies					
Advancing Conservation	Conservation	90,500	2029	2030	$750
Cedar Creek and Richland-Chambers Unpermitted Firm Yield	Operational Change	21,920	2027	2030	$0
Bridgeport Reallocation	Operational Change	--	2027	2030	$0
Portfolio Supply Strategies					
ASR	Groundwater	11,209	2039	2050	$285
Lake Palestine Purchase	Existing Reservoir	30,000	2041	2050	$215
TRWD Developed Groundwater	Groundwater	7,000	2040	2050	$68
Second Richland-Chambers Wetlands	Reuse	100,890	2040	2060	$337
Mainstem Trinity OCR	Proposed Reservoir	57,169	2040	2060	$641
Direct Potable Reuse	Reuse	20,500	2052	2070	$395
Anderson County Groundwater	Groundwater	42,000	2060	2070	$823
Tehuacana	Proposed Reservoir	27,514	2045	2070	$846

Strategy Name	Type	Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost (2023 MM)(1)
Portfolio Conveyance Strategies					
Parallel IPL	Transmission	N/A(2)	2052	2070	$3,424
Parallel EM Connection	Transmission	N/A(2)	2032	2050	$645
Totals(3)		**408,702**	**2027**	**2070**	**$8,430**

Notes:
(1) Capital costs are for external development only and do not include intrasystem conveyance to avoid double counting within this table.
(2) The conveyance capacity of the Parallel IPL and EM Connections is 350 mgd.
(3) Row shows sums of Firm Yield and Capital Cost, Minimum Planning Start Year, and Maximum Operational Start Year.

To meet the projected demands, implementation of the portfolio specific strategies (excluding the No Regrets) would need to begin as early as 2039 (ASR) with all operational by 2070. The implementation timeline of the portfolio strategies is estimated to range from 9 years (Lake Palestine Purchase) to as long as 25 years (Tehuacana). It should be noted that the firm yield of the Second Richland-Chambers Wetlands is estimated at 100,900 AFY, though its yield will likely start lower and grow over time depending on the timing of the reuse supply.

The estimated unit costs of the portfolio specific strategies range significantly from $1,260 per AF (Mainstream Trinity OCR) to as high as $2,875 per AF (Tehuacana). The total estimated capital cost of this portfolio is $8.43 billion in 2023 dollars.

If the strategies of the Mix of Smaller Portfolio are brought online by the operational start years listed in Table 8.4, the total firm yield of the water supply system would increase to 1,147,670 AFY, as shown in Figure 8.4. It should be noted that the water supply from each strategy is shown in the yield chart as immediately available when all implementation phases (planning, permitting, design, and construction) are completed, and new strategies come online only at the start of each decade. The combined yield of the strategies included in this portfolio exceed the demand target represented by the dashed line when combined with the firm yield of the baseline system.

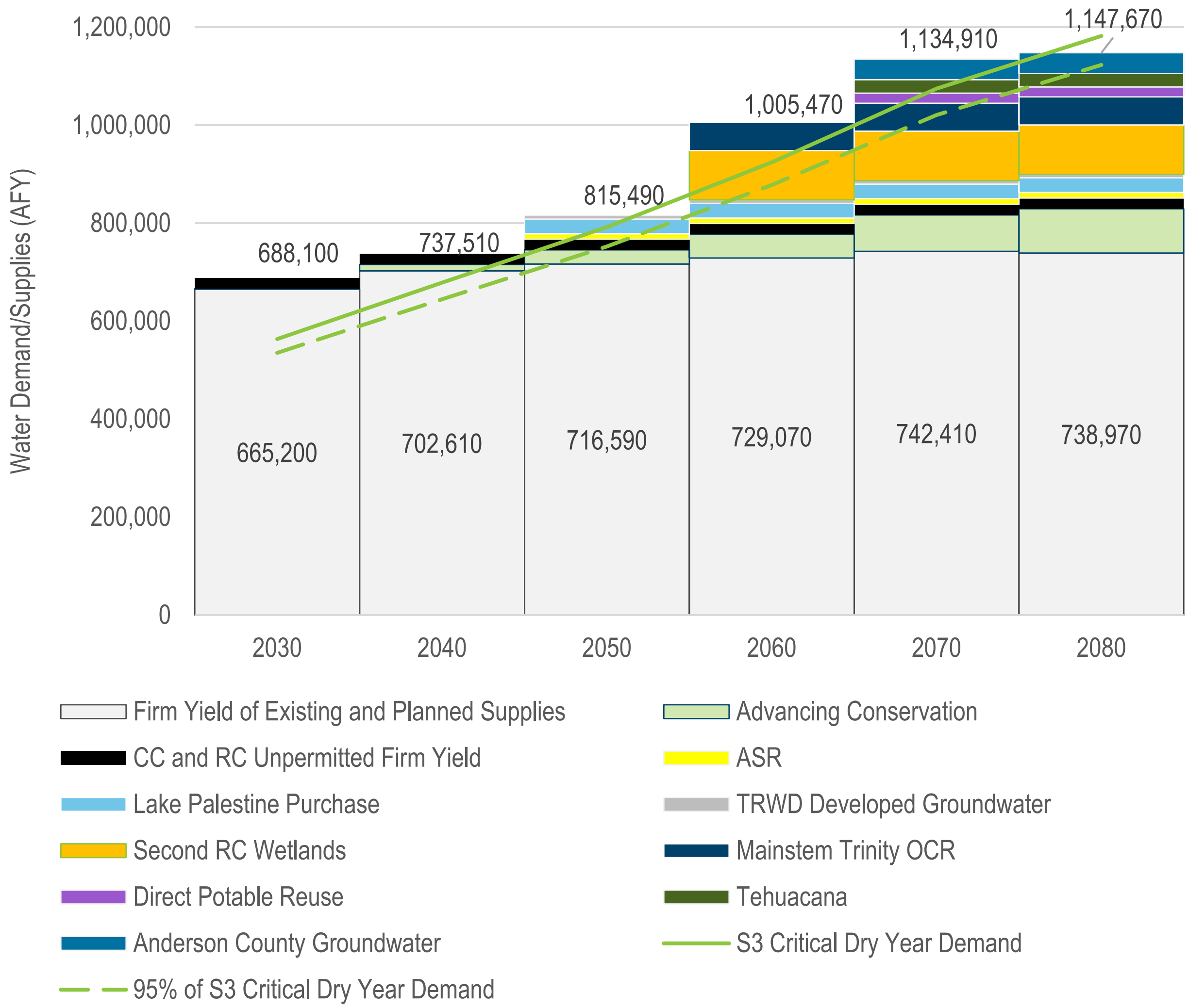


Figure 8.4 Projected Supply Against Gap with Mix of Smaller Portfolio

8.2.2 Toledo Bend Portfolio

The Toledo Bend Portfolio includes Toledo Bend as its large supply strategy, along with three other portfolio specific strategies (excluding the No Regrets). Based on the individual strategy information provided in Chapter 7, strategy firm yield, planning start year, operational start year, and capital cost are shown in Table 8.5. Toledo Bend has a firm yield of 240,000 AFY. To convey this and other new supplies from the east to the north, both major transmission projects (the Parallel IPL and the Parallel EM Connection) are included in this portfolio. The Parallel IPL is needed to convey supplies to Benbrook Lake, while the Parallel EM Connection is needed to bring supplies further north to Eagle Mountain Lake.

The Toledo Bend Portfolio offers a relatively predictable route towards achieving 2080 supply without the need to permit and construct any new reservoirs. Toledo Bend will require partnership agreements, interbasin transfer permits, and extensive conveyance and operation outside of TRWD's existing service area.

Table 8.5 Toledo Bend Portfolio Summary

Project Name	Type	Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost ($M)(1)
No Regrets Strategies					
Advancing Conservation	Conservation	90,500	2029	2030	$750
Cedar Creek and Richland-Chambers Unpermitted Firm Yield	Operational Change	21,920	2027	2030	$0
Bridgeport Reallocation	Operational Change	--	2027	2030	$0
Portfolio Supply Strategies					
Direct Potable Reuse	Reuse	20,500	2032	2050	$395
TRWD Developed Groundwater	Groundwater	7,000	2040	2050	$68
Lake Palestine Purchase	Existing Reservoir	30,000	2041	2050	$215
Toledo Bend Reservoir	Existing Reservoir	240,000	2042	2060	$4,418
Portfolio Conveyance Strategies					
Parallel IPL	Transmission	N/A(2)	2042	2060	$3,424
Parallel EM Connection	Transmission	N/A(2)	2042	2060	$645
Totals(3)		**409,920**	**2027**	**2060**	**$9,916**

Notes:
(1) Capital costs are for external development only and do not include intrasystem conveyance to avoid double counting within this table.
(2) The conveyance capacity of the Parallel IPL and EM Connections is 350 mgd.
(3) Row shows sums of Firm Yield and Capital Cost, Minimum Planning Start Year, and Maximum Operational Start Year.

To meet the projected demands, the portfolio specific strategies would need to start implementation as early as 2032 (Direct Potable Reuse) and should all be operational by 2060. The implementation timeline of the portfolio strategies is estimated to range from 9 years (Lake Palestine Purchase) to as much as 18 years (Direct Potable Reuse). The 2050 reliability is improved with Lake Palestine Purchase, TRWD Developed Groundwater, and Direct Potable Reuse strategies becoming operational by 2050. Toledo Bend provides a large supply starting in 2060, and no other supplies are needed beyond the planning horizon.

The estimated unit costs of the portfolio specific strategies range significantly from $1,507 per AF (Lake Palestine Purchase) to as much as $2,268 per AF (Toledo Bend). The total estimated capital cost of this portfolio is $9.9 billion in 2023 dollars.

If the strategies of the Toledo Bend Portfolio are brought online by the operational start years listed in Table 8.5, the firm yield of the system would increase to 1,148,870 AFY, as depicted in Figure 8.5. It should be noted that the water supply from each strategy is shown in the yield chart as immediately available when all implementation phases (planning, permitting, design, and construction) are completed, and new strategies come online only at the start of each decade.

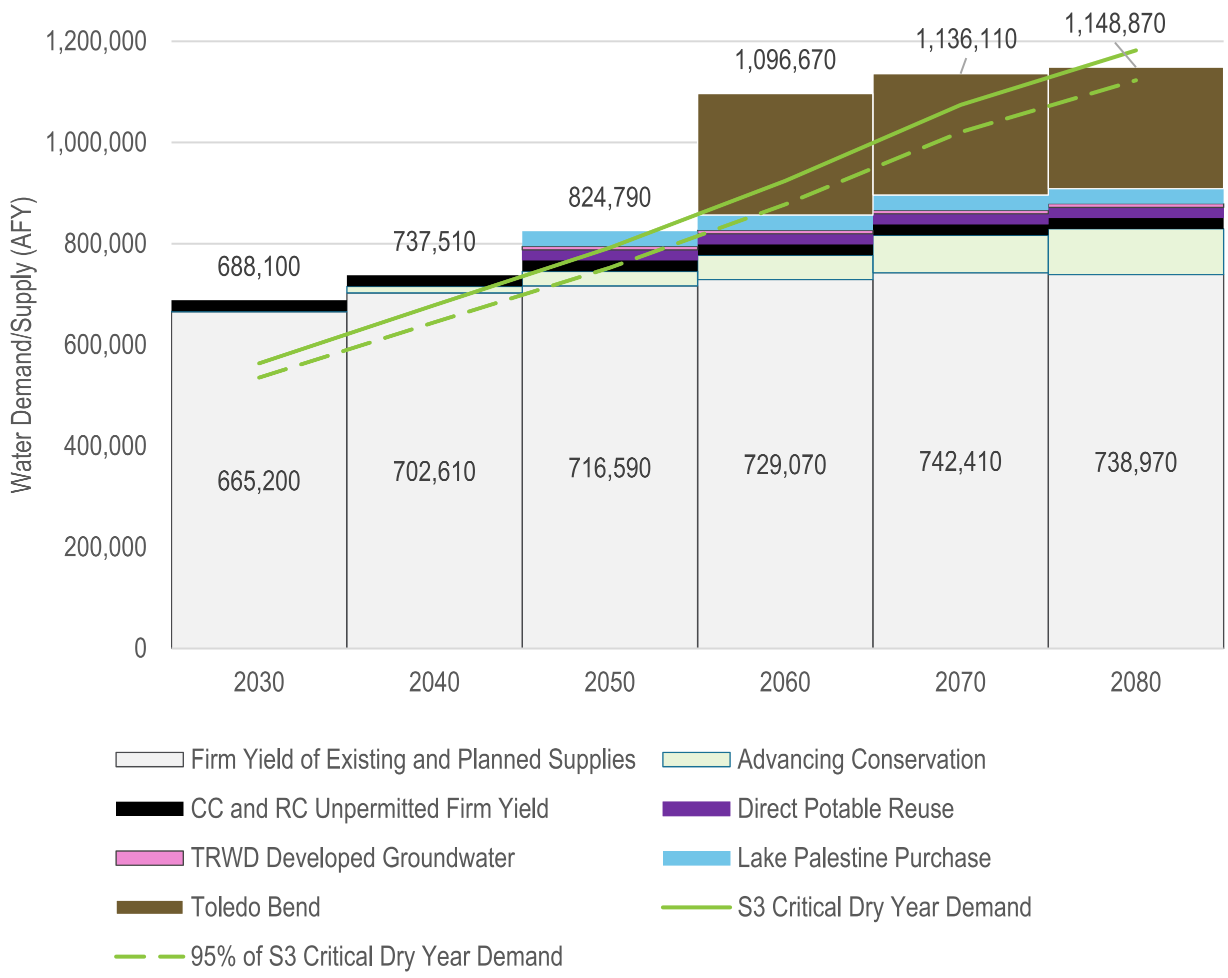


Figure 8.5 Projected Supply Against Gap with Toledo Bend Portfolio

8.2.3 Marvin Nichols Portfolio

The Marvin Nichols Portfolio includes Marvin Nichols as its large supply strategy, along with 5 other portfolio specific strategies (excluding the No Regrets). Based on the individual strategy information provided in Chapter 7, strategy firm yield, planning start year, operational start year, and capital cost are shown in Table 8.6. Marvin Nichols adds a firm yield of just over 110,000 AFY. Marvin Nichols provides water supply to the northern portion of TRWD's system, so the Parallel EM Connection transmission strategy is not needed. This portfolio includes the Parallel IPL transmission strategy, which is needed to convey Second Richland-Chambers Wetlands supplies to the metroplex.

The Marvin Nichols Portfolio provides a large northern supply that more efficiently conveys supplies to where they are needed. However, construction of a new reservoir is inherently uncertainty.

Table 8.6 Marvin Nichols Portfolio Summary

Project Name	Type	Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost ($M)(1)
No Regrets Strategies					
Advancing Conservation	Conservation	90,500	2029	2030	$750
Cedar Creek and Richland-Chambers Unpermitted Firm Yield	Operational Change	21,920	2027	2030	$0
Bridgeport Reallocation	Operational Change	--	2027	2030	$0
Portfolio Supply Strategies					
Lake Palestine Purchase(2)	Existing Reservoir	30,000	2026	2030	$215
Mainstem Trinity OCR(2)	Proposed Reservoir	57,169	2026	2040	$641
ASR	Groundwater	11,209	2029	2040	$285
TRWD Developed Groundwater	Groundwater	7,000	2040	2050	$68
Marvin Nichols	Proposed Reservoir	110,237	2030	2060	$3,062
Second Richland-Chambers Wetlands	Reuse	100,890	2050	2070	$1,143
Portfolio Conveyance Strategies					
Parallel IPL	Transmission	N/A(3)	2042	2060	$3,424
Totals(4)		**428,925**	**2026**	**2070**	**$8,784**

Notes:
(1) Capital costs are for external development only and do not include intrasystem conveyance to avoid double counting within this table.
(2) Lake Palestine Purchase requires an expedited implementation timeline of 4 years (instead of nine) to be implemented by 2030, and Mainstem Trinity OCR requires an expedited implementation timeline of 14 years (instead of 20) to be implemented by 2040. Planning will need to start immediately for both and may require additional staff resources.
(3) The conveyance capacity of the Parallel IPL is 350 mgd.
(4) Row shows sums of Firm Yield and Capital Cost, Minimum Planning Start Year, and Maximum Operational Start Year.

To meet the projected demands, the portfolio specific strategies would need to start implementation as early as 2026 and should all be operational by 2070. The implementation timeline of the portfolio strategies is estimated to range from 4 years (Lake Palestine Purchase) to as much as 30 years (Marvin Nichols Reservoir). In this portfolio, Lake Palestine Purchase requires implementation on a highly expedited timeline for implementation in 2030. ASR and Mainstem Trinity OCR both come online in 2040, with Mainstem Trinity OCR requiring an expedited timeline for implementation. TRWD Developed Groundwater provides additional low-risk local supply reliability and comes online in 2050. Marvin Nichols comes online in 2060, and Second Richland-Chambers Wetlands becomes operational in 2070 and maximizes the return flows available from the Marvin Nichols permit.

The estimated unit costs with debt service of the portfolio specific strategies range significantly from $1,143 per AF (Second Richland-Chambers Wetlands) to as much as $1,907 per AF (Marvin Nichols Reservoir). The total estimated capital cost of this portfolio is $8.8 billion in 2023 dollars.

If the strategies of the Marvin Nichols portfolio are brought online by the operational start years listed in Table 8.6, the firm yield of the system would increase to 1,167,870 AFY, as depicted in Figure 8.6. It should be noted that the water supply from each strategy is shown in the yield chart as immediately available when all implementation phases (planning, permitting, design, and construction) are completed, and new strategies come online only at the start of each decade.

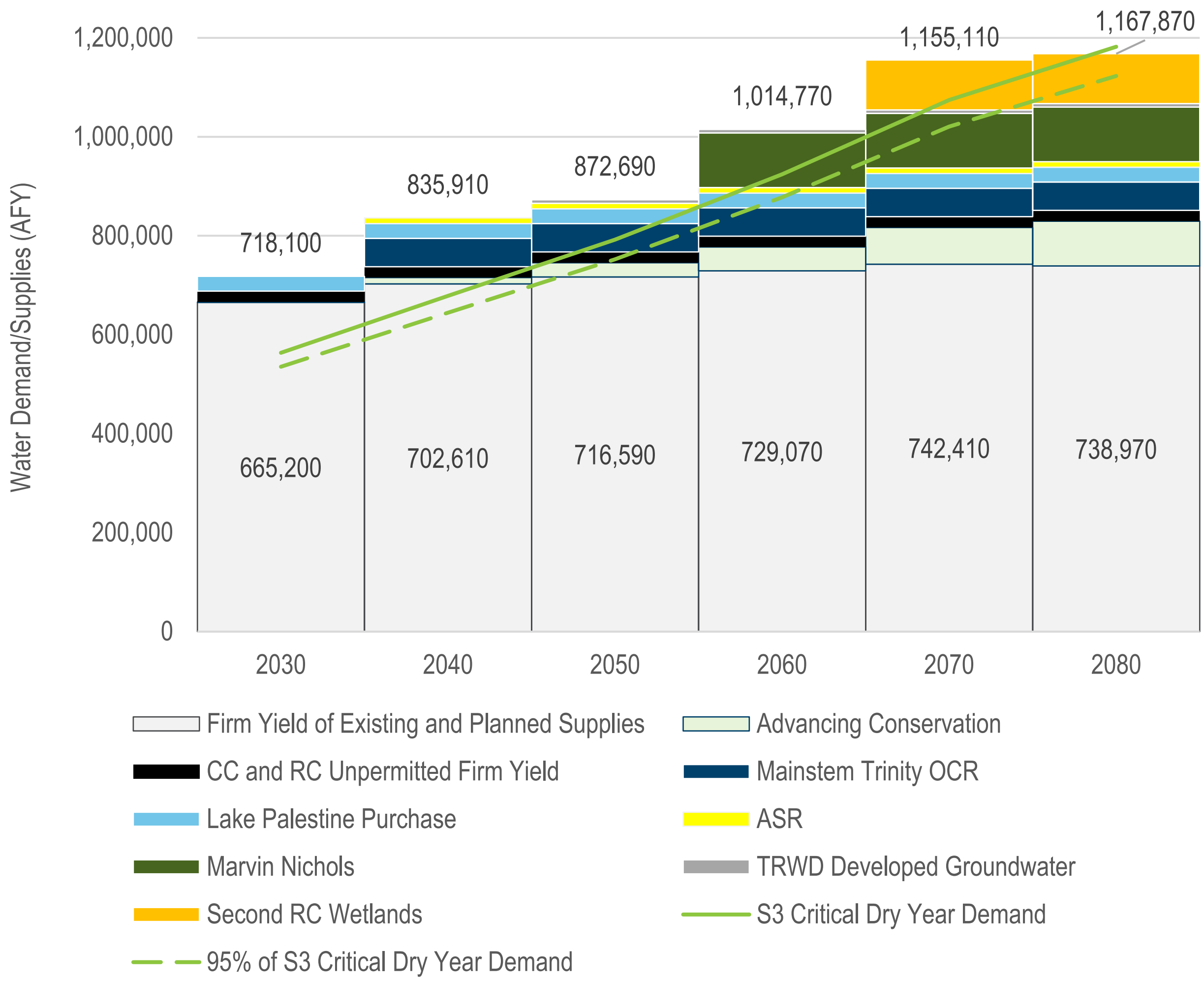


Figure 8.6 Projected Supply Against Gap with Marvin Nichols Portfolio

8.2.4 Marvin Nichols with Wright Patman Portfolio

The Marvin Nichols with Wright Patman Portfolio includes Marvin Nichols with Wright Patman as its large supply strategy, along with three other portfolio specific strategies (excluding the No Regrets). Based on the individual strategy information provided in Chapter 7, strategy firm yield, planning start year, operational start year, and capital cost are shown in Table 8.7. Marvin Nichols with Wright Patman Reservoir is the strategy with the highest firm yield of nearly 142,000 AFY, water supply to customers in the north, so the Parallel EM Connection transmission strategy is not needed. This portfolio includes the Parallel IPL transmission strategy, which is needed to convey Second Richland-Chambers Wetlands supplies to the metroplex.

The Marvin Nichols with Wright Patman Portfolio provides a large northern supply that more efficiently conveys supplies to where it is needed. However, construction of a new reservoir and USACE reallocation approval are both inherently uncertainty.

Table 8.7 Marvin Nichols with Wright Patman Portfolio Summary

Project Name	Type	Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost ($M)(1)
No Regrets Strategies					
Advancing Conservation	Conservation	90,500	2029	2030	$750
Cedar Creek and Richland-Chambers Unpermitted Firm Yield	Operational Change	21,920	2027	2030	$0
Bridgeport Reallocation	Operational Change	--	2027	2030	$0
Portfolio Supply Strategies					
Lake Palestine Purchase	Existing Reservoir	30,000	2041	2050	$215
Mainstem Trinity OCR	Proposed Reservoir	57,169	2040	2060	$641
Marvin Nichols with Wright Patman	Proposed Reservoir	141,800	2030	2060	$4,796
Second Richland-Chambers Wetlands	Reuse	100,890	2050	2070	$337
Portfolio Conveyance Strategies					
Parallel IPL	Transmission	N/A(2)	2042	2060	$3,424
Totals(3)		**442,278**	**2027**	**2070**	**$10,164**

Notes:
(1) Capital costs are for external development only and do not include intrasystem conveyance to avoid double counting within this table.
(2) The conveyance capacity of the Parallel IPL is 350 mgd.
(3) Row shows sums of Firm Yield and Capital Cost, Minimum Planning Start Year, and Maximum Operational Start Year.

To meet the projected demands, the portfolio specific strategies would need to start implementation as early as 2030 (Marvin Nichols with Wright Patman Reservoir) and should all be operational by 2070. The implementation timeline of the portfolio strategies is estimated to range from 9 years (Lake Palestine Purchase) to as much as 30 years (Marvin Nichols and Wright Patman Reservoir).

The estimated unit costs with debt service of the portfolio specific strategies range significantly from $1,143 per AF (Second Richland-Chambers Wetlands) to as much as $2,262 per AF (Marvin Nichols and Wright Patman Reservoir). The total estimated capital cost of this portfolio is $10.164 billion in 2023 dollars.

If the strategies of the Marvin Nichols and Wright Patman Portfolio are brought online by the operational start years listed in Table 8.7, the firm yield of the system would increase to 1,181,270 AFY, as depicted in Figure 8.7. It should be noted that the water supply from each strategy is shown in the yield chart as immediately available when all implementation phases (planning, permitting, design, and construction) are completed, and new strategies come online only at the start of each decade.

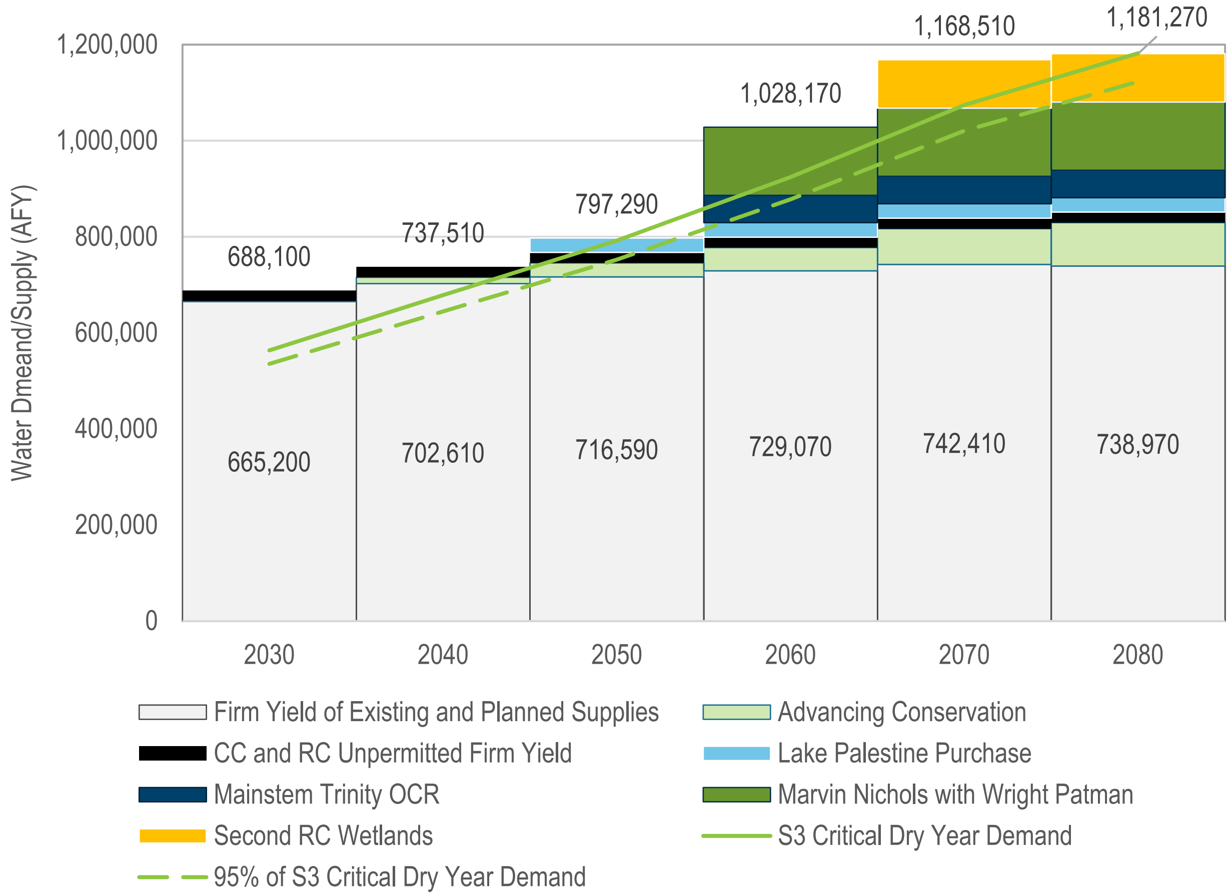


Figure 8.7 Projected Supply Against Gap with Marvin Nichols with Wright Patman Portfolio

8.2.5 Arkansas Water Portfolio

The Arkansas Portfolio includes Arkansas Water as its large supply strategy, along with two other portfolio specific strategies (excluding the No Regrets). This portfolio includes the fewest number of supply strategies, which provides operational and management benefits. Based on the individual strategy information provided in Chapter 7, strategy firm yield, planning start year, operational start year, and capital cost are shown in Table 8.8. Arkansas Water supply provides a firm yield of 260,000 AFY, more than any other single strategy. This portfolio does not require any additional transmission, as Arkansas Water would provide a significant northern supply that can reach water users in the north and metroplex, and the existing IPL has enough capacity to convey smaller new supplies coming from the east.

The Arkansas Portfolio provides a large northern source that efficiently conveys supply to where it is needed. With the large supply, only two other portfolio-specific strategies are needed. Although Arkansas has set up a framework for out-of-state transfer, there is no precedent for a transfer of this magnitude, and the viability is uncertain.

Table 8.8 Arkansas Water Portfolio Summary

Project Name	Type	Firm Yield (AFY)	Planning Start Year	Operational Start Year	Capital Cost ($M)[(1)]
No Regrets Strategies					
Advancing Conservation	Conservation	90,500	2029	2030	$750
Cedar Creek and Richland-Chambers Unpermitted Firm Yield	Operational Change	21,920	2027	2030	$0
Bridgeport Reallocation	Operational Change	-	2027	2030	$0
Portfolio Supply Strategies					
Lake Palestine Groundwater Purchase	Groundwater	15,000	2044	2050	$107
Anderson County Groundwater	Groundwater	42,000	2040	2050	$823
Arkansas Water	Water Transfer	260,000	2035	2060	$10,240
Totals[(2)]		**429,420**	**2027**	**2060**	**$11,921**

Notes:
(1) Capital costs are for external development only and do not include intrasystem conveyance from the Parallel IPL, as this portfolio met reliability targets without it.
(2) Row shows sums of Firm Yield and Capital Cost, Minimum Planning Start Year, and Maximum Operational Start Year.

To meet the projected demands, the portfolio specific strategies would need to start implementation as early as 2035 (Arkansas Water) and should all be operational by 2060. The implementation timeline of the portfolio strategies is estimated to range from 6 years (Lake Palestine Groundwater Purchase) to as long as 25 years (Arkansas Water).

The estimated unit costs with debt service of the portfolio specific strategies range significantly from $1,917 per AF (Lake Palestine Groundwater Purchase) to as much as $2,761 per AF (Arkansas Water). The total estimated capital cost of this portfolio is $11.9 billion in 2023 dollars.

If the strategies of the Arkansas Water Portfolio are brought online by the operational start years listed in Table 8.8, the firm yield of the system would increase to 1,168,370 AFY, as depicted Figure 8.8. It should be noted that the water supply from each strategy is shown in the yield chart as immediately available when all implementation phases (planning, permitting, design, and construction) are completed, and new strategies come online only at the start of each decade.

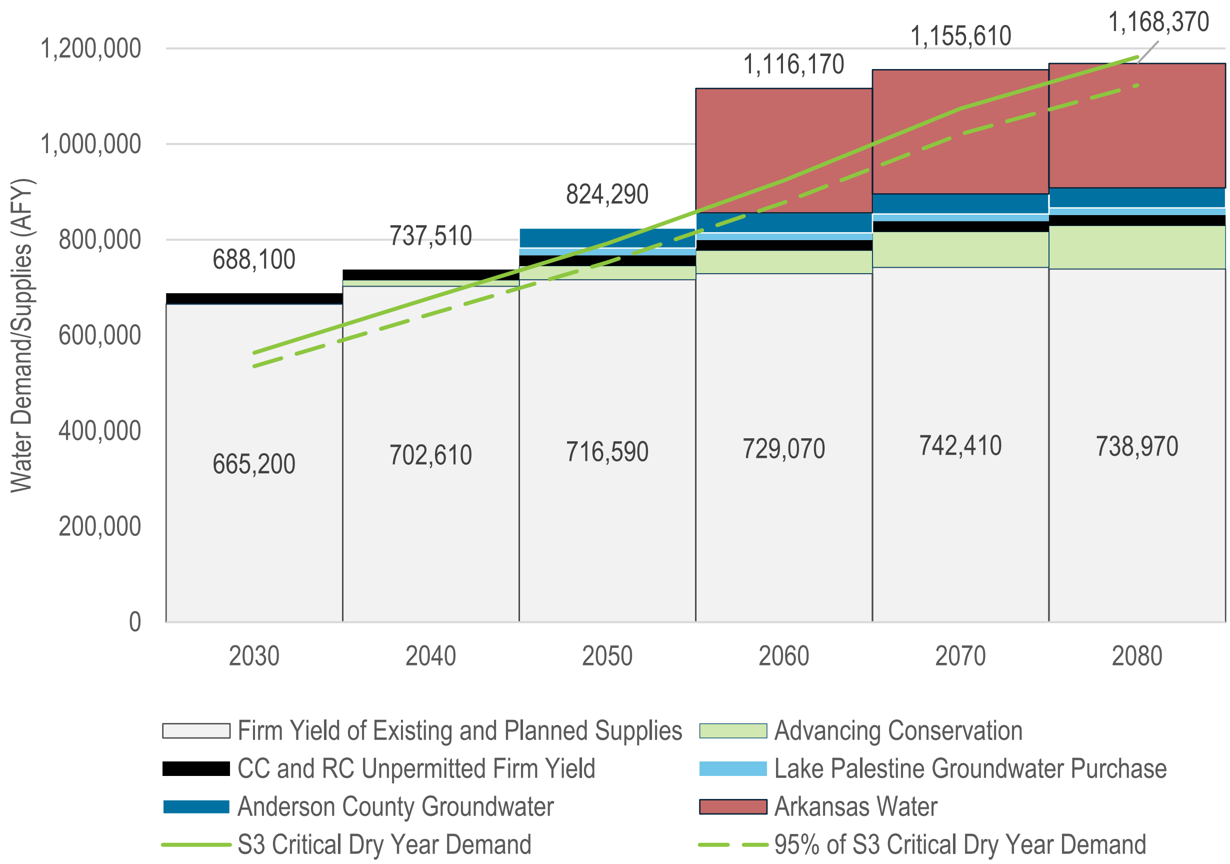


Figure 8.8 Projected Supply Against Gap with Arkansas Portfolio

8.2.6 Summary

The five portfolios are summarized in Table 8.9. These vary in capital investment from $8.4 to $11.9 billion, if built today. Portfolio planning must start within the next 2 to 3 years.

Table 8.9 Portfolio Summary

Portfolio Name	Count of Strategies	Total Firm Yield (AFY)	Planning Start Year	Latest Operational Start Year	Capital Cost (2023 $M)
Mix of Smaller	13	408,702	2027	2070	$8,430
Toledo Bend	9	409,920	2027	2060	$9,916
Marvin Nichols	10	428,925	2026	2070	$8,784
Marvin Nichols with Wright Patman	8	442,278	2027	2070	$10,164
Arkansas Water	6	429,420	2027	2060	$11,921

8.3 Trigger-Based Implementation

In the coming years, TRWD can continue implementing already planned projects and start with the implementation of No Regrets strategies. It can also start early planning steps for larger supplies that take decades to develop and implement. As many of the largest projects have the greatest uncertainties (e.g., permitting, costs), extensive modeling and feasibility studies must be started decades in advance in close collaboration with regional partners to allow sufficient time to identify other feasible projects if the large supply strategy hits a point where it will not be viable. Decision trees help outline key implementation triggers for the various potential future water supply strategies included in the portfolio.

8.3.1 All Supplies Planning

Figure 8.9 illustrates when TRWD needs to select the next large water supply strategy and the latest year to begin planning to bring the project online by 2060, considering the total implementation process of planning, permitting, design, and construction. By 2060, either a large supply option is needed or several smaller after implementation of the already planned projects and the No Regrets supply strategies.

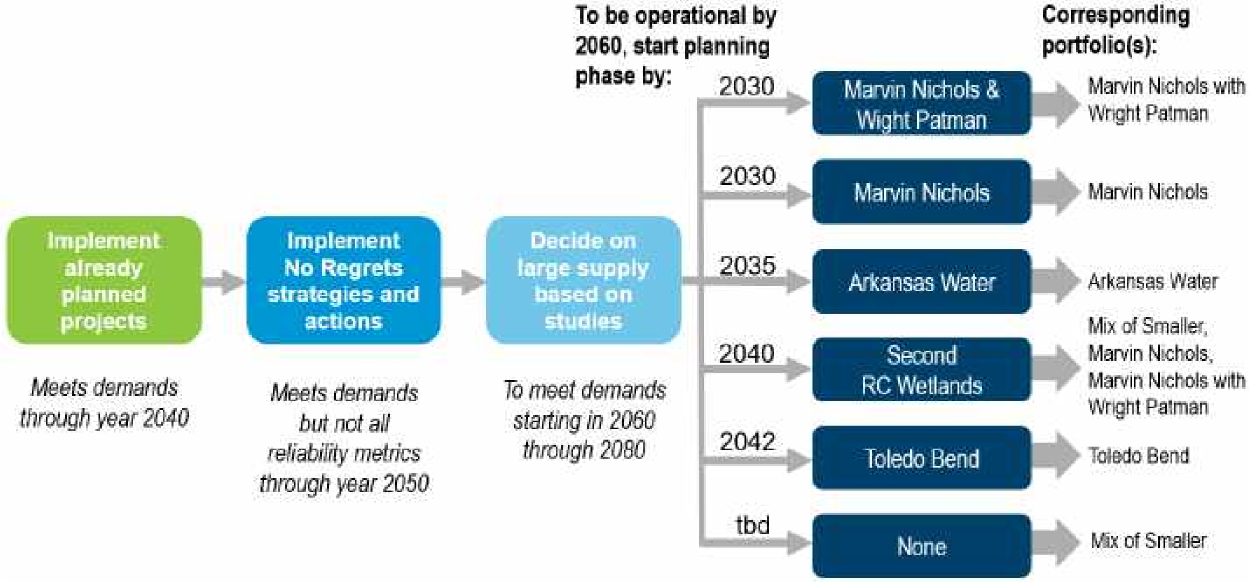


Figure 8.9 Timing Triggers to Select between Large Supply Strategies

Several of the larger strategies require initiation of planning as early as 2030. Toledo Bend planning can start as late as 2042, although TRWD would have to complete feasibility studies before then to ensure no roadblocks will be experienced. **Therefore, TRWD and its potential regional partners have no more than 5 years (from 2025 until 2030) to explore the large supply strategies in more detail, resolve uncertainties, explore political and partnership support, and gather sufficient information to select the large strategy to move forward**. Many of these large supply options have been studied for decades, while others are relatively new ideas. This near-term timeframe should focus on filling any critical information gaps, detailed system integration studies, and working towards decisive action.

There are many interim decision points along the way and a wide variety of relevant circumstances can change over time. Hence, water resources planning decisions are typically not linear or single-variable processes and should therefore be adaptive. To provide guidance, trigger-based planning can be useful as it offers a process for deciding which supplies to move forward with based on evolving conditions, such as changes in water demands, drought conditions, water supply permits, actions of other suppliers, groundwater aquifer levels, contractual agreements, state driven initiatives, and regulations, to name a few.

A trigger-based implementation plan is characterized by signposts and triggers. Signposts are markers that provide early warning indicators that a future condition (e.g., drought or demand surge) may be approaching but does not yet require immediate action. Triggers represent conditions that require a response. More specifically, triggers are defined as a predefined, measurable threshold or event that, once reached or exceeded, prompts a specific action or decision in the implementation plan.

A general trigger-based implementation process is depicted in Figure 8.10. This schematic is an intentional oversimplification of all the decisions that will need to be made to focus on the key triggers, which are selection of a large supply, selection of small supply, and demand/supply balance. As shown, the No Regrets strategies are independent of any triggers and can be implemented in parallel with the additional feasibility studies around the large supply options until 2030 for some options. The decision on when and which other small strategies are implemented also impacts the timeline of selecting the next large supply. Based on combined capacity and under the high demand scenario, it is possible to meet the projected demands through 2080 without adding any of the four large supply strategies. However, it is likely that one or more of the smaller strategies will have a fatal flaw or unforeseen condition that would hinder implementation, so relying on only small strategies would be overly risky. The actual demand growth and success of the water conservation program will determine the timing of additional supply needs. Once sufficient additional supplies are in place to meet the future forecasted demands, the decision tree comes to an end, or at least a temporary pause until the next planning cycle as represented by the grey box.

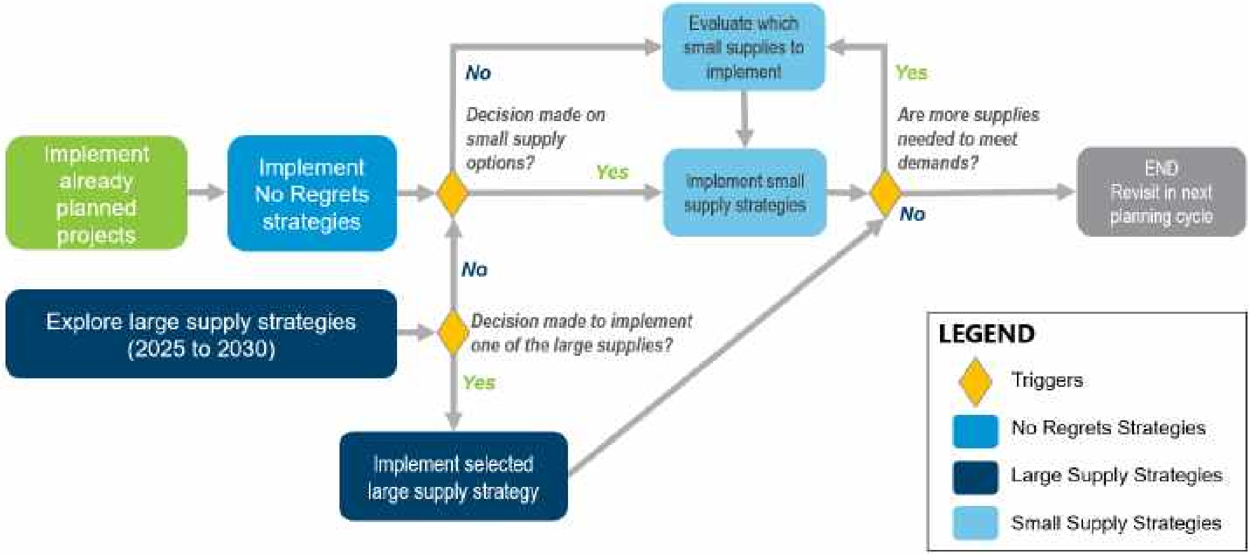


Figure 8.10 Trigger-Based Implementation for All Strategy Planning

8.3.2 Strategy Specific Planning

To help TRWD with the decision-making process for each of the large supplies plus the Second Richland-Chambers Wetlands, the key triggers for each of these options were identified. Simplified trigger-based implementation roadmaps are provided as follows.

8.3.2.1 Second Richland-Chambers Wetlands

The Second Richland-Chambers Wetlands provides over 100,000 AFY in firm yield and is estimated to require 20 years for implementation. The Second Richland-Chambers Wetlands is included in three of the five portfolios, namely the Marvin Nichols, Marvin Nichols with Wright Patman, and Mix of Smaller portfolios. Based on the timing within the portfolios, the earliest possible and assumed implementation timeline are compared side-by-side in Figure 8.11. The total estimated implementation duration of 20 years includes 6 years for planning, 5 years for permitting, and 9 years for design and construction. Hence, the earliest possible completion if this process is initiated in 2026 would be 2045.

		2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	2051-2055	2056-2060	2061-2065	2066-2070	2071-2075	2076-2080
Earliest Start		Plan	Permit	Construct	Construct	Operational in 2046						
Portfolio	Mix of Smaller				Plan	Permit	Construct	Construct	Operational in 2060			
	Marvin Nichols				Plan	Permit	Construct	Construct	Operational in 2060			
	Marvin Nichols w/ Wright Patman						Plan	Permit	Construct	Construct	Operational in 2070	

Figure 8.11 Implementation Timeline Options for Second Richland-Chambers Wetlands

As shown through the portfolio development and variation in temporal placement, TRWD has flexibility around the Second Richland-Chambers Wetlands. If additional return flows are secured early, either through direct purchase from another supplier, through a system permit approach, negotiations on the Trinity River return flows, or from development of a new supply strategy that produces return flows, the Second Richland-Chambers Wetlands can be developed to maximize these newly procured flows. The Second Richland-Chambers Wetlands can also be paired with a large, out-of-basin supply source later in the planning horizon to maximize the newly available return flows and provide a supply source that can grow alongside demands. Additional conveyance capacity is likely needed with this strategy and increases the capital and O&M costs.

Some of the near-term implementation action items to further explore this strategy include:

1. Conduct a detailed feasibility study to confirm the assimilation capacity of Richland-Chambers Reservoir, considering the balance between water supply goals and water quality impacts at the reservoir.
2. Explore sources of return flows. TRWD has a number of avenues for procurement of return flows that would dictate timing of when the wetlands would come online.
3. Conduct feasibility study for potential siting locations.
4. Acquire property for the wetlands.

Many of these early steps are inexpensive and can either rule out, indicate delay, or foster early implementation of the strategy. The potential sequence of how these triggers could play out to either decide to implement this strategy (dark blue box) or be routed to explore other options (grey box) is schematically depicted in Figure 8.12. Once the assimilation capacity of the reservoir is confirmed and sufficient return flows are identified to make this project feasible, the more detailed siting investigation and potential land purchase would be triggered.

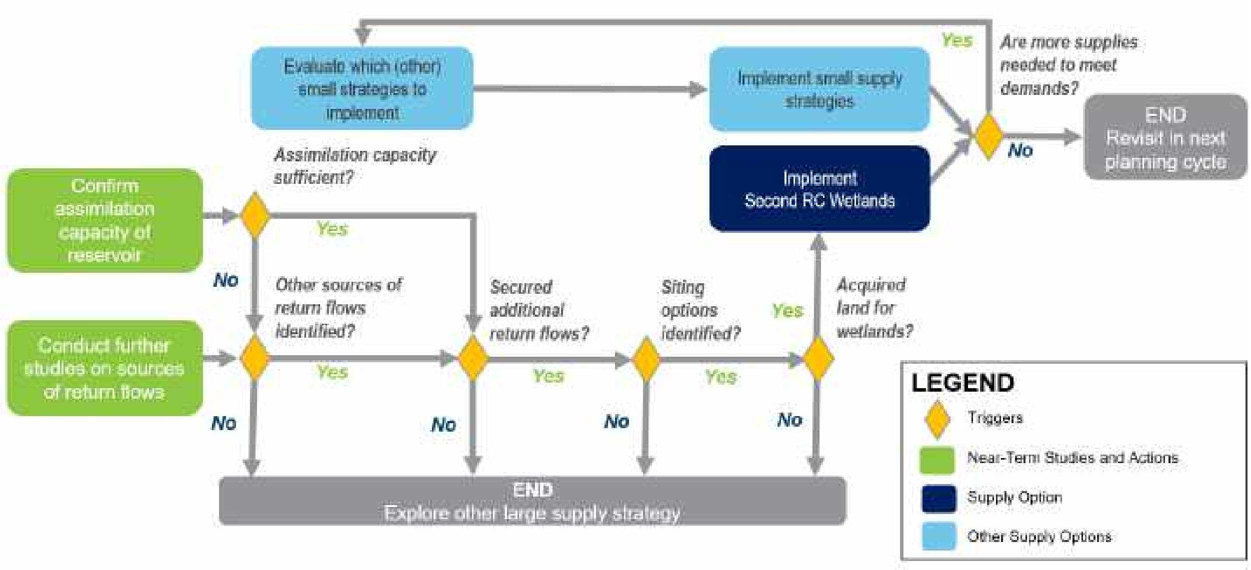


Figure 8.12 Trigger-Based Implementation for Second Richland-Chambers Wetlands

8.3.2.2 Toledo Bend

Under the IWSP Update assumptions, the Toledo Bend strategy would bring 240,000 AFY in firm yield to TRWD's system. As over 1.2 million AFY is available in Toledo Bend Reservoir for water supply, this strategy is scalable and could be phased. The IWSP Update assumed one regional partnership, although many configurations of this strategy are possible with more partners. More cost-effective options may be uncovered. Further, the return flows could be paired with the Second Richland-Chambers Wetland beyond the 2080 horizon to provide supply into the next century.

Acknowledging that there are many triggers involved in the planning, permitting, and construction process to implement the Toledo Bend strategy, the following key implementation triggers were identified:

- Successfully negotiating a partnership agreement with DWU, NTMWD, and/or other regional partner(s).
- Conducting additional feasibility and/or environmental studies to confirm detailed costs and routing.
- Obtaining an interbasin transfer permit from the Sabine to the Trinity River basin.
- Negotiating a contract with Sabine River Authority, including purchase cost.

The potential sequence of how these triggers could play out to either decide to implement this strategy (dark blue box) or be routed to explore other options (grey box) is schematically depicted in Figure 8.13.

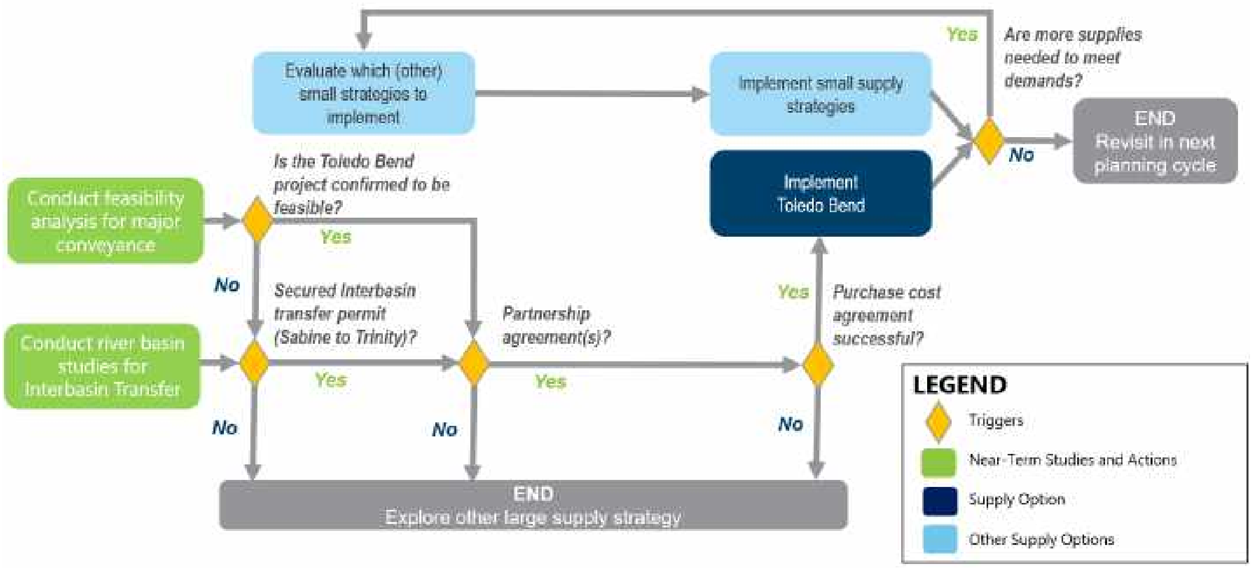


Figure 8.13 Trigger-Based Implementation for Toledo Bend

As shown in Figure 8.14, the total estimated implementation duration of this strategy is 18 years, which includes 3 years for planning, 5 years for permitting, and 10 years for design and construction. The earliest possible completion if this process is initiated in 2026 would be 2044. However, the Toledo Bend project is not assumed to be operational until 2060 in the Toledo Bend portfolio, with a corresponding planning phase starting in 2042. This timing is due to the need for the large supply as demand outpaces the baseline system supplies.

	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	2051-2055	2056-2060	2061-2065	2066-2070	2071-2075	2076-2080
Earliest Start	Plan	Permit	Construct	Operational in 2044							
Toledo Bend Portfolio				Plan	Permit	Construct	Operational in 2060				

Figure 8.14 Implementation Timeline for Toledo Bend

Toledo Bend, as modeled within the study, showed operational limitations. Should TRWD further advance Toledo Bend as a strategy, operations and integration would need to be studied and optimized to consider the new supply, higher demand levels, and storage needs.

Toledo Bend has been a strategy for water suppliers in Region C since as early as 2006.[1] There may be alternatives to Toledo Bend that have not yet been considered from a larger Trinity River Basin perspective. For example, Toledo Bend is only 90 miles from Lake Livingston and the terrain between the lakes may be more manageable for large-scale pipeline construction. An agreement could be sought between upper and lower Trinity users to swap Toledo Bend conveyance to the lower Trinity basin in exchange for renegotiation of the Lake Livingston agreement (described in Chapter 3.2.6).

[1]https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0704830688_RegionC/ToledoBendcoordination_techmemo.pdf?d=24299.70000000298

8.3.2.3 Marvin Nichols

The Marvin Nichols strategy was estimated at 110,000 AFY in firm yield delivered to Lake Bridgeport. This strategy was evaluated as a partnership, with TRWD included as one of five regional partners. Other partnership configurations are possible, with TRWD having a larger share of the yield.

Acknowledging that there are many triggers involved in the planning, permitting, and construction process to implement the Marvin Nichols project, the following key implementation triggers were identified for this large capacity supply strategy:

- Successfully negotiating partnership agreement(s) with regional partner(s).
- Obtaining a water rights permit.
- Obtaining a Section 404 USACE permit.
- Obtaining an interbasin transfer permit from the Sulphur to the Trinity basin.
- Acquisition of approximately 72,000 acres of land to construct the reservoir plus mitigation acreage of unknown quantities will also be required.
- Securing funding for the large-scale project.

The potential sequence of these triggers and pathway to implementing Marvin Nichols is shown (dark blue box) schematically in Figure 8.15.

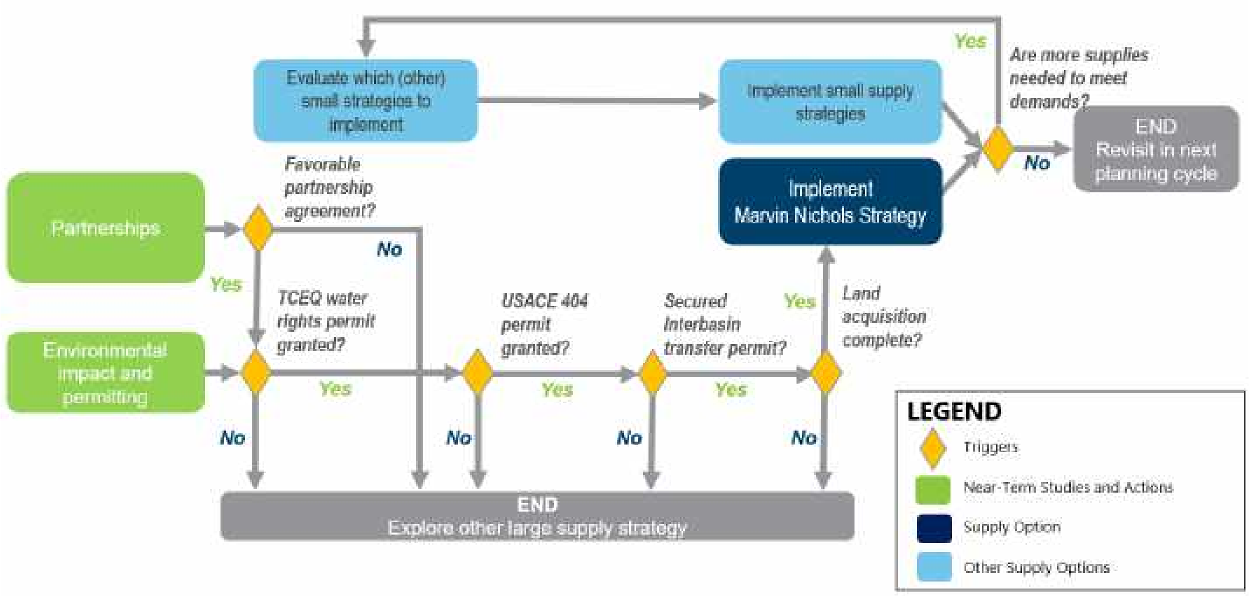


Figure 8.15 Trigger-Based Implementation for Marvin Nichols

As shown in Figure 8.16, the total estimated implementation duration of this strategy is 30 years, which includes 5 years for planning, 15 years for permitting, and 10 years for design and construction. The earliest possible completion if this process is initiated in 2026 would be 2056. However, the Marvin Nichols project is not assumed to be operational until 2060 in the Marvin Nichols portfolio, with a corresponding planning phase start in the year 2030. The timeline for permitting and construction of a large reservoir is highly uncertain. There is risk inherent to planning the supply "just in time" and TRWD would likely want to implement other water supply strategies in the meantime, as highlighted in the Marvin Nichols portfolio.

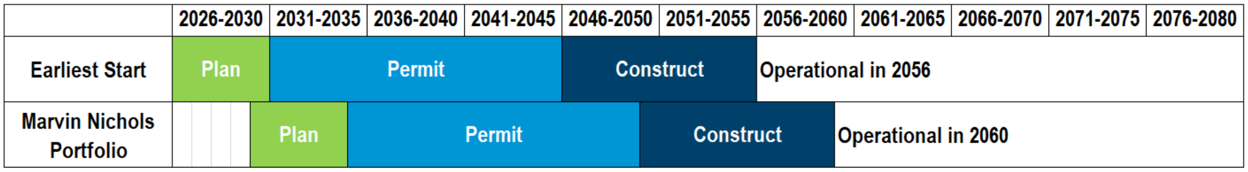


Figure 8.16 Implementation Timeline for Marvin Nichols

8.3.2.4 Marvin Nichols with Wright Patman

The Marvin Nichols with Wright Patman strategy would bring 141,000 AFY in firm yield delivered to Lake Bridgeport. This strategy was evaluated as a partnership, with TRWD included as one of five regional partners. Other partnership configurations are possible, with TRWD having a larger share of the yield.

Acknowledging that there are many triggers involved in the planning, permitting, and construction process to implement the Marvin Nichols with Wright Patman project, the following key implementation triggers were identified for this large capacity supply strategy:

- Successfully negotiating partnership agreement(s) with regional partner(s).
- Obtaining a water rights permit from TCEQ.
- Obtaining a Section 404 USACE permit.
- Obtaining an interbasin transfer permit from the Sulphur to the Trinity River basin.
- Acquisition of approximately 72,000 acres of land to construct the Marvin Nicholas reservoir, an unknown quantity of mitigation acres, plus approximately 14,000 acres to be impacted with the Wright Patman conservation level raising.
- Congressional approval to reallocate flood storage in Wright Patman.
- Acquiring land for raising the conservation pool of Wright Patman Reservoir.
- Securing funding for the large-scale project.

The potential sequence of how these triggers could play out to either decide to implement this strategy (dark blue box) or be routed to explore other options (grey box) is schematically depicted in Figure 8.17.

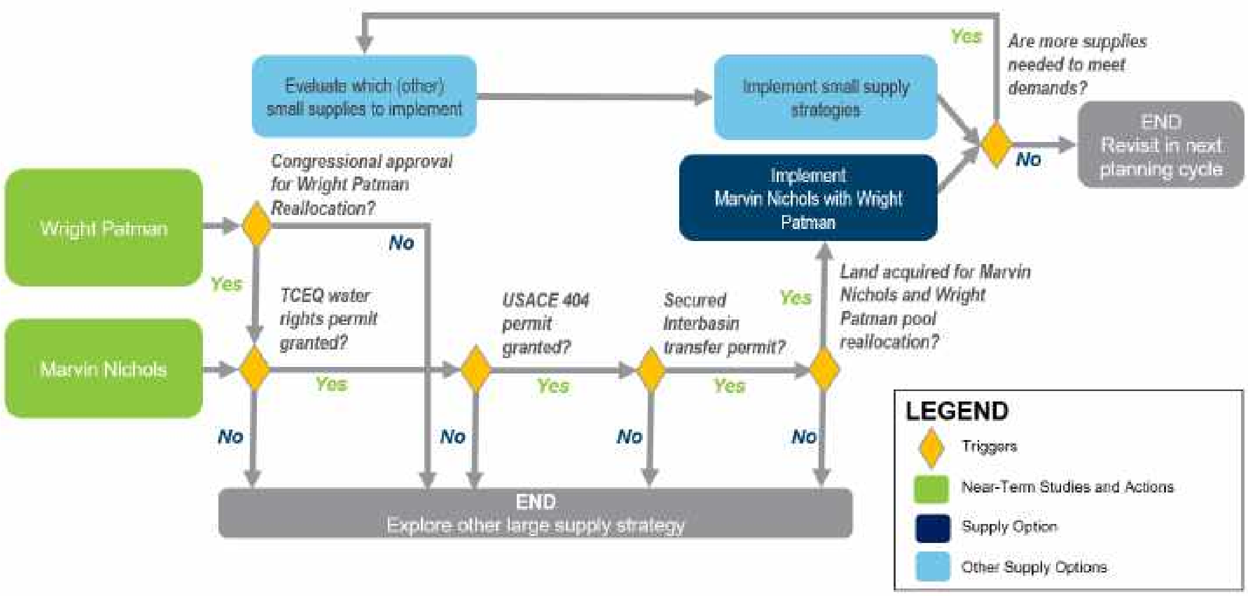


Figure 8.17 Trigger-Based Implementation for Marvin Nichols with Wright Patman

As shown in Figure 8.18, the total estimated implementation duration of this strategy is 30 years, which includes 5 years for planning, 10 years for permitting, and 15 years for design and construction. Hence, the earliest possible completion if this process is initiated in 2026 would be 2055. However, the Marvin Nichols with Wright Patman project is not assumed to be operational until 2060 in the portfolio, with a corresponding planning phase starting in 2030. The timeline for permitting and construction of a large reservoir is highly uncertain, and adding the reallocation increases the uncertainty of this portfolio. There is risk inherent to planning the supply "just in time" and TRWD would likely want to implement other water supply strategies in the meantime, as highlighted in the Marvin Nichols with Wright Patman portfolio.

	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	2051-2055	2056-2060	2061-2065	2066-2070	2071-2075	2076-2080
Earliest Start	Plan	Permit			Construct		Operational in 2056				
Marvin Nichols w/ Wright Patman Portfolio		Plan	Permit			Construct	Operational in 2060				

Figure 8.18 Implementation Timeline for Marvin Nichols with Wright Patman

8.3.2.5 Arkansas Water

The Arkansas Water strategy was assumed at 260,000 AFY in firm yield, the largest of any singe strategy evaluated. Obtaining water from Arkansas is a new strategy for TRWD and requires a more detailed feasibility study. For the IWSP Update, no partnership was assumed, although TRWD may opt to procure and convey supply with one or more regional partners. The potential sequence of triggers along the implementation pathway to Arkansas water (dark blue box) is schematically depicted in Figure 8.19.

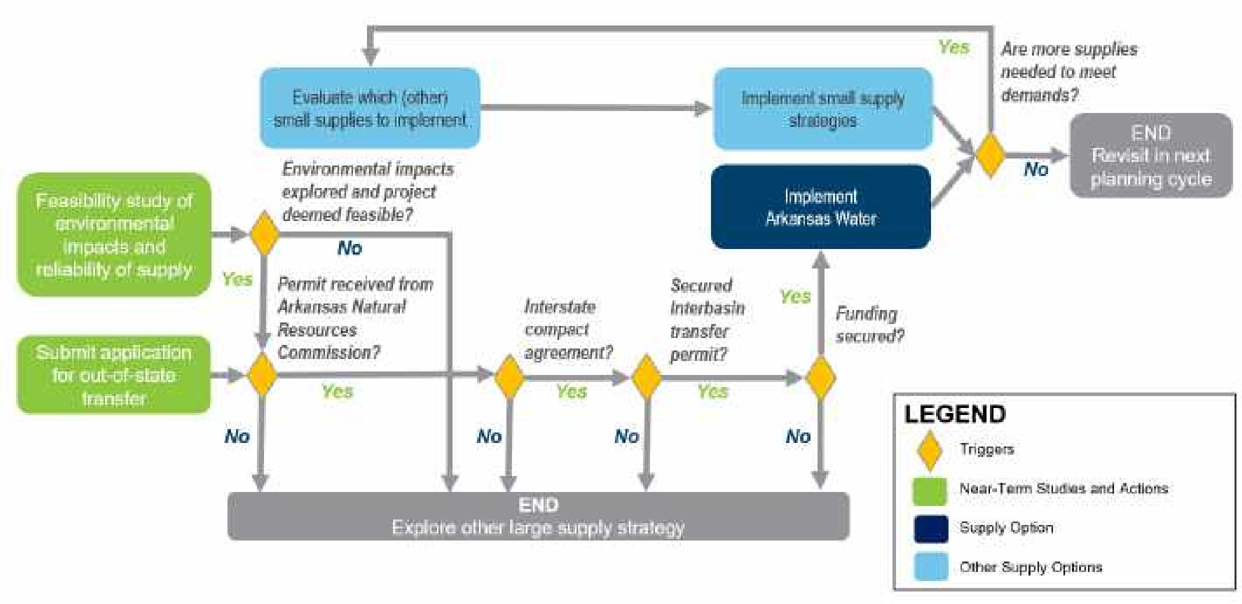


Figure 8.19 Trigger-Based Implementation for Arkansas Water

Acknowledging that there are many triggers involved in the planning, permitting, and construction process to convey supply from Arkansas to Lake Bridgeport, the following key implementation triggers were identified for this large capacity supply strategy:

- TRWD should decide if a partnership agreement would be favorable for the Arkansas Water strategy and, if yes, work to identify regional partner(s).
- Conduct a preliminary engineering, hydrologic, and economic feasibility study. Include more detailed study of the need for an off-channel reservoir, other structure to firm up supplies, or the potential for a different location for the permitted withdrawal.
- Secure an (unprecedented) out-of-state transfer agreement and surface water withdrawal permit from the Arkansas Natural Resources Commission. Must meet environmental flow and ecosystem protection standards, and prove the water is "excess" (i.e., the water is not needed by Arkansas users).
- Texas and Arkansas must negotiate a formal interstate water agreement.
- Confirm an interbasin permit would be required, and, if yes, obtain an interbasin transfer permit from TCEQ from the Little River to the Trinity Basin.
- Secure funding and pipeline alignment easements.

Once the feasibility of this option is further explored and confirmed to be viable and more attractive than the other large supply strategies, the next steps would involve the out-of-state water transfer and interbasin transfer permits.

As shown in Figure 8.20, the total estimated implementation duration of this strategy is 25 years, which includes 10 years for planning, 5 years for permitting, and 10 years for design and construction. The earliest possible completion if this process is initiated in 2026 would be 2051. Aligned with other portfolios, Arkansas Water is assumed operational in 2060 with a corresponding planning phase start in year 2035. Other smaller strategies are needed to meet water supply needs in the meantime.

	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	2051-2055	2056-2060	2061-2065	2066-2070	2071-2075	2076-2080
Earliest Start	Plan		Permit	Construct		Operational in 2051					
Arkansas Water Portfolio			Plan		Permit	Construct		Operational in 2060			

Figure 8.20 Implementation Timeline for Arkansas Water

8.4 Conclusion

The IWSP Update does not recommend a single portfolio but recommends the adaptive implementation approach to make a reasonable supply plan as more information becomes available. TRWD needs to utilize the next 5 years to conduct detailed feasibility studies to get a similar level of information about each of the large supply options. It will be important to get early triggers out of the way to make an informed decision on which strategy to pursue. If it is decided by 2030 that Marvin Nichols (with or without Wright Patman) is unfavorable, then there is more time to decide on Arkansas Water (by 2035), or Toledo Bend (by 2042) to get at least these projects operational by 2060. Conversely, determining the likelihood of Arkansas Water in the next 5 years would determine if a feasible alternative to Marvin Nichols (with or without Wright Patman) is possible.

It should also be noted that the phasing and timelines presented herein are based on meeting 95 percent of the critical dry year S3 demand forecast. It is likely that demand would either increase at a faster or slower pace than projected in this plan, which would shift timeline triggers forward or backward, respectively. In addition to growth driven by economic, demographic, and regulatory trends, the amount and pace of water conservation is another key variable that would impact implementation timelines suggested in this chapter.

CHAPTER 9 RECOMMENDATIONS

The IWSP Update serves as a strategic roadmap to ensure a reliable, resilient, and sustainable water supply to meet TRWD's customers' growing water demands. Founded on a thorough evaluation of existing and planned supplies, projected demands, and system characteristics, this plan integrates multiple future supply options, conveyance improvements, and operational strategies into a cohesive framework for future water supply.

This chapter presents actionable recommendations grounded in the technical analysis, modeling, and water supply objectives that set the foundation for the plan. These recommendations reflect the core objectives of the IWSP Update — to ensure supply reliability, select implementable projects, maintain affordability, and align solutions with the community. This provides a blueprint to guide and prioritize near-term actions and support adaptable decisions in the face of changing conditions and uncertain outcomes for water supply strategies in terms of yield, costs, and implementation certainty. The recommendations focus on near-term actions to implement the No Regrets projects and support decisions for major long-term supply strategies.

9.1 Baseline Water Supply System

The baseline water system includes the infrastructure, supplies, and operational rules that represent the existing and future planned water supply system. The IWSP provides the following recommendations for the baseline water system:

- Projects assumed in the baseline water system should be online according to schedule. Without these projects, results will be impacted.
- Further evaluate the conveyance infrastructure system requirements and operational rule changes needed as planned water supplies become operational. This IWSP employed RiverWare with only minor changes to the current operational rules and with all known planned infrastructure expansions. Analysis indicates that about 55,000 AFY of existing or planned supplies are not being utilized under the baseline modeling conditions. This could be a result of conveyance capacity assumptions and/or operational rules, specifically the operational rule that triggers pumping when metroplex reservoirs are down one foot. As RiverWare is a complex modeling tool developed over decades by TRWD, it is possible that this is simply a result of the modeling framework and not a real constraint. This should be confirmed since it directly impacts the volume of new supplies needed to meet projected demands.
- The modeling shows that a water supply shortage of 7 percent could be remaining in 2030 under critically dry conditions. While this shortage could be mitigated by enacting TRWD's drought contingency plan, TRWD should study the 2030 condition more closely to determine if other operational changes or acceleration of certain projects could alleviate the gap.
- To improve reliability from 2040 through 2070, TRWD should work towards securing additional return flows for the Cedar Creek Wetlands. Advancing those supplies earlier in the planning horizon and achieving the permitted capacity of 91,000 AFY more quickly will improve reliability and alleviate gaps projected under the baseline system. Several avenues should be explored, including a System Operations ("SysOps") permit, purchasing return flows from other users, or negotiations with lower basin suppliers to reuse larger portions of TRWD's existing permits.

9.2 Demand and Supply Planning Recommendations

Priority recommendations to focus planning efforts over the next 5 years include:

- As discussed in Chapter 8, the likelihood of enough small strategies being fully developed and brought online is very low and would not be ideal for future operations. Thus, larger projects are most likely going to be needed. TRWD should start early planning steps for larger supplies now, as these take decades to develop and implement. As many of the largest projects have the greatest uncertainties (e.g., permitting, costs), extensive modeling and feasibility studies must be started decades in advance in close collaboration with regional partners to allow sufficient time to identify other feasible projects if the large supply strategy hits a point where it will not be viable.
- Continue to closely monitor water demands and population growth. Significantly lower future supplies are needed if demands more closely align with the BL demand scenario. However, if demands accelerate beyond the S3 scenario, supplies may be needed earlier in the planning horizon.
- As the demand projections were prepared in 2020, consider a full update of the 2020 water demand projections. Triggers for a full update include (1) when new regional growth projections are released, (2) new significant users arise such as regional providers or data centers, and/or (3) if demands extend outside of the BL/S3 scenario bands.
- Further explore reliability goals in partnership with customers to define acceptable level of service goals and risk acceptance. The IWSP Update assumed a minimum reliability threshold of meeting 95 percent of water demands during a repeat of the worst drought on record. In addition to water supply timing, establishing level of service goals could provide a framework for strategic planning, asset management, affordability, environmental stewardship, and emergency preparedness and response. These goals articulate the performance standards the utility commits to meet across various dimensions of service.
- Incorporate outcomes from ongoing studies to inform near-term water supply decisions, including the SysOps study to optimize system operations and investigate permitting additional return flow, the Regional Optimization Study with other North Texas water suppliers, and the ASR pilot project. Outcomes from these studies should be incorporated into the modeling framework using the model tools delivered with this IWSP Update. Potential new supplies or agreements identified through these studies should be added to the modeling framework and reviewed against other strategies.
- Continue to seek customer feedback, conduct Board of Director’s outreach, coordinate with the development and business community, and communicate with the public on water security.

9.3 Strategy-Specific Recommendations

The following recommendations guide future decisions and planning specific to strategies.

- Prepare an Advanced Conservation Plan with detail on how to achieve the assumed 10 percent reduction in S3 demands, monitor conservation savings closely, and accelerate/decelerate other supply projects accordingly.
- As the Advancing Conservation strategy is implemented, especially if strategies are adopted that reduce peak summer demand, the modeling and gap analysis results should be reevaluated with the conservation achievements and updated decadal demands and monthly demand assumptions.
- Implement the CC and RC Unpermitted Firm Yield strategy. While this supply is only utilized during extreme conditions, having this supply available to TRWD could be essential to meeting demands at critical times.
- Implement the Bridgeport Reallocation strategy to provide flexibility at Lake Bridgeport.

- Begin discussions with the Arkansas Natural Resources Commission on the required steps for an interstate water transfer. A feasibility level study of this supply and infrastructure should be conducted in parallel. This study would include more detailed pipeline routing, sizing, and cost estimates, identification of firm supply and take location, and detail operational changes and efficiency metrics. Closely track any State of Arkansas legislative actions related to out-of-state water supplies.
- The Southwest Arkansas Water District supplies water to Texarkana Water Utilities, as does the Riverbend Water Resources District. The SRBA serves as a local sponsor in studies of supplies from NE Texas. Coordinate with all entities to work towards mutually beneficial water supply collaboration agreements. This could include supplies from Millwood Lake, supplies from upstream of Millwood Lake (Arkansas Water Strategy), and Lake Wright Patman.
- Closely track Texas legislative actions that provide boosts in funding and support for specific types of water supply strategies. For example, Senator Perry's SB 7 has passed the Senate and House and is with the Governor. This bill, if signed, supports the creation of new water sources for the state that include, in part, the acquisition of water or water rights originating from outside of Texas.[1] The funding and support for out-of-state transfers may be greatly increased by this bill. As these types of legislative actions are passed and implemented, certain strategies may be accelerated or prioritized accordingly.
- Conduct a feasibility-level study for the Toledo Bend. This study would include more detailed pipeline routing and cost estimates, identification of partnerships and cost-sharing, agreements on the purchase cost of supplies, and detail operational changes and efficiency metrics.
- Conduct rate impact studies of the four large supplies, including Marvin Nichols, Marvin Nichols with Wright Patman, Arkansas Water, and Toledo Bend.

These recommendations provide guidance on TRWD's near-term planning priorities.

- Develop smaller supplies to meet interim gaps before a large supply strategy is brought online. Priorities include Lake Palestine Purchase, Lake Palestine Groundwater Purchase, Mainstem OCR, Anderson County Groundwater, and DPR. These strategies each provide 15,000 AFY of supply or more and are included in multiple portfolios.
- With the Lake Palestine Purchase, Lake Palestine Groundwater Purchase, and Anderson County Groundwater strategies, TRWD should study operations and conveyance with more detail to determine if these supplies can be conveyed to users without the addition of the Parallel IPL, which would significantly lower the costs.
- Begin to negotiate agreements with DWU on usage of the portion of the IPL that connects Lake Palestine to the existing IPL. The agreement would allow TRWD to utilize excess capacity at a prorated fee. Establishing this agreement will allow for flexibility in either purchasing excess Lake Palestine surface water or developing groundwater around Lake Palestine.
- Begin high-level discussions with potential partners for the DPR option to assess viability and determine structure and willingness of partnership agreements. As DPR is increasingly adopted across Texas, the social viability of this strategy will increase over time. Costs may improve as the technology is implemented across the U.S. For DPR to provide a net positive increase in supply, TRWD would need to time this strategy to be online when there are return flows available to TRWD that exceed the capacity of the RC and CC Wetlands, either through existing permits, new permits, or other strategies (such as purchasing return flows).
- Continue to pursue and track ASR studies, as this project demonstrates that reliability at Eagle Mountain Lake is improved during extreme conditions with ASR.

[1] Texas Senate. *Senate Bill 7, 89th Legislature, Regular Session*. Enrolled version sent to Governor June 1, 2025. Austin, TX. https://capitol.texas.gov/BillLookup/History.aspx?Bill=SB7

APPENDIX A

RIVERWARE MODEL

To: Jessica Fritsche, Carollo Engineers; Vini de Oliveira & Nicole Rutigliano, TRWD
From: Hydros Consulting Inc.
Subject: TRWD Baseline IWSP Model Assumptions
Date: 4/3/25

Table of Contents

1. Introduction

The long-term (1941-2022) monthly-timestep planning RiverWare model was used as the IWSP Baseline model, with historical inflows, and the most-recent permits, operating rules and pipeline infrastructure. The table below highlights the specific modeling assumptions used for this study, along with another current TRWD study, for comparison:

Table 1: Summary of modeling assumptions

		Study	
	Assumption	**IWSP**	**Regional Optimization**
1	**Hydrology**	Historical, 1941-2022	
2	**Discharge Capacities**	2024 values, with exceptions:	2024 values
3	**MBR to KBR capacity**	350 MGD	130 MGD
4	**WF Holly Discharge Capacity**	100 MGD soft constraint	120 MGD
5	**CF Holly Discharge Capacity**	999 MGD	80 MGD
6	**EMC Discharge Capacity**	280 MGD	280 MGD
7	**Rolling Hills WTP Discharge Capacity**	999 MGD	999 MGD
8	**Demands**	Baseline, or Suburban Sprawl with Stressors	2026 Draft Region C Demands
9	**Demand Year**	2030, 40, 50, 60, 70, 80	2030
10	**JRC1 enabled?**	Yes, beginning with 2040 demands	Yes
11	**CC Wetlands enabled?**	Yes, beginning with 2040 demands	Yes
12	**LP1 to Joe Pool enabled?**	Yes	
13	**ExFlo permits enabled?**	Yes	
14	**EAC curves**	Variable EAC curves by decade	2030 EAC for Region C
15	**Pure Storage Optimization Pumping?**	Yes	
16	**2024 Drought Management Plan enabled?**	No	Yes
17	**West Fork Drawdown Ratios**	1.75 year-round	
18	**Mary's Creek WRF enabled?**	Yes	
19	**Return Flows**	See Table below	
20	**Min reservoir elevations**	See Table below	
21	**Permits**	See Table below	

2. IWSP Modeling Assumptions

2.1 Hydrology

The Baseline model is run with historical, period-of-record reservoir inflows from 1941-2022. These inflows are developed by TRWD using their “mass balance” spreadsheets, which take measured historical reservoir elevation changes, releases, spills, diversions, pan evaporation, rain gage data, and gaged inflows, and back-calculate the ungaged runoff into the reservoirs. As many of the reservoirs did not exist in 1941, the natural inflows were calculated before impoundment using other methods.

The Baseline model also uses historical pan-evaporation and rain-gauge measurements.

2.2 Discharge Capacities

The discharge capacity of all the nodes in the RiverWare model are shown in the following table. The monthly, 82-year RiverWare model is meant for long-term planning and is not a hydraulics model. It is therefore not meant to have every hydraulic constraint that exists in reality.

Table 2: Discharge capacity of all nodes in RiverWare model

Node	Discharge Capacity (MGD)	Notes
MBR to KBR capacity (IPL)	350	Does not limit LP1 pumping to Joe Pool
CC1 Div	240	East Texas Pumping Stations
JCC1 Div	270	
RC1 Div	240	
JRC1 Div	250	
LP1 Div	150	
Trinity to RC Wetlands	93.755	Diversions from Trinity to Wetlands
Trinity to CC Wetlands	176	
RC Wetlands to RC	93.76	Diversions from Wetlands to Reservoir
CC Wetlands to CC	176	
EM Outlet Demand Tap	280	Terminal Storage Taps
Arlington Outlet Demand Tap	225	
Benbrook Outlet Demand Tap	200	
Joe Pool Outlet Demand Tap	150	
Bardwell Outlet Demand Tap	0	
Waxahachie Outlet Demand Tap	0	
Cedar Creek Outlet Demand Tap	0	
Richland Chambers Outlet Demand Tap	0	
Benbrook Pump Div	200	Pumping from BB into pipeline
Bridgeport Diversions	999	Water users on reservoirs
Eagle Mountain Diversions	999	
Worth Diversions	999	
Benbrook Diversions	999	
Arlington Diversions	999	
Joe Pool Diversions	999	
Cedar Creek Diversions	999	
Richland Chambers Diversions	999	
Westside WTP Tap	999	Water users on legacy pipelines
Ennis Tap	999	
Waxahachie Rockett Tap	999	
Midlothian Tap	999	
Mansfield WTP Tap	999	
JFK WTP Tap	999	
Rolling Hills WTP Tap	999	
CF Outlet Demand Tap	118	Direct tap from pipeline to CF to Holly WTP
WF Holly Diversion	999	WF and CF Diversions to Holly. WF has a 100 MGD "soft constraint"
CF Holly Diversion	999	
Holly WTP	999	Total Holly WTP discharge capacity
Section 9 Tap	0	Diversions from IPL to Legacy Pipelines
Section 10 Tap	999	
Section 12 Tap	0	

2.3 MBR to KBR capacity

This is the IPL capacity. The capacity in 2024 is 130 MGD, but was increased to 350 MGD for the IWSP study (per 3/11/24 call with TRWD), as this is the future capacity.

2.4 WF Holly Discharge capacity

This is the total capacity of all water coming from the West Fork of the Trinity River to Holly WTP. In 2024, this capacity is 120 MGD, but this constraint was removed for the IWSP. However, per the 3/22/24 email from Jessica Fritsche, a 100 MGD soft constraint was added to WF Holly. This means that any Holly WTP demand above 100 MGD should be met from the Clear Fork, but if the Clear Fork is unable to satisfy the full Holly WTP (due to permit or reservoir min release elevation limitations), WF Holly can discharge above 100 MGD.

2.5 CF Holly Discharge capacity

This is the total capacity of all water coming from the Clear Fork of the Trinity River to Holly WTP, including water coming from Benbrook and directly from the pipeline through the CF Outlet. In 2024, this capacity is 80 MGD, but this constraint was removed for the IWSP, per the 3/22/24 email from Jessica Fritsche.

2.6 EMC Discharge capacity

The Eagle Mountain Connection (EMC) target discharge from the pipeline is based on the Eagle Mountain elevation. Previously, this target discharge was also based on the climate state (very wet, wet, average, or dry). For the IWSP this was simplified, and the climate state does not affect the target discharge. The table was also updated for the IWSP with a much higher maximum target discharge (280 MGD instead of 130 MGD):

Table 3: OLD EMC Discharge Table

Climate State:	Very Wet	Wet	Avg	Dry	Discharge (MGD)
Eagle Mountain Pool Elevation (feet)	500	500	500	500	150
	641.1	641.1	641.1	643.1	150
	643.1	643.1	643.1	645.1	100
	645.1	645.1	645.1	647.1	75
	682	682	682	682	0

Table 4: IWSP EMC Discharge Table; sent by Amy Kaarlela, TRWD, 3/11/24

Eagle Mountain Pool Elevation (feet)	Discharge (MGD)
500	280
639.1	280
641.1	225
643.1	150
645.1	100
647.1	50
682	0

2.7 Rolling Hills WTP Discharge Capacity

The Rolling Hills WTP Discharge Capacity is 200 MGD in 2024, but this constraint was removed entirely, based on a 3/11/24 call with TRWD, since customer-side constraints should not be causing any gaps in the IWSP.

2.8 Demands

Two sets of demands are used for the IWSP RiverWare model: “TRWD Baseline Demands” and “TRWD Suburban Sprawl with Stressors Demands”. These demands are projected to increase each decade, as shown below.

Both these tables were sent by Vini de Oliveira (TRWD) in the file "20231117 Updated RW Demands.xlsx" on 11/17/23. Updated Westside WTP demands were sent by Vini in a 12/14/23 email. Updated Arlington Local Use and Tierra Verde demands were sent by Vini in a 12/15/23 email. Updated Bachman WTP demands were sent by Vini in a 2/16/24 email. Eagle Mountain Local Use Demands include Wise Regional Water District Demands, sent by Vini in a 2/24/25 email.

Table 5: TRWD Baseline Demands by decade (acre-ft/year)

	Demand Year					
User	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**
Holly WTP	61,855	66,720	67,911	68,720	69,385	74,546
Eagle Mountain WTP	63,873	77,315	86,235	98,672	109,377	122,436
JFK WTP	46,490	50,604	50,430	52,004	53,448	57,024
Pierce Burch WTP	21,746	22,807	23,776	24,444	25,078	26,493
Rolling Hills WTP	120,804	133,711	141,769	151,155	160,075	173,681
Mansfield WTP	17,619	19,611	21,228	24,096	26,792	28,757
TRA Mosier Valley	34,376	34,325	36,502	37,132	37,743	38,972
Waxahachie Rockett	4,735	5,083	5,508	6,356	7,184	7,522
Midlothian	4,406	5,727	6,727	8,217	9,936	10,968
Ennis	0	0	0	0	0	0
Benbrook Local Use	1,611	1,611	1,611	1,611	1,611	1,611
Worth Local Use	2,790	2,770	2,755	2,753	2,752	2,734
Eagle Mountain Local Use	6,478	9,775	19,639	27,144	33,585	39,338
Bridgeport Local Use	20,280	20,450	20,867	21,261	21,666	22,067
Arlington Local Use	159	159	159	159	159	159
Richland Chambers Local Use	5,671	5,667	5,665	5,664	5,664	5,660
Cedar Creek Local Use	5,026	4,976	5,346	5,633	5,924	5,985
Westside WTP	12,377	28,835	45,260	62,050	78,475	90,347
Weatherford*	7,333	9,466	11,599	13,732	15,865	18,000
BWA	3,000	2,880	3,034	3,145	3,256	3,244
Bachman WTP	33,604	44,806	56,007	89,612	114,255	114,255
Constellation	1,000	1,000	1,000	1,000	1,000	1,000
Tierra Verde	197	197	197	197	197	197

*this Weatherford demand is reduced by 4,800 acre-ft in the model, because they have a local supply.

Table 6: TRWD Suburban Sprawl with Stressors Demands by decade (acre-ft/year)

	Demand Year					
User	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**
Holly WTP	65,547	72,450	76,041	78,887	83,918	90,913
Eagle Mountain WTP	72,802	96,364	116,292	143,442	175,191	195,016
JFK WTP	49,048	54,834	56,307	60,170	65,521	70,301
Pierce Burch WTP	23,117	24,954	27,020	28,605	30,980	33,151
Rolling Hills WTP	133,418	156,931	176,472	200,595	229,808	252,004
Mansfield WTP	20,424	25,642	30,864	38,277	47,349	51,603
TRA Mosier Valley	36,884	38,001	42,085	45,024	48,571	51,201
Waxahachie Rockett	7,143	9,670	13,382	18,506	24,241	26,613
Midlothian	7,120	11,089	15,949	22,948	29,498	33,150
Ennis	0	0	0	0	0	0
Benbrook Local Use	1,611	1,611	1,611	1,611	1,611	1,611
Worth Local Use	2,830	2,836	2,853	2,876	2,916	2,925
Eagle Mountain Local Use	6,766	10,233	20,568	28,505	35,475	41,465
Bridgeport Local Use	21,405	22,117	23,381	24,731	26,370	27,432
Arlington Local Use	159	159	159	159	159	159
Richland Chambers Local Use	6,167	6,183	6,222	6,279	6,361	6,528
Cedar Creek Local Use	5,667	6,062	7,114	8,130	9,254	9,816
Westside WTP	12,377	28,835	45,260	62,050	78,475	90,347
Weatherford*	7,406	9,655	12,063	14,556	17,134	19,800
BWA	3,395	3,574	4,087	4,616	5,024	5,377
Bachman WTP	33,604	44,806	56,007	89,612	114,255	114,255
Constellation	1,000	1,000	1,000	1,000	1,000	1,000
Tierra Verde	197	197	197	197	197	197

*this Weatherford demand is reduced by 4,800 acre-ft in the model, because they have a local supply.

2.9 Demand Year

The IWSP RiverWare model is run for the entire period of record for each combination of decade and demand set, for a total of 12 runs, as shown in the matrix below:

Table 7: Twelve Baseline runs are simulated:

2030 Baseline Demands	**2030 Suburban Sprawl with Stressors Demands**
2040 Baseline Demands	**2040 Suburban Sprawl with Stressors Demands**
2050 Baseline Demands	**2050 Suburban Sprawl with Stressors Demands**
2060 Baseline Demands	**2060 Suburban Sprawl with Stressors Demands**
2070 Baseline Demands	**2070 Suburban Sprawl with Stressors Demands**
2080 Baseline Demands	**2080 Suburban Sprawl with Stressors Demands**

2.10 Joint Richland Chambers Lake Pump Station

The Joint Richland Chambers Lake Pump Station (JRC1) is expected to come online sometime in the 2030's, and is therefore turned on for 2040 Baseline simulations and thereafter (a total of 10 simulations). This pumping station provides an additional 250 MGD of pumping capacity from Richland Chambers.

2.11 Cedar Creek Wetlands

The Cedar Creek (CC) Wetlands are expected to come online sometime in the 2030's, and are therefore turned on for 2040 Baseline simulations and thereafter (a total of 10 simulations). Whenever Cedar Creek is more than 1' below conservation, these wetlands provide up to an additional 176 MGD of supply to Cedar Creek reservoir.

2.12 Lake Palestine to Joe Pool

Lake Palestine meets the Bachman WTP demand at Joe Pool Lake in all 12 Baseline simulations, limited to the LP1 pumping capacity, and the total IPL capacity.

2.13 ExFlo permits

The Excess Flow Optimization 1 (ExFlo1) permits at Eagle Mountain and Benbrook allow TRWD to utilize flood water in these reservoirs to meet customer demands under separate permits than the ordinary reservoir permits. This allows TRWD the ability to save the ordinary permits for later in the year, and also reduces pumping from Richland Chambers and Cedar Creek. ExFlo1 permits do not affect the physical flood operations at these reservoirs.

The ExFlo2 permits at Richland Chambers and Cedar Creek wetlands allow the wetlands to divert water from the Trinity River whenever Lake Livingston is spilling. Since Lake Livingston is not modeled in the TRWD RiverWare model, TRWD found that in reality, whenever Lake Livingston is spilling, Eagle Mountain is likely also spilling, so the latter is used as an ExFlo2 trigger in the RiverWare model.

2.14 Variable EAV curves by decade

In the IWSP simulations, the reservoir Elevation-Area-Volume curves are updated for each decadal simulation (along with the customer demands) to account for sedimentation accumulation over time. 2020 and 2070 EAV curves from the Trinity Water Availability Model (WAM) model were sent by Jessica Fritsche 9/11/23 in the spreadsheet RegC_TrinityWAM_SVSAs.xlsx. Jessica explained that 2070 curves should be copied into 2080, and that 2030, 2040, 2050, and 2060 curves should be developed by interpolating between the provided 2020 and 2070 curves. It was later decided to use EAV curves sent by Vini de Oliveira in May 2022 and February 2024 for 2020. Interpolation between 2020 and 2070 was done by Hydros Consulting. Hydros also extrapolated the curves to go up to the top of the dams (the WAM curves only go up to the conservation elevations), so that RiverWare could appropriately simulate flood control. See spreadsheet "RegC_TrinityWAM_SVSAs_HydrosInterpolate.xlsx" for interpolation and extrapolation.

2.15 Pure Storage Optimization Pumping

The RiverWare model has two options for determining how the total pumping from Richland Chambers and Cedar Creek is split between the three or four pumping stations at these reservoirs. The first option is to use pumping tables provided by Devin Taylor (TRWD) on 10/5/21 in the spreadsheet "RiverwarePhase2PumpingTable.xlsx". The second option is to use "pure storage optimization", which is a set of operating rules developed by TRWD and Hydros Consulting in 2018 that attempts to balance the drawdown of Richland Chamber and Cedar Creek reservoirs.

The second option was selected for the IWSP, because the first option is not compatible with the JRC1 pumping station coming online in the 2030's, and because the second option is more flexible with any new supplies or future changes to the pumping and distribution infrastructure.

2.16 Drought Management Plan

On 4/2/24 Jessica Fritsche directed Hydros Consulting to disable the latest Drought Management Plan in the IWSP Baseline RiverWare model. The IWSP will aim to meet full demands without curtailment. For reference, TRWD's plan reduces all customer demands in the model by a percentage, depending on the drought stage (which is based on the total % storage in Cedar Creek + Richland Chambers + Bridgeport + Eagle Mountain), and the time of year:

Table 8: Customer demand reductions based on drought stage and time of year

	Customer Demand Reduction %			
Month	Stage 3 Drought Reservoir Storage =< 45%	Stage 2 Drought Reservoir Storage =<60%	Stage 1 Drought Reservoir Storage =<75%	No Drought Reservoir Storage >75%
January	0%	0%	0%	0%
February	0%	0%	0%	0%
March	0%	0%	0%	0%
April	15%	3%	0%	0%
May	23%	6%	3%	0%
June	28%	6%	8%	0%
July	25%	20%	10%	0%
August	23%	22%	12%	0%
September	23%	20%	10%	0%
October	25%	8%	3%	0%
November	0%	0%	0%	0%
December	0%	0%	0%	0%

2.17 West Fork Drawdown Ratios

The West Fork Optimization Study is ongoing by TRWD, but on 1/25/24 TRWD directed Hydros to use a West Fork Drawdown ratio (which balances the drawdown between Bridgeport and Eagle Mountain) of 1.75 for the IWSP.

2.18 Mary’s Creek Water Reclamation Facility

Mary’s Creek WRF discharges a constant value into the Eagle Mountain Connection (which take up a portion of the EMC discharge capacity), if Eagle Mountain is below conservation. This discharge is subtracted from the reuse water available for the Wetlands. This constant discharge increases every decade, as shown in the table sent by Nicole Rutigliano (TRWD) on 2/22/24:

Table 9: Mary's Creek WRF discharge by decade

	Mary’s Creek WRF Discharge (MGD)
2030	7.73
2040	11.91
2050	16.79
2060	21.67
2070	24.335
2080	27

These water reclamation facility inflows into Eagle Mountain can be used by any customers served by Eagle Mountain, and do not count against the 3809 permit.

2.19 Return Flows

The table below shows the percentage of each customer’s diversion that is returned (not consumed), and where the return flows go in the model:

Table 10: Location, customer, return flow percentages, and return flow destinations:

Location	Customer	% of diversion returned	return flow destination
Arlington	Arlington Local Use	44%	Trinity River (available to wetlands)
	Constellation	0%	
	Pierce Burch WTP	44%	
	TRA Mosier Valley	44%	
Benbrook	Benbrook Local Use	0%	
	BWA	44%	
Eagle Mountain	Eagle Mountain WTP	44%	
	Eagle Mountain Local Use	44%	
Holly WTP	Holly WTP	44%	
JFK WTP	JFK WTP	44%	
	Tierra Verde	0%	
Mansfield WTP	Mansfield WTP	44%	
Rolling Hills WTP	Eagle Mountain WTP Supplemental	44%	
	Rolling Hills WTP	44%	
Westside WTP	Westside WTP	44%	
Worth	Worth Local Use	44%	
Benbrook	Weatherford	530 acre-ft/year	Lake Benbrook
Bridgeport	Bridgeport Local Use	44%	return flows not used in model
Cedar Creek	Cedar Creek Local Use	44%	
Ennis	Ennis	44%	
Joe Pool	Bachman WTP	44%	
Midlothian	Midlothian	44%	
Richland Chambers	Richland Chambers Local Use	44%	
Waxahachie Rockett	Waxahachie Rockett	44%	

2.20 Out of Basin Return Flows

Normally, TRWD has to send 30% of its own return flows downstream in the Trinity River. However, if a WMS comes from out of basin, TRWD does not have to send the resulting return flows downstream. These WMS's include 8, 9, 10, 11, 13, 14, 17, 19, 20, 24 and 25.

2.21 Purchased TRA Return Flows

Based on a 7/17/24 call with TRWD, the TRWD Baseline model has return flows, purchased from TRA, added into the reuse water that is available for Cedar Creek and Richland Chambers wetlands. This volume of purchased water increases each decade, as shown in this table sent by TRWD on 7/23/24:

Table 11: Volume of TRA Purchased Return Flows, by Decade

	2020	2030	2040	2050	2060	2070	2080
acre-ft	14,000	25,500	37,000	48,500	60,000	60,000	60,000

These return flows are distributed throughout the year based on the averages of the 2019-2023 monthly TRA effluent volumes, sent by TRWD on 7/18/24.

These return flows are separate from the TRA Mosier Valley return flows mentioned in the previous section.

These return flows are added to the existing Cedar Creek Wetlands Reuse Permit. For example, in 2060, Cedar Creek Wetlands can divert up to 60,000 + 90,799 = 150,799 acre-ft/yr of reuse water from the Trinity River (if this water is available).

2.22 Simultaneous Eagle Mountain Connection Discharge and Benbrook Pumping

Pipeline water can be discharged into Eagle Mountain through the Eagle Mountain Connection at the same time Benbrook is Pumping (either Scheduled or Unscheduled pumping). Benbrook Scheduled Pumping is no longer cut off if Eagle Mountain drops below 647.1' or if Bridgeport + Eagle Mountain storage drop below 80%

2.23 Eagle Mountain Connection Reverse Pumping

Eagle Mountain can pump back into the pipeline, to meet pipeline water user demands and Arlington's Outlet demand, limited to the discharge capacity of the Eagle Mountain Connection. Eagle Mountain pumping and Benbrook Pumping can occur at the same time (without exceeding pipeline capacities). There are two types of Eagle Mountain Pumping:

2.23.1 Eagle Mountain ExFlo1 pumping

Eagle Mountain can pump any water above conservation into the pipeline, limited to the remaining ExFlo1 12806 permit after first using this ExFlo1 water for Eagle Mountain WTP, Eagle Mountain Local Use, Worth Local Use, and Holly WTP if possible.

2.23.2 Eagle Mountain Normal pumping

If an IWSP Water Management Strategy is actively providing water to Bridgeport or Eagle Mountain, Eagle Mountain can pump any water above 638' into the pipeline, limited to the remaining CFW 3809 permit plus the IWSP WMS supply.

2.24 Reservoir Minimum Elevations for Release and Diversion

In the RiverWare model, each reservoir has an elevation below which no water can be released or diverted from the reservoir. At some reservoirs, this elevation increases with the decade because of sediment accumulations:

Table 12: Reservoir Minimum Elevations for Release and Diversion

	Min Elevation for Diversion and Release (feet)							
	Original	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**
Arlington	515	515	515	515	515	515	515	515
Benbrook	665	665	665	665	665	665	665	665
Bridgeport*	761.44	762.15	762.15	762.15	762.57	762.79	763.75	775
Cedar Creek	256.48	259.25	259.25	259.25	259.45	259.9	260.43	273
Eagle Mountain	598.74	601.13	601.13	601.13	601.34	601.51	601.92	608
Richland Chambers	232	242.24	242.24	242.24	242.86	243.11	244.19	263
Worth	570	570	570	570	570	570	570	575.01

*Additionally, Bridgeport has an operational elevation (818’) below which no water can be released.

2.25 Permits

In the TRWD RiverWare model, customers diversions are limited by max annual permit volumes. Often these permits are shared between several customers. Table 13 below shows the permits currently in the RiverWare model, and which customers have access to these permits:

Table 13: Permits in TRWD RiverWare model, and customers with access

Permit	acre-ft/year	Customers with conditional access to this permit
Arlington^Exelon 3391	10,120	Exelon
Arlington^Pierce Burch 3391	13,000	Pierce Burch WTP
Benbrook^Benbrook 5157	72,500	Exelon, Pierce Burch WTP, TRA Mosier Valley, Benbrook Local Use, BWA, Weatherford, CF Holly Diversion, JFK WTP, Tierra Verde, Mansfield WTP, Eagle Mountain WTP Supplemental[1], Rolling Hills WTP, Westside WTP, Midlothian
Benbrook^ExFlo1 12805	78,653	
Bridgeport^Local Use 3808	27,000	Bridgeport Local Use
Bridgeport^Bridgeport EM Release 3808	66,000	Eagle Mountain WTP, Holly WTP
Eagle Mountain^CFW 3809	150,000	
Eagle Mountain^ExFlo1 12806	63,899	Eagle Mountain WTP, Holly WTP, Eagle Mountain Local Use, Worth Local Use
Eagle Mountain^Local 3809	9,600	Eagle Mountain Local Use, Worth Local Use
CC Wetlands^ExFlo2 13233	84,978	Benbrook Local Use, Arlington Local Use, Exelon, Pierce Burch WTP, TRA Mosier Valley, Benbrook Local Use, BWA, Weatherford, Eagle Mountain WTP, Eagle Mountain Local Use, Holly WTP, JFK WTP, Tierra Verde, Mansfield WTP, Eagle Mountain WTP Supplemental, Rolling Hills WTP, Westside WTP, Worth Local Use, Cedar Creek Local Use, Ennis, Midlothian, Waxahachie Rockett
CC Wetlands^Reuse 4976C	88,059	
Cedar Creek^TRWD Pipeline 4976	175,000	
RC Wetlands^ExFlo2 13234	94,500	Benbrook Local Use, Arlington Local Use, Exelon, Pierce Burch WTP, TRA Mosier Valley, Benbrook Local Use, BWA, Weatherford, Eagle Mountain WTP, Eagle Mountain Local Use, Holly WTP, JFK WTP, Tierra Verde, Mansfield WTP, Eagle Mountain WTP Supplemental, Rolling Hills WTP, Westside WTP, Worth Local Use, Richland Chambers Local Use, Ennis, Midlothian, Waxahachie Rockett
RC Wetlands^Reuse 5035C	100,465	
Richland Chambers^TRWD Pipeline 5035	210,000	
Clear Fork Native^3340	1,791	Holly WTP
Worth^CFW Permit 3340	12,143	
Clear Fork Native^3340 Irrigation	425	Benbrook Local Use
West Fork Native^3340	143	None at this time

[1]If the Eagle Mountain WTP demand (out of Eagle Mountain) cannot be met, then the model tries to meet the deficit at Rolling Hills WTP (but this water is diverted to an account called "Eagle Mountain Supplemental", for accounting purposes).

APPENDIX B

COSTING TOOL

TECHNICAL MEMORANDUM

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

801 Cherry Street, Suite 2800 + Fort Worth, Texas 76102 + 817-735-7300 + FAX 817-735-7491 www.freese.com

TO: Jessica Fritsche, Carollo Engineers

CC: Tarrant Regional Water District (TRWD)

FROM: Lissa Gregg and Kristal Williams

SUBJECT: TRWD IWSP – Cost Estimation Assumptions and Methodology

PROJECT: JCE23615 – TRWD IWSP Update

DATE: May 22, 2025

STATE OF TEXAS
LISSA JOY GREGG
126454
LICENSED
PROFESSIONAL ENGINEER
5/22/2025
FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

1.00 INTRODUCTION

Tarrant Regional Water District (TRWD) hired Carollo Engineers to develop an updated Integrated Water Supply Plan (IWSP). This is an update to the 2014 TRWD IWSP. Freese and Nichols Inc. (FNI) served as a subconsultant to Carollo in the development of cost estimation curves for planning level cost development and developed planning level costs for a subset of the strategies evaluated as part of the IWSP. This memo serves as documentation of the costing tool assumptions, cost curves (for pipeline, booster pump stations, intake pump stations, balancing reservoirs, and dams), and results for the subset of Water Management Strategies (WMS) cost estimates performed by FNI.

All costs are conceptual, planning level costs with no design information. These costs are useful for comparison of alternatives to one another but have a high level of uncertainty associated with them and are not intended as final estimates. As projects are pursued and more information on the specific strategy configuration is known, the costs should be reevaluated.

2.00 COSTING TOOL ASSUMPTIONS AND ADAPTATION

The Texas Water Development Board (TWDB) publishes a Unified Costing Model (UCM) that is required for the development of cost estimates for regional water planning. The tool captures and standardizes assumptions for a wide range of projects sizes and types because it is used across the state for very small to very large projects. However, these standardized assumptions may not always be applicable for a given entity. Therefore, FNI adapted the TWDB 2026 UCM to better align the assumptions used in the tool to what TRWD would anticipate as part of project development. FNI solicited input from TRWD on assumptions to incorporate into the costing tool used to develop strategy costs in a memo dated August 15, 2023 with TRWD responses dated September 15, 2023 (**Appendix B**).

3.00 COSTING ASSUMPTIONS

Table 1 outlines the standard UCM assumptions and assumptions adopted for the TRWD IWSP Costing Tool. TRWD requested different assumptions from the 2026 UCM for annual interest rates (4% for reservoirs and non-reservoirs), 0% interest during construction and rate of return, 30-year debt service for both reservoirs and non-reservoir projects, and $0.06 cost per kW-hr for power costs. For power connection costs for pump stations, TRWD requested $5 million per pump station if the pump station is within 2 miles of power grid. If the pump station is further than 2 miles from the power grid, $5 million plus a $0.5 million per every mile of transmission line is assumed. Due to insufficient readily available power grid data, FNI assumed an average distance of 10 miles to large power for a total cost of $9 million per pump station. All infrastructure assumes a peaking factor of 1.5. These changes in assumptions more accurately reflect assumptions for TRWD future projects but are still high-level planning level costs with no design information available. Major crossings were estimated from GIS shapefiles for TxDot major roads, TCEQ major streams, and railway crossings. It should be noted no pipeline route analysis was performed and so the number of crossings is intended to capture an estimate of major, unavoidable crossings only. Straight-line pipeline distances were increased by 10% to account for route deviations. FNI also used consistent assumptions among strategies for land acquisition for pipeline right-of-way and for storage at booster pump stations. **Table 2** shows the assumptions used for pipeline right-of-way based on the diameter of pipeline. FNI assumed 32 hours of peak flow to calculate storage capacities at booster pump station locations.

Table 1: Comparison of UCM Costing Assumptions to TRWD Assumptions

	2026 Regional Water Plan Assumptions (UCM 2026)	TRWD IWSP Costing Tool
Date for Cost Estimates	September 2023	September 2023
Annual Interest Rate		
Reservoirs	3.5%	4.0%
Non-reservoirs	3.5%	4.0%
Interest During Construction		
IDC Rate	3.5%	0*
Rate of Return	0.5%	0*
Engineering, Legal, & Contingencies (Pipes)		
Contingency	-	
Engineering	-	
Total	30%	30%
Engineering, Legal, & Contingencies (Other)		
Contingency	-	
Engineering	-	
Total	35%	35%
Debt Service Period		
Reservoir	40 years	30 Years
Non-reservoir	20 years	30 Years
Power Costs		
Cost per kwh	$0.09	$0.06

	2026 Regional Water Plan Assumptions (UCM 2026)	TRWD IWSP Costing Tool
Power Connection Costs for Pump Stations (per HP)	$150/HP	$5M per pump station if within 2 miles of power grid. If > 2 miles from power grid, $5M PLUS $0.5M/mile of transmission line.
Pipeline length	Straight line + 10%	Straight line + 10%
*TRWD begins making payments on borrowed funds immediately (at the beginning of construction), so the costing tool should not include additional interest accrued during construction.		

Table 2: Right-of-Way Widths for Transmission Projects

Diameter	Assumed ROW Width
(Inches)	(Feet)
48	60
54	60
60	80
66	80
72	80
78	100
84	100
90	120
96	120
102	120
108	120
114	120
120	120
132	120
144	120

4.00 ADAPTATION OF COST CURVES

The TWDB UCM uses cost curves to estimate the cost per linear foot of pipeline and the cost of pump station based on size and/or horsepower. The cost curves are developed based on bid data from actual projects that are ENR indexed to a standard date of September 2023 dollars. This is the same date of cost used for regional water planning for comparison purposes. FNI reviewed the cost curves from the 2021 and 2026 UCMs as well as other relevant project bid data information to adapt the cost curves to be more appropriate for potential TRWD projects. The following sections outline the data reviewed, the 2026 TWDB UCM cost curve, and any adjustments made to the cost curves for the TRWD IWSP Costing Tool for the following project component types: pipelines, pumps stations (intake and booster), and balancing/terminal storage reservoirs. Dams costs were estimated individually (not with a curve) but the general assumptions are also documented in this section.

Pipelines

The 2026 UCM includes four pipeline cost curves (soil-rural, soil-urban, rock-rural, and rock-urban), that are intended to represent state-wide conditions. For TRWD, only two new cost curves were developed (soil-urban and soil-rural), as soil conditions are the most likely to be encountered in the area in which TRWD will be developing strategies. Rock installation is assumed to be infrequent and was not used. **Table 3** is a list of projects that were considered to develop TRWD pipeline cost curves.

Table 3*:* Pipeline Projects

Project Name
2005 TRWD Eagle Mountain Connection Pipeline Contract A
2005 TRWD Eagle Mountain Connection Pipeline Contract B
2009 TRWD Mansfield Bypass Project
2010 NTMWD APFM Project B, Phase 2 Pipeline
2010 NTMWD Replacement of Plano West Side Pipeline
2010 NTMWD Tawakoni to Terrell (North) – 42”
2010 NTMWD Tawakoni to Terrell (North) – 48”
2012 NTMWD Texoma to Wylie Pipeline
2013 NTMWD North McKinney Pipeline Phase 1 & 2
2014 TRWD IPL Pipeline Section 15-1
2014 TRWD IPL Pipeline Section 12/13
2015 TRWD IPL Pipeline Section 14
2015 TRWD IPL Pipeline Section 15-2
2016 TRWD IPL Pipeline Section 10/11
2016 TRWD IPL Pipeline Sections 17/18
2016 NTMWD Mainstem Pipeline
2019 NTMWD Bois d’Arc Raw Water Pipeline
2019 Kennedale Balancing Reservoir Bypass Pipeline
2020 NTMWD Bois d’Arc Treated Water Pipeline
2020 NTMWD Wylie to Rockwall Phase 1
2023 UTRWD Ralph Hall Pipeline
Additional Projects Incorporated after Memorandum (8/15/2023)
2010 Tawakoni to Terrell South
2024 IPL Pipeline Section 19-2A
2024 McKinney Delivery Point No. 3 to 4

Bid data from the projects listed in **Table 3** was adjusted to 2023 dollars and then a cost per linear foot by diameter was developed. **Figure 1** graphically displays these costs and a linear trend line. The data was also compared to the 2026 UCM cost curves. Based on engineering judgment, the TRWD rural pipeline costs were set to equal 2026 UCM curve through 78-inch pipe diameter. For pipelines larger than 78-inches, a large deviation between the UCM and the large diameter pipeline bid data was observed. A recent TRWD bid for the IPL Section 19-2A (84 inch) in March 2023 is more in alignment with other bid data available (very near the trend line). This suggests that even older (pre-COVID) cost data using the ENR index is still relevant. Therefore, the TRWD curve continues out at a lesser, more linear slope beyond the 2026 UCM 78-inch mark instead of increasing the cost more significantly. This more conservative (slightly higher costs per linear foot) than the trendline alone but does not exponentially increase the costs for larger diameter, long distance pipeline projects where TRWD IPL experience indicates that significantly better pricing could be attainable. The TRWD urban curve was then indexed up from the rural curve to account for higher prices of development in urban areas. The TRWD resulting cost curves for both rural and urban pipes are shown in **Figure 2** in green.

Figure 1: Pipeline Bid Data and Trendline

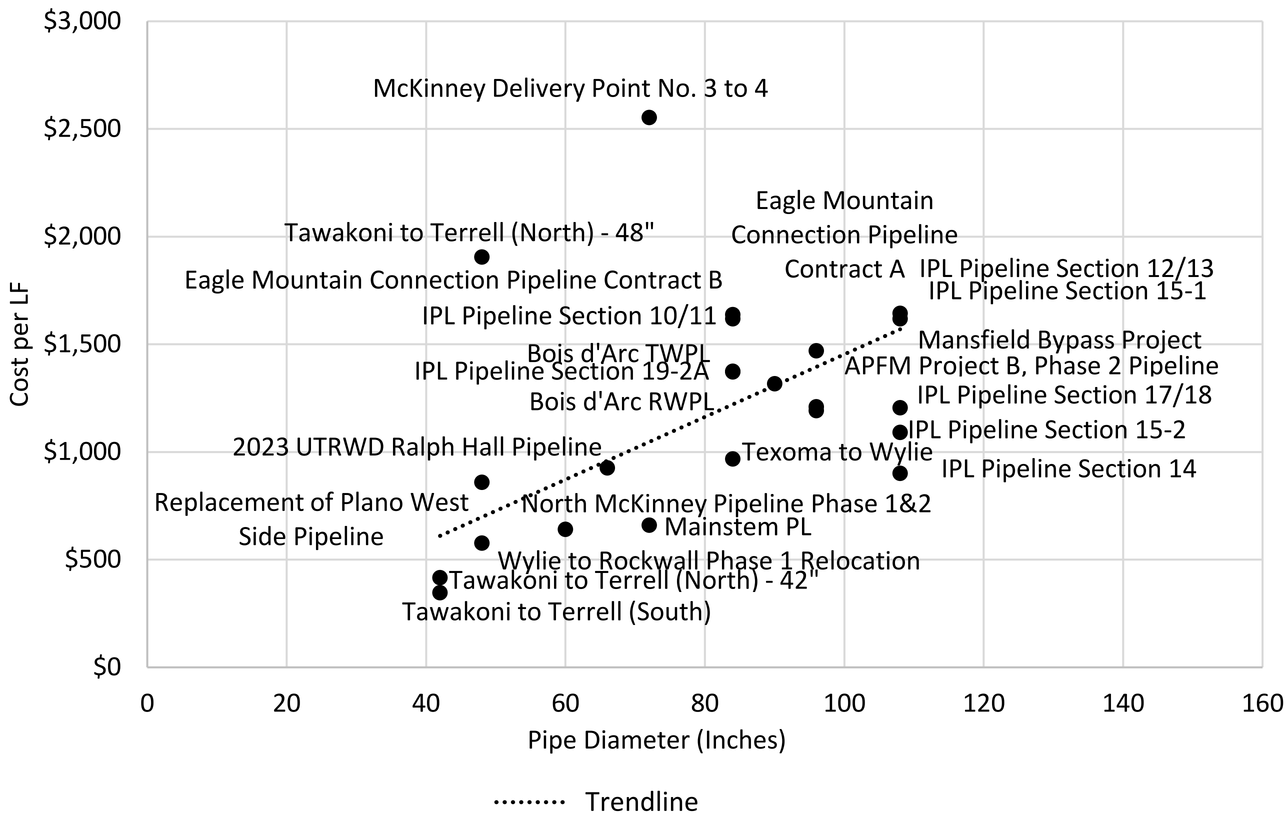
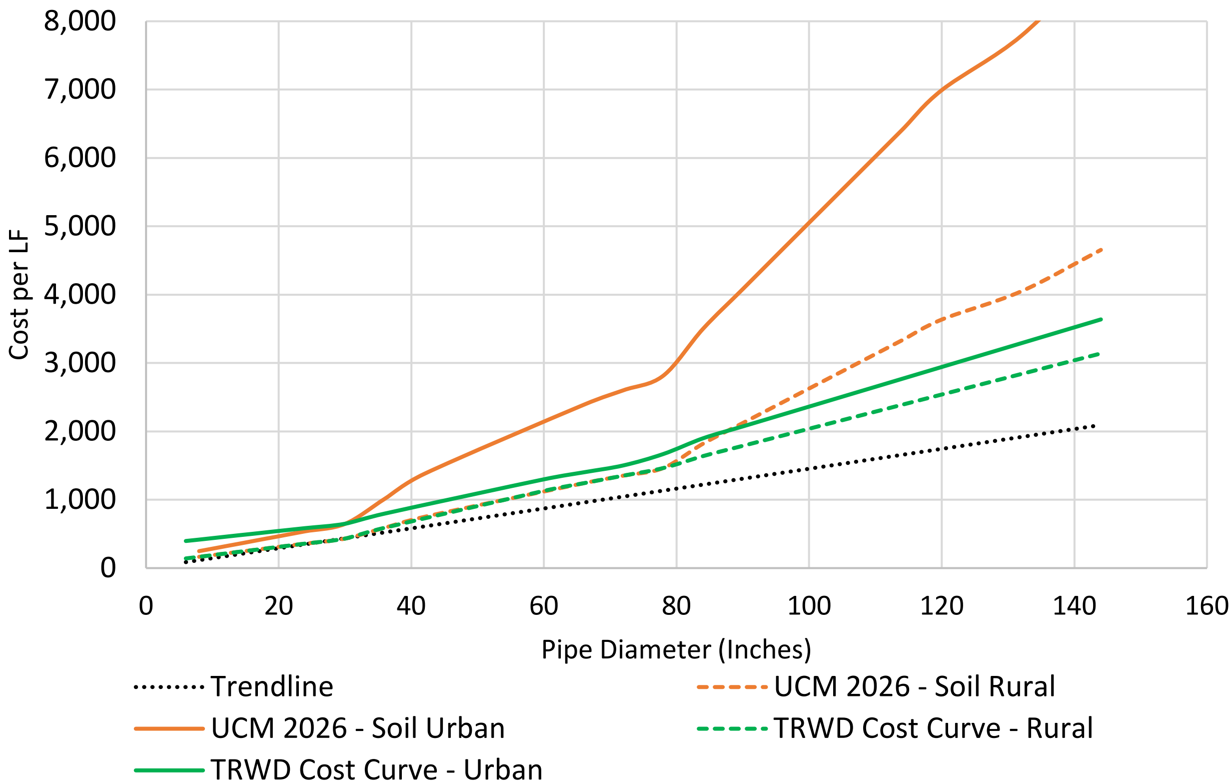


Figure 2: TRWD Pipeline Cost Curve Comparison



Pump Stations

The TWDB UCM has a cost curve for both booster pump stations (without an intake) and intake pump stations. Typically, the UCM uses a horsepower (hp) based curve but there is an optional curve based on MGD. FNI reviewed and updated the horsepower-based curves for both intake and booster pump stations. The MGD based curve was not developed or used.

Table 4 is a list of booster pump station projects considered for developing pump station costs. Two projects were dropped from consideration (shown in blue in **Figure 3**) because of their age (2006) and being outliers from the more recent data. Assumptions on the development of each curve are discussed below.

Table 4: Booster Pump Station Projects

Project Name	Additional Notes
2006 TRWD Rolling Hills Booster Pump Station	Not used in final curve
2006 TRWD Benbrook Booster Pump Station	Not used in final curve
2015 TRWD JB3 Booster Pump Station	
2019 NTMWD Leonard High Service Pump Station	
2022 Irving Carbon Pump Station Improvements	
2023 Lake Ralph Hall Pump Station	
2023 TRA Murphy Drive Pump Station	
Additional Projects Incorporated after Memorandum (8/15/2023)	
2017 McKinney Redbud	

Figure 3 shows the bid data for booster pump stations by horsepower and the final costs curve developed for TRWD. **Figure 4** compares the developed booster pump station cost curve for TRWD in horsepower to the curves from 2026 UCM. The TRWD IWSP Costing Tool curve is higher than those developed for the TWDB UCM based on other large pump station projects similar in nature to those TRWD might pursue for future water supplies.

Figure 3: TRWD Booster PS (hp) Cost Curve

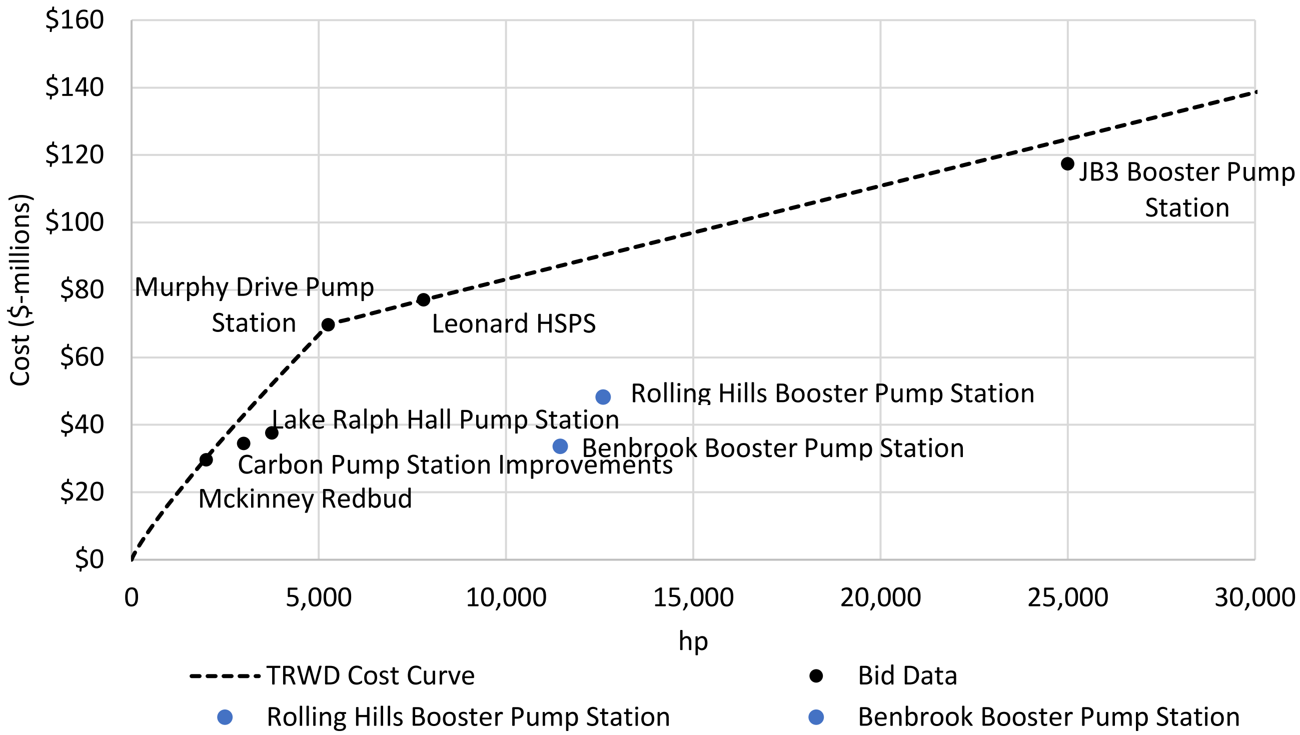


Figure 4: TRWD Booster PS (hp) Cost Curve Comparison

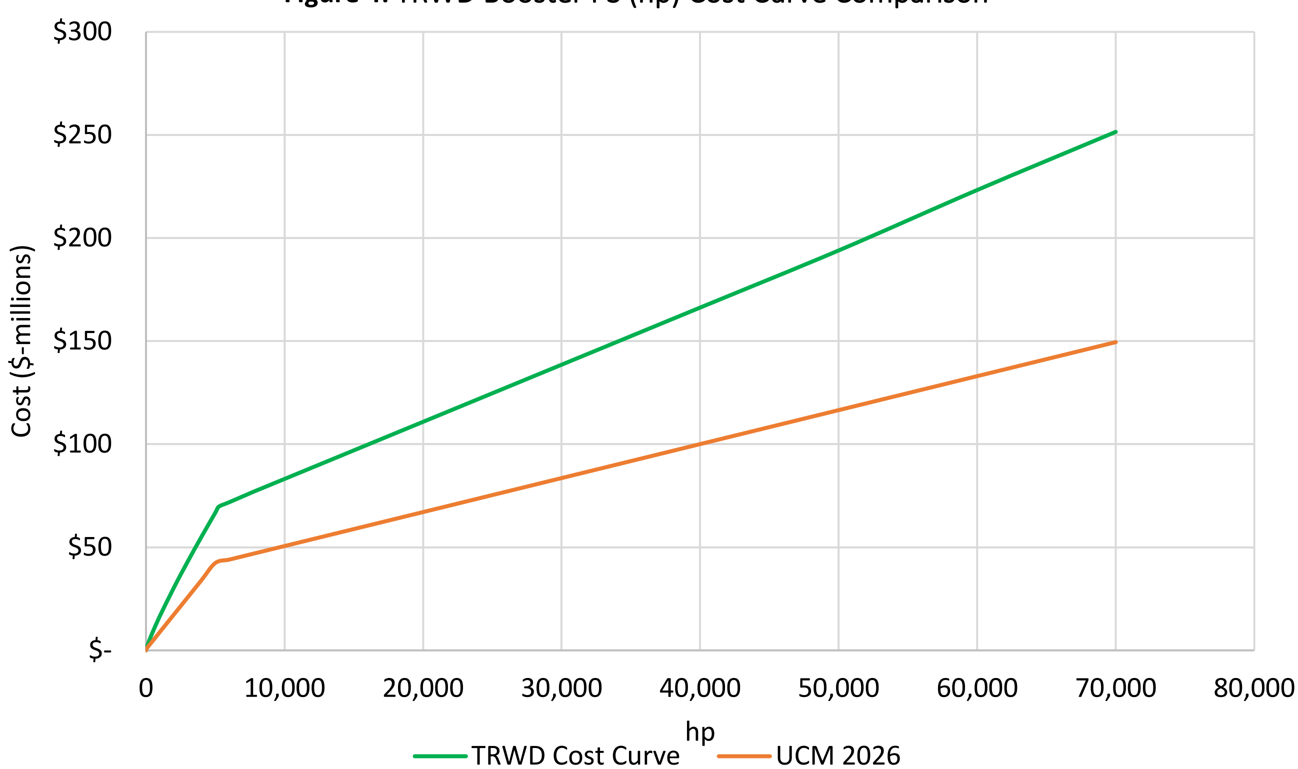


Table 5 is a list of intake pump station projects used to develop cost curves. These are the original projects sent to TRWD as well as an additional project that was considered. Note that two projects were excluded from the analysis for cost by hp because they did not have hp data available for the intake pump stations.

Table 5: Intake Pump Station Projects

Project Name	Additional Notes
2012 Lake Conroe Raw Water Intake Pump Station	
2016 TRWD JCC1	Did not have Initial hp data
2016 NTMWD Main Stem Pump Station	
2018 NTMWD Bois d'Arc Creek Reservoir Raw Water Pump Station	
2019 SRA Sabine River Pump Station	
2021 BCRUA Deep Water Intake Pump Station	Did not have Initial hp data
Additional Projects Incorporated after Memorandum (8/15/2023)	
2024 Lake Ralph Hall Intake	

Figure 5 shows the bid data for intake pump stations by horsepower and the final costs curve developed for TRWD. The developed curve captures the higher end of the data points. **Figure 6** compares the developed intake pump station cost curve for TRWD in horsepower to the curve from the 2026 UCM. The TRWD curve is higher than those developed for Regional Water Planning and is more representative of projects that TRWD might pursue.

Figure 5: TRWD Intake PS (hp) Cost Curve

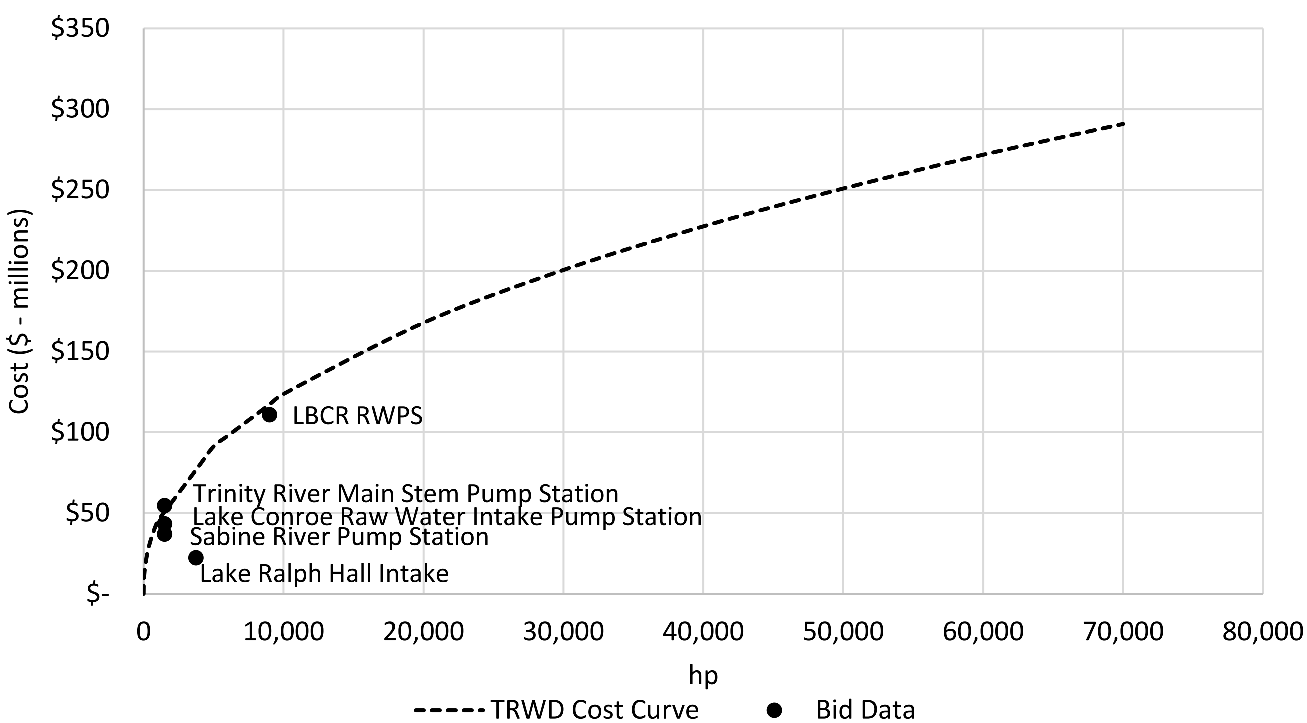
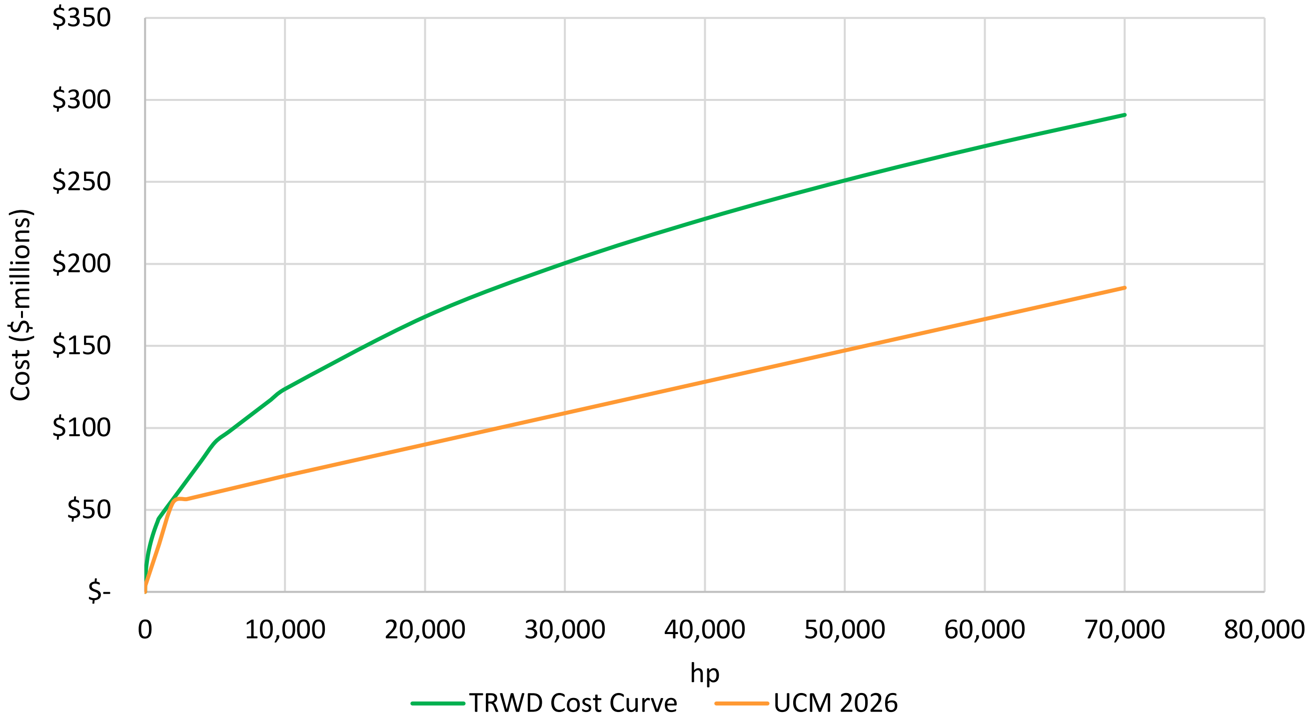


Figure 6: TRWD Intake PS (hp) Cost Curve Comparison



Balancing Reservoir/Terminal Storage Reservoirs

Table 6 is a list of balancing reservoir projects used to develop cost curves.

Table 6: Balancing Reservoir Projects

Project Name
2008 TRWD Eagle Mountain Connection Balancing Reservoir
2012 Texoma (Howe) Balancing Reservoir
2014 TRWD JB3R
2014 TRWD Midlothian Balancing Reservoir
2019 NTMWD Leonard WTP Terminal Storage Reservoir
2021 TRWD Kennedale Balancing Reservoir
Additional Projects Incorporated after Memorandum (8/15/2023)
2016 Kerrville Balancing Reservoir
2023 Leonard Terminal Storage Reservoir – Phase 2
2023 Eagle Mountain Balancing Reservoir Second Cell
2023 KBR 3rd Cell Improvements

Figure 7 shows the trendline fitted to the comparison of cost to capacity for balancing reservoirs. No adjustments were made to the trendline when developing the cost curve. **Figure 8** compares the developed balancing reservoirs cost curve for TRWD in acre-feet to the curves from the 2026 UCM.

Figure 7: Balacing Reservoir Bid Data and Trendline

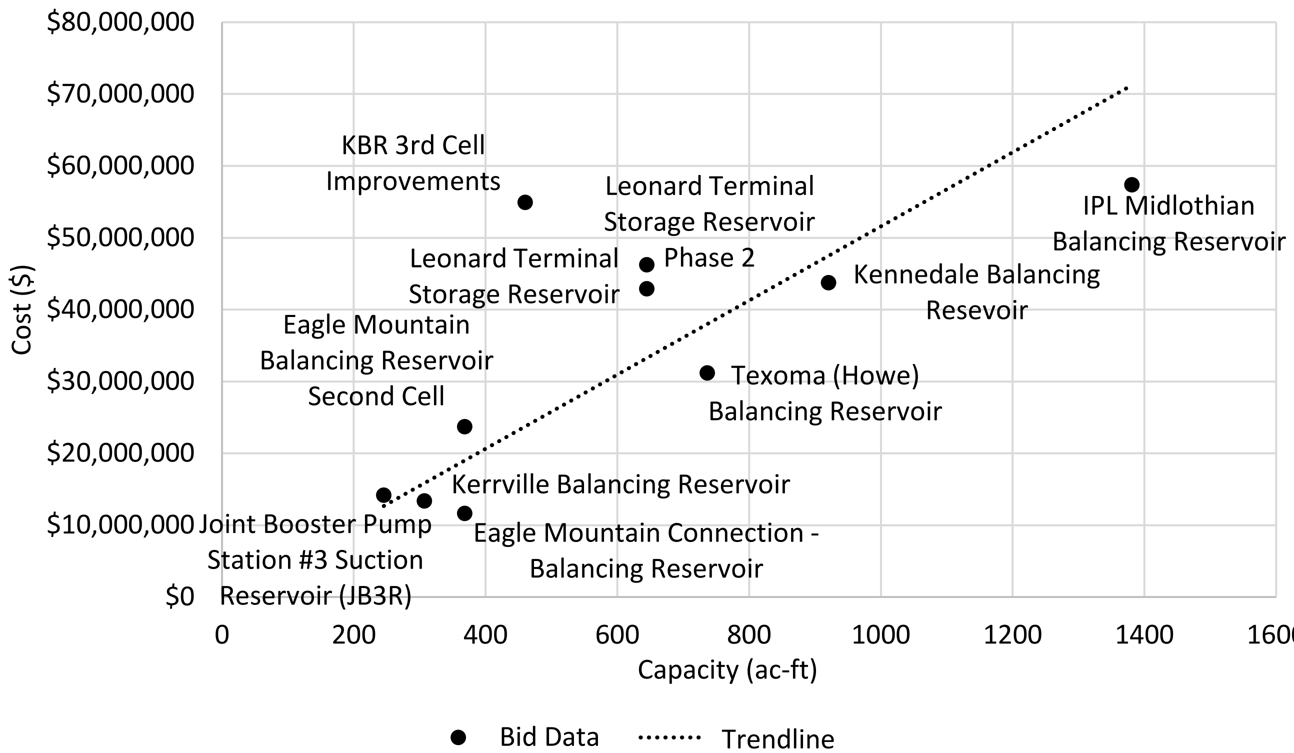
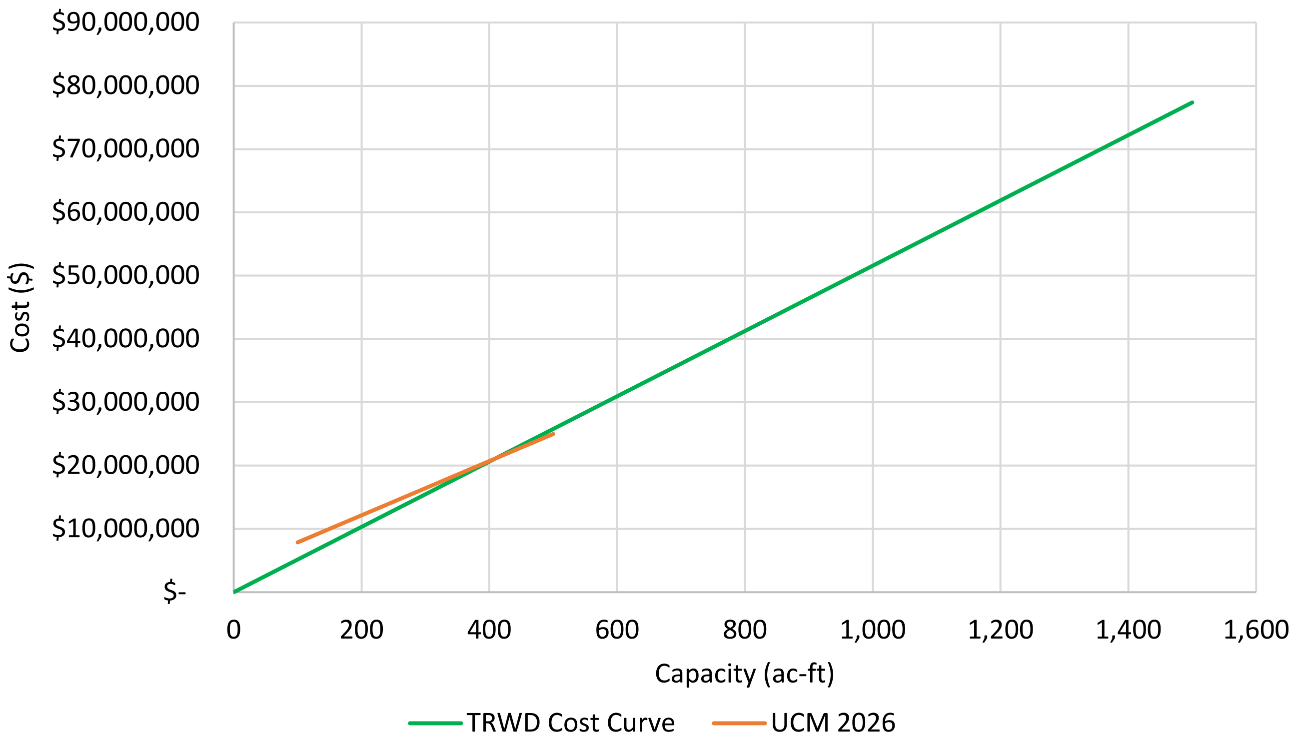


Figure 8: TRWD Balancing Reservoir Cost Curve Comparison



Dams

Because of their site-specific nature, dam costs were costed individually. Dam quantities were based on previous study and conceptual layouts. Unit costs for these quantities were based on recent projects at Bois d'Arc Lake and Lake Ralph Hall.

5.00 WMS COST ESTIMATE RESULTS

Using the adapted Costing Tool for the TRWD IWSP, FNI developed cost estimates for a subset of 14 water management strategies in the IWSP. The existing TRWD raw water system includes a "legacy pipeline" system that can transport water from Richland Chambers and Cedar Creek Reservoirs to Benbrook and Eagle Mountain. TRWD is also nearing completion of the Integrated Pipeline (IPL) which can also transport significant quantities of water from East Texas sources to their metroplex based reservoirs. As part of the IPL project, TRWD obtained additional easements and can add two additional parallel pipelines within their existing right of way. Multiple water supply options in the IWSP would develop water from the east or southeast and could potentially benefit from either existing or proposed future transmission. To account for the cost of the transmission capacity that would be used by a smaller project in these lines and to avoid overestimating the cost of small fully independent long distance transmission lines, FNI estimated the cost for a parallel IPL or "IPL-2" (WMS 21). This project has no independent yield, but a portion of the cost was assigned to each WMS that may use it. It is not intended to represent the cost of the project alone but create and more equitable comparison among strategies that may share in a portion of a much larger transmission project. Similarly, at TRWD's request, FNI developed an independent cost of the Eagle Mountain connection

(WMS 22) which would increase the capacity to move supplies from Lake Benbrook to Eagle Mountain where they can be used by a greater number of TRWD customers through releases as needed. This project also has no independent yield but may be necessary under some water supply portfolios. FNI developed a first draft of the costs shown in **Table 7**. In some instances, costs were revised by Carollo or other members of the Carollo team after FNI submittal. Both the capital and unit costs of WMS 03-19 included a prorated portion of the "IPL-2" (WMS 21), if appropriate (note: projects delivered to Bridgeport do not include this). Costs for WMS 21 and 22 are indicative of the capacity they can move but have no yield on their own and must be paired with other water supply development projects.

Table 7: FNI Assigned WMS Cost Results

Strategy Number	Strategy Name
WMS_03	New RC Wetlands
WMS_07	Tehuacana
WMS_08	Lake Ringgold
WMS_10	Toledo Bend 1
WMS_11	Toledo Bend 2
WMS_12	Mainstem Trinity OCR
WMS_13	CC Wetlands Adjacent OCR
WMS_14	Lake Palestine Purchase
WMS_16	TRWD Developed Groundwater
WMS_17	Purchased Groundwater
WMS_19	Brazos River Authority Swap (Removed)
WMS_19	Anderson County GW
WMS_21	Parallel IPL
WMS_22	Parallel Eagle Mountain

Appendix A: Cost Tables

Table A. 1: TRWD Pipeline Cost

Pipeline	Pipeline Cost (September 2023)	
x (ID)	y ($/ft)	y ($/ft)
	Rural	Urban
6	$141	$397
8	$165	$417
10	$189	$438
12	$214	$459
14	$238	$481
16	$262	$501
18	$286	$522
20	$310	$543
24	$358	$585
30	$432	$649
36	$590	$798
42	$750	$948
48	$909	$1,097
54	$1,020	$1,199
60	$1,130	$1,299
66	$1,242	$1,401
72	$1,353	$1,503
78	$1,464	$1,669
84	$1,639	$1,899
90	$1,789	$2,073
96	$1,939	$2,247
102	$2,089	$2,421
108	$2,239	$2,595
114	$2,389	$2,768
120	$2,539	$2,942
132	$2,840	$3,290
144	$3,140	$3,638

Table A. 2: TRWD Booster Pump Station Cost

Pump Station	Booster Pump Station Cost (September 2023)
x (horsepower)	y ($-millions)
0	$0.00
5	$0.16
10	$0.31
20	$0.57
25	$0.69
50	$1.25
100	$2.28
200	$4.15
300	$5.89
400	$7.55
500	$9.15
600	$10.71
700	$12.23
800	$13.73
900	$15.19
1,000	$16.64
2,000	$30.26
3,000	$42.94
4,000	$55.04
5,000	$66.73
5,250	$69.67
6,000	$71.84
7,800	$77.06
8,000	$77.61
9,000	$80.38
10,000	$83.15
20,000	$110.86
30,000	$138.57
40,000	$166.27
50,000	$193.98
60,000	$223.30
70,000	$251.51

Table A. 3: Intake Pump Station Cost

Pump Station	Intake Pump Station Cost (September 2023)
x (Capacity - hp)	y ($ - millions)
0	$0.00
5	$4.39
10	$5.95
20	$8.07
25	$8.91
50	$12.07
100	$16.36
200	$22.19
300	$26.52
400	$30.08
500	$33.18
600	$35.94
700	$38.46
800	$40.79
900	$42.96
1,000	$45.00
2,000	$56.56
3,000	$68.12
4,000	$79.68
5,000	$91.25
6,000	$97.73
7,000	$104.23
8,000	$110.73
9,000	$117.22
10,000	$123.72
20,000	$167.76
30,000	$200.47
40,000	$227.47
50,000	$250.90
60,000	$271.82
70,000	$290.87

Table A. 4: Balancing or Terminal Storage

Storage (acft)	September 2023
x (ac-ft)	y ($)
0	$ -
50	$2,579,031
100	$5,158,061
200	$10,316,123
300	$15,474,184
400	$20,632,245
500	$25,790,307
800	$41,264,491
1000	$51,580,613
1500	$77,370,920

Appendix B: Costing Tool Memo and Response

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

801 Cherry Street, Suite 2800 + Fort Worth, Texas 76102 + 817-735-7300 + FAX 817-735-7491 www.freese.com

TO: Nicole Rutigliano, Amy Kaarlela

CC: Jessica Fritsche

FROM: Lissa Gregg, Kristal Williams

SUBJECT: TRWD IWSP Cost Data Review and Request for more TRWD Bid Data

DATE: 8/15/2023

PROJECT: TRWD IWSP (FNI Project Number: JCE23615)

Tarrant Regional Water District (TRWD) hired the Carollo team to update TRWD's Integrated Water Supply Plan (IWSP). Freese and Nichols' (FNI) role on the team is to develop cost information for various future water supply options. As a part of this work, FNI is developing a modified version of the Texas Water Development Board's (TWDB)'s Unified Costing Model (UCM). The UCM estimates planning level costs based off a cost curve that relates the general size of a project to the expected cost. The modified costing tool will include updated cost curves for intake pump stations, booster bump stations, and pipelines, terminal storage or balancing reservoir storage. The costs will be developed using recent bids from projects that are reasonably similar to the type and style of facility TRWD would build.

FNI has created a list of proposed projects to consider in the development of the modified costing curves. FNI requests that TRWD review the list of proposed projects and provide feedback on them. Additionally, FNI requests that TRWD provide any additional bid data available for the relevant project types that could improve the quality of the cost curve.

Pipeline Projects for Consideration:

- 2005 TRWD Eagle Mountain Connection Pipeline Contract A
- 2005 TRWD Eagle Mountain Connection Pipeline Contract B
- 2009 TRWD Mansfield Bypass Project
- 2010 NTMWD APFM Project B, Phase 2 Pipeline
- 2010 NTMWD Replacement of Plano West Side Pipeline
- 2010 NTMWD Tawakoni to Terrell (North) – 42"
- 2010 NTMWD Tawakoni to Terrell (North) – 48"
- 2012 NTMWD Texoma to Wylie Pipeline
- 2013 NTMWD North McKinney Pipeline Phase 1 & 2
- 2014 TRWD IPL Pipeline Section 15-1
- 2014 TRWD IPL Pipeline Section 12/13
- 2015 TRWD IPL Pipeline Section 14
- 2015 TRWD IPL Pipeline Section 15-2
- 2016 TRWD IPL Pipeline Section 10/11

- 2016 TRWD IPL Pipeline Sections 17/18
- 2016 NTMWD Mainstem Pipeline
- 2019 NTMWD Bois d'Arc Raw Water Pipeline
- 2019 Kennedale Balancing Reservoir Bypass Pipeline
- 2020 NTMWD Bois d'Arc Treated Water Pipeline
- 2020 NTMWD Wylie to Rockwall Phase 1
- *2023 UTRWD Ralph Hall Pipeline (will depend on timing if available for use)*

Booster Pump Station Projects for Consideration:

- 2006 TRWD Rolling Hills Booster Pump Station
- 2006 TRWD Benbrook Booster Pump Station
- 2015 TRWD JB3 Booster Pump Station
- 2019 NTMWD Leonard High Service Pump Station
- 2022 Irving Carbon Pump Station Improvements
- 2023 Lake Ralph Hall Pump Station
- 2023 TRA Murphy Drive Pump Station

Intake Pump Station Projects for Consideration:

- 2012 Lake Conroe Raw Water Intake Pump Station
- 2016 TRWD JCC1
- 2016 NTMWD Main Stem Pump Station
- 2018 NTMWD Bois d'Arc Creek Reservoir Raw Water Pump Station
- 2019 SRA Sabine River Pump Station
- 2021 BCRUA Deep Water Intake Pump Station

Balancing Reservoir/Terminal Storage Reservoirs for Consideration:

- 2008 TRWD Eagle Mountain Connection Balancing Reservoir
- 2012 Texoma (Howe) Balancing Reservoir
- 2014 TRWD JB3R
- 2014 TRWD Midlothian Balancing Reservoir
- 2019 NTMWD Leonard WTP Terminal Storage Reservoir
- 2021 TRWD Kennedale Balancing Reservoir

Dam Costs:

Dams are proposed to be costed without using a cost curve due to the site-specific nature of a dam. Dam costs are proposed to be updated based on unit costs from Bois d'Arc Lake and Ralph Hall. Dam quantities will be based on previous study and conceptual layouts.

UCM Assumptions:

FNI also requests that TRWD review the list of UCM state-defined assumptions and provide updated assumptions more representative for TRWD. Engineering, legal and contingencies are listed as a combined 30% for pipes and 35% for all other projects in the TWDB UCM. However, TRWD may want to consider 30% for contingency and 15% for engineering, for a total of 45%. Further, the state UCM includes 40-year bonds for reservoirs and 20-years for non-reservoirs. Many entities use 30-year bonds even for large projects, such as reservoirs. It is recommended that TRWD match this assumption with what is typical for financing projects in their system. Since many of the projects TRWD will evaluate are located in more remote areas, FNI recommends TRWD consider a higher price per horsepower for pump stations along the transmission routes, with a minimum cost for remote stations. Recent other FNI planning studies have used $350/HP with a minimum cost of $5 million for remote connections.

	2026 Regional Water Plan Assumptions	TRWD UCM
Date for Cost Estimates	September 2023	
Annual Interest Rate		
Reservoirs	3.5%	
Non-reservoirs	3.5%	
Interest During Construction		
IDC Rate	3.5%	
Rate of Return	0.5%	
Engineering, Legal, & Contingencies (Pipes)		
Contingency	-	
Engineering	-	
Total	30%	
Engineering, Legal, & Contingencies (Other)		
Contingency	-	
Engineering	-	
Total	35%	
Debt Service Period		
Reservoir	40 years	
Non-reservoir	20 years	
Power Costs		
Cost per kwh	$0.09	
Power Connection Costs for Pump Stations (per HP)	$150*	
Pipeline length	Straight line + 10%	

*From 2019 UCM, updated numbers for 2026 Regional Water Plan are not yet available.

TO: Lissa Gregg (FNI)
CC: Jessica Fritsche (Carollo), Nicole Rutigliano (TRWD)
FROM: Amy Kaarlela
DATE: September 15, 2023
RE: IWSP Costing Tool Assumptions

This memo provides information in response to your request for input (memo dated Aug 15, 2023).

TRWD Staff has reviewed the list of projects to be used to develop cost curves for the IWSP Costing Tool. We have only one addition to the list. It is the Kennedale Balancing Reservoir Bypass Pipeline. Detailed cost information on this project has been added to the IWSP project SharePoint. Cost KBRBYP Pay App 016-May 2019.xlsm

As to the general assumptions to be used in the Costing Tool, we have populated the last column of the table below with our preferred assumptions. Please contact me if you have any questions.

	2026 Regional Water Plan Assumptions	TRWD UCM
Date for Cost Estimates	September 2023	September 2023
Annual Interest Rate		
Reservoirs	3.5%	4.0%
Non-reservoirs	3.5%	4.0%
Interest During Construction		
IDC Rate	3.5%	0*
Rate of Return	0.5%	0*
Engineering, Legal, & Contingencies (Pipes)		
Contingency	-	
Engineering	-	
Total	30%	30%
Engineering, Legal, & Contingencies (Other)		
Contingency	-	
Engineering	-	
Total	35%	35%
Debt Service Period		
Reservoir	40 years	30 Years
Non-reservoir	20 years	30 Years
Power Costs		
Cost per kwh	$0.09	$0.06
Power Connection Costs for Pump Stations (per HP)	$150*	$5M per pump station if within 2 miles of power grid. If > 2 miles from power grid, $5M PLUS $0.5M/mile of transmission line.
Pipeline length	Straight line + 10%	Straight line + 10%

*TRWD begins making payments on borrowed funds immediately (at the beginning of construction), so the costing tool should not include additional interest accrued during construction.

APPENDIX C

PROJECT ASSUMPTIONS

Table C.1 TRWD IWSP Update: Project Assumption Matrix

No.	Topic	Assumption	Impact on Results
1	Water Demands	The Suburban Sprawl with Stressor (S3) demand scenario was used to assess the gap and form portfolios. This is a high growth scenario under hot and dry conditions used for planning. These demands are conservatively high.	Risk of lower gap than analyzed
2	Water Demands	The S3 scenario includes temperature increases and precipitation decreases from climate change, thereby increasing both average and hot and dry demand projections. These demands are conservatively high.	Risk of lower gap than analyzed
3	Water Demands	Actual to average assumptions in RiverWare shift forecasted decadal water demands up or down based on hydrologic year data. These ratios conservatively range from 0.65 (wet/cool month) up to 1.58 (hot/dry month). These ratios are conservatively high.	Risk of lower gap than analyzed
4	Water Demands	A Wise County user group was added to the water demand forecast with supplies assumed to come from Eagle Mountain Lake. These demands have not been studied by TRWD in detail and are likely conservative. Demands for the Wise County user group begin in 2030, which may or may not occur.	Risk of lower gap than analyzed
5	RiverWare	Reservoirs are assumed full at the beginning of the simulations.	Risk of higher gap than analyzed
6	RiverWare	Historical period-of-record hydrology is assumed. Based on climate projections and paleoclimate reconstructions, there is potential for extreme events to occur that are worse than the historical record.	Risk of higher gap than analyzed
7	RiverWare	Pipelines are assumed capable of being operated at max future capacity. Due to biofouling, the potential exists that max capacity cannot be reached.	Risk of higher gap than analyzed
8	RiverWare	Reservoir space declines every decade because of sedimentation, based on EAC curves from Region C study.	Neutral, low risk
9	RiverWare	The Drought Management Plan is not active in the evaluations. During extreme drought, it is likely that customers would be asked to curtail. Thus, keeping the drought mitigation turned off is a conservative approach.	Risk of lower gap than analyzed
10	RiverWare	Mary's Creek Water Reclamation facility is active beginning in 2030, with discharge increasing by decade. This is likely to occur.	Neutral, low risk
11	RiverWare	TRA Return Flows are purchased beginning immediately, with an amount increasing each decade, and are available to pump into the wetlands, without counting against the existing wetlands permits. This is likely to occur.	Neutral, low risk
12	RiverWare	Assumed simultaneous Eagle Mountain Connection Discharge and Benbrook Pumping by 2040. This infrastructure is likely to be constructed if determined needed to improve reliability.	Neutral, low risk
13	Strategy Evaluation	DPR yield was estimated given the lower demand projections, to be conservative. This strategy could yield more supply if based on the higher demand projections and a higher base flow.	More yield available than assumed
14	Strategy Evaluation	Lake Palestine Groundwater Purchase assumed 15,000 AFY of groundwater, which may exceed the Carrizo-Wilcox MAG. A more conservative estimate would be approximately 6,400 AFY from the Queen City Aquifer, which is available according to the MAG.	Less yield available than assumed

No.	Topic	Assumption	Impact on Results
15	Strategy Evaluation	The yield of the Sulphur River Basin options (Marvin Nichols, Wright Patman, and the combined) are highly dependent on assumptions around environmental flow releases, authorized diversions from Lake Wright Patman, and the seniority of the permits. The high yield scenarios were selected for the IWSP Update, which could actualize differently.	Less yield available than assumed
16	Strategy Evaluation	The firm yield of Tehuacana is assumed to be permitted before CC and RC unpermitted firm yield. If CC and RC unpermitted firm yield is permitted first, or if environmental flows are included, the firm yield reduces by about 2,000 AF.	Less yield available than assumed
17	Strategy Evaluation	The ASR strategy is conceptual. 10 mgd was assumed at Eagle Mountain Lake, which does improve drought year reliability. If, after detailed study, ASR is not viable, this yield would not be available.	Less yield available than assumed
18	Strategy Evaluation	The Mainstem Trinity OCR is a joint project with DWU. At this time, DWU has not included water quality mitigation strategies in the design of the OCR. If this were not included, TRWD could determine this strategy would have undesired water quality impacts, precluding them as a partner.	Less yield available than assumed
19	Strategy Evaluation	Advancing water conservation adoption is generally a reliable strategy. However, as TRWD does not provide these services directly to the consumer, there is uncertainty in the ability of TRWD to meet the assumed water conservation savings.	Less yield available than assumed
20	Strategy Evaluation	The full permitted water right at Lake Ringgold was assumed. TRWD is not the holder of this water right and there is high uncertaintly in whether this yield could be negotiated for TRWD's sole use.	Less yield available than assumed

APPENDIX D

STRATEGY SCREENING

Table D.1 Strategies Identified during TRWD and Stakeholder Workshops in November 2023

No.	Description	IWSP	Potential Future Consideration[1]	Include in Baseline (✓)[2]
Conservation Strategies				
1	Moderate conservation (combination of strategies)			✓
2	Advanced conservation (combination of aggressive strategies)	✓		
3	Mandatory conservation before reservoirs hit target stage		*	
4	Zoning – remove requirements for sprinklers		*	
5	Reduce customer unaccounted for water (incentivize?)	✓		
6	Conservation strategies being employed by Las Vegas on turf		*	
7	Satellite leak detection collaboration, wide area		*	
8	Investigating the potential for conservation-oriented rate structures		*	
Reuse Strategies				
9	Current project for Mary's Creek			✓
10	Reuse from TRA Central to CC (current leftovers 60,000 AF)		*	
11	Reuse from TRA Central to CC (future flows)		*	
12	Partnership/ownership of reuse via DPR	✓		
13	Expansion of Mary's Creek (15 to 27+ mgd)		*	
14	CC wetlands collaboration w/ NTMWD		*	
15	Second RC Wetlands	✓		
16	Wetlands on West Fork			
17	Funding nutrient removal at WWTPs to increase wetland treatment		*	
System Operations				
18	Permitting future wastewater effluent		*	
19	Unpermitted firm yield in CC and RC	✓		
20	Regional optimization		✓	
21	Bridgeport Reallocation	✓		
22	Pipeline to Bridgeport from Eagle Mountain		*	
23	Sys Ops project (included as Trinity River Return Flows in some portfolios to pair with Second RC Wetlands)	✓		
24	IPL North - shared pipeline from Roberts/Lewisville that could initially utilize water from Texoma but ultimately utilize water from MN		*	
25	Pipeline between RC and CC to make use of ExFlo water		*	
26	DWU-TRWD Future Supplies Collaborative Adjustments		*	
Surface Water/Reservoirs				
27	Tehuacana	✓		
28	Marvin Nichols (regional project)	✓		
29	Wright Patman reallocation (possibly combine w/ MN)	✓		
30	Toledo Bend – TX share w/ partner	✓		

No.	Description	IWSP	Potential Future Consideration[1]	Include in Baseline (✓)[2]
31	Toledo Bend – LA share w/ partner		*	
32	Lake Columbia		✓	
33	Lake Ringgold	✓		
34	Ralph Hall		✓	
35	Parkhouse I/II		✓	
36	Lake O' the Pines		✓	
37	Red River OCR via partnership		✓	
38	Red River OCR alone		✓	
39	Dallas OCR on Trinity	✓		
40	Italy OCR		✓	
41	New potential reservoir/OCR		*	
42	Fairfield Lake		*	
43	Cable Mountain Lake		*	
44	Upper Neches RMWA uncontracted water via DWU IPL section from Palestine		*	
45	Working with Denton to bring water from Ray Roberts to Bridgeport (~50 miles)		✓	
Groundwater				
46	ASR – treated water similar to pilot	✓		
47	Carrizo Wilcox – TRWD developed	✓		
48	Carrizo Wilcox – investor developed		✓	
49	1953 Recharge Study using TRA water (mid-cities on the Trinity)		*	
50	Brackish		✓	
51	Flood scalping ASR		*	
52	Groundwater wells adjacent to RC Shannon or CC wetlands		*	
53	Shallow groundwater in Tarrant Co. – distributed irrigation for green spaces/increase floodway sumps as infiltration basins		*	
54	Shallow aquifer ASR pilot on West Fork w/ FW Westside or EM WTPs		*	
55	Regional water "banking" of groundwater (similar to Santa Clarita Valley WD in CA)		*	
Interbasin Transfer/Water Swaps				
56	Lower Trinity 70/30 (via LNVA or desal)		✓	
57	Brazos River purchase		✓	
58	Arkansas water via Texarkana/Wright Patman		✓	
59	Arkansas water	✓		
60	Denton partnership Ray Roberts for Bridgeport		✓	

No.	Description	IWSP	Potential Future Consideration[(1)]	Include in Baseline (✓)[(2)]
Oklahoma Water				
61	Oklahoma water – all options		✓	
Reservoir Management				
62	Enhanced watershed management (crop to pasture)		✓	
63	Dredging		✓	
64	Evaporative loss reduction (shade balls/floating solar)		✓	
65	Reservoir dredging study and evaporation loss control research		*	
Expanded Service Offerings				
66	Stormwater provider		*	
67	Wastewater provider		*	
68	One water concept		✓	
69	Become regional provider partnering with smaller MUDs		✓	
70	Decatur wastewater		*	
71	UTRWD partnership		✓	
72	Wichita Falls as customer		*	
73	Bring Arlington back to Village Creek WWTP		*	
74	Facilitating public private partnerships within the service area for reuse (Railport/GCA/TRA model)		*	

Notes:
CC - Cedar Creek Reservoir; DPR – Direct Potable Reuse; NTMWD – North Texas Municipal Water District; RC – Richland-Chambers Reservoir; TRA – Trinity River Authority; WS - workshop
(1) ✓ indicates strategies presented in Chapter 6.13 Other Strategies Considered.
* indicates strategies that may be considered in future planning work but may not be well-enough defined yet.
(2) ✓ indicates strategies that are already included as a planned project in the existing TRWD system.

APPENDIX E

STRATEGY FACTSHEETS

Advancing Conservation

trwd Tarrant Regional Water District

DESCRIPTION: TRWD will develop and implement a robust, cost-effective regional water conservation program in coordination with customer cities to offer direct-to-customer rebates, utility cost-share measures, expanded education, and assistance in passing key ordinances, all aimed at reducing demand, improving efficiency, and ultimately delaying the need for capital improvement projects.

Yield – 2080 Average	Yield – 2080 Max	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
80.8 mgd	108.0 mgd	$0.00 $/kgal	$2.30 $/kgal	$2.30 $/kgal	$0 $/kgal	$0 $/kgal
90,500 afy	121,000 afy	$0 $/af	$750 $/af	$750 $/af	$0 $/af	$0 $/af

OVERVIEW

Strategy Type	**Conservation**
Strategy Theme(s)	**One Water**
Phasing Potential	**Yes**
Partnerships	**Customers and Other Providers**
Current Status	**Conceptual**
Implementation Time (yrs)	**Ongoing**

KEY INFRASTRUCTURE

No infrastructure required

CAPITAL COST[5]

Total Strategy Cost (millions)	**$750.1**
External Development Cost (millions)[6]	**$750.1**
Intersystem Transmission Cost (millions)[7]	**$0.0**

Note: Conservation program costs are included under unit cost after debt service, as an expanded program would require additional annual funding but not likely debt service. Total annual costs are provided.

STRATEGY QUALITATIVE SCORES

System Risk	5	*Minimal risks although less ability for demand cutback during drought*
Permit Uncertainty & Complexity	5	*No permitting required*
Collaboration Potential	4	*Requires voluntary, willing partnerships with customers*
Operational Simplicity	5	*Conservation planning and implementation relatively simple*
Phasing Potential	5	*Conservation program can grow and adapt with demands and development conditions*
Public Acceptance	5	*Generally, voluntary conservation is widely accepted*
Multi-benefit Project	3	*Environmental benefits of leaving more water in rivers, streams, and lakes*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Advancing Conservation

KEY ASSUMPTIONS

Yield Estimate:

- The yield assumptions are broadly based on the conservation savings assumption from the TRWD Service Area Demand Update: Water Demand Forecast Report (August, 2020). Additional conservation savings are based on the Suburban Sprawl with Stressors with Adaptation scenario, which assumes an additional 10% reduction in water use by 2070 when compared to the Suburban Sprawl with Stressors forecast for which the IWSP Update is based. These targeted additional savings were the basis for the measure.
- The water conservation yield estimate assumes an overall target of 55 gallons per capita per day (gpcd) for indoor residential water use, which is a reduction from the underlying forecast assumption of 62 gpcd. Further, the measure assumes an additional 10% reduction in outdoor residential water use, and 12% savings to nonresidential use. This results in the targeted additional 10% reduction.
- Savings were calculated annually from 2030 through 2080. Savings, or yield, averaged 38,300 afy over the full 50-year period of analysis. Annual conservation savings reach 90,500 af by 2080 during an average year, and a maximum of 121,000 af.

Other:

- TRWD expanding its conservation program could include measures that provide utility funding for AMI with a connected user interface application, large water user audits, water loss control, rebate programs plumbing fixtures, cooling tower optimization, retrofits of public building, and education programs.
- Proposed programs targeting outdoor uses could include widespread adoption of irrigation watering guidelines, and rebate programs for efficient irrigation equipment and native landscape conversions.

Cost Estimate:

- The cost of water conservation programs are based on selection of pre-defined conservation measures from the Municipal Water Conservation Planning Tool, developed by the Texas Water development Board (TWDB) in 2018.
- The selected measures include a mix of rebates, retrofits, distributions, site visits, and customer assistance programs for indoor and outdoor uses in the residential and nonresidential sectors. The average unit cost (adjusted for inflation) in the tool is approximately $750 per AF.
- This WMS assumes annual programmatic costs to achieve the additional savings each year. Program costs grow over time, with increased demands and new saving targets.

STRATEGY INFOGRAPHIC

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Direct Potable Reuse

Tarrant Regional Water District

DESCRIPTION: Enhance water efficiency and optimize local supplies in the Fort Worth metroplex by using purified recycled water to augment drinking water supplies. Relative to the Cedar Creek and Richland-Chambers wetlands reuse systems, this would reduce the amount of conveyance infrastructure and energy needed to recycle water in the TRWD service area. This option was conceptualized as constructing an advanced water purification facility (AWPF) to further treat a portion of the tertiary-treated flow and then convey to augment raw water supplies. This strategy represents a direct potable reuse (DPR) scenario and would require contractual agreements between multiple parties.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
18.3 mgd	18.3 mgd	$5.88 $/kgal	$2.47 $/kgal	$2.43 $/kgal	$0 $/kgal	$0 $/kgal
20,500 afy	20,500 afy	$1,917 $/af	$804 $/af	$792 $/af	$12 $/af	$0 $/af

OVERVIEW

Strategy Type	Reuse
Strategy Theme(s)	Resiliency, One Water
Phasing Potential	Yes
Partnerships	TRA, City of Fort Worth
Current Status	Conceptual
Implementation Time (yrs)	18

KEY INFRASTRUCTURE

Pipelines	1 mile of 36" 0.5 miles of 30"
Pump Stations	1 pump station
Facility	20 mgd AWPF

CAPITAL COST[5]

Total Strategy Cost (millions)	$394.6
External Development Cost (millions)[6]	$394.6
Intersystem Transmission Cost (millions)[7]	$0.0

STRATEGY LOCATION

STRATEGY QUALITATIVE SCORES

Criterion	Score	Rationale
System Risk	5	*If water quality parameters are triggered at the AWTF, could result in flow diversion; drought resistant supply*
Permit Uncertainty & Complexity	1	*DPR permitting required*
Collaboration Potential	2	*Complex agreements between multiple parties required*
Operational Simplicity	1	*Advanced treatment operations required*
Phasing Potential	5	*Capacity can be expanded over time and grow as wastewater and water demands grow*
Public Acceptance	2	*Acceptance of DPR as a reliable, efficient, and safe water supply is increasing but there may be initial obstacles to acceptance*
Multi-benefit Project	2	*Some environmental benefits from reduced energy consumption*

The highest possible score is 5, indicating a positive qualitative attribute.

Direct Potable Reuse

KEY ASSUMPTIONS

Yield Estimate:

- This option was conceptualized as constructing an advanced water purification facility (AWPF) to further treat a portion of the tertiary-treated flow produced at the Village Creek Wastewater Treatment Plant (VCWWTP), then using that purified recycled water to augment existing raw water supply sources to the TRA Tarrant County Water Supply Project (WPS).
- The VCWWTP is owned and operated by the City of Fort Worth and has a permitted treatment capacity of 166 mgd. Current discharge flows are approximately 95 mgd. The VCWWTP discharges most of its treated effluent to the Trinity River that ultimately feeds TRWD's existing wetlands at Richland-Chambers and future wetlands at Cedar Creek. These systems are part of TRWD's reuse permits. Liquids treatment at VCWWTP includes headworks, primary clarification, conventional activated sludge, final clarification, and effluent filtration by traveling and deep sand filter beds. Most filtered effluent is sent to chlorine disinfection prior to discharge to the Trinity River. A portion of filtered effluent (up to 6 mgd) is sent to ultraviolet (UV) disinfection where it is then classified as type 1 reclaimed water and pumped to wholesale customers like Dallas Fort Worth (DFW) Airport. Chlorine booster stations are used to maintain a chlorine residual in the distribution system.
- The VCWWTP minimum monthly flow from 2019-2023 was 90 mgd. The VCWWTP can supply as much as 95 percent of the flow in the Trinity River immediately downstream of Fort Worth, effectively making it a significant contribution of the Trinity River during certain times of the year. The amount of water that could be diverted requires close coordination.
- Yield potential for this strategy was estimated by assessing the 2040 TRA WPS demand projections. Winter demand was assessed at a minimum of 18.6 mgd, with potential peaks as high as 67 mgd. As AWPFs are typically designed for base flow with little peaking, a yield of 20 mgd (targeted finished water capacity) was assumed, with slightly lower winter yield of 18 mgd.
- The targeted influent capacity of the AWPF (fed from the VCWWTP) will be higher than the targeted finished water capacity due to losses across the treatment process at the AWPF. Losses vary based on technology, but were assumed at 80% efficiency, resulting in an assumed 25 mgd VCWWTP flow.
- This strategy has high phasing potential and can increase alongside wastewater flows and water demands.

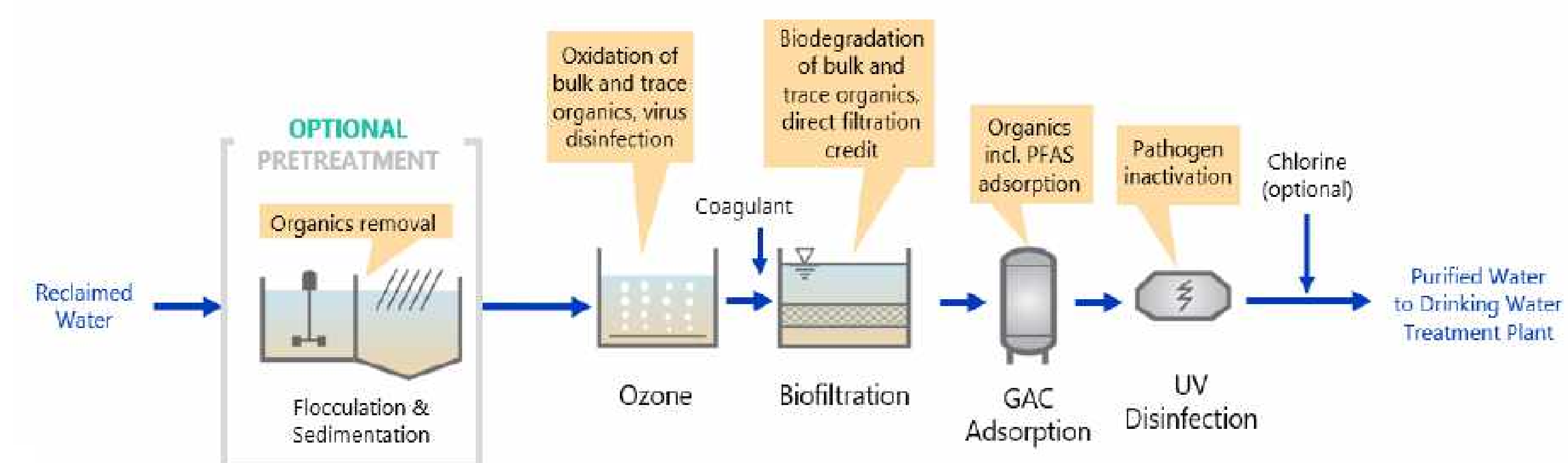
Cost Estimate:

- Capital and O&M costs were estimated using Carollo's DPR Costing Tool (for the facility and treatment). Those costs were incorporated into the IWSP Costing Tool to capture the additional costs for pipelines and the pump station.
- Treatment at the AWPF can either be based on a reverse osmosis (RO) based treatment train or a carbon-based treatment train. There are pros and cons of each treatment train, but both are feasible options. The cost estimate is based on the carbon treatment train because it does not create a RO brine that requires handling and disposal. However, since carbon-based AWPFs do not remove salinity, a system-level salinity management assessment would be needed. Process flow diagram for this treatment train is shown to the right.

Other:

- The evaluation of this strategy is limited to a planning-level feasibility effort to illustrate a proof-of-concept for any version of a DPR focused WMS. To conduct a proof-of-concept evaluation, reasonable assumptions were made to assess the potential DPR scenario.
- DPR is an "off-channel" practice meaning that new (or treated) water is not introduced into a "water of the state" and therefore, does not trigger the same regulatory permitting as indirect potable reuse (IPR). IPR permitting may require stricter water quality targets following advanced treatment than DPR permitting. Additionally, once water is introduced to a "water of the state," a discussion of water rights must occur. By maintaining DPR treated water in a closed-loop system, TRWD can access that water as deemed fit. Texas Commission on Environmental Quality (TCEQ) currently regulates DPR through the rule exception process. In November 2022, TCEQ released reuse guidelines titled RG-64. The guidelines cover an overview of the treatment requirements, operator requirements, additional permitting requirements, and the DPR approval process. On a national level, DPR regulations are being adopted quickly which will continue to improve permitting clarity for this strategy. On a state level, an AWPF owned and operated by El Paso Water in El Paso, Texas is designed for direct-to-distribution DPR and is scheduled to begin construction in 2024/2025.

Carbon-based AWPF treatment train flow diagram



Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Second RC Wetlands

DESCRIPTION: Create a second Richland-Chambers wetland to treat excess reuse supply available from TRWD permits (current or future from another strategy) or reuse purchased from a regional partner. Richland-Chambers can assimilate approximately 90 mgd of supply thus the wetlands would be approximately sized at 2,000 acres. The strategy assumes that a second IPL will be needed to transmit the supply from Richland-Chambers to Benbrook Lake and includes a proportional cost.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
90 mgd	90 mgd	$3.51 $/kgal	$0.78 $/kgal	$0.55 $/kgal	$0.26 $/kgal	$0 $/kgal
100,890 afy	100,890 afy	$1,143 $/af	$254 $/af	$179 $/af	$84 $/af	$0 $/af

OVERVIEW

Strategy Type	Reuse
Strategy Theme(s)	Resiliency, One Water
Phasing Potential	Yes
Partnerships	TRA, NTMWD, Others
Current Status	Conceptual
Implementation Time (yrs)	20

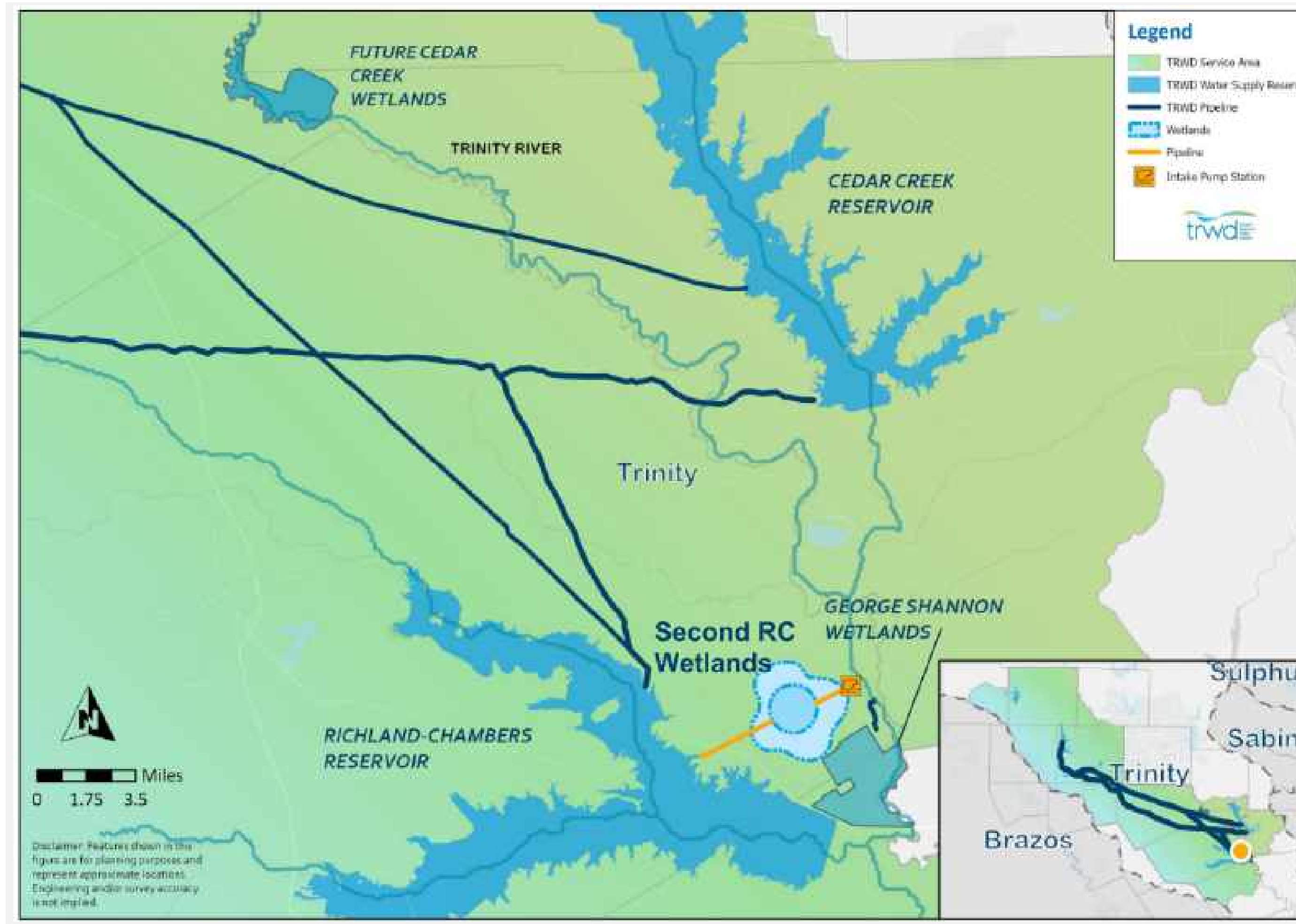
KEY INFRASTRUCTURE

Second IPL to transmit supply	
Pipelines	19.2 miles of 90"
Pump Stations	135 mgd intake pump station
Facility	2,000 wetland acres

CAPITAL COST[5]

Total Strategy Cost (millions)	$1,544.6
External Development Cost (millions)[6]	$337.2
Intersystem Transmission Cost (millions)[7]	$1,207.3

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	4	*Moderately resilient to drought; more susceptible to wildfire and contamination*
Permit Uncertainty & Complexity	4	*Existing precedent for wetlands permitting*
Collaboration Potential	5	*Partnership could be beneficial but not required*
Operational Simplicity	4	*TRWD has extensive knowledge of operating wetlands*
Phasing Potential	4	*Build capacity over time as reuse volume increases*
Public Acceptance	4	*Requires acquisition of land for wetlands; generally high political and public support*
Multi-benefit Project	5	*Provides water quality and recreation benefits*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Second RC Wetlands

KEY ASSUMPTIONS

Yield Estimate:

- Assumes 90 mgd ultimate yield achievable on an average annual basis. Could be fully or partially supplied by TRWD return flows or from return flows purchased from a regional partner.
- Yield will likely start smaller and grow over time, as return flows in the Trinity River increase.
- Yield potential determined by TRWD through analysis of reservoir assimilation capacity. The 90 mgd could be assimilated in additional to the wetlands and reuse already in place. Additional study will be needed to confirm the assimilation capacity when more sophisticated modeling tools become available.

Other:

- There are multiple avenues by which the wetlands could be sourced, including purchase of supply from a regional partner, new reuse opportunities from inter-basin transfers, negotiation on the Lake Livingston agreement, or a SysOps permit, for examples. This strategy could be included with other strategies to determine the most cost-effective opportunities.

Cost Estimate:

- Assumed 2,000 acres for wetland at $7,238 per acre.
- New intake on Trinity River sized for a peak day capacity of 135 mgd (1.5 PF*90 mgd).
- Currently no channel dam cost is included, as these infrastructure components are site specific. If this strategy is pursued, it is recommended to study this further when specific site information is available.
- Discharge into the upper Chambers arm of the reservoir.
- Cost of wetlands indexed up from Plummer's Cedar Creek Wetlands $/acre.
- There is currently no purchase cost of return flows included in the estimate. Its possible that the return flows would be associated with a cost.
- Price per acre is for wetland only. Does not include pump station, pipeline, mitigation, or land cost. Assumed 1.5% for wetland annual O&M.
- Pipeline from the river to the wetland and from the wetland to Richland-Chambers assumes 100 PSI pressure class pipe.
- Assumed 120' easement for 90" pipe.
- Intersystem transmission assumes 49% of the costs of the second IPL from RC to JB2 and 39% of the costs from JB2 to Benbrook Lake.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

CC and RC Unpermitted Firm Yield

DESCRIPTION: TRWD's original water rights for Cedar Creek and Richland-Chambers Reservoirs authorize annual diversions that are based on the safe yield of the reservoirs. This strategy is to obtain a permit for the additional yield associated with the firm yield of the reservoir, referred to as the safe-to-firm amount. The additional permitted supply would then be available to TRWD during periods of drought. The strategy assumes that a second IPL will be needed to transmit the additional supply to Benbrook Lake and includes a proportional cost.

Annual Yield				Unit Cost with Debt Service[1]		Unit Cost after Debt Service Retired[2]		Unit O&M Cost[3]		Unit Pumping Energy Cost[4]		Purchase Cost of Water	
Firm		Safe											
19.6	mgd	0	mgd	$2.65	$/kgal	$0.23	$/kgal	$0.39	$/kgal	$0.23	$/kgal	$0	$/kgal
21,920	afy	0	afy	$864	$/af	$76	$/af	$127	$/af	$76	$/af	$0	$/af

OVERVIEW

Strategy Type	Operational Change
Strategy Theme(s)	Resiliency
Phasing Potential	None
Partnerships	None
Current Status	Studied
Implementation Time (yrs)	3

KEY INFRASTRUCTURE

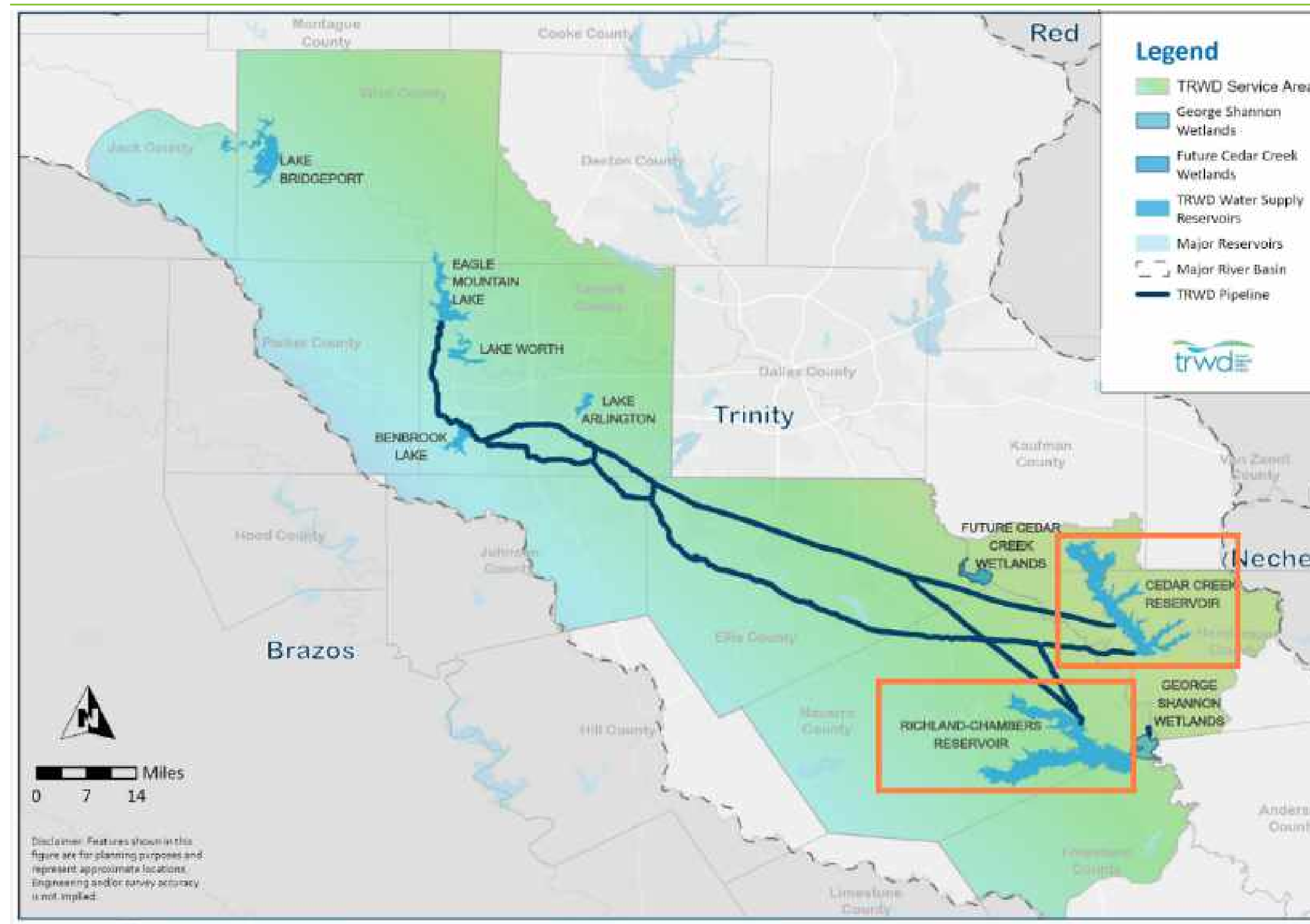
Second IPL to transmit supply

CAPITAL COST[5]

Total Strategy Cost (millions)	$252.3
External Development Cost (millions)[6]	$0.25
Intersystem Transmission Cost (millions)[7]	$252.1

Note: The cost associated with this strategy is the additional pipeline capacity needed to convey the supply to Benbrook. A nominal amount would also be needed to revise the permits.

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	2	*Reliance on surface water which can be impacted by wildfires; safe-to-firm supply may not be available under a drought worse than record*
Permit Uncertainty & Complexity	5	*Low complexity permitting required*
Collaboration Potential	5	*Partnership not required*
Operational Simplicity	5	*Water rights accounting*
Phasing Potential	5	*No phasing required*
Public Acceptance	5	*Generally acceptable across landowners, political entities, and the general public*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

CC and RC Unpermitted Firm Yield

KEY ASSUMPTIONS

Yield Estimate:

- Yield was estimated via a separate study conducted by TRWD (SysOps Existing System Evaluation, June 2023, Carollo Engineers).
- Since the time that RC and CC were originally permitted, additional water rights have been granted within the Trinity River Basin. The additional authorizations for the increased amount of water to be stored, taken, or diverted would be junior to other existing, senior water rights in the basin, which limits the amount of additional yield to be realized.
- Additionally, authorized wetlands at RC and CC utilize some of the available storage in the reservoirs. The amount of additional firm yield that could be realized from each reservoir is reduced when the wetlands are being utilized. The determination of the safe-to-firm amount included an analysis of wetland operations.
- The safe-to-firm amounts were evaluated using the modified WAM Run 3.
- Reservoir design has traditionally been based on the historical drought of record, but because a more severe drought could potentially occur, the firm yield may not be 100% reliable.

Cost Estimate:

- This strategy will require an amended water use permit, which is assumed to cost $250,000.
- Infrastructure will be needed to have transmission capacity to convey the additional yield from RC and CC to Benbrook Lake. Intersystem transmission assumes 3.5% of the costs of the second IPL from RC to JB2; 4.9% of the costs from CC to JB2; and 8.4% of the costs from JB2 to Benbrook Lake.

Reservoir	TRWD Authorizations (AFY)		Firm Yield (AFY)		Unpermitted Safe-to-Firm Yield (AFY)	
	Original	Amended	Original	Amended	Original	Amended
West Fork Water Supply Reservoirs						
Eagle Mountain (1)	159,600		90,500		-	
Bridgeport (2)	27,000		27,000		-	
Total	**159,600**		**117,500**		**-**	
East Texas Water Supply Reservoirs						
Richland-Chambers	210,000	310,465	229,450	319,535	19,450	9,070
Cedar Creek	175,000	263,059	213,060	275,909	38,060	12,850
Total	**385,000**	**573,524**	**442,510**	**595,444**	**57,510**	**21,920**
TRWD Total	**544,600**	**733,124**	**560,010**	**712,944**	**57,510**	**21,920**

Notes:
(1) Firm yield of Eagle Mountain Lake is based on release of up to 66,000 AFY from Lake Bridgeport diverted from Eagle Mountain in accordance with Certificate of Adjudication 08-3808C.
(2) Lake Bridgeport yield based on satisfying local demand of 27,000 AFY (Certificate of Adjudication 08-3808C 1.b. and 1.c.). Remaining releases contribute to estimated yield of Eagle Mountain Lake.

Summary of safe-to-firm yield (SysOps Existing System Evaluation, June 2023, Carollo Engineers, Inc.)

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

IWSP Update | Water Management Strategy Factsheet

Bridgeport Reallocation

Tarrant Regional Water District

DESCRIPTION: Currently, the majority of Bridgeport Lake water rights are released to Eagle Mountain for users surrounding that lake. This strategy does not bring new water into the system, but rather Bridgeport Lake supply would be reallocated for users at Bridgeport Lake, with less water released to Eagle Mountain. This strategy represents an operational change only and, if implemented, would be paired with other strategies that bring new supply to Eagle Mountain.

Annual Yield				Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
Firm		Safe						
0	mgd	0	mgd	$0 $/kgal	$0 $/kgal	$0 $/kgal	$0 $/kgal	$0 $/kgal
0	afy	0	afy	$0 $/af	$0 $/af	$0 $/af	$0 $/af	$0 $/af

OVERVIEW

Strategy Type	**Operational Change**
Strategy Theme(s)	**Resiliency**
Phasing Potential	**Yes**
Partnerships	**None**
Current Status	**Conceptual**
Implementation Time (yrs)	3

KEY INFRASTRUCTURE

No infrastructure required

CAPITAL COST[5]

Total Strategy Cost (millions)	$0.25
External Development Cost (millions)[6]	$0.3
Intersystem Transmission Cost (millions)[7]	$0.0

Note: The only cost associated with this strategy is the cost to revise the water rights permits, assumed at $250,000 (one time cost).

STRATEGY LOCATION

STRATEGY QUALITATIVE SCORES

System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	5	*Low complexity permitting required*
Collaboration Potential	5	*Partnership not required*
Operational Simplicity	4	*Requires accounting and operational changes*
Phasing Potential	5	*No phasing required*
Public Acceptance	5	*Support from Bridgeport landowners and water users*
Multi-benefit Project	3	*Maintain higher lake levels for improved recreation*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Bridgeport Reallocation

KEY ASSUMPTIONS

Yield Estimate:

- Alone this strategy does not have new supply yield associated with it. Rather, this strategy involves an operational change in how TRWD manages Bridgeport Lake. Specifically, this conceptual strategy includes reallocating 40,000 af of permitted use from the "Bridgeport to Eagle Mountain" authorization to the "Bridgeport Local Use" authorization. The reallocation amount was estimated based on potential build out demands at Bridgeport. Carollo confirmed through a WAM evaluation that no significant impact to the reservoir firm or safe yield would occur from this operational change.
- This strategy would likely occur in combination with other strategies that develop new supplies for Eagle Mountain such as Lake Ringgold, Marvin Nichols, Westfork Reuse, for examples.

Cost Estimate:

- This strategy will require a revised permit, which is assumed to cost $250,000. No other costs are associated with this strategy.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

ASR

DESCRIPTION: Aquifer storage and recovery (ASR) is the storage of water in an underground aquifer with the intent of later recovering that water for beneficial use. For the IWSP Update, ASR was considered as a conceptual strategy evaluated to better understand the potential for ASR to improve system reliability. Currently, TRWD is working towards an ASR pilot project with TRA. There may be other partnership opportunities to develop ASR schemes across TRWD's service area. This strategy includes a 10 mgd conceptual ASR project around Eagle Mountain Lake using Exflo.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
10 mgd	10 mgd	$4.03 $/kgal	$0.67 $/kgal	$0.58 $/kgal	$0.09 $/kgal	$0 $/kgal
11,209 afy	11,209 afy	$1,313 $/af	$218 $/af	$188 $/af	$30 $/af	$0 $/af

OVERVIEW

Strategy Type	**Groundwater**
Strategy Theme(s)	**Resiliency**
Phasing Potential	**Yes**
Partnerships	**TRA, Others**
Current Status	**Studied**
Implementation Time (yrs)	**11**

KEY INFRASTRUCTURE

Pipelines	**5.5 miles of 30"** **8" well pipelines**
Pump Stations	**11 mgd Intake Pump Station** **479 HP Pump Station**
Wellfields	**20 wells at .5 mgd capacity**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$285.4**
External Development Cost (millions)[6]	**$285.4**
Intersystem Transmission Cost (millions)[7]	**$0.0**

STRATEGY LOCATION

STRATEGY QUALITATIVE SCORES

Criterion	Score	Notes
System Risk	4	*Slight risk of leaching from chemical interaction; not fully drought proof as multi-year droughts are possible*
Permit Uncertainty & Complexity	2	*TCEQ permit required*
Collaboration Potential	4	*Beneficial willing partnerships*
Operational Simplicity	2	*add notes*
Phasing Potential	4	*Can add ASR wells over time*
Public Acceptance	4	*Some land acquisition required; political support for alternative supply development*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

ASR

KEY ASSUMPTIONS

Yield Estimate:

- The supply goal for the ASR project is 10 mgd.
- The source of the water is assumed to be TRWD's Excess Flow (ExFlo) permit at Eagle Mountain Lake. Supply is added to the 56,000 af storage capacity "bubble" periods when ExFlo is available, and then recovered and pumped back to the Lake.
- It is assumed the aquifer formation is able to store the required "bubble".
- The TRWD pilot project with TRA was permitted for 88% recovery and is assumed to be the recovery for additional ASR strategies.

Other:

- Other sources of supply would increase supply (or decrease cost by reducing the need for additional wells or storage), and could include reuse, or water from other surface water rights besides the ExFlo permit.
- Recharge wells for ASR projects are regulated by TCEQ's Underground Injection Control program and are classified as Class V Injection Wells. Thus, they must be permitted pursuant to Chapter 27, Texas Code, and Chapter 331, Title 30 of the Texas Administrative Code.
- The 2020 TWDB study on ASR suitability shows the Eagle Mountain Lake area as suitable (right).

Cost Estimate:

- This cost estimate is a rough order of magnitude, assuming $5M per well plus costs for a pipeline and intake pump station.
- Water may need to be treated prior to injection and may only require disinfection after extraction. These costs are not reflected in the cost estimate, consistent with the way they were done in the Region C plan. It is assumed that TRWD customers would pay for the cost of treatment.
- The ASR wellfield is operated continuously, whether injecting or extracting, and is not left idle for months or years on end. Operating the wellfield with long periods of downtime would change the assumptions about annual O&M costs.
- TRWD may consider purchasing additional property around the wellfield to protect the groundwater bubble, but we are assuming no more land than required by the Costing Tool.

Suitability Study

Statewide Survey of Aquifer Suitability for Aquifer Storage and Recovery Projects or Aquifer Recharge Projects

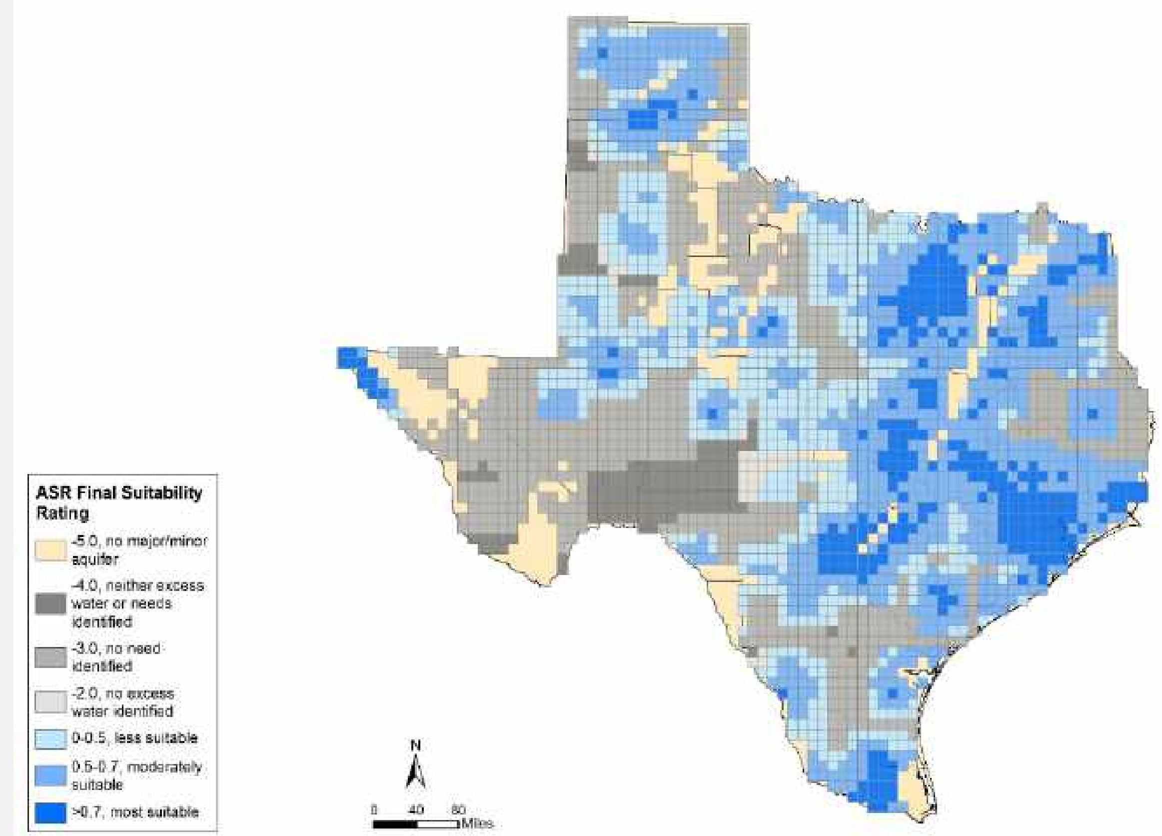


Figure 26. ASR Final Suitability Rating

https://www.twdb.texas.

Statewide Survey of Aquifer Suitability for Aquifer Storage and Recovery Projects or Aquifer Recharge Projects. 2020. Prepared by HDR for TWDB.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

TRWD Developed Groundwater

DESCRIPTION: This conceptual groundwater strategy was included to improve TRWD's understanding for the potential of groundwater to improve system reliability, especially during droughts. Groundwater availability and the cost to pump those supplies was assessed on land owned by TRWD in Freestone County. Water would be pumped to Richland-Chambers. The strategy assumes that a second IPL will be needed to transmit the supply from Richland-Chambers to Benbrook Lake and includes a proportional cost.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
6.2 mgd	6.2 mgd	$4.86 $/kgal	$1.04 $/kgal	$0.75 $/kgal	$0.28 $/kgal	$0 $/kgal
7,000 afy	7,000 afy	$1,585 $/af	$337 $/af	$245 $/af	$92 $/af	$0 $/af

OVERVIEW

Strategy Type	**Groundwater**
Strategy Theme(s)	**Resiliency**
Phasing Potential	**Yes**
Partnerships	**None**
Current Status	**Planned**
Implementation Time (yrs)	**10**

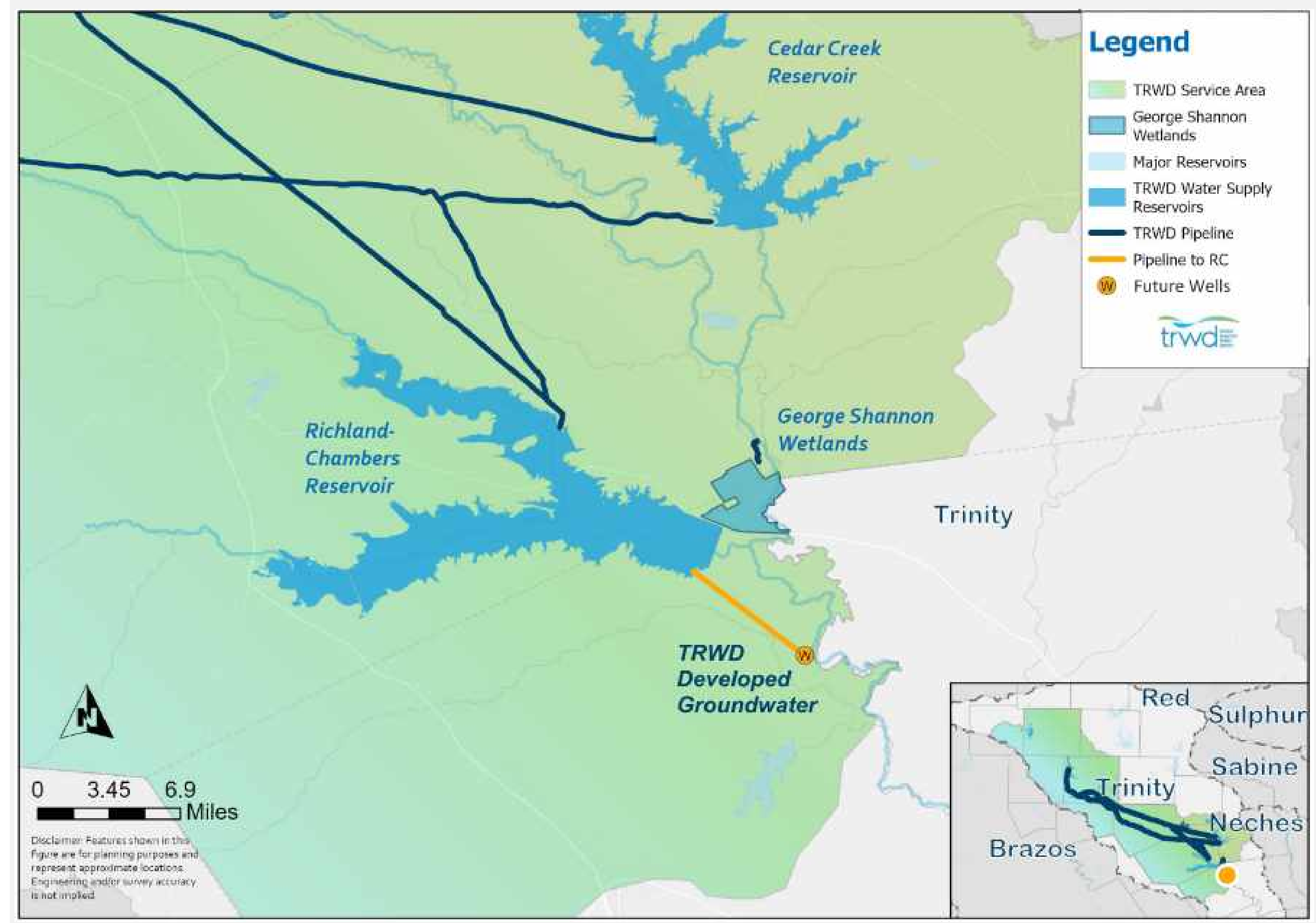
KEY INFRASTRUCTURE

Pipelines	**6.7 miles of 24"**
Pump Stations	**9.4 mgd pump station**
Facility	**15 wells with 675 gpm max pumping at 300' depth**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$151.7**
External Development Cost (millions)[6]	**$67.9**
Intersystem Transmission Cost (millions)[7]	**$83.8**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	5	*Resistant to droughts and wildfires; slight contamination risk*
Permit Uncertainty & Complexity	4	*Permitting groundwater relatively low complexity*
Collaboration Potential	5	*Partnership not required*
Operational Simplicity	4	*Groundwater wells close proximity to TRWD's existing infrastructure*
Phasing Potential	4	*Can add wells over time*
Public Acceptance	4	*Developed on TRWD property; low opposition likely*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

TRWD Developed Groundwater

KEY ASSUMPTIONS

Yield Estimate:

• The 2016 TRWD Impaired Groundwater Study indicated that a well field consisting of 11 to 15 wells on the Amerada property in Freestone County would be capable of producing 7,000-8,000 afy of water from the Carrizo-Wilcox Aquifer.
• The amount of Managed Available Groundwater (MAG) for 2070 from the Carrizo-Wilcox Aquifer in Freestone County was set by the Mid-East Groundwater Conservation District (GCD) at 11,304 afy. After subtracting out the maximum historical pumping from 2002-2021 (3,639 afy) as a reserve for current users, then 7,665 afy would be available in 2070. This is approximately equivalent to the yield sought by the proposed strategy.

Other:

• In final design, it may be possible to use some of the well pumps to power transmission to RC but at this stage it is unknown so a pump station was included.
• Much of the area is floodplain and construction may require additional requirements.

Cost Estimate:

• Using a 1.5 peaking factor (6.2 mgd x 1.5) = 9.4 mgd peak day capacity.
• Includes 15 wells at 675 gpm max pumping and 300 foot depth.
• The well field may be placed or partially placed on TRWD owned property, but the exact location is unknown. As a conservative assumption, land acquisition of a 0.5 acre per well site is included.
• Includes well field collection piping.
• Assumes a 9.4 mgd pump station.
• Includes small transmission pipeline from well field to the Richland-Chambers reservoir. Assumes a 50 ft ROW.
• Intersystem transmission assumes 3% of the costs of the second IPL from RC to JB2 and 3% of the costs from JB2 to Benbrook Lake.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)
1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Lake Palestine Groundwater Purchase

Tarrant Regional Water District

DESCRIPTION: Purchase groundwater from water marketer with point of transfer in Lake Palestine. To convey the supply, this strategy assumes that DWU would be willing to allow TRWD to utilize a portion of DWU's IPL between Lake Palestine and Cedar Creek for a fee. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake and includes a proportional cost.

Annual Yield		Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
Firm	Safe					
13.4 mgd	13.4 mgd	$5.88 $/kgal	$2.34 $/kgal	$0.64 $/kgal	$0.24 $/kgal	$1.46 $/kgal
15,000 afy	15,000 afy	$1,917 $/af	$762 $/af	$209 $/af	$78 $/af	$475 $/af

OVERVIEW

Strategy Type	Groundwater
Strategy Theme(s)	Diversification
Phasing Potential	Yes
Partnerships	None
Current Status	Studied
Implementation Time (yrs)	6

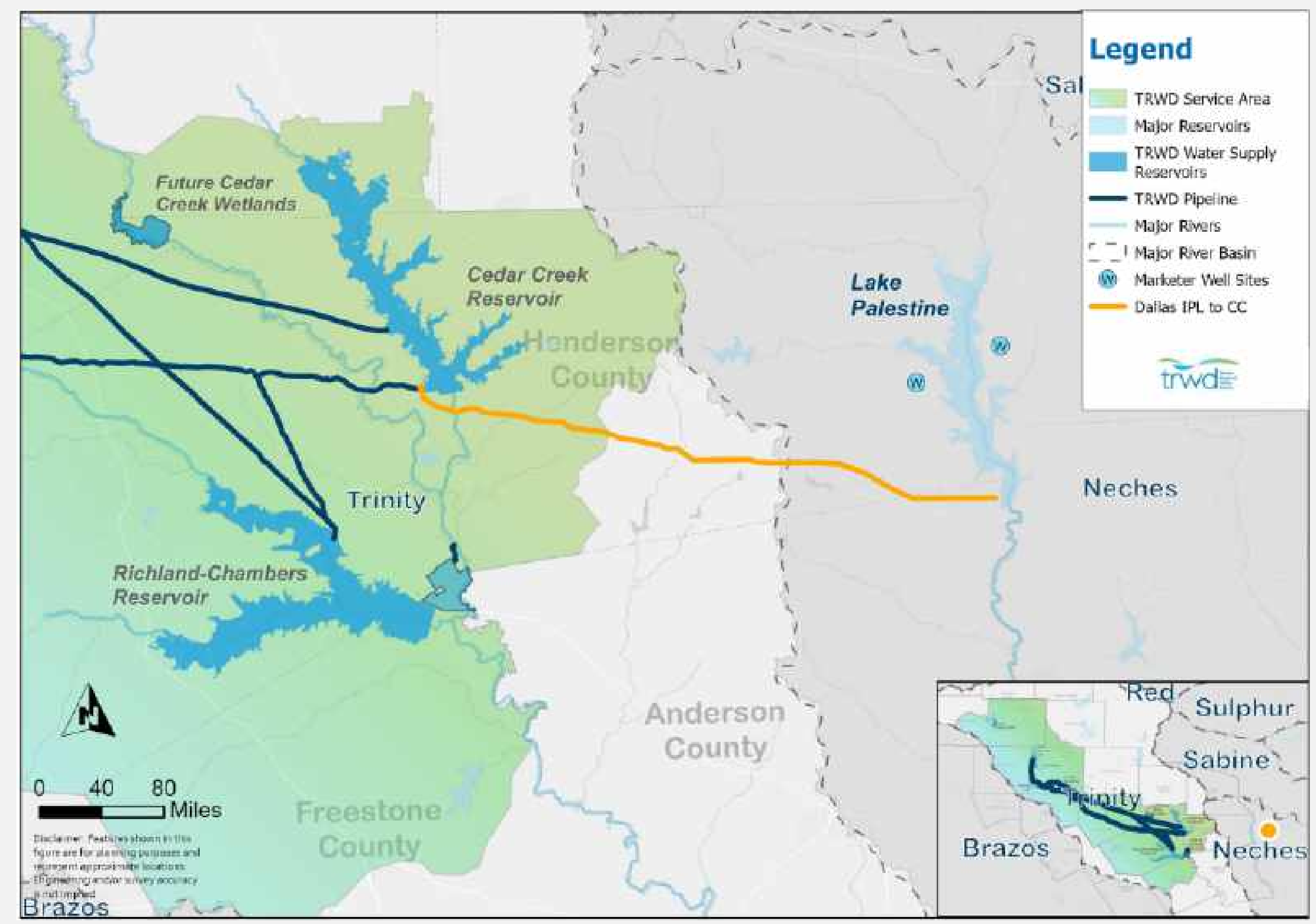
KEY INFRASTRUCTURE

Second IPL to transmit supply

CAPITAL COST[5]

Total Strategy Cost (millions)	$286.0
External Development Cost (millions)[6]	$107.3
Intersystem Transmission Cost (millions)[7]	$178.7

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

Criterion	Score	Comment
System Risk	5	*Resistant to droughts and wildfires; slight contamination risk*
Permit Uncertainty & Complexity	4	*Permitting groundwater relatively low complexity*
Collaboration Potential	4	*Beneficial willing partnership through seller*
Operational Simplicity	4	*Utilize DWU's infrastructure*
Phasing Potential	3	*Marketer may allow some phasing*
Public Acceptance	3	*Requires acquisition of land by marketer; may be perceived poorly by local land owners and groundwater users*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Lake Palestine Groundwater Purchase

KEY ASSUMPTIONS

Yield Estimate:

- Groundwater purchase by TRWD From Conservation Equity Management (CEM) who has offered to develop the project and provided pricing.
- CEM provides two scenarios: one for 11,000 afy and one for 27,500 afy. Based on direction from TRWD, assumed the average volume of 15,000 afy taken to Lake Palestine by CEM.
- Based on maximum historical pumping and the 2070 MAGs, a conservative estimate may be that around 9,400 AFY to 9,800 afy may be available to permit without increasing the MAG, however the majority of that would have to come from the Queen City Aquifer.
- LRE proposed pumping between 5,256 afy and 6,348 afy from the Queen City Aquifer.
- Extracting additional water from the Carrizo-Wilcox may involve proving that the MAG is not violated or increasing the MAG.

Cost Estimate:

- Costs from CEM include the infrastructure to develop the groundwater and deliver it to Lake Palestine. CEM proposal included option to deliver supply directly to IPL.
- Cost of water and transportation is assumed to be $475/af, which is the midpoint from CEM price ranges for water calls.
- Cost of transporting water from Lake Palestine to Cedar Creek assumes the percentage of DWU's IPL portion (19-2 and 19-1) actual cost and Dallas' LP1 cost estimate. This assumes that DWU would be willing to allow TRWD to utilize a portion of the line for a fee.
- Cost estimate included pro-rating DWU's pipeline and intake costs per the percentage of the pipeline that would be needed to convey the supply. Cost estimates were indexed up to September 2023 dollars.
- Intersystem transmission assumes 7% of the costs of the second IPL from CC to JB2 and 6% of the costs from JB2 to Benbrook Lake.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Anderson County Groundwater

Tarrant Regional Water District

DESCRIPTION: Purchase groundwater from water marketer in Anderson County and convey supply to Cedar Creek via a pipeline. This supply falls within the Neches and Trinity Valley Groundwater Conservation District. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake and includes a proportional cost.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
37.5 mgd	37.5 mgd	$7.24 $/kgal	$1.66 $/kgal	$0.59 $/kgal	$0.23 $/kgal	$0.20 $/kgal
42,000 afy	42,000 afy	$2,359 $/af	$542 $/af	$192 $/af	$74 $/af	$65 $/af

OVERVIEW

Strategy Type	**Groundwater**
Strategy Theme(s)	**Resiliency**
Phasing Potential	**None**
Partnerships	**None**
Current Status	**Conceptual**
Implementation Time (yrs)	**10**

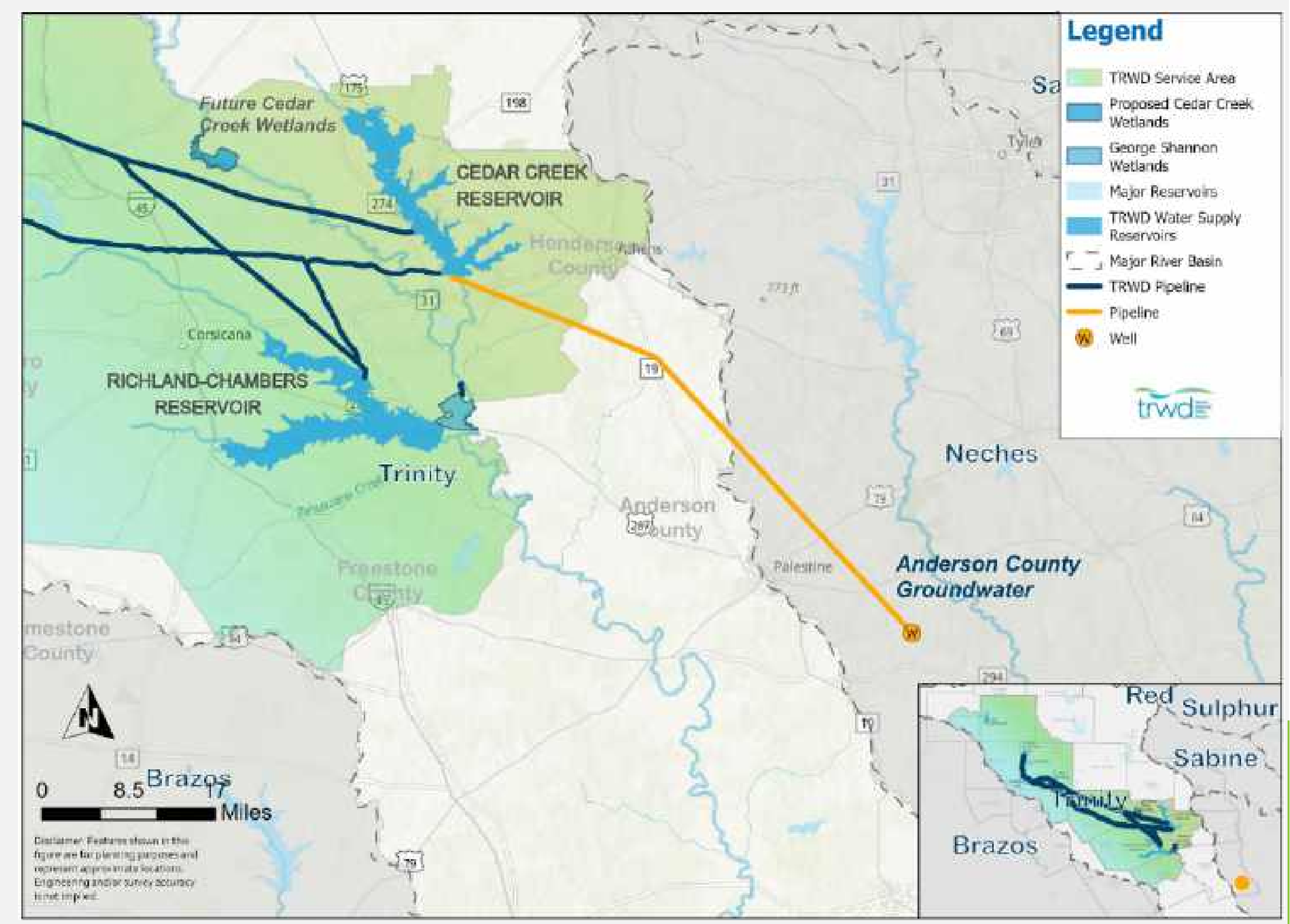
KEY INFRASTRUCTURE

Pipelines	**57.9 miles of 54"**
Pump Stations	**56 mgd intake pump station**
	3,733 HP booster pump station
Wells	**46 wells at 1,050 ft depth**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$1,324.0**
External Development Cost (millions)[6]	**$823.4**
Intersystem Transmission Cost (millions)[7]	**$500.5**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	5	*Resistant to droughts and wildfires; slight contamination risk*
Permit Uncertainty & Complexity	4	*Permitting groundwater relatively low complexity, permits already held by outside entity*
Collaboration Potential	5	*Partnership not required*
Operational Simplicity	4	*Groundwater wells reasonable proximity to TRWD's existing infrastructure*
Phasing Potential	2	*Low phasing potential*
Public Acceptance	3	*Requires ROW acquisition for pipeline; some local opposition possible against transferring groundwater*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Anderson County Groundwater

KEY ASSUMPTIONS

Yield Estimate:

• Available yield for groundwater supply was assumed at 42,000 af. Note that this volume exceeds the current Modeled Available Groundwater (MAG) in Anderson County. If the MAG is not adjusted, it may preclude TRWD from accessing SWIFT funding for this project.
• Anderson County falls within the Neches and Trinity Valley Groundwater Conservation District (GCD).
• Water Solutions LLC has existing production (but not export) permits from the GCD for a portion of the volume. Permits were granted in 2020 and have 5-year renewal periods. Permits are subject to potential cutbacks by the GCD in the future.

Cost Estimate:

• Assumed 46 well sites with wells completed in both the Carrizo and Upper Wilcox formations.
• Well depths assumed to range from 850 to 1160 feet, with an average depth of 1050 feet.
• Peak well capacity of 850 gpm.
• Production reaches an average annual volume of 42,000 afy (or 37.5 mgd).
• Peaking factor of 1.5 for peak day production fo 56 mgd.
• Well costs from the TWDB UCM (TRWD's Costing Tool are equal).
• Assume the well field and initial pump station share a power connection.
• The entire route is considered rural soil.
• Storage at the booster pump station is assumed to be tanks instead of balancing reservoir storage since groundwater will not yet be mixed with surface water. This would preserve the option to sell to customers along the pipeline route. Ultimately, type of storage would be determined later.
• No terminal storage reservoir is assumed since the end delivery point in Cedar Creek.
• No treatment or chlorination included since it is assumed to be delivered through the IPL -2 and mixed with raw surface water.
• Purchase cost of water is assumed at $65/ac-ft, consistent with other strategies. Note this is lower than the assumption in NTMWD Long Range Water Supply Plan.
• A 60-foot permanent right-of-way is assumed.
• The wellfield and initial pump station are assumed in Anderson County. Land costs for Anderson County are based on LMA 30 Piney Woods with an annual 2023 cost of $6,000. The land for the Booster Pumpstation also falls within the same LMA.
• The pipeline route passes through Anderson and Henderson Counties, all of which are in LMA 30 Piney Woods with an annual 2023 cost of $6,000.

Other:

This strategy is also considered by NTMWD.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)
1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

IWSP Update | Water Management Strategy Factsheet

Lake Palestine Purchase

DESCRIPTION: Lake Palestine is located in the Neches River Basin, 60 miles east of Cedar Creek Reservoir. UNRMWA owns and operates the reservoir and has municipal supply contracts with multiple cities. TRWD would purchase unused yield from one or more entity with contracts for Lake Palestine supply. To convey the supply, this strategy assumes that DWU would be willing to allow TRWD to utilize a portion of DWU's IPL between Lake Palestine and Cedar Creek for a fee. The strategy assumes that a second IPL will be needed to transmit the supply from Cedar Creek to Benbrook Lake and includes a proportional cost.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
26.8 mgd	26.8 mgd	$4.63 $/kgal	$1.08 $/kgal	$0.64 $/kgal	$0.24 $/kgal	$0.20 $/kgal
30,000 afy	30,000 afy	$1,507 $/af	$352 $/af	$209 $/af	$78 $/af	$65 $/af

OVERVIEW

Strategy Type	Existing Reservoir
Strategy Theme(s)	Regionalization
Phasing Potential	Yes
Partnerships	TRA, NTMWD, Others
Current Status	Conceptual
Implementation Time (yrs)	9

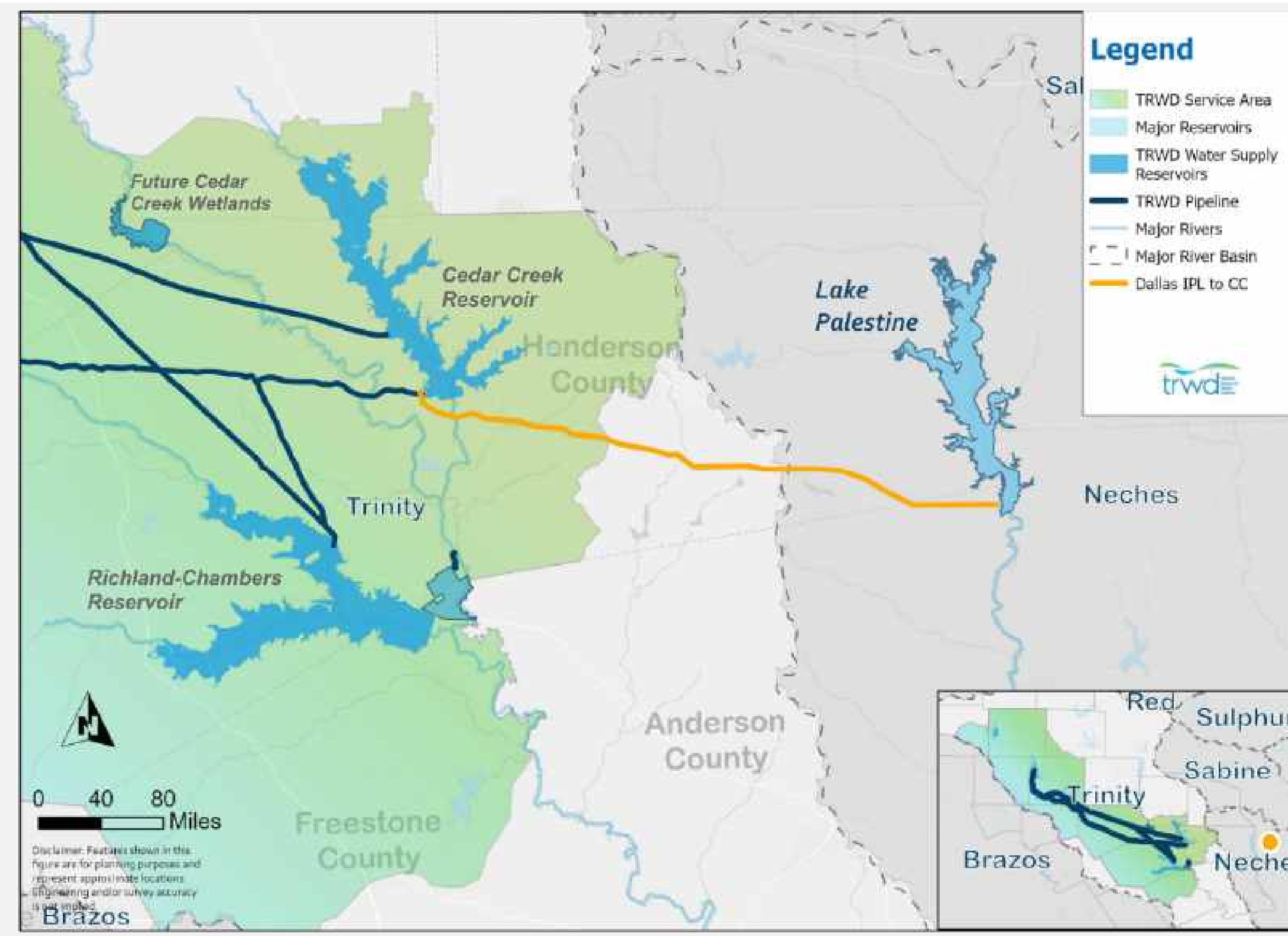
KEY INFRASTRUCTURE

- Second IPL to transmit supply

CAPITAL COST[5]

Total Strategy Cost (millions)	$572.1
External Development Cost (millions)[6]	$214.6
Intersystem Transmission Cost (millions)[7]	$357.5

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; Neches River less drought prone; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	4	*Permitting for pipelines, pump stations, and intakes; out of basin transfer*
Collaboration Potential	3	*Unclear if willing partnership*
Operational Simplicity	4	*Utilize DWU's infrastructure*
Phasing Potential	4	*Could phase if seller is willing*
Public Acceptance	4	*Use of existing reservoir and pipelines may garner widespread support*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Lake Palestine Purchase

KEY ASSUMPTIONS

Yield Estimate:

- Lake Palestine is owned and operated by the Upper Neches River Municipal Water Authority (UNRMWA). Permitted diversions total 238,110 af, however firm supply is lower due to sedimentation impacts in the reservoir. City of Tyler is contracted for 67,200 af. City of Dallas is contracted for 114,337 af. City of Palestine is contracted for 28,000 af. Additional contracts are for domestic, irrigation, and industrial uses.
- This strategy would require TRWD to negotiate the purchase of 30,000 af of Lake Palestine water from a willing contract holder.

Cost Estimate:

- Cost of transporting water from Lake Palestine to Cedar Creek assumes the percentage of DWU's IPL portion (19-2 and 19-1) actual cost and Dallas' LP1 cost estimate. This assumes that DWU would be willing to allow TRWD to utilize a portion of the line for a fee.
- Cost estimate included pro-rating DWU's pipeline and intake costs per the percentage of the pipeline that would be needed to convey the supply. Cost estimates were indexed up to September 2023 dollars.
- The purchase cost of raw water from a Lake Palestine contract holder is unknown and would be subject to negotiations. In the absence of any data, the Region C wholesale raw water cost of $0.50/kgal was assumed.
- Intersystem transmission assumes 11% of the costs of the second IPL from CC to JB2 and 15% of the costs from JB2 to Benbrook Lake.

Other:

- The potential for this strategy to continue across the 2080 planning horizon is unknown. It is possible that the strategy might yield supply for interim years, for example purchasing a portion of DWU or Tyler's contractual amount while their service areas grow.
- This strategy would require an interbasin transfer permit to transfer water from the Neches to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

IWSP Update | Water Management Strategy Factsheet

Toledo Bend

DESCRIPTION: Convey available supply from Toledo Bend, an existing reservoir in the Sabine River Basin (located on the Texas and Louisiana border), to TRWD's service area. The Sabine River Authority (SRA) in Texas holds water right permit for the Texas portion of the reservoir yield. This strategy assumes that TRWD and one regional partner purchases and conveys half of SRA's available supply, 480,000 af. The infrastructure was assumed to be phased with dual pipelines. The strategy assumes that a second IPL will be needed to transmit the supply from JB2 to Benbrook Lake and includes a proportional cost.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
214.3 mgd	214 mgd	$6.96 $/kgal	$1.60 $/kgal	$0.96 $/kgal	$0.44 $/kgal	$0.20 $/kgal
240,000 afy	240,000 afy	$2,268 $/af	$522 $/af	$313 $/af	$144 $/af	$65 $/af

OVERVIEW

Strategy Type	**Existing Reservoir**
Strategy Theme(s)	**Diversification, Large Supply**
Phasing Potential	**Yes**
Partnerships	**Dallas Water Utilities, NTMWD, Others**
Current Status	**Studied**
Implementation Time (yrs)	**18**

KEY INFRASTRUCTURE

Second IPL to transmit supply

Pipelines
- **173 miles of 108" pipe**
- **173 miles of 120" pipe**

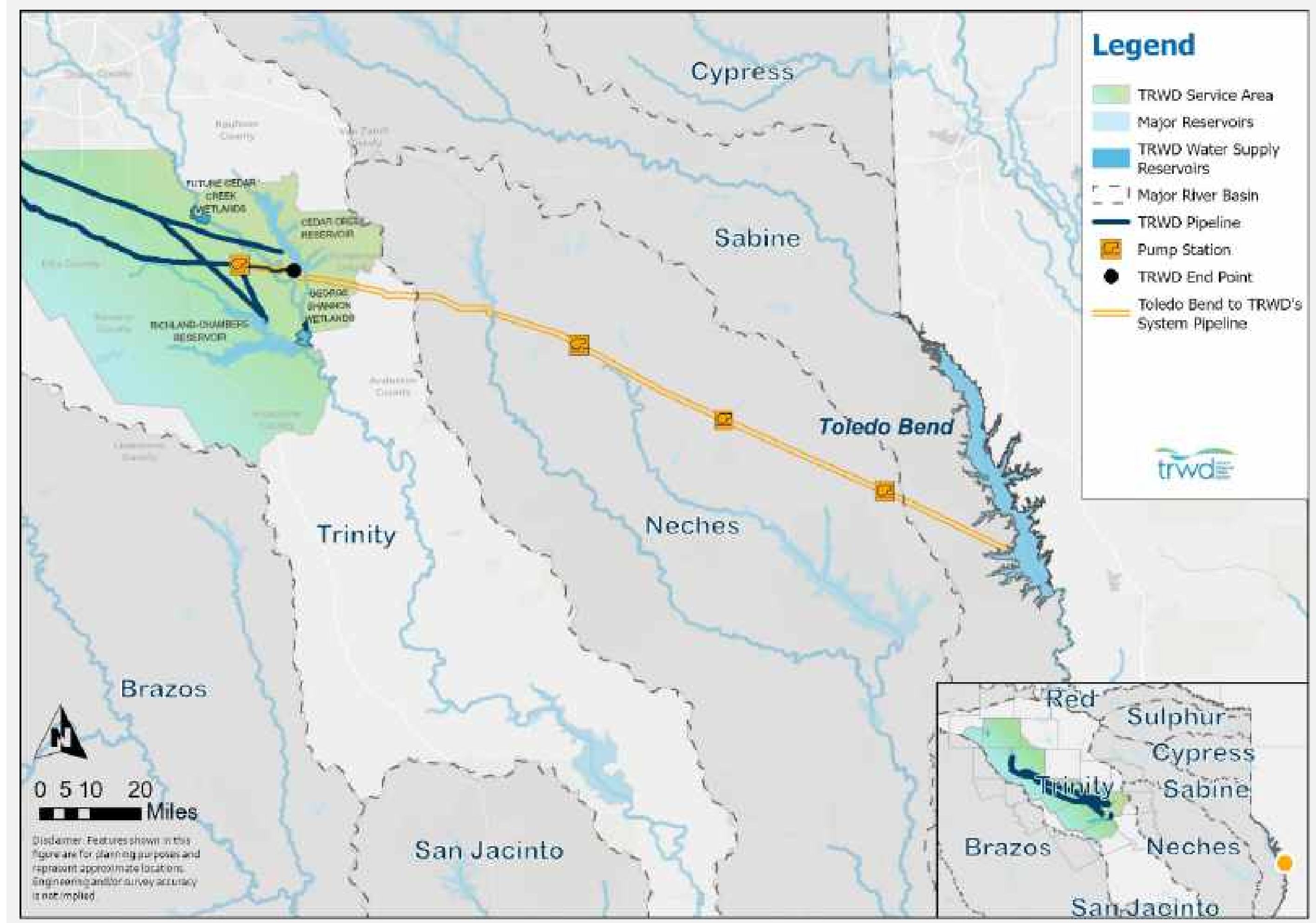
Pump Stations
- **2 intake pump stations (402 and 241 mgd)**
- **3 booster pump stations in Phase I**
- **2 booster pump stations in Phase II**

Facility
- **3 terminal storage for 2,630 af**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$7,278.6**
External Development Cost (millions)[6]	**$4,418.4**
Intersystem Transmission Cost (millions)[7]	**$2,860.1**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; Sabine River Basin less drought prone; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	4	*Permitting for pipelines, pump stations, and intakes; out of basin transfer*
Collaboration Potential	4	*Partnership required but not yet identified*
Operational Simplicity	2	*Infrastructure and operations stretch 280 miles beyond TRWD's existing system*
Phasing Potential	3	*Can construct two pipelines, one and then another, to phase supply and capital investment*
Public Acceptance	3	*Potential opposition due to perception around costs; requires ROW acquisition*
Multi-benefit Project	1	*No new multi-project benefits*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Toledo Bend

KEY ASSUMPTIONS

Yield Estimate:

- Toledo Bend is jointly owned and operated by Sabine River Authority in Texas (SRA TX) and Sabine River Authority in Louisiana (SRA LA). The yield of the reservoir is 2.1 million af, split equally between the authorities. SRA TX has approximately 970,000 af permitted, with current use of 6,000 af.
- The TRWD yield estimate of 480,000 af represents a purchase agreement from SRA for half of their remaining yield.
- This strategy assume TRWD would procure and convey the supply with a 50/50 regional partner.

Other:

- Based on discussions with TRWD, the assumed partner end point is JB2. This does not affect TRWD's cost for this strategy but does reduce capacity in the second IPL (Cedar Creek to JB2) that would otherwise be available to TRWD.
- This strategy would require an interbasin transfer permit to transfer water from the Sabine to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.

Cost Estimate:

- The purchase price of water was assumed at $0.20 per kgal. Actual purchase price would be subject to negotiation between parties.
- Conveyance of supply was assumed to occur in two phases. Phase I includes a 120" pipeline from Toledo Bend to JB2; an intake pump station sized for 401 mgd; three booster stations of 31,698 HP, 26,667 HP, and 29,686 HP.
- Phase II includes a 108" pipeline from Toledo Bend to JB2; an intake pump station sized for 241 mgd; two booster stations of 16,000 HP and 17,811 HP.
- Assumed a terminal storage reservoir at each Phase I booster pump station. Terminal storage is sized at 2,630 af of storage capacity and 198 acres.
- Intersystem transmission for Phase I assumes 73% of the costs of the second IPL from CC to JB2 and 57% of the costs from JB2 to Benbrook Lake. Intersystem transmission for Phase II assumes and additional 44% of the costs of the second IPL from CC to JB2 and 34% of the costs from JB2 to Benbrook Lake.
- Cost share is assumed at 50/50.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

IWSP Update | Water Management Strategy Factsheet

Wright Patman Reallocation

DESCRIPTION: The strategy includes reallocation of flood storage to water supply from Wright Patman, a U.S. Army Corps of Engineers reservoir in the Sulphur River Basin. This joint, regional strategy includes six sponsors, including TRWD. Water from Wright Patman would be conveyed to Lake Bridgeport and then released for downstream TRWD customers.

Annual Yield		Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
Firm	Safe					
58.1 mgd	35.6 mgd	$7.81 $/kgal	$1.50 $/kgal	$1.09 $/kgal	$0.41 $/kgal	$0 $/kgal
65,067 afy	39,896 afy	$2,545 $/af	$488 $/af	$356 $/af	$132 $/af	$0 $/af

OVERVIEW

Strategy Type	**Existing Reservoir**
Strategy Theme(s)	**Regionalization, Large Northern Supply**
Phasing Potential	**None**
Partnerships	**DWU, NTMWD, UTRWD, Irving**
Current Status	**Studied**
Implementation Time (yrs)	**22**

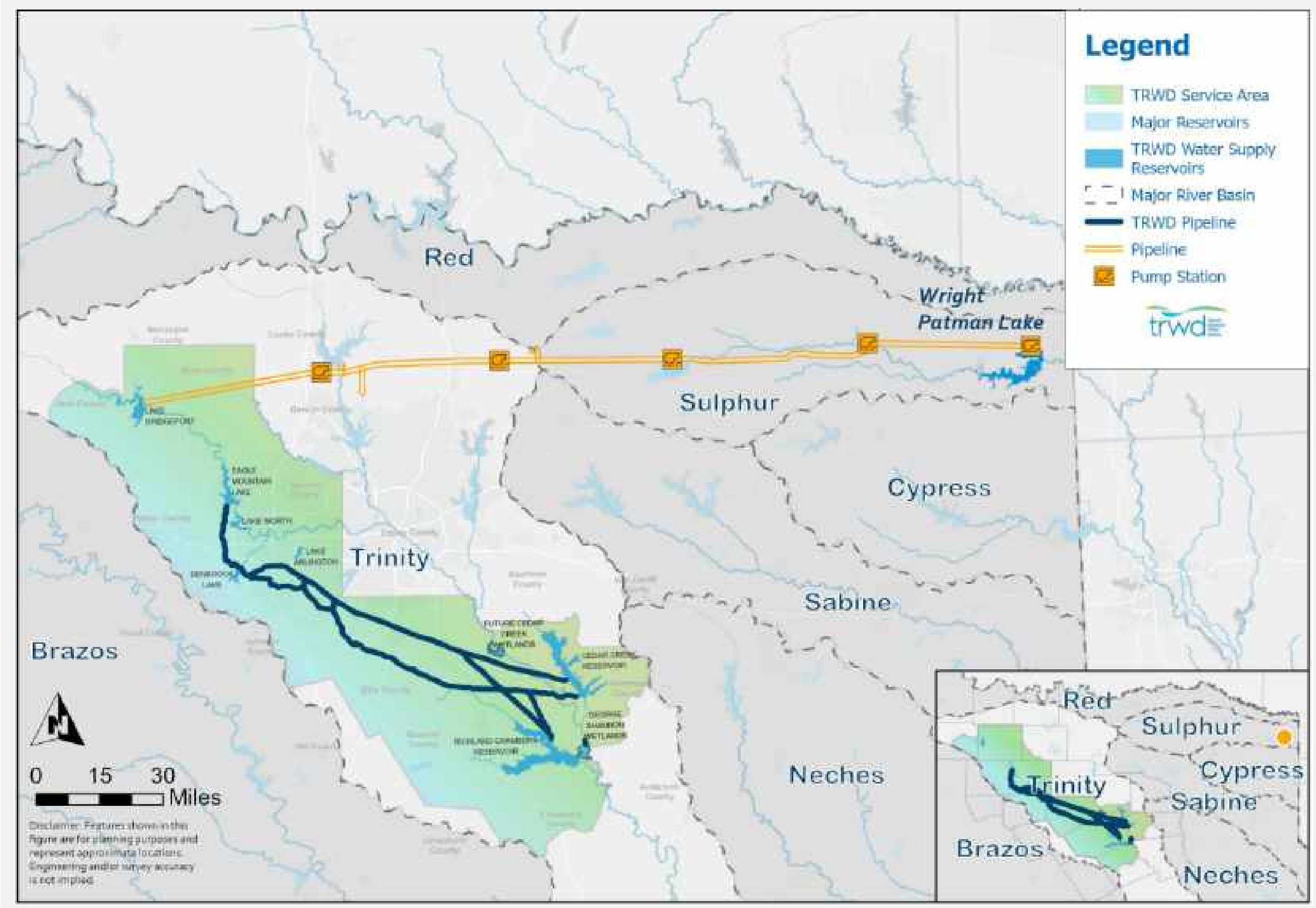
KEY INFRASTRUCTURE

Pipelines	**5 segments from WP to Bridgeport** **Pipelines range from 72-102"**
Pump Stations	**Reservoir intake pump stations** **4 booster pump stations with storage**
Reservoir	**Dam Modification**
Other	**Eagle Mountain Reversal**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$2,456.0**
External Development Cost (millions)[6]	**$2,456.0**
Intersystem Transmission Cost (millions)[7]	**$0.0**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	1	*Environmental permits required for reallocation; out of basin transfer*
Collaboration Potential	2	*Mixed benefits from multiple partnerships; local collaboration needed*
Operational Simplicity	2	*Remote reservoir operations required; remote pipelines and infrastructure*
Phasing Potential	2	*Reallocation cannot be easily phased*
Public Acceptance	2	*Requires flooding of areas to raise dam; strong local opposition; requires ROW acquisition*
Multi-benefit Project	3	*Recreation benefits exist, would create some environment offsets*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Wright Patman Reallocation

KEY ASSUMPTIONS

Yield Estimate:

- The firm and safe yields are based on 222.0 feet MSL, scenario WPR-4b from the February 1, 2024 report Marvin Nichols Reservoir and Lake Wright Patman (WP) Reallocation Yield Update (Yield Update). See Table 4-3 (right).
- The firm yield with reallocation assumes Wright Patman is permitted as senior to Marvin Nichols Reservoir, which increases the yield available to project partners to 202,070.
- TRWD's portion of the yield is 32.2% at Wright Patman (202,070 afy * 32.2%).

Cost Estimate:

- Costs for Wright Patman Reallocation were adapted from Table H.24 in the 2021 Region C Water Plan (November 2020), escalated from September 2018 dollars to September 2023 dollars, and input into TRWD's Costing Tool (using TRWD cost curves).
- Project costs include cost to purchase land for mitigation, with 14,372 acres assumed to be impacted. Costs assume a total of 28,744 acres needed for mitigation.
- Termnial storage of 59 acres was uncluded in the costs.
- Assumed the same pipeline route as Marvin Nichols with Wright Patman.
- The delivery location for TRWD is Lake Bridgeport.

Other:

- Reallocation at Wright Patman is a change in the use of storage in an existing reservoir project from its present use as flood control to Municipal and Industrial use. Reallocation requires approval by the U.S. Congress.
- The Yield Update report presented multiple configurations and yields for the Sulphur Basin supplies.
- For the purpose of the IWSP, TRWD is using option C-3 based on the following reasoning:
  - The project sponsor(s) will also be the one securing the WP reallocation water right, so presumably they would be able to specify which one would be senior and would choose the option that would result in higher yield.
  - Lyons method is a widely accepted standard method for environmental flows and results in higher yields, and TRWD prefers to use the best-case scenario for the IWSP.
  - Texarkana's water right application is less likely to be granted now that they have secured large water rights in Arkansas.
- This strategy would require an interbasin transfer permit to transfer water from the Sulphur to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.

Table 4-3: Comparison of Reallocation Yields Using 220.0 feet MSL Minimum and Full Storage

Scenario	Environ-mental Flows	Minimum Storage Assumption	Current Authorization (ac-ft/yr)	Texarkana Application Diversions (ac-ft/yr)	New Yield (ac-ft/yr)	Total Patman (ac-ft/yr)	Change (ac-ft/yr)
WPR-4a	Lyons	Full use	180,000	175,000	109,290	464,290	82,220
WPR-4b	Lyons	Storage above 220.0 feet MSL	180,000	--	202,070	382,070	
WPR-5a	RPS	Full Use	180,000	175,000	95,530	450,530	100,840
WPR-5b	RPS	Storage above 220.0 feet MSL	180,000	--	169,690	349,690	

Yields use the 2010 volumetric survey and do not include a minimum release of 10 cfs

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1 1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.

2 2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.

3 3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.

4 4. Assumes an energy cost of 0.06 $/kWh.

5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20%
5 for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.

6 6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.

7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Marvin Nichols

DESCRIPTION: Marvin Nichols Reservoir is a proposed water supply reservoir in the Sulphur River Basin, located 115 miles from Dallas Fort Worth. The reservoir would store 1.5 million af of water and inundate approximately 71,440 acres. This joint, regional strategy includes six sponsors, including TRWD. Water from Marvin Nichols would be conveyed to Lake Bridgeport and then released for downstream TRWD customers.

Annual Yield (Firm)	Annual Yield (Safe)	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
98.4 mgd	79.3 mgd	$5.85 $/kgal	$1.14 $/kgal	$0.78 $/kgal	$0.36 $/kgal	$0 $/kgal
110,237 afy	88,810 afy	$1,907 $/af	$371 $/af	$253 $/af	$117 $/af	$0 $/af

OVERVIEW

Strategy Type	**Proposed Reservoir**
Strategy Theme(s)	**Regionalization, Large Northern Supply**
Phasing Potential	**None**
Partnerships	**DWU, NTMWD, UTRWD, Irving**
Current Status	**Studied**
Implementation Time (yrs)	**30**

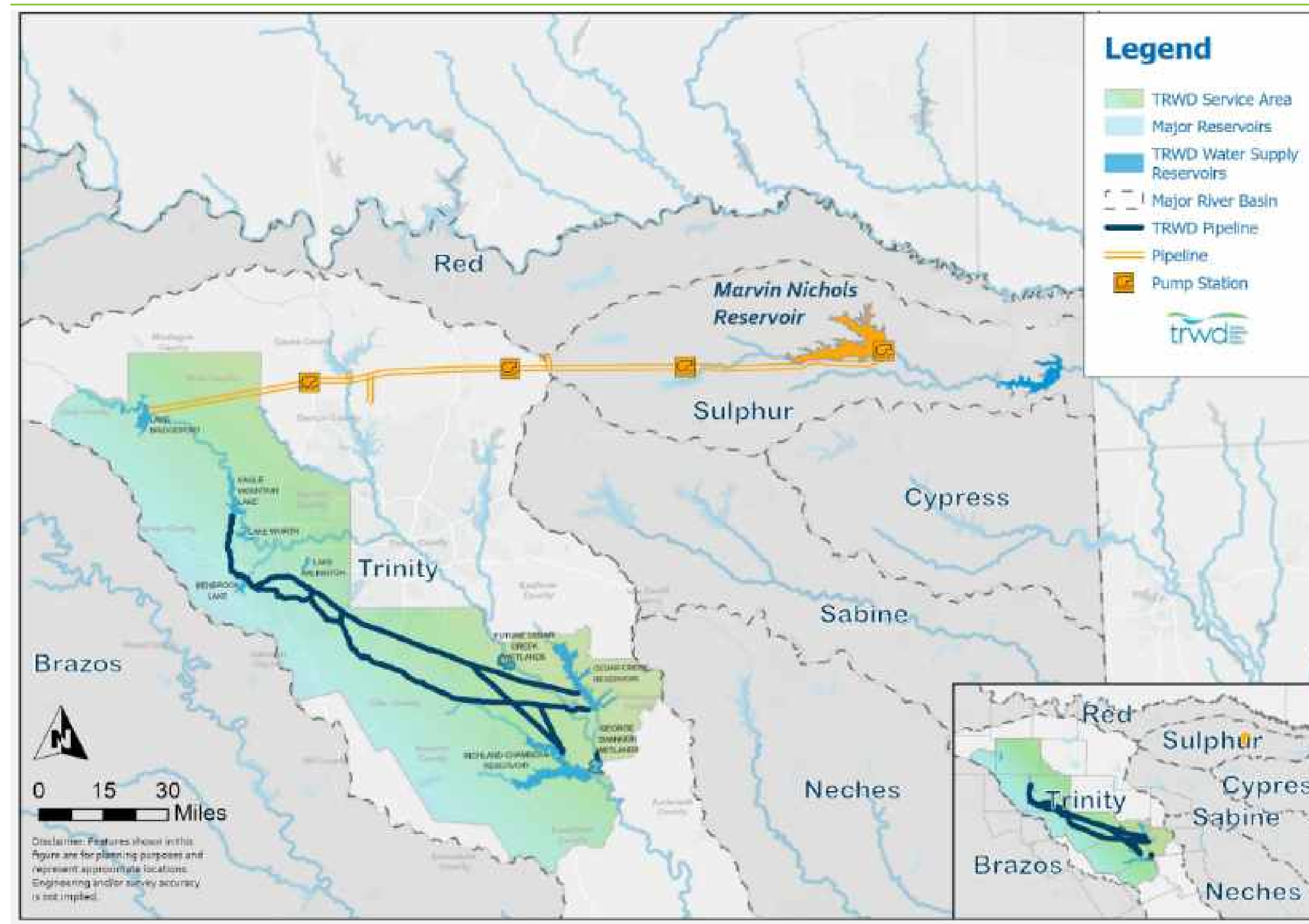
KEY INFRASTRUCTURE

Pipelines	**7 segments from MNR to Bridgeport** **Pipelines range from 78-120"**
Pump Stations	**Reservoir intake pump stations** **3 booster pump stations**
Reservoir	**71,440 surface acres**
Other	**Eagle Mountain Reversal**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$3,062.5**
External Development Cost (millions)[6]	**$3,062.5**
Intersystem Transmission Cost (millions)[7]	**$0.0**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	1	*Environmental permits required for new reservoir; out of basin transfer*
Collaboration Potential	2	*Mixed benefits from multiple partnerships; local collaboration needed*
Operational Simplicity	2	*Remote reservoir operations required; remote pipelines and infrastructure*
Phasing Potential	1	*Construction of a new reservoir cannot be easily phased*
Public Acceptance	2	*Requires acquisition of land for reservoir footprint; strong local opposition; requires ROW acquisition*
Multi-benefit Project	4	*High recreation opportunities partially offset by environmental impacts*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Marvin Nichols

KEY ASSUMPTIONS

Yield Estimate:

- The firm and safe yields are based on a High Yield Scenario (C-3) from the February 1, 2024 report Marvin Nichols Reservoir and Lake Wright Patman (WP) Reallocation Yield Update (Yield Update). See Table C-4 from Appendix C.
- The Yield Update is the first major update since 2014 and reflects recent drought impacts and a new design storm for the dam. The drought of record for Marvin Nichols is the 2006 timeframe, which was worse than the drought of the 1950's.
- Scenario C-3 assumes Texarkana water rights application in Wright Patman is not granted, Wright Patman minimum elevation of 220.0 feet, the Lyons Method environmental flows from the Sulphur River Basin Feasibility Study, and Wright Patman is junior to Marvin Nichols (no Patman 10 cfs release).
- TRWD's portion of the yield at Marvin Nichols is 25.76%.

Cost Estimate:

- Project costs for Marvin Nichols are based on the Conceptual Cost Assumptions from the 2024 report "Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update." Costs are estimated for TRWD share only. See Table C-4 from Appendix C.
- Conceptual dam and spillway cost assumptions consider the level of uncertainty at the current stage of design along with increases in interest rates and electricity costs.
- The costs for pipelines, terminal storage, and pump stations were updated using the IWSP cost curves. Land acquisition costs were updated to $6,066/acre, consistent with LMA 29, and includes 72,192 acres acquired. All other costs are escalated to September 2023 dollars by multiplying the September 2021 costs by 1.082.
- The Yield Update report assumes the costs of Marvin Nichols to be divided among the five project sponsors (excluding the local sponsor) proportional to their export supply from the reservoir.
- The pumping energy costs were adjusted to align with the IWSP assumptions of 0.06$/kW-hr. Debt service was updated to reflect the IWSP assumptions.
- The delivery location for TRWD is Lake Bridgeport.
- Cost was added for reversing the Eagle Mountain Connection.

Other:

- Marvin Nichols is assumed to be divided among five project sponsors from the Dallas-Fort Worth Metroplex and one local sponsor with 20% reserved for local supply.
- The Yield Update report presented multiple configurations and yields for the Sulphur Basin supplies.
- For the purpose of the IWSP, TRWD is using option C-3 based on the following reasoning:
  · The project sponsor(s) will also be the one securing the WP reallocation water right, so presumably they would be able to specify which one would be senior and would choose the option that would result in higher yield.
  · Lyons method is a widely accepted standard method for environmental flows and results in higher yields, and TRWD prefers to use the best-case scenario for the IWSP.
  · Texarkana's water right application is less likely to be granted now that they have secured large water rights in Arkansas.
- This strategy would require an interbasin transfer permit to transfer water from the Sulphur to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.

Table C-4 (continued)

Item	*Total*	*TRWD Share*	*DWU Share*	*NTMWD Share*	*UTRWD Share*	*Irving Share*
Interest During Construction (3.5% for 4 years with a 0.5% ROI)	$449,651,000	$208,876,000	$105,996,000	$106,717,000	$21,014,000	$7,048,000
Reservoir Interest During Construction (3.5% for 4 years with a 0.5% ROI)	$268,324,000	$86,400,000	$62,520,000	$86,400,000	$19,319,000	$13,685,000
TOTAL COST OF PROJECT WITH INTEREST DURING CONSTRUCTION	**$5,938,855,000**	**$2,442,429,000**	**$1,393,908,000**	**$1,597,404,000**	**$333,621,000**	**$171,493,000**
ANNUAL COST						
Debt Service (3.5 percent, 30 years)	$202,227,000	$93,940,000	$47,671,000	$47,995,000	$9,451,000	$3,170,000
Reservoir Debt Service (3.5 percent, 40 years)	$103,932,000	$33,466,000	$24,216,000	$33,466,000	$7,483,000	$5,301,000
Operation and Maintenance						
Pipelines (1% of Facilities + 20%) and Pump Stations (2.5% of Facilities + 20%)	$42,171,000	$19,478,000	$9,873,000	$10,257,000	$1,894,000	$669,000
Dam and Reservoir (1.5% of Facilities + 20%)	$7,246,000	$2,333,212	$1,688,318	$2,333,212	$521,712	$369,546
Pumping Energy Costs (0.09 $/kW-hr)	$45,404,000	$20,502,000	$10,555,000	$11,591,000	$1,937,000	$819,000
TOTAL ANNUAL COST	**$400,980,000**	**$169,719,000**	**$94,003,000**	**$105,642,000**	**$21,287,000**	**$10,329,000**
Available Project Yield (acft/yr)	342,352	110,237	79,768	110,237	24,649	17,460
Annual Cost until Amortized ($ per acft)	$1,171	$1,540	$1,178	$958	$864	$592
Annual Cost until Amortized ($ per 1,000 gallons)	$3.59	$4.72	$3.62	$2.94	$2.65	$1.82
Annual Cost after Amortization ($ per acft)	$277	$384	$277	$219	$177	$106
Annual Cost after Amortization ($ per 1,000 gallons)	$0.85	$1.18	$0.85	$0.67	$0.54	$0.33

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Marvin Nichols with Wright Patman

Tarrant Regional Water District

DESCRIPTION: Marvin Nichols Reservoir is a proposed water supply reservoir in the Sulphur River Basin, located 115 miles from Dallas Fort Worth. The reservoir would store 1.5 million af of water and inundate approximately 71,440 acres. The strategy includes reallocation of and supply from Wright Patman, a U.S. Army Corps of Engineers reservoir just to the east of the proposed Marvin Nichols. This joint, regional strategy includes six sponsors, including TRWD and a local sponsor. Water from Marvin Nichols and Wright Patman would be conveyed to Lake Bridgeport and then released for downstream TRWD customers.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
126.6 mgd	100.3 mgd	$6.94 $/kgal	$1.12 $/kgal	$0.83 $/kgal	$0.29 $/kgal	$0 $/kgal
141,800 afy	112,371 afy	$2,262 $/af	$365 $/af	$270 $/af	$95 $/af	$0 $/af

OVERVIEW

Strategy Type	**Proposed Reservoir**
Strategy Theme(s)	**Large Northern Supply, Regionalization**
Phasing Potential	**Yes**
Partnerships	**DWU, NTMWD, UTRWD, Irving**
Current Status	**Studied**
Implementation Time (yrs)	**30**

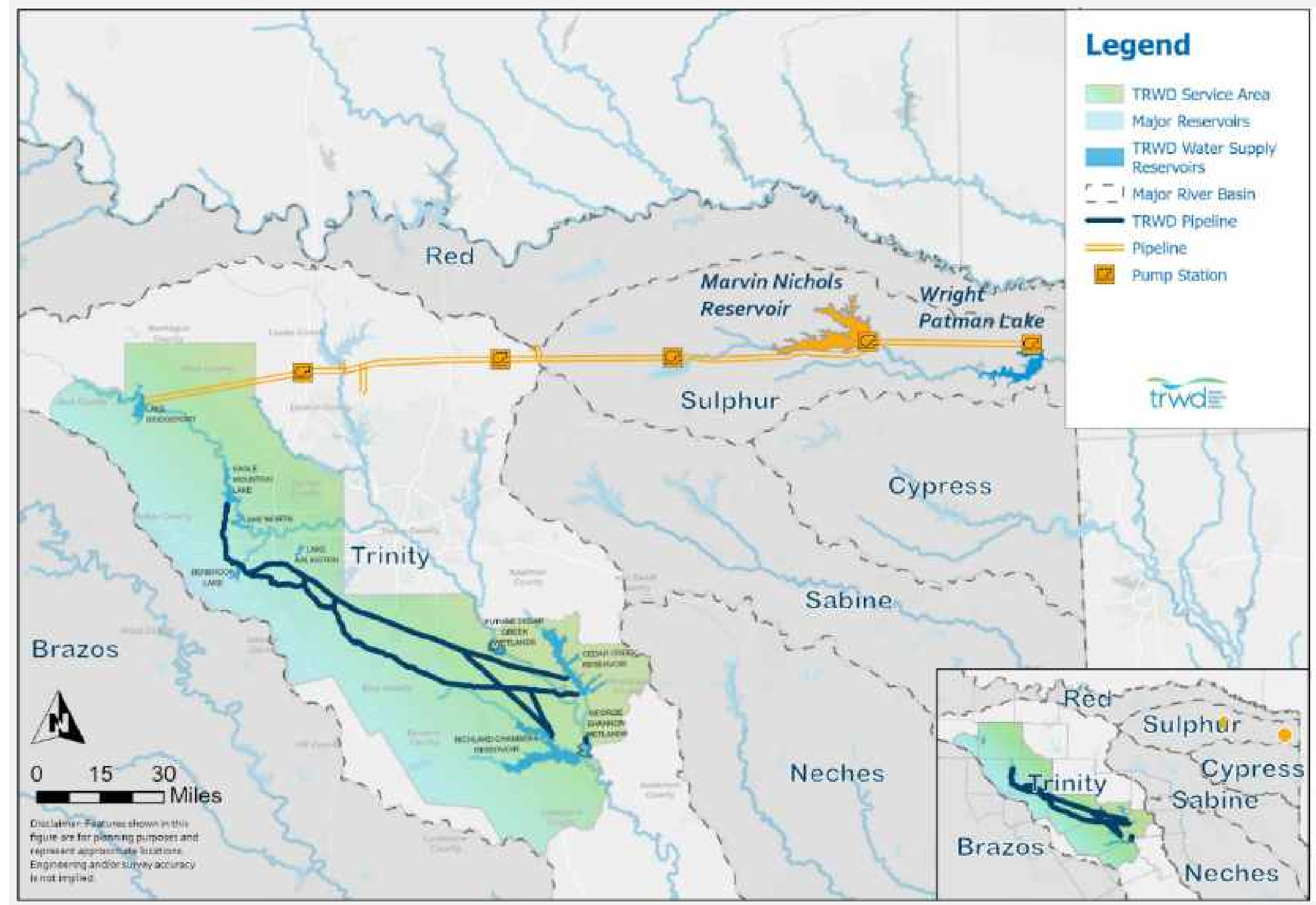
KEY INFRASTRUCTURE

Pipelines	**5 segments** **Pipelines range from 84-144"**
Pump Stations	**Reservoir intake pump stations** **3 booster pump stations**
Reservoir	**71,440 surface acres for Marvin Nichols** **Conservation pool raise on Wright Patman**
Other	**Eagle Mountain Reversal**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$4,795.9**
External Development Cost (millions)[6]	**$4,795.9**
Intersystem Transmission Cost (millions)[7]	**$0.0**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	1	*Environmental permits required for new reservoir and the reallocation; out of basin transfer*
Collaboration Potential	2	*Mixed benefits from multiple partnerships; local collaboration needed*
Operational Simplicity	2	*Remote reservoir operations required; remote pipelines and infrastructure*
Phasing Potential	2	*Construction of a new reservoir cannot be easily phased, but could phase second pipeline*
Public Acceptance	2	*Requires acquisition of land for reservoir footprint; strong local opposition; requires ROW acquisition*
Multi-benefit Project	4	*High recreation opportunities partially offset by environmental impacts*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Marvin Nichols with Wright Patman

KEY ASSUMPTIONS

Yield Estimate:

- The firm and safe yields are based on a High Yield Scenario (C-3) from the February 1, 2024 report Marvin Nichols Reservoir and Lake Wright Patman (WP) Reallocation Yield Update (Yield Update).
- The Yield Update is the first major update since 2014 and reflects recent drought impacts and a new design storm for the dam. The drought of record for Marvin Nichols is the 2006 timeframe, which was worse than the drought of the 1950's.
- Scenario C-3 assumes Texarkana water rights application in Wright Patman is not granted, Wright Patman minimum elevation of 220.0 feet, the Lyons Method environmental flows from the Sulphur River Basin Feasibility Study, and Wright Patman is junior to Marvin Nichols (no Patman 10 cfs release).
- TRWD's portion of the yield at Marvin Nichols is 25.76% and 32.2% at Wright Patman.

Cost Estimate:

- Project costs for Marvin Nichols are based on the Conceptual Cost Assumptions from the 2024 report "Marvin Nichols Reservoir and Lake Wright Patman Reallocation Yield Update." Costs are assumed for "TRWD Share".
- Conceptual Cost assumptions consider the level of uncertainty at the current stage of design along with increases in interest rates and electricity costs.
- The costs from the Yield Update report are escalated to September 2023 dollars by multiplying the September 2021 costs by 1.082.
- Costs for Wright Patman Reallocation come from Table H.24 in the 2021 Region C Water Plan (November 2020) and were escalated from September 2018 dollars to September 2023 dollars.
- The Yield Update report assumes the costs of Marvin Nichols to be divided among the five project sponsors proportional to their export supply from the reservoir.
- The pumping energy costs are 0.06$/kW-hr.
- The delivery location for TRWD is Lake Bridgeport.

Other:

- Marvin Nichols is assumed to be divided among five project sponsors from the Dallas-Fort Worth Metroplex and one local sponsor with 20% reserved for local supply.
- The Yield Update report presented multiple configurations and yields for the Sulphur Basin supplies.
- For the purpose of the IWSP, TRWD is using option C-3 based on the following reasoning:
  - The project sponsor(s) will also be the one securing the WP reallocation water right, so presumably they would be able to specify which one would be senior and would choose the option that would result in higher yield.
  - Lyons method is a widely accepted standard method for environmental flows and results in higher yields, and TRWD prefers to use the best-case scenario for the IWSP.
  - Texarkana's water right application is less likely to be granted now that they have secured large water rights in Arkansas.
- This strategy would require an interbasin transfer permit to transfer water from the Sulphur to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

carollo

IWSP Update | Water Management Strategy Factsheet

Lake Ringgold

DESCRIPTION: Construct Lake Ringgold, a new reservoir on the Little Wichita River just upstream of the confluence of the Red River. Lake Ringgold would have a storage capacity of 275,000 af of water with an approximate surface area of 15,500 acres. This strategy assumes TRWD would be fully responsible for the permitting, planning, design, construction, and O&M for Lake Ringgold.

Annual Yield Firm	Annual Yield Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
25.0 mgd	25.0 mgd	$7.66 $/kgal	$1.09 $/kgal	$0.98 $/kgal	$0.11 $/kgal	$0 $/kgal
28,000 afy	28,000 afy	$2,497 $/af	$356 $/af	$319 $/af	$37 $/af	$0 $/af

OVERVIEW

Strategy Type	**Proposed Reservoir**
Strategy Theme(s)	**Northern Supply**
Phasing Potential	**None**
Partnerships	**None**
Current Status	**Studied**
Implementation Time (yrs)	**25**

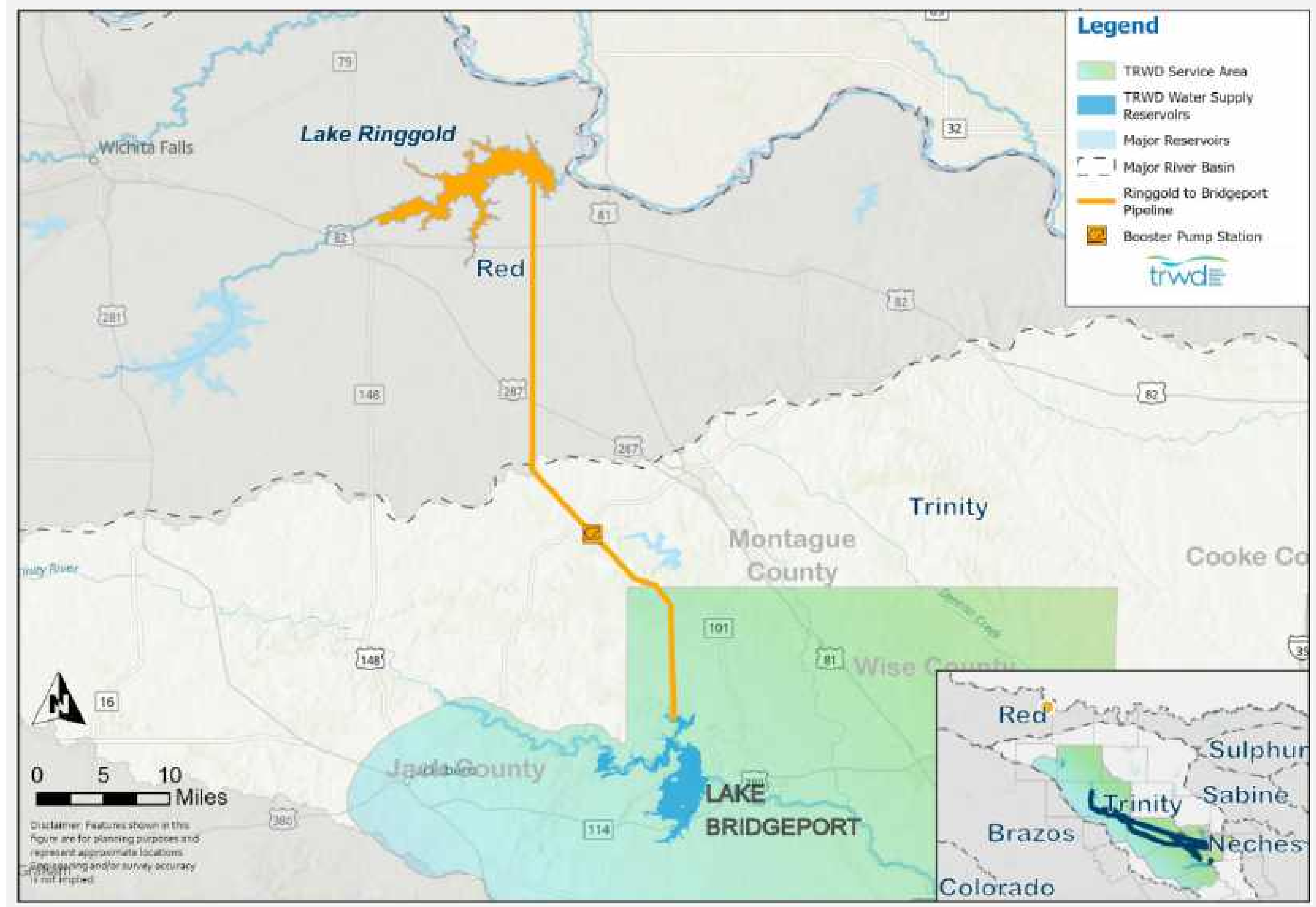
KEY INFRASTRUCTURE

Pipelines	**50 miles of 48"**
Pump Stations	**4,669 HP pump station** **37.5 mgd intake pump station** **1 booster pump station (1268 HP)**
Reservoir	**17,280 surface acres** **82 af terminal storage**
Other	**Eagle Mountain Reversal**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$1,037.8**
External Development Cost (millions)[6]	**$1,037.8**
Intersystem Transmission Cost (millions)[7]	**$0.0**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	2	*Reliance on surface water; Red River Basin more drought prone*
Permit Uncertainty & Complexity	2	*Environmental permits required for new reservoir; water rights approved*
Collaboration Potential	3	*Partnership not assumed, but regional complexities are present*
Operational Simplicity	3	*Reservoir operations required*
Phasing Potential	1	*Construction of a new reservoir cannot be easily phased*
Public Acceptance	3	*Requires acquisition of land for reservoir footprint; potential environmental opposition; requires ROW acquisition*
Multi-benefit Project	4	*High recreation opportunities partially offset by environmental impacts*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Lake Ringgold

KEY ASSUMPTIONS

Yield Estimate:

- Firm yield of Lake Ringgold is estimated at 30,115 af based on Region B most recently updated firm yield.
- TRWD is assumed to have rights to 28,000 af.
- TRWD would begin pumping from Lake Ringgold when Lake Bridgeport is one foot down in elevation.

Other:

- TCEQ granted the City of Wichita Falls a water rights permit for Lake Ringgold in May of 2024.
- A Section 404 permit under the Clean Water Act from the U.S. Army Corps of Engineers is needed, which authorizes construction of the reservoir.
- This strategy would require an interbasin transfer permit to transfer water from the Red to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.

Cost Estimate:

- The reservoir would inundate 17,280 acres.
- The reservoir dam cost is indexed from the 2021 Region B plan. Environmental mitigation and relocation costs were also indexed from the 2021 Region B plan. The intake pump station was sized for TRWD's yield using a 1.5 peaking factor.
- The pipeline from Lake Ringgold to Lake Bridgeport would be approximately 50 miles of single 48".
- One booster pump of 1268 HP is required.
- No further transportation is assumed once the supply is delivered to Lake Bridgeport.
- Assuming that TRWD bores all costs.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Tehuacana

Tarrant Regional Water District

DESCRIPTION: Construct a new reservoir on Tehuacana Creek, a tributary to the Trinity River in Freestone County, located south of Richland-Chambers. Tehuacana would be hydraulically connected to Richland-Chambers with a small channel. Water from Tehuacana would be transported from Richland-Chambers and then into TRWD's transmission system. The strategy assumes that a second IPL will be needed to transmit the supply from Richland-Chambers to Benbrook Lake and includes a proportional cost.

Annual Yield Firm	Annual Yield Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
24.6 mgd	19.6 mgd	$8.82 $/kgal	$1.26 $/kgal	$1.02 $/kgal	$0.24 $/kgal	$0.00 $/kgal
27,514 afy	21,936 afy	$2,875 $/af	$409 $/af	$332 $/af	$77 $/af	$0 $/af

OVERVIEW

Strategy Type	**Proposed Reservoir**
Strategy Theme(s)	**Trinity Priority**
Phasing Potential	**None**
Partnerships	**None**
Current Status	**Studied**
Implementation Time (yrs)	**25**

KEY INFRASTRUCTURE

Second IPL to transmit supply

Pump Stations

80 HP intake pump station

Reservoir

Zoned earthen embankment with maximum 81 ft height

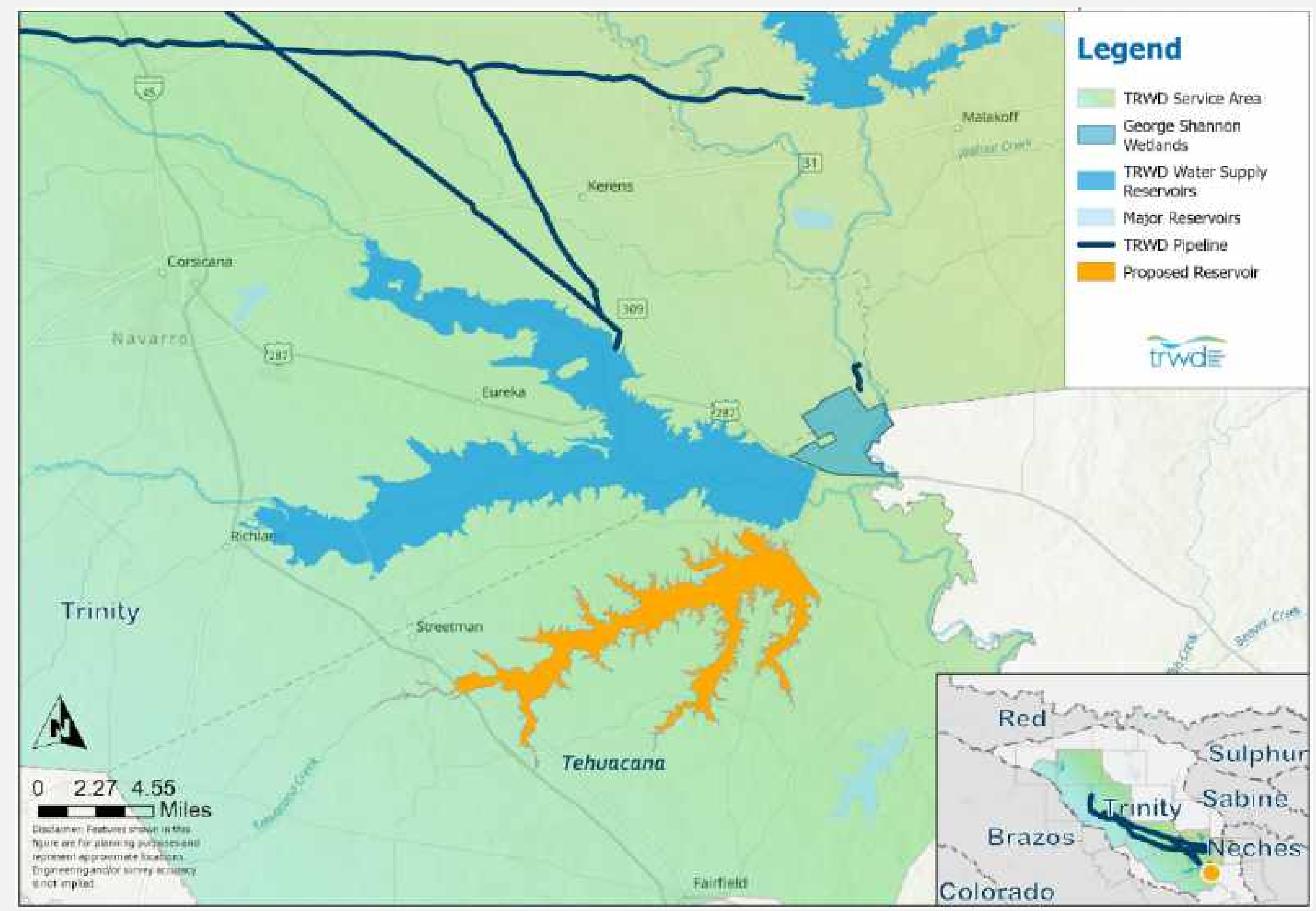
9,000 ft channel

337,947 af reservoir

CAPITAL COST[5]

Total Strategy Cost (millions)	$1,175.4
External Development Cost (millions)[6]	$846.2
Intersystem Transmission Cost (millions)[7]	$329.2

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

Criterion	Score	Rationale
System Risk	3	*Reliance on surface water which can be impacted by wildfires and drought; reservoirs susceptible to contamination*
Permit Uncertainty & Complexity	1	*Environmental permits required for new reservoir*
Collaboration Potential	4	*No partnership required*
Operational Simplicity	4	*Operating large reservoir, but located in close proximity to TRWD's existing infrastructure*
Phasing Potential	1	*Construction of a new reservoir cannot be easily phased*
Public Acceptance	3	*Requires acquisition of land for reservoir footprint; potential environmental opposition*
Multi-benefit Project	4	*High recreation opportunities partially offset by environmental impacts*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Tehuacana

KEY ASSUMPTIONS

Yield Estimate:

- Tehuacana is situated in Freestone and will inundate approximately 15,000 acres. The reservoir will hold 338,000 af.
- Based on the assumptions reflected in the October 2023 TCEQ Water Availability Model (WAM), the firm yield of Tehuacana is estimated to be 27,514 afy.
- The following modifications were made to the TCEQ WAM, consistent with Region C: added TRWD's ExFlo2 permit and uses a control point on Tehuacana Creek rather than a gage on the mainstem of the Trinity River to compute naturalized flows for ungaged control points on Tehuacana Creek.
- If the unpermitted yield in Richland-Chambers and Cedar Creek Reservoirs is permitted before the yield of Lake Tehuacana, then the yield of Tehuacana is estimated to decrease to 26,000 afy.
- If the WAM includes local environmental flows at Tehuacana, consistent with yields previously reported for Region C, the firm yield decreases further to 25,225 afy.
- The safe yield of Tehuacana is estimated to be 21,270 afy, assuming local environmental flows and a diversion junior to the unpermitted yield of RC and CC.

Cost Estimate:

- Assumed Tehuacana would be hydraulically connected to Richland-Chambers Reservoir via a small channel. TRWD already owns the land for channel connection.
- It is unknown if structural components may be needed for the channel connection. Assumed no structural components are needed to be consistent with previous estimates for the 2014 IWSP.
- Used 2014 TRWD IWSP dam assumptions as directed by TRWD.
- An 80 HP pump station is needed to access water between elevation 290' and 270' in Tehuacana, per the 2014 IWSP. Once pumped to the appropriate elevation, the two reservoirs would be hydrologically connected by a channel.
- Extensive information has been collected over the years on the oil/gas deposits and current operations/wells within the footprint of Tehuacana. This information is included in land acquisition cost estimate, so there is no need to include additional factors for oil/gas. Cost of land was assumed at $10,000 per acre, with additional costs added for parcels with residential structures (19 total).
- The existing spillway for Richland-Chambers Reservoir was designed to provide enough discharge capacity to accommodate the increased flood flows from Tehuacana Reservoir for the probable maximum flood (PMF) event. Previous studies indicate the dam for Tehuacana Reservoir can be constructed without a spillway. If this strategy is moved forward, TRWD should confirm if the current sizing of Richland-Chambers spillway is adequate given a new PMF.
- Intersystem transmission assumes 13% of the costs of the second IPL from RC to JB2 and 11% of the costs from JB2 to Benbrook Lake.

Other:

- The study team considered reducing or eliminating the escalation factor for the land containing lignite deposits since it has thus far not been economically feasible to mine the lignite deposits and the local need for lignite has essentially been eliminated by the closure of Big Brown Power Plant. Ultimately, the escalation factor was maintained because:
  - The escalation factor was embedded in the land price such that it is difficult to separate out and eliminate or reduce.
  - The possibility remains that current landowners will not zero out the lignite value when considering a selling price.
  - The energy market is highly uncertain and there is a potential for lignite to again be used as a source of fuel in the future.
- Past studies on oil/gas for Tehuacana include one performed by Freese & Nichols around 1990 and one in 2012 by Fugro.
- TRWD would need to submit a water rights application to TCEQ for Tehuacana, which would give TRWD the right to use and impound the water. If granted, the next step is to obtain a Section 404 permit under the Clean Water Act from the U.S. Army Corps of Engineers, which provides authorization to construct the reservoir.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

IWSP Update | Water Management Strategy Factsheet

Mainstem Trinity OCR

Tarrant Regional Water District

DESCRIPTION: Proposed off-channel reservoir (OCR) located near the main stem of the Trinity River. The OCR could store approximately 300,000 af of supply from Dallas Water Utilities (DWU) return flows, stormwater runoff originating in the upstream Trinity River watershed, or reuse water from other partners. Water would be diverted to the OCR and then conveyed via pipeline to Joe Pool. TRWD would then convey the supply from Joe Pool to JB4. This strategy assumes a 50/50 cost share with DWU for construction of the OCR and pipeline to Joe Pool. Given the supply will be return flows in the Trinity River, nutrient impacts will need to be mitigated to maintain TRWD raw water quality standards.

Annual Yield – Firm	Annual Yield – Safe	Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
51.0 mgd	51.0 mgd	$3.87 $/kgal	$1.18 $/kgal	$0.51 $/kgal	$0.47 $/kgal	$0.20 $/kgal
57,169 afy	57,169 afy	$1,260 $/af	$385 $/af	$167 $/af	$153 $/af	$65 $/af

*Storage volume 150,000 af

OVERVIEW

Strategy Type	**Proposed Reservoir**
Strategy Theme(s)	**Regionalization, Trinity Priority**
Phasing Potential	**Yes**
Partnerships	**Dallas Water Utilities**
Current Status	**Studied**
Implementation Time (yrs)	**20**

KEY INFRASTRUCTURE

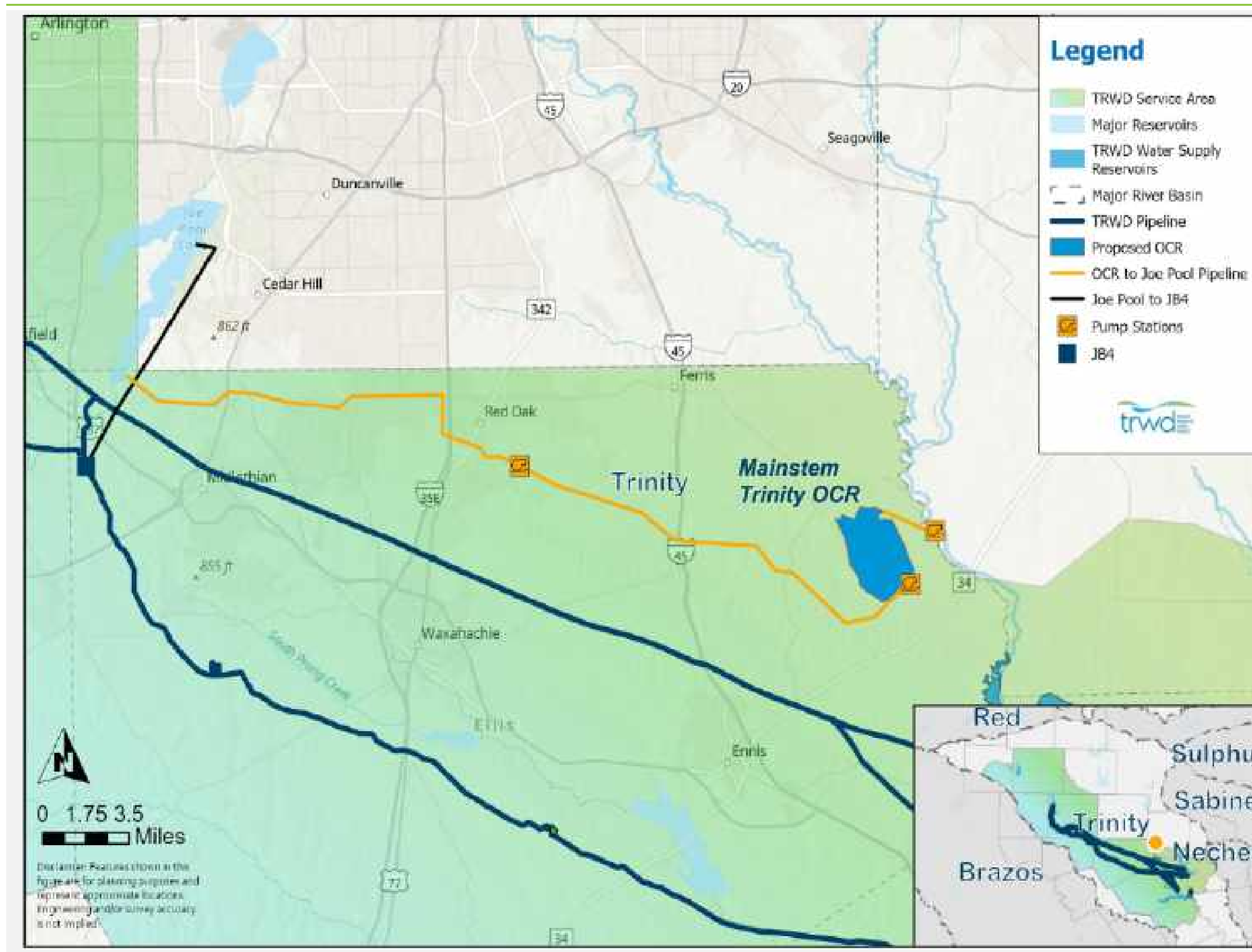
Portion of second IPL to transmit supply

Pipelines	**40 miles of 66" from OCR to Joe Pool** **12 miles of 66" from Joe Pool to JB4**
Pump Stations	**3,200 HP primary pump station** **76.5 mgd intake pump station**
Reservoir	**4,337 surface acres**

CAPITAL COST[5]

Total Strategy Cost (millions)	**$867.5**
External Development Cost (millions)[6]	**$641.1**
Intersystem Transmission Cost (millions)[7]	**$226.5**

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

Criterion	Score	Notes
System Risk	4	*Less likely to be contaminated or impacted by wildfire; reuse supply available during drought but not Exflo*
Permit Uncertainty & Complexity	3	*Environmental permits required for new reservoir; off-channel less environmental impacts*
Collaboration Potential	3	*Partnership required*
Operational Simplicity	3	*Operations require filling and release; located in close proximity to TRWD's existing infrastructure*
Phasing Potential	1	*No phasing potential*
Public Acceptance	3	*Requires acquisition of land for reservoir footprint; requires ROW acquisition for pipeline; potential environmental opposition*
Multi-benefit Project	2	*Some opportunity for recreation benefits via trails*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Mainstem Trinity OCR

KEY ASSUMPTIONS

Yield Estimate:

- Proposed DWU project in 2014 DWU LRWSP for large OCR near the main stem of Trinity River to capture DWU return flows (and possibly other flows).
- Assume 50/50 partnership with DWU.
- Assume OCR can store approximately 300,000 af based on 2014 DWU LRWSP.
- The 114,337 afy (102 mgd) of yield is based on the 2014 DWU LRWSP. No modeling was conducted to confirm the firm yield. Assumed that TRWD could purchase half of the firm yield, or 51 mgd per year from DWU.

Other:

- Although not studied or costed, there are multiple potential alternatives for how this strategy could ultimately be implemented, including:
    - Connecting directly into TRWD system at JB4 (breaking off from DWU line to Joe Pool), water quality permitting.
    - Bypass Joe Pool and connect to KBR to deliver the supply to Lake Arlington, water quality permitting.
    - Potential swap with DWU (to reduce new infrastructure).
- Given the volume of supply will be return flows in the Trinity, nutrient impacts will need to be mitigated to maintain TRWD raw water quality standards.

Cost Estimate:

- Purchase cost of DWU return flows is unknown. Consistent with other strategies for the IWSP and TRWD direction, a unit cost of $0.50/1,000 gallons was assumed. This is consistent with the assumed raw water wholesale purchase price in Region C. All prices would be subject to negotiation between the parties.
- Indexed up costs developed for 2014 DWU LRWSP:
    - Channel dam
    - Intake river pump station at 158 cfs
    - Transmission pipelines from Trinity River to OCR (72") and OCR to Joe Pool (84")
    - Transmission pump station (12,000 HP) and booster pump station (10,700 HP)
    - Relocations, Environmental & Archaeology Studies and Mitigation, and Land Acquisition and Surveying
    - OCR as described above.
- Additional site investigation and geotechnical work at OCR site to confirm assumptions that impact costs if this option is pursued.
- Assume TRWD will pick up water out of Joe Pool and connect to JB4. Intake and pipeline costs are included.
- Intersystem conveyance is then 22% of the costs from JB4 to Benbrook.

Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

Arkansas Water

Tarrant Regional Water District

DESCRIPTION: Submit a legislative request for out-of-state transfer of up to 378,000 af of supply annually from Arkansas. The diversion would be just above Millwood Lake and would convey the supply to Bridgeport Lake. This strategy was estimated at the full amount available at the point of diversion and as a run-of-river strategy. A lesser permitted amount would be more reliable, and an OCR could further improve reliability. While the legislative process is established for an out-of-state transfer, there is no precedent for such a transfer.

Annual Yield		Unit Cost with Debt Service[1]	Unit Cost after Debt Service Retired[2]	Unit O&M Cost[3]	Unit Pumping Energy Cost[4]	Purchase Cost of Water
Firm	Safe					
232.1 mgd	232.1 mgd	$8.47 $/kgal	$1.50 $/kgal	$1.06 $/kgal	$0.23 $/kgal	$0.20 $/kgal
260,000 afy	260,000 afy	$2,761 $/af	$488 $/af	$347 $/af	$76 $/af	$65 $/af

See note on next page

OVERVIEW

Strategy Type
Water Transfer
Strategy Theme(s)
Diversification, Large Northern Supply
Phasing Potential
Yes
Partnerships
TRA, NTMWD, Others
Current Status
Conceptual
Implementation Time (yrs)
25

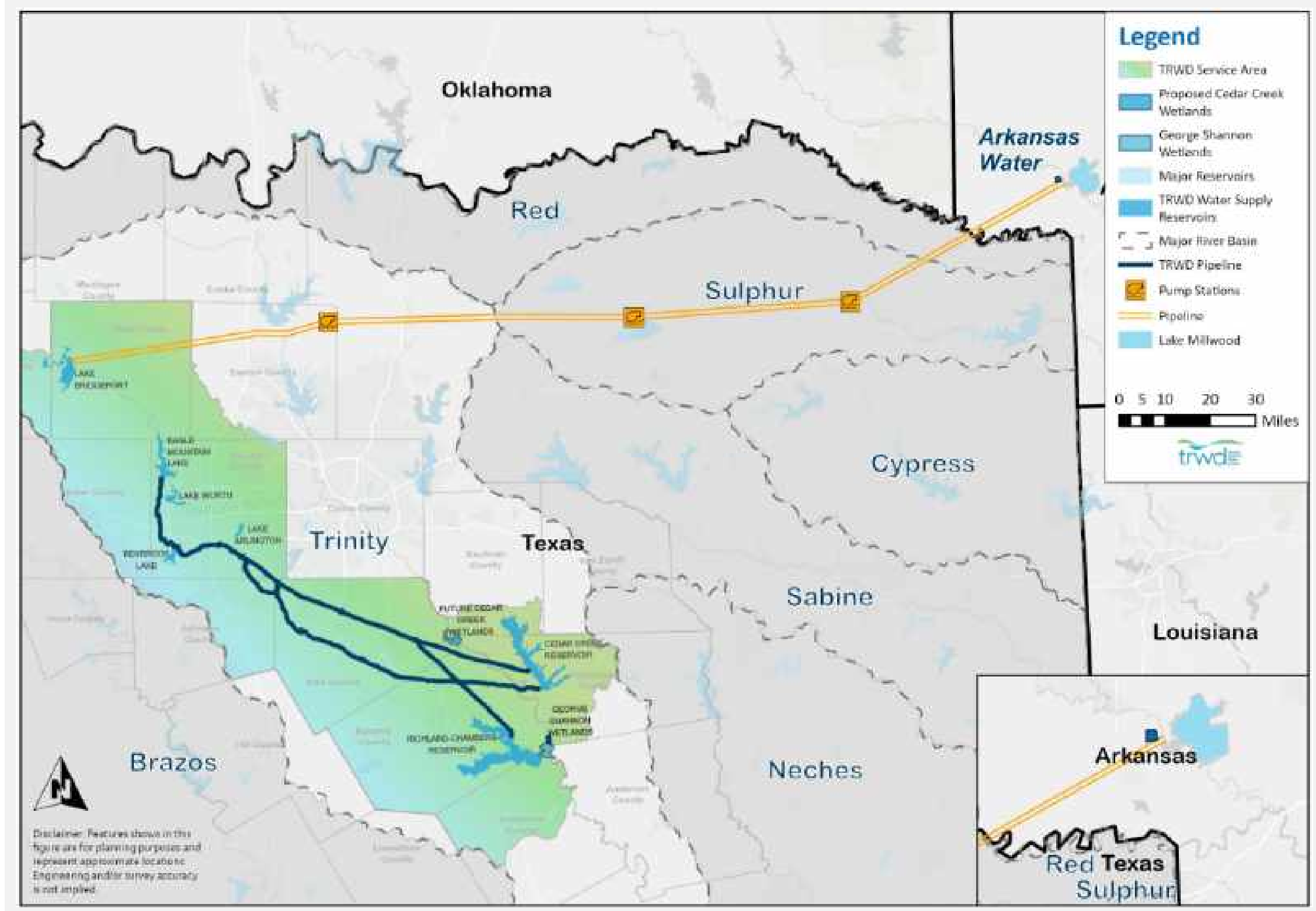
KEY INFRASTRUCTURE

Pipelines
Two parallel pipelines
497 miles of 120" (2 pipelines at 248 miles)
Pump Stations
70,000 & 35,000 HP primary pump stations
Two 254 mgd intake pump stations
6 booster pump stations
Transmission & Facility Footprint
2,778 acres of land acquisition
Other
Eagle Mountain Reversal
OCR at Intake Location

CAPITAL COST[5]

Total Strategy Cost (millions)
$10,239.8
External Development Cost (millions)[6]
$10,239.8
Intersystem Transmission Cost (millions)[7]
$0.0

STRATEGY LOCATION



STRATEGY QUALITATIVE SCORES

System Risk	2	*Reliance on surface water which can be impacted by wildfires; reliabililty of supply needs additional study; flow susceptible to contamination*
Permit Uncertainty & Complexity	1	*Although state has outlined procedures, no precedent for out-of-state water transfers*
Collaboration Potential	5	*Partnership not required*
Operational Simplicity	1	*Infrastructure and operations stretch 250 miles beyond TRWD's existing system*
Phasing Potential	3	*Could phase two pipelines*
Public Acceptance	3	*Requires ROW acquisition for pipeline; environmental opposition possible; strong local Arkansas opposition possible; Texas legislative support for out-of-state supplies*
Multi-benefit Project	1	*Not considered to have project benefits beyond water supply*

The highest possible score is 5, indicating a positive qualitative attribute.

Water Management Strategy Factsheet

Arkansas Water

KEY ASSUMPTIONS

Yield Estimate:

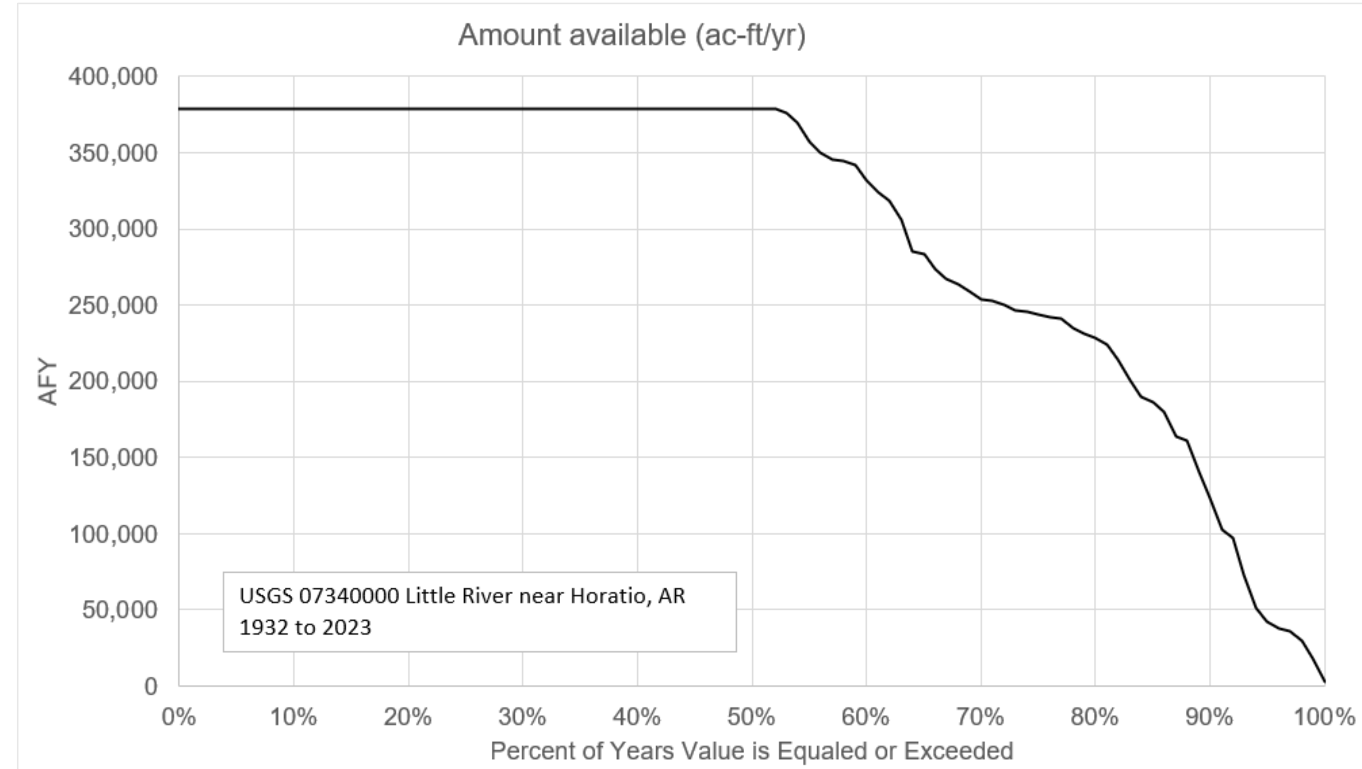
- The strategy assumes 260,000 afy in any year, firmed up through the inclusion of an OCR.
- The water availability is constrained by pumping capacity, assuming 1.5 peaking factor.
- Supply available for permitted use was determined from the 2014 Arkansas State Plan. The Red River has an "excess" supply available of 1,220,000 af in the Red River basin, with 378,000 originating in the Little River. The excess supply is less existing commitments and instream flow requires and represents mean annual supply available for permitting. Arkansas is updating their state plan, so these numbers may change.
- Cursory review of streamflow statistics from the USGS gage 07340000 (Little River near Horatio, Arkansas) indicate the 260,000 annual supply would be available 68% of the time. That supply is available during the 1950s drought of record associated with TRWD's existing supplies.

Cost Estimate:

- The path of the pipeline from Lake Millwood in Arkansas to Lake Bridgeport in Texas was assumed to follow the same route as the Marvin Nichols transmission system, from Marvin Nichols reservoir to Bridgeport. More efficient routing may be determined with additional study.
- Dual pipelines and intakes were assumed. The strategy requires two primary pump stations and six booster pump stations.

Other:

- Arkansas has a state approval process in place to allow for out-of-state transfers of surface water. The applicant must show the need, and the State considers if other parts of the state could use that supply now or in the future. No known out-of-state transfer has been requested or issued at this time.
- This strategy would require an interbasin transfer permit to transfer water from the Red to the Trinity (to the extent applicable from TWC §11.085). Additional detailed studies for the receiving and the source basins will be required as part of the permitting process for new interbasin transfers. Section 11.085 of the Texas Water Code includes permitting requirements for interbasin transfers.
- This strategy was also considered as a contract for supply out of the Tri-Lakes (U.S. Army Corps of Engineers reservoir). There is currently 70,500 af of uncommitted supply in Gillhan, DeQueen, and Dierks Lakes (collectively "Tri-Lakes"). Procurement of this supply would require an allocation study (taking approximately 5 years), but would still require Arkansas legislative approval.



Notes:

Acronyms | af = acre-feet | afy = acre-feet per year | IPL = integrated pipeline | kgal = thousand gallons | kWh = kilowatt hour | mgd = million gallons per day | O&M = operation and maintenance | PF = peaking factor | yr(s) = year(s)

1. Debt service assumed at 4% for 30 years. Unit cost with debt service includes the capital cost with debt service, O&M, pumping energy costs, and the purchase cost of water.
2. Unit cost after debt service is retired includes O&M, pumping energy costs, and the purchase cost of water.
3. Includes operation and maintenance costs of pipelines, wells, and storage tanks at 1% of the facility capital costs; intakes and pump stations at 2.5% of facility capital costs; dam and reservoir at 1.5% of facility capital costs.
4. Assumes an energy cost of 0.06 $/kWh.
5. All costs in September 2023 dollars (to align with Regional Planning). Capital cost includes the cost to construct facilities plus 3% for engineering, 7% for design, 1% for construction engineering, 2% for legal assistance, 2% for fiscal services, 15% for pipeline contingency, and 20% for all other facility contingency. Costs also include environmental and archaeology studies and mitigation, land acquisition and surveying, and interest during construction.
6. Includes the cost to develop the strategy and delivery supply to the nearest end point of TRWD's existing water supply infrastructure, if applicable.
7. Includes the cost to convey supply from TRWD's nearest existing water supply end point to Lake Benbrook via the proportional cost of a second IPL, if applicable.

APPENDIX F

STRATEGY DETAILED COST ESTIMATES

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD IWSP - WMS 02 - DPR
Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 278.502 for September 2023

Item	***Estimated Costs for WMS 02 - DPRDPR***	***Estimated Costs for Intersystme Conveyance***	***Total Estimated Costs for WMS 02 - DPR***
CAPITAL COST			
Intake Pump Stations (26.3 MGD)	$80,911,000	$0	$80,911,000
Transmission Pipeline (30-36 in. dia., 1.7 miles)	$819,000	$0	$819,000
Advanced Water Treatment Facility (20 MGD)	$208,900,000	$0	$208,900,000
Integration, Relocations, Backup Generator & Other	$257,000	$0	$257,000
TOTAL COST OF FACILITIES	**$290,887,000**	**$0**	**$290,887,000**
Engineering:			
- Planning (3%)	$8,727,000	$0	$8,727,000
- Design (7%)	$20,362,000	$0	$20,362,000
- Construction Engineering (1%)	$2,909,000	$0	$2,909,000
Legal Assistance (2%)	$5,818,000	$0	$5,818,000
Fiscal Services (2%)	$5,818,000	$0	$5,818,000
Pipeline Contingency (15%)	$123,000	$0	$123,000
All Other Facilities Contingency (20%)	$58,014,000	$0	$58,014,000
Environmental & Archaeology Studies and Mitigation	$866,000	$0	$866,000
Land Acquisition and Surveying (69 acres)	$1,034,000	$0	$1,034,000
TOTAL COST OF PROJECT	**$394,558,000**	**$0**	**$394,558,000**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$22,802,000	$0	$22,802,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$11,000	$0	$11,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$2,023,000	$0	$2,023,000
Advanced Water Treatment Facility	$14,203,000	$0	$14,203,000
Pumping Energy Costs (4216491 kW-hr @ 0.06 $/kW-hr)	$253,000	$0	$253,000
Purchase of Water (acft/yr @ $/acft)	$0	$0	$0
TOTAL ANNUAL COST	**$39,292,000**	**$0**	**$39,292,000**
Available Project Yield (acft/yr)	20,500	-	20,500
Annual Cost of Water ($ per acft), based on PF=1.14	$1,917	-	$1,917
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.14	$804	-	$804
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.14	$5.88	-	$5.88
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.14	$2.47	-	$2.47

Note: One or more cost element has been calculated externally

Becky Gates *8/15/2024*

Cost Estimate Summary *Water Supply Project Option* *September 2023 Prices* *TRWD - WMS 3 Second RC Wetland* *Cost based on ENR CCI 13485.67 for September 2023 and* *a PPI of 278.502 for September 2023*			
Item	***Estimated Costs for WMS 3 Second RC Wetland to Richland Chambers***	***Estimated Costs for Intersystem Conveyance***	***Total Estimated Costs for WMS 3 Second RC Wetland***
CAPITAL COST			
Terminal Storage (Conservation Pool acft, acres)	$0	$60,198,000	$60,198,000
Intake Pump Stations	$128,726,000	$155,345,000	$284,071,000
Transmission Pipelines	$40,670,000	$570,862,000	$611,532,000
Transmission Pump Station(s)	$0	$118,163,000	$118,163,000
Integration, Relocations, Backup Generator & Other	$59,816,000	$7,914,000	$67,730,000
TOTAL COST OF FACILITIES	**$229,212,000**	**$912,482,000**	**$1,141,694,000**
Engineering:			
- Planning (3%)	$6,876,000	$27,375,000	$34,251,000
- Design (7%)	$16,045,000	$63,874,000	$79,919,000
- Construction Engineering (1%)	$2,292,000	$9,125,000	$11,417,000
Legal Assistance (2%)	$4,584,000	$18,249,000	$22,833,000
Fiscal Services (2%)	$4,584,000	$18,249,000	$22,833,000
Pipeline Contingency (15%)	$6,101,000	$85,629,000	$91,730,000
All Other Facilities Contingency (20%)	$37,708,000	$68,324,000	$106,032,000
Environmental & Archaeology Studies and Mitigation	$14,686,000	$2,629,000	$17,315,000
Land Acquisition and Surveying (2071 acres)	$15,160,000	$1,395,000	$16,555,000
TOTAL COST OF PROJECT	**$337,248,000**	**$1,207,331,000**	**$1,544,579,000**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$17,822,000	$64,509,000	$82,331,000
Reservoir Debt Service (4 percent, 30 years)	$1,681,000	$4,854,000	$6,535,000
Operation and Maintenance			
Wetlands (1.5% of Cost of Facilities)	$897,000	$0	$897,000
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$407,000	$5,788,000	$6,195,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$3,218,000	$6,837,000	$10,055,000
Pumping Energy Costs (10861558 kW-hr @ 0.06 $/kW-hr)	$652,000	$7,790,000	$8,442,000
Purchase of Water (acft/yr @ $/acft)	$0	$0	$0
TOTAL ANNUAL COST	**$24,677,000**	**$90,681,000**	**$115,358,000**
Available Project Yield (acft/yr)	100,890	100,890	100,890
Annual Cost of Water ($ per acft), based on PF=1.5	$245	$899	$1,143
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$51	$211	$254
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$0.75	$2.76	$3.51
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$0.16	$0.65	$0.78
Note: One or more cost element has been calculated externally			
KW Update: Becky Gates			*7/18/2024 Update: 11/5/2024*

Water Supply Project Option TRWD - WMS 05 - CC and RC Unpermitted Firm Yield				
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023				
Item	**Costs for Facilities Related to Strategy**	**JB2 to Benbrook**	**Cedar Creek to JB2**	**Richland Chambers to JB2**
Project Yield (acft/yr)	***261,566***	261,566	261,566	261,566
Strategy Yield (acft/yr)	***21,920***	21,920	12,850	9,070
Percent of Cost Applied to Strategy		8.4%	4.9%	3.5%
CAPITAL COST				
Terminal Storage (Conservation Pool 2839 acft, 236 acres)	$13,079,041	$13,079,041	$0	$0
Intake Pump Stations (0 MGD)	$29,187,699	$15,468,012	$7,793,634	$5,926,053
Transmission Pipeline (108 in. dia., 79.5 miles)	$120,931,118	$108,635,680	$7,306,047	$4,989,391
Transmission Pump Station(s) & Storage Tank(s)	$25,672,947	$25,672,947	$0	$0
Integration, Relocations, Backup Generator & Other	$1,684,610	$1,529,655	$93,440	$61,515
TOTAL COST OF FACILITIES	**$190,555,414**	$164,385,334	$15,193,121	$10,976,959
Engineering:				
- Planning (3%)	$5,716,669	$4,931,552	$455,802	$329,316
- Design (7%)	$13,338,867	$11,506,982	$1,063,505	$768,380
- Construction Engineering (1%)	$1,905,612	$1,643,878	$151,950	$109,783
Legal Assistance (2%)	$3,811,057	$3,287,673	$303,852	$219,532
Fiscal Services (2%)	$3,811,057	$3,287,673	$303,852	$219,532
Pipeline Contingency (15%)	$18,139,650	$16,295,314	$1,095,929	$748,407
All Other Facilities Contingency (20%)	$13,924,849	$11,149,897	$1,577,425	$1,197,527
		$0	$0	$0
Environmental & Archaeology Studies and Mitigation	$558,234	$522,511	$19,946	$15,777
Land Acquisition and Surveying (256 acres)	$301,850	$298,841	$1,621	$1,387
Interest During Construction (3.5% for 1 years with a 0.5% ROI)	$0	$0	$0	$0
TOTAL COST OF PROJECT	**$252,063,261**	$217,309,657	$20,167,002	$14,586,601
ANNUAL COST				
Debt Service (3.5 percent, 20 years)	$13,424,878	$11,424,017	$1,160,875	$839,986
Reservoir Debt Service (3.5 percent, 40 years)	$1,054,576	$1,054,576	$0	$0
Operation and Maintenance				
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,226,182	$1,101,673	$73,986	$50,523
Intakes and Pump Stations (2.5% of Cost of Facilities)	$1,371,487	$1,028,513	$194,838	$148,135
Dam and Reservoir (1.5% of Cost of Facilities)	$196,183	$196,183	$0	$0
Pumping Energy Costs (294535119 kW-hr @ 0.09 $/kW-hr)	$1,658,330	$1,505,771	$92,015	$60,544
Purchase of Water (acft/yr @ $/acft)	$0	$0	$0	$0
TOTAL ANNUAL COST	**$18,931,635**	$16,310,734	$1,521,714	$1,099,187
Average Annual Project Transport Volume (acft/yr)	**21,920**			
PF=1.5	**$864**			
Annual Cost of Water Transmission in IPL 2 After Debt Service ($ per acft), based on PF=1.5	**$76**			
Annual Cost of Water Transmission in IPL 2 ($ per 1,000 gallons), based on PF=1.5	**$2.65**			
Annual Cost of Water Transmission in IPL 2 After Debt Service ($ per 1,000 gallons), based on PF=1.5	**$0.23**			
Note: One or more cost element has been calculated externally				
Prepared by J. Fritsche, 08/19/2024				

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS # 15 ASR
Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 277.68 for September 2023

Item	*Total Estimated Costs for WMS # 15 ASR*
CAPITAL COST	
Transmission Pipeline (30 in. dia., 5.5 miles)	$10,984,000
Well Fields (Wells, Pumps, and Piping)	$200,000,000
TOTAL COST OF FACILITIES	**$210,984,000**
Engineering:	
- Planning (3%)	$6,330,000
- Design (7%)	$14,769,000
- Construction Engineering (1%)	$2,110,000
Legal Assistance (2%)	$4,220,000
Fiscal Services (2%)	$4,220,000
Pipeline Contingency (15%)	$1,648,000
All Other Facilities Contingency (20%)	$40,000,000
Environmental & Archaeology Studies and Mitigation	$406,000
Land Acquisition and Surveying (57 acres)	$694,000
TOTAL COST OF PROJECT	**$285,381,000**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$12,265,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,110,000
Pumping Energy Costs (5648481 kW-hr @ 0.06 $/kW-hr)	$339,000
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$14,714,000**
Available Project Yield (acft/yr)	11,209
Annual Cost of Water ($ per acft), based on PF=1.1	$1,313
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.1	$218
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.1	$4.03
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.1	$0.67
Note: One or more cost element has been calculated externally	

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS # 16 TRWD Developed Groundwater
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 277.68 for September 2023

Item	*Estimated Costs for WMS # 16 TRWD Developed Groundwater to Richland Chambers*	*Estimated Costs for Intersystem Conveyance*	*Total Estimated Costs for WMS # 16 TRWD Developed Groundwater*
CAPITAL COST			
Terminal Storage	$0	$4,177,000	$4,177,000
Intake Pump Stations	$18,976,000	$10,778,000	$29,754,000
Transmission Pipelines	$11,932,000	$39,608,000	$51,540,000
Transmission Pump Station(s) & Storage Tank(s)	$0	$8,198,000	$8,198,000
Well Fields (Wells, Pumps, and Piping)	$18,590,000	$0	$18,590,000
Integration, Relocations, Backup Generator & Other	$104,000	$549,000	$653,000
TOTAL COST OF FACILITIES	**$49,602,000**	**$63,310,000**	**$112,912,000**
Engineering:			
- Planning (3%)	$1,485,000	$1,899,000	$3,384,000
- Design (7%)	$3,465,000	$4,432,000	$7,897,000
- Construction Engineering (1%)	$495,000	$633,000	$1,128,000
Legal Assistance (2%)	$990,000	$1,266,000	$2,256,000
Fiscal Services (2%)	$990,000	$1,266,000	$2,256,000
Pipeline Contingency (15%)	$1,790,000	$5,941,000	$7,731,000
All Other Facilities Contingency (20%)	$7,513,000	$4,741,000	$12,254,000
Environmental & Archaeology Studies and Mitigation	$822,000	$182,000	$1,004,000
Land Acquisition and Surveying (93 acres)	$743,000	$97,000	$840,000
TOTAL COST OF PROJECT	**$67,895,000**	**$83,767,000**	**$151,662,000**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$3,920,000	$4,476,000	$8,396,000
Reservoir Debt Service (4 percent, 30 years)	$0	$337,000	$337,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$305,000	$402,000	$707,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$474,000	$474,000	$948,000
Dam and Reservoir (1.5% of Cost of Facilities)	$0	$63,000	$63,000
Pumping Energy Costs (1698178 kW-hr @ 0.06 $/kW-hr)	$102,000	$541,000	$643,000
TOTAL ANNUAL COST	**$4,801,000**	**$6,293,000**	**$11,094,000**
Available Project Yield (acft/yr)	7,000	7,000	7,000
Annual Cost of Water ($ per acft), based on PF=1.5	$686	$899	$1,585
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$126	$211	$337
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$2.10	$2.76	$4.86
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$0.39	$0.65	$1.03

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TWRD - WMS 17 - Lake Palestine Groundwater Purchase
Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 278.502 for September 2023

Item	*Estimated Costs for WMS 17 - Lake Palestine Groundwater Purchase to Cedar Creek*	*Estimated Costs for Intersystem Conveyance*	*Total Estiamted Costs for WMS 17 - Lake Palestine Groundwater Purchase*
CAPITAL COST			
Terminal Storage	$0	$8,950,074	$8,950,074
Intake Pump Stations	$14,306,000	$22,191,602	$36,497,602
Transmission Pipelines	$78,999,000	$85,220,706	$164,219,706
Transmission Pump Stations	$0	$17,568,166	$17,568,166
Integration, Relocations, Backup Generator & Other	$0	$1,185,909	$1,185,909
TOTAL COST OF FACILITIES	**$93,305,000**	**$135,116,457**	**$228,421,457**
Engineering:			
- Planning (3%)	$2,799,000	$4,053,500	$6,852,500
- Design (7%)	$6,531,000	$9,458,138	$15,989,138
- Construction Engineering (1%)	$933,000	$1,351,210	$2,284,210
Legal Assistance (2%)	$1,866,000	$2,702,290	$4,568,290
Fiscal Services (2%)	$1,866,000	$2,702,290	$4,568,290
Pipeline Contingency (15%)	$0	$12,783,113	$12,783,113
All Other Facilities Contingency (20%)	$0	$9,979,142	$9,979,142
Environmental & Archaeology Studies and Mitigation	$0	$387,262	$387,262
Land Acquisition and Surveying (0 acres)	$0	$206,913	$206,913
TOTAL COST OF PROJECT	**$107,300,000**	**$178,740,316**	**$286,040,316**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$7,056,000	$9,546,374	$16,602,374
Reservoir Debt Service (4 percent, 30 years)	$0	$721,653	$721,653
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$790,000	$864,066	$1,654,066
Intakes and Pump Stations (2.5% of Cost of Facilities)	$358,000	$993,983	$1,351,983
Dam and Reservoir (1.5% of Cost of Facilities)	$0	$134,249	$134,249
Pumping Energy Costs (0 kW-hr @ 0.06 $/kW-hr)	$0	$1,167,444	$1,167,444
Purchase of Water (15000 acft/yr @ 475 $/acft)	$7,125,000	$0	$7,125,000
TOTAL ANNUAL COST	**$15,329,000**	**$13,427,769**	**$28,756,769**
Available Project Yield (acft/yr)	15,000	15,000	15,000
Annual Cost of Water ($ per acft), based on PF=0	$1,022	$895	$1,917
Annual Cost of Water After Debt Service ($ per acft), based on PF=0	$552	$210.65	$762
Annual Cost of Water ($ per 1,000 gallons), based on PF=0	$3.14	$2.75	$5.88
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=0	$1.69	$0.65	$2.34

Note: One or more cost element has been calculated externally

KW *7/16/2024*

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS # 19 Anderson County Groundwater
Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 277.68 for September 2023

Item	***Estimated Costs for WMS # 19 Anderson County Groundwater to Cedar Creek***	***Estimated Costs for Intersystem Conveyance***	***Total Estimated Costs for WMS # 19 Anderson County Groundwater***
CAPITAL COST			
Terminal Storage	$0	$25,060,000	$25,060,000
Intake Pump Stations	$68,251,000	$62,157,000	$130,408,000
Transmission Pipelines	$338,199,000	$238,637,000	$576,836,000
Transmission Pump Station(s) & Storage Tank(s)	$66,097,000	$49,191,000	$115,288,000
Well Fields (Wells, Pumps, and Piping)	$140,620,000	$0	$140,620,000
Integration, Relocations, Backup Generator & Other	$1,093,000	$3,321,000	$4,414,000
TOTAL COST OF FACILITIES	**$614,260,000**	**$378,366,000**	**$992,626,000**
Engineering:			
- Planning (3%)	$18,395,000	$11,351,000	$29,746,000
- Design (7%)	$42,922,000	$26,486,000	$69,408,000
- Construction Engineering (1%)	$6,132,000	$3,784,000	$9,916,000
Legal Assistance (2%)	$12,263,000	$7,567,000	$19,830,000
Fiscal Services (2%)	$12,263,000	$7,567,000	$19,830,000
Pipeline Contingency (15%)	$50,730,000	$35,796,000	$86,526,000
All Other Facilities Contingency (20%)	$54,994,000	$27,946,000	$82,940,000
Environmental & Archaeology Studies and Mitigation	$6,051,000	$1,084,000	$7,135,000
Land Acquisition and Surveying (823 acres)	$5,429,000	$579,000	$6,008,000
TOTAL COST OF PROJECT	**$823,439,000**	**$500,526,000**	**$1,323,965,000**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$47,556,000	$26,733,000	$74,289,000
Reservoir Debt Service (4 percent, 30 years)	$0	$2,021,000	$2,021,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$4,841,000	$2,420,000	$7,261,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$3,227,000	$2,784,000	$6,011,000
Dam and Reservoir (1.5% of Cost of Facilities)	$0	$376,000	$376,000
Water Treatment Plant	$0	$0	$0
Advanced Water Treatment Facility	$0	$0	$0
Pumping Energy Costs (51965633 kW-hr @ 0.06 $/kW-hr)	$3,118,000	$3,269,000	$6,387,000
Purchase of Water (42000 acft/yr @ 65.1702 $/acft)	$2,737,000	$0	$2,737,000
TOTAL ANNUAL COST	**$61,479,000**	**$37,603,000**	**$99,082,000**
Available Project Yield (acft/yr)	42,000	42,000	42,000
Annual Cost of Water ($ per acft), based on PF=1.5	$1,464	$895	$2,359
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$332	$211	$542
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$4.49	$2.75	$7.24
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$1.02	$0.65	$1.66

Cost Estimate Summary Water Supply Project Option September 2023 Prices TWRD - WMS 14 - Lake Palestine Purchase			
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023			
Item	***Estimated Costs for WMS 14 - Lake Palestine Purchase to Cedar Creek***	***Estimated Costs for Intersystem Conveyance***	***Total Estimated Costs for WMS 14 - Lake Palestine Purchase***
CAPITAL COST			
Terminal Storage	$0	$17,900,148	$17,900,148
Intake Pump Stations	$28,615,000	$44,383,204	$72,998,204
Transmission Pipelines	$158,009,000	$170,441,411	$328,450,411
Transmission Pump Station(s)	$0	$35,136,333	$35,136,333
Integration, Relocations, Backup Generator & Other	$0	$2,371,818	$2,371,818
TOTAL COST OF FACILITIES	**$186,624,000**	**$270,232,914**	**$456,856,914**
Engineering:			
- Planning (3%)	$5,599,000	$8,107,001	$13,706,001
- Design (7%)	$13,064,000	$18,916,276	$31,980,276
- Construction Engineering (1%)	$1,866,000	$2,702,421	$4,568,421
Legal Assistance (2%)	$3,732,000	$5,404,580	$9,136,580
Fiscal Services (2%)	$3,732,000	$5,404,580	$9,136,580
Pipeline Contingency (15%)	$0	$25,566,226	$25,566,226
All Other Facilities Contingency (20%)	$0	$19,958,284	$19,958,284
Environmental & Archaeology Studies and Mitigation	$0	$774,524	$774,524
Land Acquisition and Surveying (0 acres)	$0	$413,827	$413,827
TOTAL COST OF PROJECT	**$214,617,000**	**$357,480,633**	**$572,097,633**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$14,113,000	$19,092,748	$33,205,748
Reservoir Debt Service (4 percent, 30 years)	$0	$1,443,307	$1,443,307
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$1,580,000	$1,728,132	$3,308,132
Intakes and Pump Stations (2.5% of Cost of Facilities)	$715,000	$1,987,967	$2,702,967
Dam and Reservoir (1.5% of Cost of Facilities)	$0	$268,498	$268,498
Pumping Energy Costs (0 kW-hr @ 0.06 $/kW-hr)	$0	$2,334,887	$2,334,887
Purchase of Water (30000 acft/yr @ 65.1702 $/acft)	$1,955,000	$0	$1,955,000
TOTAL ANNUAL COST	**$18,363,000**	**$26,855,539**	**$45,218,539**
Available Project Yield (acft/yr)	30,000	30,000	30,000
Annual Cost of Water ($ per acft), based on PF=0	$612	$895	$1,507
Annual Cost of Water After Debt Service ($ per acft), based on PF=0	$142	$211	$352
Annual Cost of Water ($ per 1,000 gallons), based on PF=0	$1.88	$2.75	$4.62
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=0	$0.43	$0.65	$1.08
Note: One or more cost element has been calculated externally			
KW / Updated Purchase Cost of Water JF			*11/15/2024*

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS 10 - Toledo Bend 1
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023

Item	Estimated Costs for WMS 10 - Toledo Bend 1 to Cedar Creek	Estimated Costs for Intersystem Conveyance (Phase 1 and 2)	Total Estimated Costs for WMS 10 - Toledo Bend 1
CAPITAL COST			
Terminal Storage	$203,485,500	$143,201,000	$346,686,500
Intake Pump Stations	$247,756,500	$355,182,000	$602,938,500
Transmission Pipeline (108-120 in. dia., 347.5 miles)	$2,555,635,000	$1,363,640,000	$3,919,275,000
Transmission Pump Stations	$329,935,000	$281,091,000	$611,026,000
Integration, Relocations, Backup Generator & Other	$16,218,000	$18,976,000	$35,194,000
TOTAL COST OF FACILITIES	**$3,353,030,000**	**$2,162,090,000**	**$5,515,120,000**
Engineering:			
- Planning (3%)	$100,591,000	$64,863,000	$165,454,000
- Design (7%)	$234,712,000	$151,346,000	$386,058,000
- Construction Engineering (1%)	$33,530,500	$21,622,000	$55,152,500
Legal Assistance (2%)	$67,060,500	$43,241,000	$110,301,500
Fiscal Services (2%)	$67,060,500	$43,241,000	$110,301,500
Pipeline Contingency (15%)	$383,345,000	$204,546,000	$587,891,000
All Other Facilities Contingency (20%)	$159,479,000	$159,690,000	$319,169,000
Environmental & Archaeology Studies and Mitigation	$5,250,500	$6,196,000	$11,446,500
Land Acquisition and Surveying (5224 acres)	$14,381,500	$3,311,000	$17,692,500
TOTAL COST OF PROJECT	**$4,418,440,500**	**$2,860,146,000**	**$7,278,586,500**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$238,693,500	$152,759,000	$391,452,500
Reservoir Debt Service (4 percent, 30 years)	$15,887,500	$11,546,000	$27,433,500
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$25,718,500	$13,826,000	$39,544,500
Intakes and Pump Stations (2.5% of Cost of Facilities)	$14,442,500	$15,907,000	$30,349,500
Dam and Reservoir (1.5% of Cost of Facilities)	$3,052,500	$2,148,000	$5,200,500
Pumping Energy Costs (532148807 kW-hr @ 0.06 $/kW-hr)	$15,964,500	$18,680,000	$34,644,500
Purchase of Water (240000 acft/yr @ 65.1702 $/acft)	$15,641,000	$0	$15,641,000
TOTAL ANNUAL COST	**$329,400,000**	**$214,866,000**	**$544,266,000**
Available Project Yield (acft/yr)	240,000	240,000	240,000
Annual Cost of Water ($ per acft), based on PF=1.5	$1,373	$895	$2,268
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$312	$211	$522
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$4.21	$2.75	$6.96
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$0.96	$0.65	$1.60

Note: One or more cost element has been calculated externally

KW / Cost of Purchased Water Updated 11/15/2024 by JF *7/9/2024*

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
WMS # 25 Wright Patman
Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 278.502 for September 2023

Item	*Total Estimated Costs for WMS # 25 Wright Patman*
CAPITAL COST	
Dam and Reservoir (Conservation Pool acft, acres)	$100,695,518
Terminal Storage (Conservation Pool acft, 59.4 acres)	$14,050,771
Intake Pump Stations (265 MGD)	$73,555,385
Transmission Pipeline (72-102 in. dia., 240.1 miles)	$1,187,956,207
Transmission Pump Station(s) & Storage Tank(s)	$252,047,569
Integration, Relocations, Backup Generator, EM Reversal & Other	$146,512,889
TOTAL COST OF FACILITIES	**$1,774,818,339**
Engineering:	
- Planning (3%)	$53,244,550
- Design (7%)	$124,237,284
- Construction Engineering (1%)	$17,748,183
Legal Assistance (2%)	$35,496,367
Fiscal Services (2%)	$35,496,367
Pipeline Contingency (15%)	$178,193,431
All Other Facilities Contingency (20%)	$117,372,427
Environmental & Archaeology Studies and Mitigation	$116,463,160
Land Acquisition and Surveying (1612 acres)	$8,723,621
TOTAL COST OF PROJECT	**$2,461,793,729**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$118,379,713
Reservoir Debt Service (4 percent, 30 years)	$15,513,207
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$13,344,691
Intakes and Pump Stations (2.5% of Cost of Facilities)	$8,140,074
Dam and Reservoir (1.5% of Cost of Facilities)	$1,721,194
Pumping Energy Costs (555097833 kW-hr @ 0.06 $/kW-hr)	$16,815,623
TOTAL ANNUAL COST	**$173,914,503**
Available Project Yield (acft/yr)	65,067
Annual Cost of Water ($ per acft), based on PF=1.46925	$2,673
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.46925	$615
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.46925	$8.20
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.46925	$1.89

Note: One or more cost element has been calculated externally

Spencer Schnier *1/0/1900*

WMS_24 Cost Estimate Summary Marvin Nichols Reservoir - High Yield Scenario Conceptual Cost Assumptions TRWD, DWU, NTMWD, UTRWD, Irving, & Local Users - High Yield Marvin Nichols (328) Cost based on September 2023 dollars	
Item	**TRWD Share**
Project Cost	
Dam and Reservoir	$203,346,864
Land Acquisition and Surveying	$142,938,698
Conflicts	$66,714,858
Environmental & Archaeology Studies and Mitigation	$425,328,834
Permitting	$24,150,000
Transmission System	
Pipeline Segment 1: MN Intake LPS to Lake Chapman Split/BPS#1	$329,265,464
MNR Intake LPS	$134,163,379
Pipeline Segment 2: BPS #1/Lake Chapman Split to Leonard TSR Split	$238,332,187
BPS #1/Lake Chapman Split and Storage Reservoir	$112,961,647
Pipeline Segment 3: Leonard TSR Split to BPS #2	$79,846,643
Pipeline Segment 4: BPS #2 to Lake Ralph Hall TSR Split	$310,062,332
BPS #2 and Storage Reservoir	$106,725,111
Pipeline Segment 5: Lake Ralph Hall TSR Split to Trinity River/Ray Roberts Split	$30,815,110
Pipeline Segment 6: Trinity River/Ray Roberts Split to BPS #3	$107,121,000
BPS #3 and Storage Reservoir	$168,956,000
Pipeline Segment 7: BPS #3 to Lake Bridgeport	$444,370,000
Discharge Structure 5: Lake Bridgeport	$1,977,000
EM Reversal	$135,390,000
Total Cost of Project	**$3,062,465,000**
Interest During Construction (0%)[a]	$0
Reservoir Interest During Construction (3% for 4 years with a 1.5% ROI)[a]	$0
Total Cost of Project with Interest During Construction	**$3,062,465,000**
Annual Cost	
Debt Service (4%, 30 years)	$119,396,000
Reservoir Debt Service (4%, 30 years)	$49,877,000
Operation and Maintenance	
Pipelines (1% of Facilities + 20%) and Pump Stations (2.5% of Facilities + 20%)[a]	$25,419,000
Dam and Reservoir (1.5% of Facilities + 20%)	$2,524,158
Pumping Energy Costs (0.06 $/kW-hr)	$14,645,000
Total Annual Cost	**$211,861,000**
Available Project Yield (acft/yr)	110,237
Annual Cost until Amortized ($ per acft)	$1,922
Annual Cost until Amortized ($ per 1,000 gallons)	$5.90
Annual Cost After Amortization ($ per acft)	$386
Annual Cost After Amortization ($ per 1,000 gallons)	$1.19

[a]Assumes 0% interest during construction consistent with assumption in TRWD costing tool
Updated Pumping Energy Costs from 0.10 $/kW-hr to 0.06$/kW-hr.
Updated "Debt Service" and "Reservoir Debt Service" to 4 percent and 30 years.

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
WMS # 9 Marvin Nichols and WP

Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 278.502 for September 2023

Item	***Estimated Costs for WMS # 9 Marvin Nichols and WP to - Lake Bridgeport***
CAPITAL COST	
Dam and Reservoir (Conservation Pool acft, acres)	$394,907,240
Terminal Storage (Conservation Pool acft, acres)	$25,201,476
Intake Pump Stations (156.9 MGD)	$58,835,761
Transmission Pipeline (84-144 in. dia., 240.1 miles)	$2,180,944,871
Transmission Pump Station(s) & Storage Tank(s)	$346,785,238
Integration, Relocations, Backup Generator, EM Reversal, & Other	$150,721,737
TOTAL COST OF FACILITIES	$3,157,396,322
Engineering:	
- Planning (3%)	$90,660,190
- Design (7%)	$211,540,443
- Construction Engineering (1%)	$30,220,063
Legal Assistance (2%)	$60,440,126
Fiscal Services (2%)	$60,440,126
Pipeline Contingency (15%)	$327,141,731
All Other Facilities Contingency (20%)	$168,212,290
Environmental & Archaeology Studies and Mitigation	$541,793,016
Land Acquisition and Surveying (2230 acres)	$154,933,585
TOTAL COST OF PROJECT	**$4,802,777,893**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$196,805,237
Reservoir Debt Service (4 percent, 30 years)	$72,223,632
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$21,962,766
Intakes and Pump Stations (2.5% of Cost of Facilities)	$10,140,525
Dam and Reservoir (1.5% of Cost of Facilities)	$6,301,631
Pumping Energy Costs (765155229 kW-hr @ 0.06 $/kW-hr)	$22,004,139
Purchase of Water (acft/yr @ $/acft)	$0
TOTAL ANNUAL COST	**$329,437,929**
Available Project Yield (acft/yr)	141,800
Annual Cost of Water ($ per acft), based on PF=1.46925	$2,323
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.46925	$426
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.46925	$7.13
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.46925	$1.31

Note: One or more cost element has been calculated externally

TOTALS ARE FOR TRWD COSTS ONLY

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS 08 - Lake Ringgold

Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 278.502 for September 2023

Item	***for WMS 08 - Lake Ringgold***
Dam and Reservoir (Conservation Pool acft, 17280 acres)	$87,807,000
Terminal Storage (Conservation Pool 153 acft, 12 acres)	$7,892,000
Intake Pump Stations (37.5 MGD)	$96,415,000
Transmission Pipeline (48 in. dia., 50.1 miles)	$289,069,000
Transmission Pump Station	$29,290,000
Integration, Relocations, Backup Generator, Other, EM Reversal	$145,987,000
TOTAL COST OF FACILITIES	**$656,460,000**
- Planning (3%)	$19,694,000
- Design (7%)	$45,952,000
- Construction Engineering (1%)	$6,565,000
Legal Assistance (2%)	$13,129,000
Fiscal Services (2%)	$13,129,000
Pipeline Contingency (15%)	$43,360,000
All Other Facilities Contingency (20%)	$73,478,000
Environmental & Archaeology Studies and Mitigation	$105,302,000
Land Acquisition and Surveying (17854 acres)	$60,696,000
TOTAL COST OF PROJECT	**$1,037,765,000**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$43,203,000
Reservoir Debt Service (4 percent, 30 years)	$16,750,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$4,351,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$3,143,000
Dam and Reservoir (1.5% of Cost of Facilities)	$1,435,000
Pumping Energy Costs (17158040 kW-hr @ 0.06 $/kW-hr)	$1,029,000
Purchase of Water (acft/yr @ 1456.55397 $/acft)	$0
TOTAL ANNUAL COST	**$69,911,000**
Available Project Yield (acft/yr)	28,000
Annual Cost of Water ($ per acft), based on PF=1.5	$2,497
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$356
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$7.66
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$1.09

Note: One or more cost element has been calculated externally

Aven Ault Update: J Fritsche *8/1/2024 Update: 4/8/2025*

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS 07 - Tehuacana
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023

Item	Estimated Costs for WMS 07 - Tehuacana to Richland Chambers	Estimated Costs for Intersystem Conveyance	Total Estimated Costs for WMS 07 - Tehuacana
CAPITAL COST			
Dam and Reservoir (Conservation Pool 337947 acft, 14938 acres)	$275,471,000	$0	$275,471,000
Terminal Storage	$0	$16,417,000	$16,417,000
Intake Pump Stations	$23,643,000	$42,350,000	$65,993,000
Transmission Pipeline	$0	$155,669,000	$155,669,000
Transmission Pump Station(s) & Storage Tank(s)	$0	$32,225,000	$32,225,000
Integration, Relocations, Backup Generator & Other	$72,478,000	$2,158,000	$74,636,000
TOTAL COST OF FACILITIES	**$371,592,000**	**$248,819,000**	**$620,411,000**
Engineering:			
- Planning (3%)	$11,148,000	$7,465,000	$18,613,000
- Design (7%)	$26,011,000	$17,417,000	$43,428,000
- Construction Engineering (1%)	$3,716,000	$2,488,000	$6,204,000
Legal Assistance (2%)	$7,432,000	$4,976,000	$12,408,000
Fiscal Services (2%)	$7,432,000	$4,976,000	$12,408,000
Pipeline Contingency (15%)	$0	$23,350,000	$23,350,000
All Other Facilities Contingency (20%)	$74,318,000	$18,630,000	$92,948,000
Environmental & Archaeology Studies and Mitigation	$171,837,000	$717,000	$172,554,000
Land Acquisition and Surveying (14943 acres)	$172,737,000	$380,000	$173,117,000
TOTAL COST OF PROJECT	**$846,223,000**	**$329,220,000**	**$1,175,441,000**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$7,509,000	$17,590,000	$25,099,000
Reservoir Debt Service (4 percent, 30 years)	$41,429,000	$1,324,000	$42,753,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$725,000	$1,578,000	$2,303,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$591,000	$1,864,000	$2,455,000
Dam and Reservoir (1.5% of Cost of Facilities)	$4,132,000	$246,000	$4,378,000
Pumping Energy Costs (0 kW-hr @ 0.06 $/kW-hr)	$0	$2,124,000	$2,124,000
TOTAL ANNUAL COST	**$54,386,000**	**$24,727,000**	**$79,112,000**
Available Project Yield (acft/yr)	27,514	$27,514	27,514
Annual Cost of Water ($ per acft), based on PF=0	$1,977	$899	$2,875
Annual Cost of Water After Debt Service ($ per acft), based on PF=0	$198	$211	$409
Annual Cost of Water ($ per 1,000 gallons), based on PF=0	$6.07	$2.76	$8.82
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=0	$0.61	$0.65	$1.26

Note: One or more cost element has been calculated externally

KW / Land Costs Update by JF *11/1/2024*

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS 12 Mainstem Trinity OCR
Cost based on ENR CCI 13485.67 for September 2023 and
a PPI of 277.68 for September 2023

Item	*Estimated Costs for WMS 12 Mainstem Trinity OCR to JB4*	*Estimated Costs for Intersystem Conveyance*	*Total Estimated Costs for WMS 12 Mainstem Trinity OCR*
CAPITAL COST			
Dam and Reservoir (Conservation Pool 300000 acft, 4337 acres)	$141,064,000	$0	$141,064,000
Terminal Storage (Conservation Pool acft, acres)	$0	$21,567,000	$21,567,000
Intake Pump Stations (76.5 MGD)	$116,431,000	$42,861,000	$159,292,000
Transmission Pipeline (66 in. dia., 11.7 miles)	$202,596,000	$104,521,000	$307,117,000
Integration, Relocations, Backup Generator & Other	$4,669,000	$1,996,000	$6,665,000
TOTAL COST OF FACILITIES	**$464,760,000**	**$170,945,000**	**$635,705,000**
Engineering:			
- Planning (3%)	$13,925,000	$5,128,000	$19,053,000
- Design (7%)	$32,491,000	$11,966,000	$44,457,000
- Construction Engineering (1%)	$4,642,000	$1,709,000	$6,351,000
Legal Assistance (2%)	$9,283,000	$3,419,000	$12,702,000
Fiscal Services (2%)	$9,283,000	$3,419,000	$12,702,000
Pipeline Contingency (15%)	$30,389,000	$15,678,000	$46,067,000
All Other Facilities Contingency (20%)	$52,313,000	$13,285,000	$65,598,000
Environmental & Archaeology Studies and Mitigation	$11,480,000	$563,000	$12,043,000
Land Acquisition and Surveying (4471 acres)	$12,497,000	$365,000	$12,862,000
TOTAL COST OF PROJECT	**$641,063,000**	**$226,477,000**	**$867,540,000**
ANNUAL COST			
Debt Service (4 percent, 30 years)	$24,691,000	$11,257,000	$35,948,000
Reservoir Debt Service (4 percent, 30 years)	$12,347,000	$1,724,000	$14,071,000
Operation and Maintenance			
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$2,067,000	$1,065,000	$3,132,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$2,911,000	$1,072,000	$3,983,000
Dam and Reservoir (1.5% of Cost of Facilities)	$2,116,000	$323,000	$2,439,000
Pumping Energy Costs (9883646 kW-hr @ 0.06 $/kW-hr)	$6,785,000	$1,965,000	$8,750,000
Purchase of Water (57168.5 acft/yr @ 65.1702 $/acft)	$3,726,000	$0	$3,726,000
TOTAL ANNUAL COST	**$54,643,000**	**$17,406,000**	**$72,049,000**
Available Project Yield (acft/yr)	57,169	57,169	57,169
Annual Cost of Water ($ per acft), based on PF=1.5	$956	$304	$1,260
Annual Cost of Water After Debt Service ($ per acft), based on P	$308	$77	$385
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$2.93	$0.93	$3.87
Annual Cost of Water After Debt Service ($ per 1,000 gallons), b	$0.94	$0.24	$1.18
Note: One or more cost element has been calculated externally			

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS 20 - Arkansas Water
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023

Item	*Total Estimated Costs for WMS 20 - Arkansas Water*
CAPITAL COST	
Dam and Reservoir (Conservation Pool acft, acres)	$0
Off-Channel Storage/Ring Dike (Conservation Pool 25000 acft, 250 acres)	$38,661,000
Terminal Storage (Conservation Pool acft, acres)	$0
Intake Pump Stations (174.1 MGD)	$376,072,000
Transmission Pipeline (108 in. dia., 497 miles)	$6,815,311,000
Transmission Pump Station(s) & Storage Tank(s)	$421,128,000
Integration, Relocations, Backup Generator, EM Reversal & Other	$155,515,000
TOTAL COST OF FACILITIES	**$7,806,687,000**
Engineering:	
- Planning (3%)	$234,201,000
- Design (7%)	$546,468,000
- Construction Engineering (1%)	$78,067,000
Legal Assistance (2%)	$156,134,000
Fiscal Services (2%)	$156,134,000
Pipeline Contingency (15%)	$1,022,297,000
All Other Facilities Contingency (20%)	$198,275,000
Environmental & Archaeology Studies and Mitigation	$15,586,000
Land Acquisition and Surveying (3018 acres)	$25,992,000
TOTAL COST OF PROJECT	**$10,239,841,000**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$587,910,000
Reservoir Debt Service (4 percent, 30 years)	$3,097,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$69,708,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$19,930,000
Dam and Reservoir (1.5% of Cost of Facilities)	$580,000
Pumping Energy Costs (330167456 kW-hr @ 0.06 $/kW-hr)	$19,810,000
Purchase of Water (260000 acft/yr @ 65.1702 $/acft)	$16,944,000
TOTAL ANNUAL COST	**$717,979,000**
Available Project Yield (acft/yr)	260,000
Annual Cost of Water ($ per acft), based on PF=1.5	$2,761
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$488
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$8.47
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$1.50
Note: One or more cost element has been calculated externally	

Becky Gates Update: Becky Gates 5/2024 Update: 11/07/2024

Water Supply Project Option TRWD Parallel IPL	
Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023	
Item	Estimated Costs for Facilities
CAPITAL COST	
Cedar Creek(CC) to Joint Booster Pump Station 2 (JB2)	
Intake Pump Station at CC (274.3 MGD)	$158,642,000
Transmission Pipeline (108 in. dia., 12.5 miles)	$148,717,000
Integration, Relocations, Backup Generator & Other	$1,902,000
Richland Chambers (RC) to Joint Booster Pump Station 2 (JB2)	
Intake Pump Station at RC (274.3 MGD)	$170,899,000
Transmission Pipeline (96 in. dia., 14 miles)	$143,887,000
Integration, Relocations, Backup Generator & Other	$1,774,000
Joint Booster Pump Station 2 (JB2) to Benbrook (BB)	
Pump Station (JB2) (350.2 MGD)	$184,576,000
Pump Station (JB3) (350.2 MGD)	$165,329,000
Pump Station (JB4) (350.2 MGD)	$141,020,000
Transmission Pipeline (108 in. dia., 89.8 miles)	$1,296,323,000
Balancing Reservoir Storage (KBR 475 MG, MBR 450 MG)	$156,069,000
Integration, Relocations, Backup Generator & Other	$18,253,000
TOTAL COST OF FACILITIES	**$2,587,391,000**
Engineering:	
- Planning (3%)	$77,622,000
- Design (7%)	$181,117,000
- Construction Engineering (1%)	$25,875,000
Legal Assistance (2%)	$51,747,000
Fiscal Services (2%)	$51,747,000
Pipeline Contingency (15%)	$238,339,000
All Other Facilities Contingency (20%)	$199,693,000
Environmental & Archaeology Studies and Mitigation	$7,096,000
Land Acquisition and Surveying (310 acres)	$3,639,000
TOTAL COST OF PROJECT	**$3,424,266,000**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$196,758,000
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$16,109,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$20,511,000
Dam and Reservoir (1.5% of Cost of Facilities)	$2,341,000
Pumping Energy Costs (366141935 kW-hr @ 0.06 $/kW-hr)	$21,587,000
TOTAL ANNUAL COST	**$257,306,000**
Average Annual Project Transport Volume (acft/yr)	261,566
Annual Cost of Water Transmission in IPL 2 ($ per acft), based on PF=1.5	$984
Annual Cost of Water Transmission in IPL 2 After Debt Service ($ per acft), based on PF=1.5	$231
Annual Cost of Water Transmission in IPL 2 ($ per 1,000 gallons), based on PF=1.5	$3.02
Annual Cost of Water Transmission in IPL 2 After Debt Service ($ per 1,000 gallons), based on PF=1.5	$0.71
Note: One or more cost element has been calculated externally	
Lissa Gregg	*7/24/2024*

Cost Estimate Summary
Water Supply Project Option
September 2023 Prices
TRWD - WMS # 22 Parallel Benbrook to Eagle Mountain Connection

Cost based on ENR CCI 13485.67 for September 2023 and a PPI of 278.502 for September 2023

Item	Estimated Costs for WMS # 22 Parallel Benbrook to Eagle Mountain Connection
CAPITAL COST	
New BB2 Pump Station (350.2 MGD)	$173,264,000
Transmission Pipeline (96 in. dia., 21.9 miles)	$309,415,000
Integration, Relocations, Backup Generator & Other	$6,091,000
TOTAL COST OF FACILITIES	**$488,770,000**
Engineering:	
- Planning (3%)	$14,663,000
- Design (7%)	$34,214,000
- Construction Engineering (1%)	$4,888,000
Legal Assistance (2%)	$9,775,000
Fiscal Services (2%)	$9,775,000
Pipeline Contingency (15%)	$46,412,000
All Other Facilities Contingency (20%)	$35,871,000
Environmental & Archaeology Studies and Mitigation	$725,000
Land Acquisition and Surveying (5 acres)	$75,000
TOTAL COST OF PROJECT	**$645,168,000**
ANNUAL COST	
Debt Service (4 percent, 30 years)	$36,958,000
Reservoir Debt Service (4 percent, 30 years)	$0
Operation and Maintenance	
Pipeline, Wells, and Storage Tanks (1% of Cost of Facilities)	$3,155,000
Intakes and Pump Stations (2.5% of Cost of Facilities)	$4,332,000
Pumping Energy Costs (99925611 kW-hr @ 0.06 $/kW-hr)	$5,996,000
TOTAL ANNUAL COST	**$50,441,000**
Average Annual Project Transport Volume (acft/yr)	261,566
Annual Cost of Water ($ per acft), based on PF=1.5	$193
Annual Cost of Water After Debt Service ($ per acft), based on PF=1.5	$52
Annual Cost of Water ($ per 1,000 gallons), based on PF=1.5	$0.59
Annual Cost of Water After Debt Service ($ per 1,000 gallons), based on PF=1.5	$0.16

Lissa Gregg *7/26/2024*