TEXAS WATER DEVELOPMENT BOARD

P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

AGENDA ITEM MEMO

BOARD MEETING DATE: January 16, 2025

TO: Board Members

THROUGH: Bryan McMath, Executive Administrator
Ashley Harden, General Counsel
John Dupnik, P.G., Deputy Executive Administrator, Water Science & Conservation
Matt Nelson, Deputy Executive Administrator, Office of Planning

FROM: Sarah Lee, Manager, Regional Water Planning
Elizabeth McCoy, P.G., Senior Planner, Regional Water Planning

SUBJECT: Groundwater availabilities for the 2026 Region D Regional Water Plan

ACTION REQUESTED

Consider approving the groundwater availabilities requested by the Region D regional water planning group for regional water planning purposes in accordance with Texas Water Code (TWC) § 16.053(e)(2-a) and 31 Texas Administrative Code (TAC) § 357.32(d)(2).

BACKGROUND

Modeled available groundwater (MAG) is the amount of water that the Texas Water Development Board (TWDB) Executive Administrator determines may be produced on an average annual basis to achieve desired future conditions (DFC), which are established by groundwater conservation districts (GCD) within groundwater management areas (GMA) during the joint planning process.

TWC § 16.053(e)(2-a) requires regional water plans to be consistent with DFCs and authorizes a planning group with no GCDs within its planning area to determine its supply of groundwater for regional water planning purposes. Region D is the only planning group with no GCDs within its planning area.

The TWDB Board is required to review and consider approving the groundwater availability requested by Region D that exceeds the MAG. The availability must be determined to be physically compatible with the DFCs for the relevant aquifers in GCDs within co-located GMAs to ensure that the regional water plan is consistent with the DFCs developed during the joint planning process.

On September 18, 2024, the Region D planning group authorized its consultant, Carollo Engineers, to submit the methodology to be used to determine groundwater availability volumes in areas within Region D where existing water supply volumes or water management strategy supply volumes may exceed the MAG. On October 18, 2024, Region D submitted a request for the TWDB to consider allowing the use of specific availability volumes, which are greater than the MAG for 20 aquifer, county, basin splits. TWDB Groundwater Availability Modeling staff reviewed the Region D estimated availability volumes and determined that they are physically compatible with the DFCs for relevant aquifers in the GCDs in the co-located GMAs.

Table 1 lists the revised availability volumes for each aquifer, county, and river basin recommended for approval.

Table 1 Recommended groundwater availability values that exceed the MAG and are physically compatible with DFCs in Region D (acre-feet per year)

Source aquifer	Source county	Source basin	Revised groundwater source availability values					
			2030	2040	2050	2060	2070	2080
Carrizo-	Cass	Sulphur	2,190	2,190	2,190	2,190	2,190	2,190
Carrizo-	Franklin	Sulphur	2,594	2,594	2,594	2,594	2,594	2,594
Carrizo-	Gregg	Sabine	8,841	8,841	8,841	8,841	8,841	8,841
Carrizo-	Hopkins	Sabine	4,677	4,677	4,677	4,677	4,677	4,677
Carrizo-	Hopkins	Sulphur	3,125	3,125	3,125	3,125	3,125	3,125
Carrizo-	Morris	Sulphur	769	769	769	769	769	769
Carrizo-	Smith	Sabine	11,743	11,743	11,743	11,743	11,743	11,743
Carrizo-	Titus	Cypress	7,330	7,330	7,330	7,330	7,330	7,330
Carrizo-	Upshur	Cypress	6,918	6,918	6,918	6,918	6,918	6,918
Carrizo-	Upshur	Sabine	1,948	1,948	1,948	1,948	1,948	1,948
Carrizo-	Van Zandt	Neches	4,136	4,136	4,136	4,136	4,136	4,136
Carrizo-	Van Zandt	Sabine	5,033	5,033	5,033	5,033	5,033	5,033
Carrizo-	Van Zandt	Trinity	1,651	1,651	1,651	1,651	1,651	1,651
Carrizo-	Wood	Sabine	18,206	18,206	18,206	18,206	18,206	18,206
Queen City	Camp	Cypress	1,810	1,810	1,810	1,810	1,810	1,810
Queen City	Cass	Sulphur	758	758	758	758	758	758
Queen City	Morris	Cypress	3,308	3,308	3,308	3,308	3,308	3,308
Trinity	Hunt	Sabine	213	213	213	213	213	213
Trinity	Red River	Sulphur	233	234	233	234	233	233
Woodbine	Lamar	Red	22	22	22	22	22	22

RECOMMENDATION

The Executive Administrator recommends approval of this item because it meets the intent of the law and the recommended groundwater availability volumes are physically compatible with the DFCs for relevant aquifers.

Attachment:

TWDB technical review of revised groundwater availability in Region D (includes the Region D submittal as Attachment)

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TO: Elizabeth McCoy, Project Manager, Region D Regional Water Planning Area

THROUGH: John T. Dupnik, P.G., Deputy Executive Administrator for Water Science and Conservation JTD
Natalie Ballew, P.G., Director, Groundwater
Daryn Hardwick, Ph.D., Manager, Groundwater Modeling DH

FROM: Shirley Wade, Ph.D., P.G., Groundwater Modeling SW

DATE: November 12, 2024

SUBJECT: Technical Review of Revised Groundwater Availability in Region D

SUMMARY

TWDB Groundwater Modeling staff reviewed a request for revisions to groundwater availability in Region D for regional water planning purposes and recommend approval of the request.

BACKGROUND

Texas Water Code § 16.053(e)(2-a) authorizes a regional water planning group with no groundwater conservation districts in its regional water planning area to estimate groundwater availability for planning purposes. Currently, North East Texas Regional Water Planning Group (Region D) is the only regional water planning group with no groundwater conservation districts in its planning area. The Texas Water Development Board (TWDB) is required to review and approve groundwater availability requests if the availability is physically compatible with the desired future conditions adopted for the relevant aquifers in groundwater conservation districts within co-located groundwater management areas. The TWDB uses groundwater availability models to determine physical compatibility.

Region D consultants submitted a technical memorandum on October 16, 2024 requesting revised groundwater availability values for the Carrizo-Wilcox, Queen City, Nacatoch, Trinity, and Woodbine aquifers (Tables 1, 2, and 3).

TECHNICAL REVIEW RESULTS

Groundwater modeling analyses conducted to support 2021 joint groundwater planning for Groundwater Management Area 11 identified areas where the groundwater availability model for the northern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers could not sustain pumping equal to Region D groundwater availability (Hutchison, 2020). The modeling code dynamically reduces pumping to maintain saturated thickness in several aquifer-county-basin splits in Region D. Because of these model limitations, we cannot confirm compatibility with desired future conditions using the groundwater availability model. TWDB Groundwater Modeling and Regional Water Planning staff met with Region D consultants in April 2024 and agreed that an alternate analysis could be used to evaluate the groundwater availability for those areas.

Region D consultants (Donnelly and others, 2024) determined that the modeled available groundwater volumes from the groundwater availability model were less than current or historic pumping volumes in many Region D aquifer-county-basin splits (Donnelly and others, 2024). Nineteen aquifer-county-basin splits were identified where the 2026 regional water planning groundwater availability (2021 Groundwater Management Area 11 modeled available groundwater) is less than the 2026 assigned supplies plus the 2022 recommended water management strategies. These 19 aquifer-county-basin splits were evaluated to determine a reasonable estimate of groundwater availability by comparing assigned supplies to historic groundwater pumping.

To identify where the aquifer could support increased availability, Region D consultants tabulated assigned supply and historic pumping for each water user group within the aquifer-county-basin splits and compared the maximum historic pumping that occurred in a single year to the assigned supply. Increased availability is the difference between the maximum historic pumping and the assigned supply. The proposed groundwater availability revisions (Table 1) are equal to the 2021 modeled available groundwater plus the increased availability.

The Nacatoch Aquifer was declared non-relevant for joint planning in groundwater management areas 8 and 11 and has no desired future conditions. Therefore, Groundwater Modeling staff did not review the proposed groundwater availability in the Nacatoch Aquifer for compatibility with desired future conditions (Table 2).

In 2019, Groundwater Modeling staff performed a modeling analysis as part of a technical review of Region D’s proposed methodology for determining groundwater availability for the 2021 Regional Water Plan. This analysis determined the optimal amount of pumping that met the Groundwater Management Area 8 desired future conditions for the Trinity and Woodbine aquifers in several Region D aquifer-county-basin-splits (Shi and Wade, 2019). The optimal values of groundwater pumping from that analysis, which are compatible with the desired future conditions, are Region D’s proposed groundwater availability revisions listed in Table 3.

RECOMMENDATION

TWDB Groundwater Modeling staff recommend approval of the Region D request for revised groundwater availability values for the Carrizo-Wilcox, Queen City, Nacatoch, Trinity, and Woodbine aquifers (Tables 1, 2, and 3).

Attachments:

1. Recommended Updates to Region D Groundwater Availability, Technical Memorandum to Tony Smith, Carollo and Region D Water Planning Group, October 16, 2024.

2. GMA 11 Technical Memorandum 20-05: Base Simulation for Joint Planning with Updated Groundwater Availability Model for the Sparta, Queen City, and Carrizo-Wilcox Aquifers, Prepared for Groundwater Management Area 11, December 30, 2020.

REFERENCES

Donnelly, A., Puente, M., and Beach, J., 2024, Recommended Updates to Region D Groundwater Availability, Technical Memorandum to Tony Smith, Carollo and Region D Water Planning Group, October 16, 2024.

Hutchison, W.R., 2020, GMA 11 Technical Memorandum 20-05: Base Simulation for Joint Planning with Updated Groundwater Availability Model for the Sparta, Queen City, and Carrizo-Wilcox Aquifers, Prepared for Groundwater Management Area 11, December 30, 2020.

Shi, J. and Wade, S., 2019, Technical Review of North East Texas Regional Water Planning Group Proposed Methodology for Determining Groundwater Availability in Region D, Memorandum to Ron Ellis, TWDB Project Manager, Region D Regional Water Planning Area, August 27, 2019.

Table 1. Proposed groundwater availability for the Carrizo-Wilcox and Queen City aquifers in Region D in acre-feet per year (Donnelly and others, 2024).

Aquifer	County	Basin	2030	2040	2050	2060	2070	2080
Carrizo-Wilcox	Cass	Sulphur	2,190	2,190	2,190	2,190	2,190	2,190
Carrizo-Wilcox	Franklin	Sulphur	2,594	2,594	2,594	2,594	2,594	2,594
Carrizo-Wilcox	Gregg	Sabine	8,841	8,841	8,841	8,841	8,841	8,841
Carrizo-Wilcox	Hopkins	Sabine	4,677	4,677	4,677	4,677	4,677	4,677
Carrizo-Wilcox	Hopkins	Sulphur	3,125	3,125	3,125	3,125	3,125	3,125
Carrizo-Wilcox	Morris	Sulphur	769	769	769	769	769	769
Carrizo-Wilcox	Smith	Sabine	11,743	11,743	11,743	11,743	11,743	11,743
Carrizo-Wilcox	Titus	Cypress	7,330	7,330	7,330	7,330	7,330	7,330
Carrizo-Wilcox	Titus	Sulphur	1,942	1,942	1,942	1,942	1,942	1,942
Carrizo-Wilcox	Upshur	Cypress	6,918	6,918	6,918	6,918	6,918	6,918
Carrizo-Wilcox	Upshur	Sabine	1,948	1,948	1,948	1,948	1,948	1,948
Carrizo-Wilcox	Van Zandt	Neches	4,136	4,136	4,136	4,136	4,136	4,136
Carrizo-Wilcox	Van Zandt	Sabine	5,033	5,033	5,033	5,033	5,033	5,033
Carrizo-Wilcox	Van Zandt	Trinity	1,651	1,651	1,651	1,651	1,651	1,651
Carrizo-Wilcox	Wood	Sabine	18,206	18,206	18,206	18,206	18,206	18,206
Queen City	Camp	Cypress	1,810	1,810	1,810	1,810	1,810	1,810
Queen City	Cass	Sulphur	758	758	758	758	758	758
Queen City	Harrison	Sabine	561	561	561	561	561	561
Queen City	Morris	Cypress	3,308	3,308	3,308	3,308	3,308	3,308

Table 2. Proposed groundwater availability for the Nacatoch Aquifer in Region D in acre-feet per year (Donnelly and others, 2024).

Aquifer	County	Basin	2030	2040	2050	2060	2070	2080
Nacatoch	Hunt	Sulphur	2,052	2,052	2,052	2,052	2,052	2,052
Nacatoch	Red River	Sulphur	2,924	2,923	2,923	2,923	2,923	2,923

Table 3. Recommended groundwater availability updates for the Trinity and Woodbine aquifers in Region D in acre-feet per year (Donnelly and others, 2024).

Aquifer	County	Basin	2030	2040	2050	2060	2070	2080
Trinity	Hunt	Sabine	213	213	213	213	213	213
Trinity	Red River	Sulphur	233	234	233	234	233	233
Woodbine	Lamar	Red	22	22	22	22	22	22

Attachment 1

Advanced Groundwater Solutions, LLC
www.advancedgw.com

Technical Memorandum

TO: Tony Smith, Carollo
Region D Water Planning Group

FROM: Andrew Donnelly, P.G., Meghan Puente, and James Beach, P.G.

COPY: Jennifer Jackson

SUBJECT: Recommended Updates to Region D Groundwater Availability

DATE: October 16, 2024

Introduction

This memo summarizes the recommended 2027 modeled available groundwater (MAG) availability updates in Region D. These recommended updates are for the Carrizo-Wilcox, Queen City, Trinity, and Woodbine aquifers. The methodologies used to derive the recommended changes to the MAG availabilities, as well as the recommended updated MAGs, are described below.

Carrizo-Wilcox and Queen City Aquifers

Evaluation of Supplies, Historic Pumping, and Availabilities

The current (DB27) MAG availabilities decreased significantly in the Carrizo-Wilcox and Queen City aquifers compared to the previous regional water planning cycle (DB22). This appears to be the result of the use of a new groundwater availability model (GAM) during the most recent cycle of joint groundwater planning conducted by Groundwater Management Area (GMA) 11. The aquifer properties used in the new GAM have resulted in the model automatically reducing pumping in order to keep cells from going dry during the final MAG model run. This reduction in pumping in the model simulation resulted in reduced MAGs for use in regional water planning for the Carrizo-Wilcox and Queen City aquifers. In many aquifer-county-basin splits, the new availabilities are less than the current or historic pumping volumes.

Each aquifer-county-basin split in the most recent final MAG run was evaluated to determine which splits had current MAGs that warranted a detailed evaluation to determine if an increase in the MAG is both justifiable and necessary. In many cases, the new MAGs- even ones that had decreased significantly- were significantly higher than the currently assigned supplies and recommended water management strategies (WMSs) included in the 2022 State Water Plan for that aquifer-county-basin split. Therefore, the new MAGs did not cause any issues of concern for most of the aquifer-county-basin splits.

However, there are 19 aquifer-county-basin splits that have been identified where the 2027 MAG availabilities are lower, or only slighter higher, than the sum of the 2026 assigned supplies and 2022 WMSs. These 19 aquifer-county-basin splits (summarized in Table 1) have been included in a more detailed evaluation by the NETRWPG. Also included in Table 1 are the current and previous MAG availabilities, the 2026 assigned groundwater supplies, and the 2022 recommended WMSs, all by aquifer-county-basin. The 2022 recommended WMSs have been utilized as the surrogate maximum starting point from which the 2026 WMSs are based.

Each water user group (WUG) in the 19 splits shown in Table 1 was evaluated to determine the supply that has been assigned to it in DB27 as well as the historic groundwater pumping for that WUG from the TWDB water use survey. Historic pumping for public water supply (PWS) WUGs was based on the historic municipal intake estimates available from the TWDB water use survey (https://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/index.asp). Municipal intake data is available on an aquifer-county-basin basis. Irrigation, livestock, manufacturing, mining, and steam-electric power historic pumping estimates were also obtained from the TWDB water use survey (https://www.twdb.texas.gov/waterplanning/waterusesurvey/historical-pumpage.asp). However, these historic groundwater pumping estimates are only available on an aquifer-county basis. The TWDB provided County-Other groundwater pumping estimates for this evaluation based on a data request. County-Other estimates provided by the TWDB were on an aquifer-county-basin basis.

Once the assigned supply and historic pumping was gathered for each WUG, they were compared to determine whether the assigned supply was less than the maximum amount of historic pumping that occurred in a single year. This comparison allowed the identification where historic pumping could support increased availability from the aquifer. The difference between the assigned supply and the maximum historic pumping is the amount that is recommended for the MAG availability to be increased. The sum of the increases in each aquifer-county-basin split is added to the current MAG availability to determine the new recommended MAG availability for use in this cycle of regional water planning. Note that irrigation, livestock, manufacturing, mining, and steam-electric power historic pumping estimates were not available by aquifer-county-basin. Therefore, the supplies from other basins with each county for these uses were added to the supply to obtain a county total supply to compare to the historic pumping.

Table 2 summarizes the WUGs in the 19 aquifer-county-basin splits that have historic pumping that are higher than the assigned supply, and Table 3 summarizes the total recommended increase in MAG in each aquifer-county-basin split based on the increases shown in Table 2. All but 2 of the 19 aquifer-county-basin splits have a recommended increase in the MAG, with increases ranging from 30 to 3,804 ac-ft/yr. A total of 24,063 ac-ft/yr of additional MAG is recommended for all of Region D. The recommended increases in Table 3 were added to the current MAGs for each aquifer-county-basin split to generate new recommended MAGs for the 19 aquifer-county-basin splits, which are shown in Table 4.

Trinity and Woodbine Aquifers

Previous Adjustment of MAG Availabilities

MAG availabilities in four aquifer-county-basin splits were adjusted in the previous cycle of regional water planning by Region D. These adjustments were reviewed and approved by the

TWDB in 2019. The relevant correspondence between Region D and the TWDB from 2019 is included as an attachment to this report.

However, the MAG availabilities in three of these splits were reset to their original values in the current cycle of regional water planning. Region D is recommending that these MAGs be set to the value established in the 2022 plan, summarized in Table 5. As noted, these recommended MAG availabilities were previously reviewed and approved by the TWDB during the last cycle of regional water planning.

Nacatoch Aquifer

Previous Adjustment of non-MAG Availabilities

Non-MAG availabilities in two aquifer-county-basin splits were adjusted in the previous cycle of regional water planning by Region D. These adjustments were reviewed and approved by the TWDB in 2019. The relevant correspondence between Region D and the TWDB is included as attachments to this report. The previous adjustment for the Red River-Sulphur split was carried over to the current cycle of regional water planning. However, the previous adjustment for the Hunt-Sulphur split was inadvertently decreased in the current cycle. To simplify this non-MAG availability, we recommend that a single value of 2,052 acre-feet/year be assigned as the non-MAG availability for the Nacatoch Aquifer in the Sulphur basin in Hunt County for all decades in the planning cycle.

Summary

MAGs in 19 aquifer-county-basin splits in the Carrizo-Wilcox and Queen City aquifers in Region D were decreased in the current planning cycle due to the use of an updated GAM by GMA 11 in the most recent round of joint groundwater planning. We evaluated the assigned supplies for WUGs in these 19 splits and compared them to the maximum annual estimated historic groundwater pumping for each WUG to determine if the maximum historic pumping was greater than the assigned supply. The splits with an historic pumping that was greater than the assigned supply were identified, and the difference between the pumping and supply was recommended as an increase in the MAG. The sum of all recommended increases in each of the 19 aquifer-county-basin splits was used to update the current MAGs in these two aquifers.

The MAGs in three aquifer-county-basin splits in the Trinity and Woodbine aquifers were updated in the last cycle of regional water planning. These changes were reviewed and approved by the TWDB at that time. However, the MAGs in these splits were reset to their original values. We recommend that the changes made and approved during the last cycle be restored for the current cycle of regional water planning. One non-MAG availability in the Nacatoch Aquifer was inadvertently decreased in the current cycle of regional water planning. We recommend that a single value of 2,052 acre-feet/year be assigned for all decades for this split in the current cycle of regional water planning.

Table 1. Summary of Carrizo-Wilcox and Queen City Aquifer-County-Basin Splits Evaluated.

Aquifer	County	Basin	2022 Availability (ac-ft/yr)	2027 Availability (ac-ft/yr)	Decrease in Availability (ac-ft/yr)	Percent Decrease in Availability	Sum of 2026 Assigned Supplies (ac-ft/yr)	Sum of 2022 Recommended WMSs (ac-ft/yr)
Carrizo-Wilcox	Cass	Sulphur	2,532	777	1,755	69%	479	216
Carrizo-Wilcox	Franklin	Sulphur	2,021	398	1,623	80%	371	1,129
Carrizo-Wilcox	Gregg	Sabine	7,179	5,346	1,833	26%	5,215	135
Carrizo-Wilcox	Hopkins	Sabine	2,842	2,426	416	15%	1,625	931
Carrizo-Wilcox	Hopkins	Sulphur	6,795	2,017	4,778	70%	1,193	5,606
Carrizo-Wilcox	Morris	Sulphur	402	415	-13	-3%	384	0
Carrizo-Wilcox	Smith	Sabine	13,196	7,939	5,257	40%	4,770	646
Carrizo-Wilcox	Titus	Cypress	7,194	5,594	1,600	22%	3,258	560
Carrizo-Wilcox	Titus	Sulphur	2,838	1,942	896	32%	918	1,445
Carrizo-Wilcox	Upshur	Cypress	5,442	5,107	335	6%	4,614	216
Carrizo-Wilcox	Upshur	Sabine	1,689	1,550	139	8%	1,487	0
Carrizo-Wilcox	Van Zandt	Neches	4,317	2,616	1,701	39%	2,616	298
Carrizo-Wilcox	Van Zandt	Sabine	4,370	3,286	1,084	25%	3,272	172
Carrizo-Wilcox	Van Zandt	Trinity	1,384	1,030	354	26%	1,030	143
Carrizo-Wilcox	Wood	Sabine	19,360	16,977	2,383	12%	14,059	214
Queen City	Camp	Cypress	4,150	1,594	2,556	62%	136	4,000
Queen City	Cass	Sulphur	3,010	624	2,386	79%	496	966
Queen City	Harrison	Sabine	2,310	561	1,749	76%	151	1,949
Queen City	Morris	Cypress	9,362	3,278	6,084	65%	3,247	1,127

Table 2. Comparison of Maximum Supply to Maximum Historic Pumping by Water User Group in the Carrizo-Wilcox and Queen City Aquifers (in acre-feet per year).

WUG	Aquifer	County	Basin	Maximum Supply	Historic High Pumping	Pumping Minus Supply
COUNTY-OTHER, CASS	Carrizo-Wilcox	Cass	Sulphur	80	282	202
LIVESTOCK, CASS	Carrizo-Wilcox	Cass	Sulphur	39	188	149
MINING, CASS	Carrizo-Wilcox	Cass	Sulphur	33	902	869
QUEEN CITY	Carrizo-Wilcox	Cass	Sulphur	100	293	193
LIVESTOCK, FRANKLIN	Carrizo-Wilcox	Franklin	Sulphur	361	1,149	788
MINING, FRANKLIN	Carrizo-Wilcox	Franklin	Sulphur	0	1,408	1,408
COUNTY-OTHER, GREGG	Carrizo-Wilcox	Gregg	Sabine	1,134	1,530	396
ELDERVILLE WSC	Carrizo-Wilcox	Gregg	Sabine	38	148	110
KILGORE	Carrizo-Wilcox	Gregg	Sabine	1,504	1,733	229
MANUFACTURING, GREGG	Carrizo-Wilcox	Gregg	Sabine	30	250	220
MINING, GREGG	Carrizo-Wilcox	Gregg	Sabine	411	2,672	2,261
STEAM ELECTRIC POWER, GREGG	Carrizo-Wilcox	Gregg	Sabine	242	267	25
TRYON ROAD SUD	Carrizo-Wilcox	Gregg	Sabine	128	382	254
LIVESTOCK, HOPKINS	Carrizo-Wilcox	Hopkins	Sabine	549	2,800	2,251
BRINKER WSC	Carrizo-Wilcox	Hopkins	Sulphur	253	311	58
COUNTY-OTHER, HOPKINS	Carrizo-Wilcox	Hopkins	Sulphur	124	514	390
IRRIGATION, HOPKINS	Carrizo-Wilcox	Hopkins	Sulphur	49	330	281

WUG	Aquifer	County	Basin	Maximum Supply	Historic High Pumping	Pumping Minus Supply
MARTIN SPRINGS WSC	Carrizo-Wilcox	Hopkins	Sulphur	446	825	379
LIVESTOCK, MORRIS	Carrizo-Wilcox	Morris	Sulphur	150	162	12
NAPLES	Carrizo-Wilcox	Morris	Sulphur	109	411	302
OMAHA	Carrizo-Wilcox	Morris	Sulphur	125	165	40
COUNTY-OTHER, SMITH	Carrizo-Wilcox	Smith	Sabine	0	1,900	1,900
IRRIGATION, SMITH	Carrizo-Wilcox	Smith	Sabine	0	251	251
LIBERTY CITY WSC	Carrizo-Wilcox	Smith	Sabine	23	428	405
LINDALE RURAL WSC	Carrizo-Wilcox	Smith	Sabine	1,011	1,034	23
MINING, SMITH	Carrizo-Wilcox	Smith	Sabine	0	506	506
STAR MOUNTAIN WSC	Carrizo-Wilcox	Smith	Sabine	213	254	41
STARRVILLE-FRIENDSHIP WSC	Carrizo-Wilcox	Smith	Sabine	130	214	84
WEST GREGG SUD	Carrizo-Wilcox	Smith	Sabine	132	726	594
MINING, TITUS	Carrizo-Wilcox	Titus	Cypress	0	1,736	1,736
COUNTY-OTHER, UPSHUR	Carrizo-Wilcox	Upshur	Cypress	194	747	553
DIANA SUD	Carrizo-Wilcox	Upshur	Cypress	598	695	97
GILMER	Carrizo-Wilcox	Upshur	Cypress	1,226	1,652	426
MANUFACTURING, UPSHUR	Carrizo-Wilcox	Upshur	Cypress	6	296	290
ORE CITY	Carrizo-Wilcox	Upshur	Cypress	214	260	46

WUG	Aquifer	County	Basin	Maximum Supply	Historic High Pumping	Pumping Minus Supply
PRITCHETT WSC	Carrizo-Wilcox	Upshur	Cypress	441	636	195
UNION GROVE WSC	Carrizo-Wilcox	Upshur	Cypress	72	277	205
COUNTY-OTHER, UPSHUR	Carrizo-Wilcox	Upshur	Sabine	157	280	123
EAST MOUNTAIN WATER SYSTEM	Carrizo-Wilcox	Upshur	Sabine	154	254	100
PRITCHETT WSC	Carrizo-Wilcox	Upshur	Sabine	580	756	176
EDOM WSC	Carrizo-Wilcox	Van Zandt	Neches	102	158	56
LITTLE HOPE MOORE WSC	Carrizo-Wilcox	Van Zandt	Neches	121	211	90
LIVESTOCK, VAN ZANDT	Carrizo-Wilcox	Van Zandt	Neches	477	848	371
MINING, VAN ZANDT	Carrizo-Wilcox	Van Zandt	Neches	1,117	1,795	678
R P M WSC	Carrizo-Wilcox	Van Zandt	Neches	130	455	325
CANTON	Carrizo-Wilcox	Van Zandt	Sabine	298	728	430
COUNTY-OTHER, VAN ZANDT	Carrizo-Wilcox	Van Zandt	Sabine	827	1,122	295
GRAND SALINE	Carrizo-Wilcox	Van Zandt	Sabine	374	841	467
MACBEE SUD	Carrizo-Wilcox	Van Zandt	Sabine	66	68	2
MANUFACTURING, VAN ZANDT	Carrizo-Wilcox	Van Zandt	Sabine	163	684	521
MYRTLE SPRINGS WSC	Carrizo-Wilcox	Van Zandt	Sabine	157	190	33
COUNTY-OTHER, VAN ZANDT	Carrizo-Wilcox	Van Zandt	Trinity	604	635	31
IRRIGATION, VAN ZANDT	Carrizo-Wilcox	Van Zandt	Trinity	33	623	590

WUG	Aquifer	County	Basin	Maximum Supply	Historic High Pumping	Pumping Minus Supply
ALGONQUIN WATER RESOURCES OF TEXAS	Carrizo-Wilcox	Wood	Sabine	0	439	439
FOUKE WSC	Carrizo-Wilcox	Wood	Sabine	1,026	1,233	207
IRRIGATION, WOOD	Carrizo-Wilcox	Wood	Sabine	147	400	253
PRITCHETT WSC	Carrizo-Wilcox	Wood	Sabine	5	102	97
SHARON WSC	Carrizo-Wilcox	Wood	Sabine	471	705	234
LIVESTOCK, CAMP	Queen City	Camp	Cypress	136	352	216
LIVESTOCK, CASS	Queen City	Cass	Sulphur	115	249	134
LIVESTOCK, MORRIS	Queen City	Morris	Cypress	84	114	30

Table 3. Total Recommended Increase in MAG for Each Aquifer-County-Basin Split in the Carrizo-Wilcox and Queen City Aquifers (in acre-feet per year)

Aquifer	County	Basin	Increase in MAG
Carrizo-Wilcox	Cass	Sulphur	1,413
Carrizo-Wilcox	Franklin	Sulphur	2,196
Carrizo-Wilcox	Gregg	Sabine	3,495
Carrizo-Wilcox	Hopkins	Sabine	2,251
Carrizo-Wilcox	Hopkins	Sulphur	1,108
Carrizo-Wilcox	Morris	Sulphur	354
Carrizo-Wilcox	Smith	Sabine	3,804
Carrizo-Wilcox	Titus	Cypress	1,736
Carrizo-Wilcox	Titus	Sulphur	0
Carrizo-Wilcox	Upshur	Cypress	1,811
Carrizo-Wilcox	Upshur	Sabine	398
Carrizo-Wilcox	Van Zandt	Neches	1,520
Carrizo-Wilcox	Van Zandt	Sabine	1,747
Carrizo-Wilcox	Van Zandt	Trinity	621
Carrizo-Wilcox	Wood	Sabine	1,229
Queen City	Camp	Cypress	216
Queen City	Cass	Sulphur	134
Queen City	Harrison	Sabine	0
Queen City	Morris	Cypress	30

Table 4. Current and Recommended MAGs for the Carrizo-Wilcox and Queen City Aquifers in Region D (in acre-feet per year).

Aquifer	County	Basin	Current MAG (ac-f/yr)						Recommended Increase in MAG (ac-f/yr)						Recommended MAG (ac-f/yr)					
			2030	2040	2050	2060	2070	2080	2030	2040	2050	2060	2070	2080	2030	2040	2050	2060	2070	2080
Carrizo-Wilcox	Cass	Sulphur	777	777	777	777	777	777	1,413	1,413	1,413	1,413	1,413	1,413	2,190	2,190	2,190	2,190	2,190	2,190
Carrizo-Wilcox	Franklin	Sulphur	398	398	398	398	398	398	2,196	2,196	2,196	2,196	2,196	2,196	2,594	2,594	2,594	2,594	2,594	2,594
Carrizo-Wilcox	Gregg	Sabine	5,346	5,346	5,346	5,346	5,346	5,346	3,495	3,495	3,495	3,495	3,495	3,495	8,841	8,841	8,841	8,841	8,841	8,841
Carrizo-Wilcox	Hopkins	Sabine	2,426	2,426	2,426	2,426	2,426	2,426	2,251	2,251	2,251	2,251	2,251	2,251	4,677	4,677	4,677	4,677	4,677	4,677
Carrizo-Wilcox	Hopkins	Sulphur	2,017	2,017	2,017	2,017	2,017	2,017	1,108	1,108	1,108	1,108	1,108	1,108	3,125	3,125	3,125	3,125	3,125	3,125
Carrizo-Wilcox	Morris	Sulphur	415	415	415	415	415	415	354	354	354	354	354	354	769	769	769	769	769	769
Carrizo-Wilcox	Smith	Sabine	7,939	7,939	7,939	7,939	7,939	7,939	3,804	3,804	3,804	3,804	3,804	3,804	11,743	11,743	11,743	11,743	11,743	11,743
Carrizo-Wilcox	Titus	Cypress	5,594	5,594	5,594	5,594	5,594	5,594	1,736	1,736	1,736	1,736	1,736	1,736	7,330	7,330	7,330	7,330	7,330	7,330
Carrizo-Wilcox	Titus	Sulphur	1,942	1,942	1,942	1,942	1,942	1,942	0	0	0	0	0	0	1,942	1,942	1,942	1,942	1,942	1,942
Carrizo-Wilcox	Upshur	Cypress	5,107	5,107	5,107	5,107	5,107	5,107	1,811	1,811	1,811	1,811	1,811	1,811	6,918	6,918	6,918	6,918	6,918	6,918
Carrizo-Wilcox	Upshur	Sabine	1,550	1,550	1,550	1,550	1,550	1,550	398	398	398	398	398	398	1,948	1,948	1,948	1,948	1,948	1,948
Carrizo-Wilcox	Van Zandt	Neches	2,616	2,616	2,616	2,616	2,616	2,616	1,520	1,520	1,520	1,520	1,520	1,520	4,136	4,136	4,136	4,136	4,136	4,136
Carrizo-Wilcox	Van Zandt	Sabine	3,286	3,286	3,286	3,286	3,286	3,286	1,747	1,747	1,747	1,747	1,747	1,747	5,033	5,033	5,033	5,033	5,033	5,033
Carrizo-Wilcox	Van Zandt	Trinity	1,030	1,030	1,030	1,030	1,030	1,030	621	621	621	621	621	621	1,651	1,651	1,651	1,651	1,651	1,651
Carrizo-Wilcox	Wood	Sabine	16,977	16,977	16,977	16,977	16,977	16,977	1,229	1,229	1,229	1,229	1,229	1,229	18,206	18,206	18,206	18,206	18,206	18,206
Queen City	Camp	Cypress	1,594	1,594	1,594	1,594	1,594	1,594	216	216	216	216	216	216	1,810	1,810	1,810	1,810	1,810	1,810
Queen City	Cass	Sulphur	624	624	624	624	624	624	134	134	134	134	134	134	758	758	758	758	758	758
Queen City	Harrison	Sabine	561	561	561	561	561	561	0	0	0	0	0	0	561	561	561	561	561	561
Queen City	Morris	Cypress	3,278	3,278	3,278	3,278	3,278	3,278	30	30	30	30	30	30	3,308	3,308	3,308	3,308	3,308	3,308

Table 5. Current and Recommended MAGs for the Trinity and Woodbine Aquifers.

Aquifer	County	Basin	Current Modeled Available Groundwater (ac-ft/yr)						Recommended Modeled Available Groundwater (ac-ft/yr)					
			2030	2040	2050	2060	2070	2080	2030	2040	2050	2060	2070	2080
Trinity	Hunt	Sabine	0	0	0	0	0	0	213	213	213	213	213	213
Trinity	Red River	Sulphur	125	125	125	125	125	125	233	234	233	234	233	233
Woodbine	Lamar	Red	0	0	0	0	0	0	22	22	22	22	22	22

Table 6. Current and Recommended non-MAG Availabilities for the Nacatoch Aquifer.

Aquifer	County	Basin	Current Modeled Available Groundwater (ac-ft/yr)						Recommended Modeled Available Groundwater (ac-ft/yr)					
			2030	2040	2050	2060	2070	2080	2030	2040	2050	2060	2070	2080
Nacatoch	Hunt	Sulphur	491	491	513	868	1,347	2,052	2,052	2,052	2,052	2,052	2,052	2,052
Nacatoch	Red River	Sulphur	2,924	2,923	2,923	2,923	2,923	2,923	2,924	2,923	2,923	2,923	2,923	2,923

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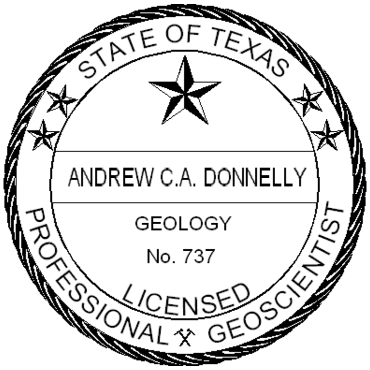

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ATTACHMENTS

MEMO

TO: **Ms. Sarah Backhouse**

FROM: **Kristie Laughlin, P.G., James Beach, P.G. and Jennifer Herrera**

SUBJECT: **Proposed Methodology for Determining Groundwater Availability in Region D on behalf of the North East Texas Regional Water Planning Group**

DATE: **Revised May 21, 2019**

Introduction

There are no Groundwater Conservation Districts (GCDs) in Region D. Chapter 357 states:

> *If no groundwater conservation district exists within the RWPA, then the RWPG shall determine the Availability of groundwater for regional planning purposes. The Board shall review and consider approving the RWPG-Estimated Groundwater Availability, prior to inclusion in the IPP, including determining if the estimate is physically compatible with the desired future conditions for relevant aquifers in groundwater conservation districts in the co-located groundwater management area or areas. The EA shall use the Board's groundwater availability models as appropriate to conduct the compatibility review.*

Because there are no GCDs in Region D, the region wanted to exercise the right to refine the groundwater availability estimates to determine if the Modeled Available Groundwater (MAG) volumes estimated by the TWDB were appropriate for the region. Region D believes that local entities that operate wells and wellfields in the region have insight and information that may be helpful in refining the groundwater availability estimates. The refined evaluation is deemed necessary to ensure that historical use and local aquifer characteristics and conditions are properly considered when estimating local groundwater availability. Without local GCD representation and data, it is difficult for Groundwater Management Area (GMA) 11 and GMA 8 to assess groundwater availability at the level that may be required for local groundwater sources. Refinement of the groundwater availability estimates entailed comparing the MAGs for each county-aquifer-basin and calculated municipal pumpage in nine county-aquifer-basins. The term "relevant" as applied to groundwater aquifers, determines whether they are considered critical to joint groundwater planning. The 'relevant' designation can change from one planning cycle to the next.

Based on an initial evaluation, the county-aquifer-basins listed below appear to have historical pumping estimates that exceed the TWDB assigned MAG volumes, and thus have been analyzed herein:

1. Hunt County – Nacatoch Aquifer – Sulphur Basin
2. Delta County – Trinity Aquifer – Sulphur Basin
3. Hunt County – Trinity Aquifer – Trinity Basin
4. Lamar County – Trinity Aquifer – Red Basin
5. Hunt County – Woodbine Aquifer – Sabine Basin
6. Hunt County – Woodbine Aquifer – Sulphur Basin
7. Lamar County – Woodbine Aquifer – Red River Basin
8. Lamar County – Woodbine Aquifer – Sulphur Basin
9. Red River County – Woodbine Aquifer – Red River Basin

Data

To investigate these nine county-aquifer-basin areas, WSP reviewed the following data:

- public water supply well locations, well depths, well tested capacities, and public water supply system average daily consumption volumes available via the Texas Commission on Environmental Quality (TCEQ) Texas Drinking Water Watch;
- groundwater well locations, depths and well yields available via TCEQ water well databases;
- groundwater well locations, depths and well yields available via the Texas Water Development Board (TWDB);
- TWDB groundwater availability model (GAM) run reports requested by GMA-8 for both the 2016 and 2021 planning cycles;
- structure surfaces derived for either the Northern Trinity Woodbine Groundwater Availability Model (NTWGAM) (Kelley and others, 2013) or the Nacatoch Brackish Availability Study (Laughlin and others, 2017; and
- TWDB historical groundwater pumping; (as described on the TWDB website):

  "Each year the Texas Water Development Board conducts an annual survey of ground and surface water use by municipal and industrial entities within the state of Texas. The information obtained, as well as water use estimates for irrigation, livestock and mining is then utilized by the Texas Water Development Board for water resources planning. The historical water use estimates and survey information is subject to revision as additional data and corrections are made available to the TWDB."

Methodology

Municipal Pumping

The focus of the analyses is primarily on municipal pumping because it accounts for 65 percent of all groundwater used in Region D, based on 2016 historical pumping estimates. Additionally, the municipal estimates are the actual pumping reported by PWS entities to TWDB via annual surveys. To determine if the MAG volumes were adequate to support public water supply (PWS) pumping, PWS locations were verified to be active and to have the correct aquifer designation based on geologic structure. River basin splits, where applicable, were noted for each public system, so that pumping could be properly allocated to compare to MAG volumes split out by basin.

Total tested well capacities were then summed for PWS wells per county-aquifer-basin. Total tested well capacity actually represents maximum system capacity, which is how much a system could pump if it pumped its wells 24 hours a day, seven days a week, for 365 days a year at full capacity. To adjust the total system capacity to a more realistic pumping volume, it is assumed that wells typically pump for only six hours a day. Thus, the maximum system capacity is divided by four to derive the expected average annual pumping for the system. The average daily consumption of the system, if reported, is also converted to an annual volume to represent the average annual PWS system pumping. The estimates of average annual pumping volume are then compared to the MAG volume.

Non-municipal Pumping

The only non-municipal estimates that are based on annual surveys are pumping estimates reported by industrial users, which accounted for approximately four percent of Region D pumping in 2016. To verify non-municipal historical pumping estimates, existing non-municipal well locations were verified (when possible) to be active and aquifer designations were either determined (from state well reports) or verified (for TWDB historical wells) using the geologic structure sources mentioned previously. Non-surveyed estimates were then evaluated to determine if they can be substantiated by existing active wells found within the county-aquifer-basin. Note that the non-surveyed estimates for irrigation and livestock are calculated by the TWDB as follows:

> *Livestock water-use estimates are derived from annual livestock population estimates produced by the Texas Agricultural Statistics Service. Estimated water use per animal unit is based on research conducted by the Texas Agricultural Experiment Station.*
>
> *Irrigated agriculture water-use estimates are based on annual crop acreage from the Natural Resources Conservation Service (prior to 2001) and the Farm Service Administration*

(2001 and later). Irrigation rates per acre are estimated based on potential evapotranspiration, with final estimates reviewed by local authorities.

Since the non-surveyed volumes are county-wide estimates and are not location-specific, in some areas they can erroneously assign pumping to water users that cannot be substantiated using the publicly-available state well databases and other resources. WSP considered the non-surveyed historical pumping estimates to be questionable when there is no well data to support the assumption that the demands are supplied by wells in that specific county-aquifer-basin. TWDB's non-surveyed historical estimates may not have any direct relationship to MAG volumes or regional supply estimates but they can be provide insight for water resource planning.

The above analyses identify where and by how much WUGs within Region D have existing groundwater supplies that exceed MAG amounts, with recommendations for two specific county-aquifer-basins to be increased based on a local hydrogeologic assessment based on available information base. Additional consideration has been given by Region D to the identification of amounts of groundwater available for future water management strategies (WMSs) in the region.

At present, the evaluation of potentially feasible WMSs is underway, but are not yet complete. An analysis has been performed to develop an estimate of the maximum amount of groundwater for individual county-aquifer-basins that may be identified as an available source for Region D. The approach proposed herein is that these estimated maximums be reviewed and possibly approved by TWDB, with an acknowledgement that local hydrogeologic analyses similar to the methods presented herein for existing groundwater availability in Region D will be performed which may further limit the amount of groundwater availabilities for each county-aquifer-basin combination within the region. Said another way, the estimates presented within this memorandum represent the maximum amount of groundwater available within Region D above the MAG, and if the local hydrogeological assessment performed by Region D during WMS evaluations indicates an amount lower than these estimated maximums, then whichever between the two is the lower amount becomes the limiting factor that establishes the availability to be employed for characterizing groundwater availability for the purposes of the 2021 Region D Plan.

To derive the estimated maximum amounts of groundwater availability above existing MAG amounts for each county-aquifer-basin, the following analyses were performed:

1. WUG second-tier needs were evaluated to determine whether groundwater is a potential source of supply. If groundwater was identified as a potential source, the second-tier WUG needs were summed by county and basin.
2. Source water balances for each county-aquifer-basin combination were then summed to represent the amount of MAG available after allocation of existing groundwater supplies to Region D entities.
3. The summed second tier need by county-basin for each Region D WUG (from Item 1) was then compared to the remaining available MAG amount by county-aquifer-basin (from Item 2) to determine the amount of water, by county-aquifer-basin, potentially needed above the MAG.
4. Those instances where the summed second tier need exceeds MAG availability were then tabulated by county-aquifer-basin by the total amount over the MAG.
5. The maximum amount over the MAG over the 50-year planning period was then calculated for each county-aquifer-basin.

This approach results in a conservative estimate of the amount of water to be identified by Region D as being potentially available above the MAG, and is conservative in two aspects:

a) WUGs may have alternative sources more viable than groundwater; and
b) WUGs may utilize one county-aquifer-basin over another, but for the present purposes it has been assumed that either county-aquifer-basin may be used, so the resultant maximum amounts may be higher than the application of a specific source to meet an identified need.

Results

Table 1 is a summary of findings for existing groundwater use using the methods described above. MAG volumes for two of the nine county-aquifer basins are probably not sufficient. It is recommended that further communication with TWDB be made regarding these areas. Table 2 details the recommended existing supply volumes for all county-aquifer-basins, while Table 3 presents the recommended additional maximum amounts of availability of groundwater to meet potential future water management strategies within Region D. It should be noted that the amounts presented in Table 3 are *in addition* to the amounts recommended in Table 2.

For the purposes of the 2021 Region D Water Plan, the methodologies used herein are proposed for estimating groundwater availability in Region D. Using these methods, for the identified county-aquifer-basins where existing supplies potentially exceed the TWDB MAG volumes, it appears that the MAG volumes are sufficient for existing supply amounts for seven of the county-aquifer-basins.

It is proposed that these methods be used to comparatively assess and evaluate TWDB MAG volumes and groundwater availabilities for potentially feasible Water Management Strategies within the Region D Planning Area. While Region D has not completed a thorough assessment of local aquifer conditions for each WUG that may need a groundwater strategy, conservative estimates of the maximum amount above the MAG for each county-aquifer-basin have been derived and are presented herein. Local hydrogeologic evaluations consistent with the methods described herein are proposed to be completed on a case-by-case basis for WUGs with identified needs, and where a potential groundwater strategy is considered, the lower of either the requested maximums presented herein or the result of the local evaluation will be employed to establish groundwater availability for the specific county-aquifer-basin for the purposes of the 2021 Region D Plan.

Table 1. Summary of Findings: Source Water Evaluation and MAGs, in acre-feet per year

County-Aquifer-Basin	2021 MAG	Historical Estimate	Municipal Pumping	Findings
Hunt – Nacatoch - Sulphur	491 (non-relevant = 2016 MAG)	608 (MUN, IRR, STK)	730 (Commerce, Campbell WSC, Maloy WSC, TAMU)	The MAG is not sufficient. Cumulative pumping volumes for non-municipal users is unknown.
Delta – Trinity – Sulphur	56	145 (IRR, STK)	41 (Ben Franklin and West Delta WSCs)	The MAG is sufficient for municipal supply. Historical pumping estimates are not substantiated. The only existing Trinity wells are public water supply wells and over 3,000 feet deep. Professional judgement indicates that 3000 feet deep wells are not economically feasible to meet irrigation and livestock demands.
Hunt – Trinity – Trinity -	0	0	No Trinity municipal pumping	Historical pumping erroneously reported in Hunt County but should be reported in Fannin County.
Lamar – Trinity – Red	0	0	No Trinity municipal pumping	There are no Trinity wells in Lamar County in the Red River basin.
Hunt - Woodbine - Sabine	269	79 (MUN)	267 (Celeste, Hickory Creek SUD – 1 well)	The MAG should be sufficient for municipal supply. There are no other uses reported.
Hunt - Woodbine - Sulphur	165	89 (MUN)	110 This is 22 percent of the total volume reported for Hickory Creek SUD system (405 afy). Pumpage is weighted by basin based on tested well capacities.	The MAG should be sufficient for municipal supply. Only one of the four system wells is located in the Sulphur Basin. There are no other uses reported.
Lamar - Woodbine – Red	0	18 (MUN, STK)	No Woodbine PWS pumping.	The MAG is probably not sufficient. No active public supply wells. There are a few newer domestic wells, livestock and irrigation wells drilled within the last 6 years. Cumulative pumping is unknown, but is likely greater than 18 afy.
Lamar - Woodbine - Sulphur	49	5 (MUN)	No Woodbine PWS pumping after 2011	This MAG should be sufficient. No active public supply wells. No active livestock wells.
Red River - Woodbine – Red	2	1 (MUN)	No Woodbine PWS pumping	The MAG is probably adequate. Historical pumping is questionable based on existing well data. One domestic well is possibly active.

MUN = municipal; IRR = irrigation; STK = livestock

Table 2. Recommended Availability Volumes, in acre-feet per year

County-Aquifer-Basin	2021 MAG	Historical Estimate	Municipal Pumping	Recommended Volume	Justification
Hunt - Nacatoch - Sulphur	491 (non-relevant = 2016 MAG)	608 (MUN, IRR, STK)	730 (Commerce, Campbell WSC, Maloy WSC, TAMU)	**1,092** 730 municipal pumping plus 362 other uses	There are approximately 50 domestic, irrigation and livestock wells in the state driller's report database in this county-aquifer-basin. The average well yield is 18 gpm. Assume wells pump 6 hours a day. Total of 225 gpm is 362 acre-feet/year.
Delta – Trinity - Sulphur	56	145 (IRR, STK)	41	**56**	MAG volume is recommended. It is sufficient for municipal supply. The only Trinity wells are for public supply (over 3,000 ft. deep).
Hunt – Trinity -Trinity -	0	0	0	**0**	MAG of zero is recommended, since the North Hunt SUD pumping is in Fannin County.
Lamar – Trinity – Red	0	0	0	**0**	MAG of zero is recommended, since there are no Trinity wells.
Hunt - Woodbine - Sabine	269	79 (MUN)	267	**269**	MAG volume recommended. It is currently sufficient for municipal supply, and there are no other uses reported.
Hunt - Woodbine - Sulphur	165	89 (MUN)	110	**165**	MAG volume recommended. It is currently sufficient for municipal supply, and there are no other uses reported.
Lamar - Woodbine - Red	0	18 (MUN, STK)	No Woodbine PWS pumping.	**60**	There are approximately 10 domestic, irrigation and livestock wells in the state driller's report database in this county-aquifer-basin. The average well yield is 15 gpm. Assume wells pump 6 hours a day. Total of 37.5 gpm is 60 acre-feet/year.
Lamar - Woodbine - Sulphur	49	5 (MUN)	No Woodbine PWS pumping after 2011	**49**	MAG volume recommended. No active public supply wells. No active domestic, irrigation or livestock wells.
Red River - Woodbine - Red	2	1 (MUN)	No Woodbine PWS pumping	**2**	MAG volume recommended. One domestic well is possibly active.

MUN = municipal; IRR = irrigation; STK = livestock

Table 3. Region D Maximum Requested Groundwater Availability above MAG by County-Aquifer-Basin Combination (ac-ft)

County/Aquifer/Basin	Maximum Amount (ac-ft)
BOWIE/BLOSSOM AQUIFER/RED	231
BOWIE/BLOSSOM AQUIFER/SULPHUR	237
CAMP/CARRIZO-WILCOX AQUIFER/CYPRESS	2,120
DELTA/TRINITY AQUIFER/SULPHUR	15
HARRISON/CARRIZO-WILCOX AQUIFER/CYPRESS	1,058
HOPKINS/NACATOCH AQUIFER/SABINE	100
HOPKINS/CARRIZO-WILCOX AQUIFER/SULPHUR	4,305
HOPKINS/NACATOCH AQUIFER/SULPHUR	6,353
HUNT/NACATOCH AQUIFER/SABINE	16,533
HUNT/TRINITY AQUIFER/SABINE	19,262
HUNT/WOODBINE AQUIFER/SABINE	19,262
HUNT/NACATOCH AQUIFER/SULPHUR	2,425
HUNT/TRINITY AQUIFER/SULPHUR	2,425
HUNT/WOODBINE AQUIFER/SULPHUR	2,405
HUNT/TRINITY AQUIFER/TRINITY	124
LAMAR/BLOSSOM AQUIFER/RED	1,565
LAMAR/TRINITY AQUIFER/RED	1,888
LAMAR/WOODBINE AQUIFER/RED	1,888
LAMAR/BLOSSOM AQUIFER/SULPHUR	370
LAMAR/NACATOCH AQUIFER/SULPHUR	331
LAMAR/TRINITY AQUIFER/SULPHUR	435
LAMAR/WOODBINE AQUIFER/SULPHUR	441
RAINS/NACATOCH AQUIFER/SABINE	149
RED RIVER/NACATOCH AQUIFER/RED	134
RED RIVER/TRINITY AQUIFER/RED	155
RED RIVER/WOODBINE AQUIFER/RED	184

County/Aquifer/Basin	Maximum Amount (ac-ft)
RED RIVER/BLOSSOM AQUIFER/SULPHUR	2,391
RED RIVER/CARRIZO-WILCOX AQUIFER/SULPHUR	2,391
RED RIVER/NACATOCH AQUIFER/SULPHUR	2,212
RED RIVER/TRINITY AQUIFER/SULPHUR	2,326
TITUS/CARRIZO-WILCOX AQUIFER/CYPRESS	2,207
TITUS/QUEEN CITY AQUIFER/CYPRESS	2,063
VAN ZANDT/CARRIZO-WILCOX AQUIFER/SABINE	132

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DATE: August 27, 2019

SUBJECT: Technical Review of North East Texas Regional Water Planning Group Proposed Methodology for Determining Groundwater Availability in Region D

SUMMARY

Groundwater modeling of the methodology for groundwater availability proposed by the North East Texas Regional Water Planning Group results in widespread exceedances of desired future conditions and in some areas dewatering of multiple aquifers. Therefore, groundwater staff do not recommend approval of the submitted groundwater availability estimates for the Carrizo-Wilcox, Trinity, Queen City, and Woodbine aquifers. Although modeling results for the Carrizo-Wilcox and Queen City aquifers do not generate water-level drawdowns that exceed the desired future conditions in any groundwater conservation district adjacent to Region D, modeling results do suggest that these aquifers may not be able to produce the proposed groundwater availability amounts requested by the Northeast Texas Regional Water Planning Group (Region D) in some areas within Region D. For the Trinity and Woodbine aquifers, the modeling results suggest the desired future conditions in Upper Trinity, North Texas, Prairielands, Red River, Southern Trinity, Middle Trinity, and Northern Trinity groundwater conservation districts may be exceeded.

BACKGROUND

On May 24, 2019, Kristie Laughlin, James Beach, and Jennifer Herrera from WSP on behalf of Region D, submitted a proposed methodology for determining groundwater availability in Region D to Sarah Backhouse, manager of the TWDB Regional Water Planning

Department. Because there are no groundwater conservation districts in Region D, the planning group estimated groundwater availability for the aquifers in Region D. Aquifers in Region D include the Carrizo-Wilcox, Queen City, Nacatoch, Blossom, Trinity, and Woodbine aquifers. TWDB Groundwater Availability Modeling Department staff have reviewed the proposed groundwater availability estimates to determine whether they are compatible with the desired future conditions of the aquifers in Groundwater Management Areas 8 and 11. The Blossom and Nacatoch aquifers were declared nonrelevant in Groundwater Management Area 8 and they do not have desired future conditions, so their compatibility does not need to be reviewed. The Trinity and Woodbine aquifers have desired future conditions in Groundwater Management Area 8 and the Carrizo-Wilcox and Queen City aquifers have desired future conditions in Groundwater Management Area 11.

KEY ISSUES

The technical review of the proposed groundwater availability estimates consisted of verifying that the pumping rates will not generate drawdowns that exceed the desired future conditions for the Trinity and Woodbine aquifers in Groundwater Management Area 8 and for the Carrizo-Wilcox, Queen City, and Sparta aquifers in Groundwater Management Area 11.

Our review of the technical materials provided by Region D showed several inconsistencies. For example, proposed estimates of groundwater availability for the Carrizo-Wilcox and Queen City aquifers in Region D are not discussed in the text of the WSP memo; however, proposed estimates for these aquifers are listed in Table 3 of the WSP memo. In addition, some of the groundwater availability estimates proposed in the text of the WSP memo for the Trinity and Woodbine aquifers were also listed at higher levels in Table 3.

ANALYSIS

Groundwater Management Area 11: Carrizo-Wilcox and Queen City aquifers

Groundwater staff revised the model pumping file for "Scenario 4" – the model simulation that resulted in values of modeled available groundwater for the adopted desired future conditions in the Groundwater Management Area 11 (Wade, 2017). The revision to Scenario 4 increased the groundwater availability amounts for the county/basin combinations shown in Tables 1 through 3. In areas where no pumping was present in Scenario 4, the requested county/basin pumping volume was evenly distributed. Factors were applied where pumping in Scenario 4 were less than the Region D requested pumping volumes. Groundwater staff then ran the groundwater availability model for the northern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers (version 2.01; Figure 1) using the modified pumping file. Drawdowns from 2000 through 2070 were extracted from the model results and averaged by county and overall (Table 4). The methods and assumptions are the same as those discussed in the Groundwater Management Area 11 modeled available groundwater report (Wade, 2017). The drawdowns are consistent with the desired future conditions if the difference between the modeled drawdown is within a 1-foot variance. The drawdown averages were compared with the Groundwater Management Area 11 desired future conditions (Table 4). While the desired future conditions were not exceeded in a groundwater conservation district, the overall desired future condition for Groundwater Management Area 11 and several counties without a groundwater conservation district were exceeded.

In addition to analyzing county average drawdowns from the proposed groundwater availability model run, groundwater staff also analyzed the model water budget to verify the groundwater availability values. Some of the pumping discharge volumes were reduced in the model run because of model cells going dry. A model cell going dry suggests that the aquifer may not be able to produce the modeled amount of pumping in a particular area. The maximum number of dry cells in 2070 were noted for each county basin for the desired future condition/modeled available groundwater run and for the revised groundwater availability model run (Table 2). The pumping values listed in Tables 2 and 3, Region D Actual Groundwater Availability, suggest the maximum amount of pumping that appears feasible in a particular aquifer, county, and basin.

Groundwater Management Area 8: Trinity and Woodbine aquifers

The groundwater availability model simulation that met the desired future conditions (Shi, 2018) was revised to accommodate the increased pumping in the Trinity (Figure 2) and Woodbine (Figure 3) aquifers requested by Region D. The increased pumping was evenly distributed in the official boundary extent of the Trinity and Woodbine aquifers by county, basin, and regional planning area. In applying the additional pumping, we used 365 days in a year except for 366 days in leap years. Pumping is slightly more in leap years to account for one more additional day of pumping.

After the model run, the pumping information extracted from the revised model budget file was compared with the modeled available groundwater from Shi (2018) as a quality control measure. The comparisons are presented in Table 5 for the Trinity Aquifer and Table 6 for the Woodbine Aquifer. The comparisons indicate that the revised model reflected the increased pumping requested by Region D, with slightly more pumping in leap years.

Using the same approach by Shi (2018), the simulated head values from the revised model were used to calculate drawdown values between 2070 and 2009 for both aquifers by counties (Tables 7 and 8), groundwater conservation districts (Table 9), and Groundwater Management Area 8 (Table 10). A desired future condition is exceeded if the drawdown from the revised model changes more than five feet and five percent relative to the desired future condition at the same time. Tables 7 through 10 indicate that, with the increased pumping in Region D, the desired future conditions would be exceeded in several counties and groundwater conservation districts within Groundwater Management Area 8.

Additional model simulations were performed to estimate the optimal pumping rates that could be used by Region D and still do not exceed the desired future conditions by county, groundwater conservation district, and Groundwater Management Area 8.

CONCLUSIONS

The proposed groundwater availability estimates for the Queen City Aquifer do not affect the model estimated 2070 desired future conditions for Groundwater Management Area 11. Drawdown results are not presented for the Queen City Aquifer because the drawdowns with the revised pumping were within 1 foot of the desired future conditions listed in Table 1 of the modeled available groundwater report (Wade, 2017). The proposed groundwater availability estimates for the Carrizo-Wilcox Aquifer cause modeled average drawdowns which exceed the desired future conditions for Groundwater Management Area 11 in eight counties and overall (Table 4). However, none of the desired future conditions that are exceeded are in groundwater conservation districts.

Note, drawdown results are not presented for Red River County in Table 4 because Groundwater Management Area 11 did not adopt a desired future condition for the Carrizo-Wilcox Aquifer in Red River County. Although Red River County is not specifically mentioned in the joint resolution for Groundwater Management Area 11, the resolution did note that all counties with less than 200 square miles were considered non-relevant due to size.

An additional finding of concern is that the Region D proposed availability for the Carrizo-Wilcox Aquifer groundwater availability estimates also cause some model cells to go dry. The dry cells suggest that the aquifer may not be able to produce the proposed groundwater availability amounts in these areas.

The proposed groundwater availability estimates for the Trinity and Woodbine aquifers are expected to cause water level declines. The declines may be greater than the desired future conditions for both Trinity and Woodbine aquifer in several counties and groundwater conservation districts within Groundwater Management Area 8 where the desired future conditions were defined (Tables 7 through 10).

The maximum feasible amount of pumping for Region D for the Carrizo-Wilcox and Queen City aquifers is noted in Table 3 and the optimal amount of pumping in Groundwater Management Area 8 that meets the desired future condition for the Trinity and Woodbine aquifers is noted in Table 11.

REFERENCES

Wade, S.C., 2017, GAM Run 17-024 MAG: Modeled Available Groundwater for the Carrizo-Wilcox, Queen City, and Sparta Aquifers in Groundwater Management Area 11, Texas Water Development Board, 24 p., http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR17-024_MAG.pdf

Shi, J., 2018, Gam Run 17-029 MAG: Modeled Available Groundwater for the Trinity, Woodbine, Edwards (Balcones Fault Zone), Marble Falls, Ellenburger-San Saba, And Hickory Aquifers in Groundwater Management Area 8, Texas Water Development Board, 102 p., https://www.twdb.texas.gov/groundwater/docs/GAMruns/GR17-029_MAG.pdf

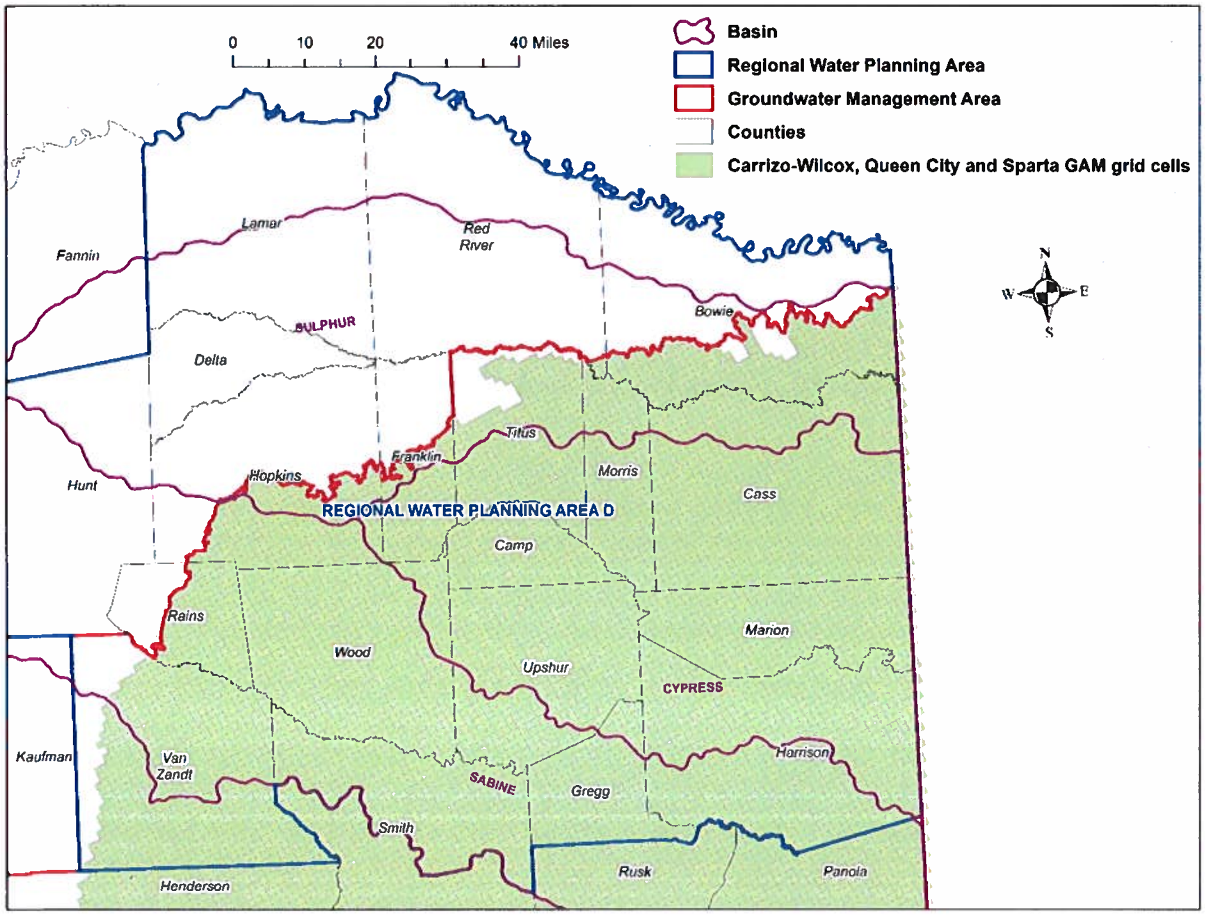

Figure 1 **Groundwater Availability Model for the Northern Part of the Carrizo-Wilcox, Queen City, and Sparta Aquifers in Groundwater Management Area 11 and Region D.**

Table 1 Region D Proposed Groundwater Availability Compared with Modeled Available Groundwater (MAG) for Groundwater Management Area 11. All values in acre-feet per year.

County	Basin	Aquifer	Region D	MAG (2020)	Factor	Additional
Camp	Cypress	Carrizo-Wilcox	6,170	4,050	1.52	NA
Harrison	Cypress	Carrizo-Wilcox	7,241	6,183	1.17	NA
Hopkins	Sulphur	Carrizo-Wilcox	7,542	3,237	2.33	NA
Red River	Sulphur	Carrizo-Wilcox	2,391	0	NA	2,391
Titus	Cypress	Queen City	2,207	144	NA	2,063
Titus	Cypress	Carrizo-Wilcox	9,422	7,215	1.31	NA
Van Zandt	Sabine	Carrizo-Wilcox	4,761	4,629	1.03	NA

NA: not applicable

Table 2 Reductions of Modeled Groundwater Pumping Due to Dry Cells in Groundwater Management Area 11 and Region D. All values in acre-feet per year.

County	Basin	Aquifer	Region D request	Region D Actual (2070)	Region D dry cell count (2070)	MAG (2070)	MAG dry cell count (2070)
Camp	Cypress	Carrizo-Wilcox	6,170	6,101	4	4,050	0
Harrison	Cypress	Carrizo-Wilcox	7,241	6,951	29	5,990	25
Hopkins	Sulphur	Carrizo-Wilcox	7,542	6,907	16	3,237	9
Red River	Sulphur	Carrizo-Wilcox	2,391	478	4	0	0
Titus	Cypress	Queen City	2,207	490	14	144	0
Titus	Cypress	Carrizo-Wilcox	9,422	8,494	35	6,634	32
Van Zandt	Sabine	Carrizo-Wilcox	4,761	4,398	15	4,270	15

Table 3 Region D Actual Groundwater Availability (Region D request decreased by pumping from dry cells). All values in acre-feet per year.

County	Basin	Aquifer	Region D Actual Groundwater Availability					
			2020	2030	2040	2050	2060	2070
Camp	Cypress	Carrizo-Wilcox	6,156	6,127	6,127	6,101	6,101	6,101
Harrison	Cypress	Carrizo-Wilcox	7,188	7,115	7,028	6,994	6,951	6,951
Hopkins	Sulphur	Carrizo-Wilcox	7,228	7,228	7,228	7,057	7,057	6,907
Red River	Sulphur	Carrizo-Wilcox	478	478	478	478	478	478
Titus	Cypress	Queen City	2,207	1,716	1,226	1,103	735	490
Titus	Cypress	Carrizo-Wilcox	9,234	9,016	8,889	8,753	8,560	8,494
Van Zandt	Sabine	Carrizo-Wilcox	4,768	4,768	4,590	4,528	4,528	4,398

Table 4 **Desired Future Conditions for the Carrizo-Wilcox Aquifer compared with Results from GAM Run 17-024 for Groundwater Management Area 11 and estimated drawdowns resulting from simulation of the requested groundwater availability from Region D.**

County	Desired Future Conditions (feet)[1]	Scenario 4 (feet)	Region D (feet)
Anderson	90	90	90
Angelina	48	48	48
Bowie	5	5	5
Camp	33	33	44
Cass	68	68	69
Cherokee	99	99	99
Franklin	14	14	16
Gregg	58	58	59
Harrison	18	19	21
Henderson	50	50	50
Hopkins	3	3[2]	6[2]
Houston	80	80	80
Marion	45	45	47
Morris	46	46	51
Nacogdoches	29	29	29
Panola	3	2[2]	4[2]
Rains	1	1[2]	1[2]
Rusk	23	23	23
Sabine	9	9	9
San Augustine	7	7	7
Shelby	1	1	1
Smith	119	119	120
Titus	11	11	16
Trinity	51	51	51
Upshur	77	77	81
Van Zandt	21	21	21
Wood	89	89	90
Overall	**56**	**56**	**61**

[1] Drawdown in feet from 2000 to 2070.
[2] For county average drawdown calculations negative drawdowns were set to zero, but not for overall Groundwater Management Area 11 drawdown average.

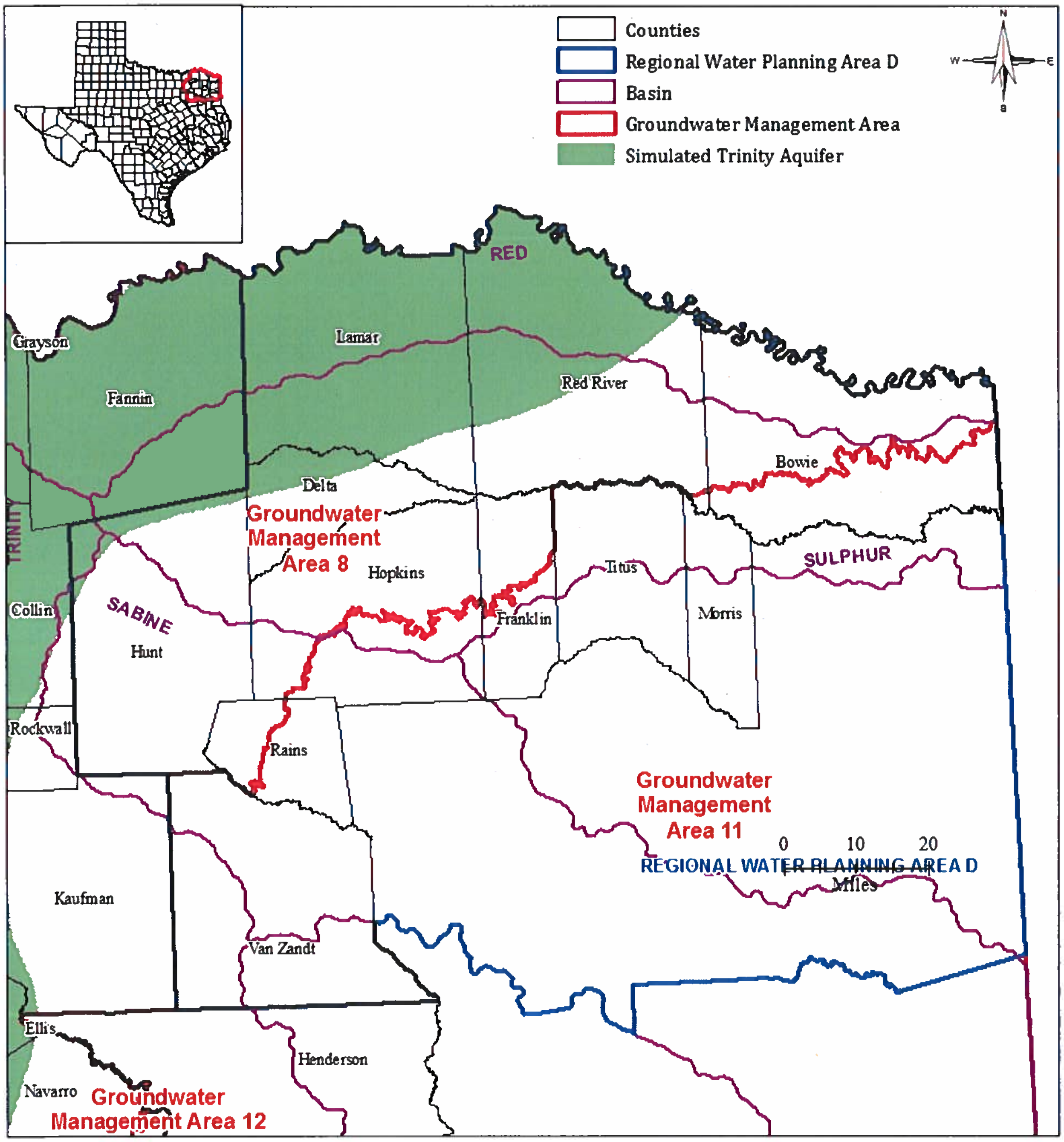

Figure 2 **Simulated Trinity Aquifer in Groundwater Availability Model for the Northern Portion of the Trinity Aquifer and Woodbine Aquifer in Region D.**

Table 5 Region D Requested Groundwater Availability Compared with Existing Available Groundwater and Re-Modeled Groundwater Availability for Trinity Aquifer.

Pumping Scenario	County	Delta	Hunt	Hunt	Hunt	Lamar	Lamar	Red River	Red River
	Basin / Year	Sulphur	Sabine	Sulphur	Trinity	Red	Sulphur	Red	Sulphur
Modeled Available Groundwater[1]	2020	56	0	3	0	0	8	52	125
	2030	56	0	3	0	0	8	52	125
	2040	56	0	3	0	0	8	52	125
	2050	56	0	3	0	0	8	52	125
	2060	56	0	3	0	0	8	52	125
	2070	56	0	3	0	0	8	52	125
Requested Groundwater Availability[2]	2020	71	19,262	2,428	124	1,888	443	207	2,451
	2030	71	19,262	2,428	124	1,888	443	207	2,451
	2040	71	19,262	2,428	124	1,888	443	207	2,451
	2050	71	19,262	2,428	124	1,888	443	207	2,451
	2060	71	19,262	2,428	124	1,888	443	207	2,451
	2070	71	19,262	2,428	124	1,888	443	207	2,451
Re-Modeled Groundwater Availability[3]	2020	71	19,315	2,434	125	1,894	444	208	2,457
	2030	71	19,261	2,428	125	1,888	443	208	2,451
	2040	71	19,315	2,434	125	1,894	444	208	2,457
	2050	71	19,261	2,428	125	1,888	443	208	2,451
	2060	71	19,315	2,434	125	1,894	444	208	2,457
	2070	71	19,261	2,428	125	1,888	443	208	2,451

1. Modeled Available Groundwater (Shi, 2018).
2. Requested Groundwater Availability data are from Region D.
3. Re-Modeled Groundwater Availability data are from model run based on Requested Groundwater Availability pumping data from Region D.

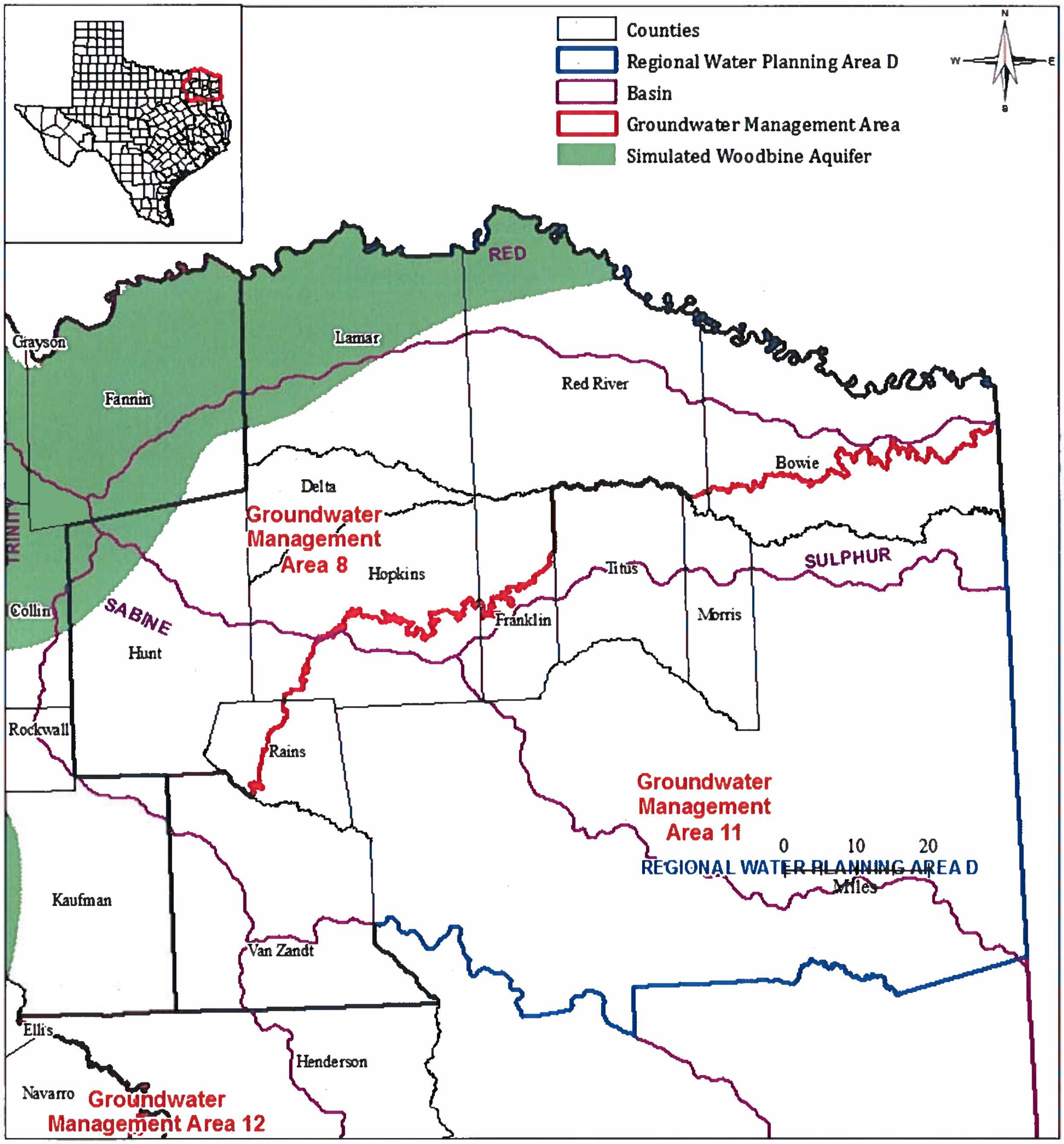

Figure 3 **Simulated Woodbine Aquifer in Groundwater Availability Model for the Northern Portion of the Trinity Aquifer and Woodbine Aquifer in Region D.**

Table 6 Region D Requested Groundwater Availability Compared with Existing Available Groundwater and Re-Modeled Groundwater Availability for Woodbine Aquifer.

Pumping Scenario	County	Hunt	Hunt	Lamar	Lamar	Red River
	Year \ Basin	Sabine	Sulphur	Red	Sulphur	Red
Modeled Available Groundwater[1]	2020	269	165	0	49	2
	2030	268	165	0	49	2
	2040	269	165	0	49	2
	2050	268	165	0	49	2
	2060	269	165	0	49	2
	2070	268	165	0	49	2
Requested Groundwater Availability[2]	2020	19,531	2,570	1,948	490	186
	2030	19,530	2,570	1,948	490	186
	2040	19,531	2,570	1,948	490	186
	2050	19,530	2,570	1,948	490	186
	2060	19,531	2,570	1,948	490	186
	2070	19,530	2,570	1,948	490	186
Re-Modeled Groundwater Availability[3]	2020	19,584	2,577	1,953	492	187
	2030	19,530	2,570	1,948	490	187
	2040	19,584	2,577	1,953	492	187
	2050	19,530	2,570	1,948	490	187
	2060	19,584	2,577	1,953	492	187
	2070	19,530	2,570	1,948	490	187

1. Modeled Available Groundwater (Shi, 2018).
2. Requested Groundwater Availability data are from Region D.
3. Re-Modeled Groundwater Availability data are from model run based on Requested Groundwater Availability pumping data from Region D.

Table 7 Comparison of Simulated Drawdowns by Model with Desired Future Conditions of Trinity And Woodbine Aquifers by Counties Not in Upper Trinity Groundwater Conservation District.

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
			Woodbine			
Bell	—	—	—	—	—	—
Bosque	—	—	—	—	—	—
Brown	—	—	—	—	—	—
Burnet	—	—	—	—	—	—
Callahan	—	—	—	—	—	—
Collin	459	459	977	518	113%	Yes
Comanche	—	—	—	—	—	—
Cooke	2	2	2	0	0%	No
Coryell	—	—	—	—	—	—
Dallas	123	123	282	159	129%	Yes
Delta	—	—	—	—	—	—
Denton	22	19	44	22	100%	Yes
Eastland	—	—	—	—	—	—
Ellis	61	61	112	51	84%	Yes
Erath	—	—	—	—	—	—
Falls	—	—	—	—	—	—
Fannin	247	247	644	397	161%	Yes
Grayson	160	157	272	112	70%	Yes
Hamilton	—	—	—	—	—	—
Hill	20	16	21	1	5%	No
Hunt	598	598	1,652	1,054	176%	Yes
Johnson	2	3	4	2	100%	No
Kaufman	208	208	500	292	140%	Yes
Lamar	38	38	266	228	600%	Yes
Lampasas	—	—	—	—	—	—
Limestone	—	—	—	—	—	—
McLennan	6	6	7	1	17%	No
Milam	—	—	—	—	—	—
Mills	—	—	—	—	—	—

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Navarro	92	92	125	33	36%	Yes
Red River	2	2	11	9	450%	Yes
Rockwall	243	243	744	501	206%	Yes
Somervell	—	—	—	—	—	—
Tarrant	7	6	7	0	0%	No
Taylor	—	—	—	—	—	—
Travis	—	—	—	—	—	—
Williamson	—	—	—	—	—	—
Paluxy						
Bell	19	19	19	0	0%	No
Bosque	6	6	7	1	17%	No
Brown	—	—	—	—	—	—
Burnet	—	—	—	—	—	—
Callahan	—	—	—	—	—	—
Collin	705	705	1,391	686	97%	Yes
Comanche	—	—	—	—	—	—
Cooke		—	—	—	—	—
Coryell	7	7	7	0	0%	No
Dallas	324	324	542	218	67%	Yes
Delta	264	264	854	590	223%	Yes
Denton	552	552	603	51	9%	Yes
Eastland	—	—	—	—	—	—
Ellis	107	107	215	108	101%	Yes
Erath	1	1	1	0	0%	No
Falls	144	144	150	6	4%	No
Fannin	688	688	1,811	1,123	163%	Yes
Grayson	922	922	1,712	790	86%	Yes
Hamilton	2	2	2	0	0%	No
Hill	38	38	51	13	34%	Yes
Hunt	586	586	2,199	1,613	275%	Yes
Johnson	-61	-61	-48	13	-21%	No
Kaufman	276	276	599	323	117%	Yes
Lamar	93	93	349	256	275%	Yes
Lampasas	—	—	—	—	—	—
Limestone	178	178	195	17	10%	Yes

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
McLennan	35	35	39	4	11%	No
Milam	—	—	—	—	—	—
Mills	1	1	1	0	0%	No
Navarro	119	119	175	56	47%	Yes
Red River	21	21	150	129	614%	Yes
Rockwall	401	401	981	580	145%	Yes
Somervell	1	1	1	0	0%	No
Tarrant	101	101	122	21	21%	Yes
Taylor	—	—	—	—	—	—
Travis	—	—	—	—	—	—
Williamson	—	—	—	—	—	—
Glen Rose						
Bell	83	83	85	2	2%	No
Bosque	49	49	53	4	8%	No
Brown	2	2	2	0	0%	No
Burnet	2	2	2	0	0%	No
Callahan	—	—	—	—	—	—
Collin	339	339	1,122	783	231%	Yes
Comanche	1	1	1	0	0%	No
Cooke	—	—	—	—	—	—
Coryell	14	14	15	1	7%	No
Dallas	263	263	551	288	110%	Yes
Delta	181	181	823	642	355%	Yes
Denton	349	349	551	202	58%	Yes
Eastland	—	—	—	—	—	—
Ellis	194	194	336	142	73%	Yes
Erath	5	5	5	0	0%	No
Falls	215	215	225	10	5%	No
Fannin	280	280	1,421	1,141	408%	Yes
Grayson	337	337	1,264	927	275%	Yes
Hamilton	4	4	4	0	0%	No
Hill	133	133	166	33	25%	Yes
Hunt	299	299	1,900	1,601	535%	Yes
Johnson	58	58	90	32	55%	Yes
Kaufman	269	269	607	338	126%	Yes

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Lamar	97	97	514	417	430%	Yes
Lampasas	1	1	1	0	0%	No
Limestone	271	271	305	34	13%	Yes
McLennan	133	133	146	13	10%	Yes
Milam	212	212	216	4	2%	No
Mills	1	1	1	0	0%	No
Navarro	232	232	337	105	45%	Yes
Red River	36	36	253	217	603%	Yes
Rockwall	311	311	925	614	197%	Yes
Somervell	4	4	4	0	0%	No
Tarrant	148	148	217	69	47%	Yes
Taylor	—	—	—	—	—	—
Travis	85	85	85	0	0%	No
Williamson	77	76	77	0	0%	No
Twin Mountains						
Bell	—	—	—	—	—	—
Bosque	—	—	—	—	—	—
Brown	—	—	—	—	—	—
Burnet	—	—	—	—	—	—
Callahan	—	—	—	—	—	—
Collin	526	526	1244	718	137%	Yes
Comanche	—	—	—	—	—	—
Cooke	—	—	—	—	—	—
Coryell	—	—	—	—	—	—
Dallas	463	463	823	360	78%	Yes
Delta	—	—	—	—	—	—
Denton	716	716	1,017	301	42%	Yes
Eastland	—	—	—	—	—	—
Ellis	333	333	511	178	53%	Yes
Erath	6	6	6	0	0%	No
Falls	—	—	—	—	—	—
Fannin	372	372	1,380	1,008	271%	Yes
Grayson	417	417	1,287	870	209%	Yes
Hamilton	—	—	—	—	—	—
Hill	—	—	—	—	—	—

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Hunt	370	370	1,509	1,139	308%	Yes
Johnson	156	156	199	43	28%	Yes
Kaufman	381	381	841	460	121%	Yes
Lamar	—	—	—	—	—	—
Lampasas	—	—	—	—	—	—
Limestone	—	—	—	—	—	—
McLennan	—	—	—	—	—	—
Milam	—	—	—	—	—	—
Mills	—	—	—	—	—	—
Navarro	—	—	—	—	—	—
Red River	—	—	—	—	—	—
Rockwall	426	426	1,036	610	143%	Yes
Somervell	31	31	34	3	10%	No
Tarrant	315	315	409	94	30%	Yes
Taylor	—	—	—	—	—	—
Travis	—	—	—	—	—	—
Williamson	—	—	—	—	—	—
Travis Peak						
Bell	300	294	297	-3	-1%	No
Bosque	167	167	178	11	7%	Yes
Brown	1	1	1	0	0%	No
Burnet	16	16	16	0	0%	No
Callahan	—	—	—	—	—	—
Collin	—	—	—	—	—	—
Comanche	2	2	2	0	0%	No
Cooke	—	—	—	—	—	—
Coryell	99	100	102	3	3%	No
Dallas	348	350	655	307	88%	Yes
Delta	186	186	822	636	342%	Yes
Denton	—	—	—	—	—	—
Eastland	—	—	—	—	—	—
Ellis	301	305	496	195	65%	Yes
Erath	19	19	19	0	0%	No
Falls	462	460	473	11	2%	No
Fannin	269	269	1,181	912	339%	Yes

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Grayson	—	—	—	—	—	—
Hamilton	24	24	25	1	4%	No
Hill	298	299	351	53	18%	Yes
Hunt	324	324	1,426	1,102	340%	Yes
Johnson	179	184	243	64	36%	Yes
Kaufman	323	323	672	349	108%	Yes
Lamar	114	114	549	435	382%	Yes
Lampasas	6	6	6	0	0%	No
Limestone	392	393	433	41	10%	Yes
McLennan	471	468	488	17	4%	No
Milam	345	344	348	3	1%	No
Mills	7	7	7	0	0%	No
Navarro	290	291	413	123	42%	Yes
Red River	51	51	301	250	490%	Yes
Rockwall	—	—	—	—	—	—
Somervell	51	52	57	6	12%	Yes
Tarrant	—	—	—	—	—	—
Taylor	—	—	—	—	—	—
Travis	141	142	143	2	1%	No
Williamson	173	172	173	0	0%	No
Hensell						
Bell	137	137	138	1	1%	No
Bosque	129	129	136	7	5%	Yes
Brown	1	1	1	0	0%	No
Burnet	7	7	7	0	0%	No
Callahan	—	—	—	—	—	—
Collin	—	—	—	—	—	—
Comanche	2	2	2	0	0%	No
Cooke		—	—	—	—	—
Coryell	66	66	67	1	2%	No
Dallas	332	332	599	267	80%	Yes
Delta	—	—	—	—	—	—
Denton	—	—	—	—	—	—
Eastland	—	—	—	—	—	—
Ellis	263	263	409	146	56%	Yes

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Erath	11	11	11	0	0%	No
Falls	271	271	280	9	3%	No
Fannin	—	—	—	—	—	—
Grayson	—	—	—	—	—	—
Hamilton	13	13	13	0	0%	No
Hill	186	186	217	31	17%	Yes
Hunt	—	—	—	—	—	—
Johnson	126	126	167	41	33%	Yes
Kaufman	309	309	590	281	91%	Yes
Lamar	—	—	—	—	—	—
Lampasas	1	1	1	0	0%	No
Limestone	183	183	212	29	16%	Yes
McLennan	220	220	234	14	6%	Yes
Milam	229	229	231	2	1%	No
Mills	2	2	2	0	0%	No
Navarro	254	254	350	96	38%	Yes
Red River	—	—	—	—	—	—
Rockwall	—	—	—	—	—	—
Somervell	26	26	29	3	12%	No
Tarrant	—	—	—	—	—	—
Taylor	—	—	—	—	—	—
Travis	50	51	51	1	2%	No
Williamson	74	73	73	-1	-1%	No
Hosston						
Bell	330	330	333	3	1%	No
Bosque	201	201	214	13	6%	Yes
Brown	1	1	1	0	0%	No
Burnet	20	20	20	0	0%	No
Callahan	—	—	—	—	—	—
Collin	—	—	—	—	—	—
Comanche	3	3	3	0	0%	No
Cooke	—	—	—	—	—	—
Coryell	130	130	133	3	2%	No
Dallas	351	351	665	314	89%	Yes
Delta	—	—	—	—	—	—

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Denton	—	—	—	—	—	—
Eastland	—	—	—	—	—	—
Ellis	310	310	509	199	64%	Yes
Erath	31	31	32	1	3%	No
Falls	465	465	478	13	3%	No
Fannin	—	—	—	—	—	—
Grayson	—	—	—	—	—	—
Hamilton	35	35	36	1	3%	No
Hill	337	337	396	59	18%	Yes
Hunt	—	—	—	—	—	—
Johnson	235	235	307	72	31%	Yes
Kaufman	295	295	584	289	98%	Yes
Lamar	—	—	—	—	—	—
Lampasas	11	11	11	0	0%	No
Limestone	404	404	445	41	10%	Yes
McLennan	542	542	564	22	4%	No
Milam	345	345	349	4	1%	No
Mills	13	13	13	0	0%	No
Navarro	291	291	415	124	43%	Yes
Red River	—	—	—	—	—	—
Rockwall	—	—	—	—	—	—
Somervell	83	83	91	8	10%	Yes
Tarrant	—	—	—	—	—	—
Taylor	—	—	—	—	—	—
Travis	146	148	148	2	1%	No
Williamson	177	176	177	0	0%	No
Antlers						
Bell	—	—	—	—	—	—
Bosque	—	—	—	—	—	—
Brown	2	2	2	0	0%	No
Burnet	—	—	—	—	—	—
Callahan	1	1	1	0	0%	No
Collin	570	570	1,046	476	84%	Yes
Comanche	9	9	9	0	0%	No
Cooke	176	179	236	60	34%	Yes

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Coryell	—	—	—	—	—	—
Dallas	—	—	—	—	—	—
Delta	—	—	—	—	—	—
Denton	395	398	527	132	33%	Yes
Eastland	3	3	3	0	0%	No
Ellis	—	—	—	—	—	—
Erath	12	11	11	-1	-8%	No
Falls	—	—	—	—	—	—
Fannin	251	251	910	659	263%	Yes
Grayson	348	348	678	330	95%	Yes
Hamilton	—	—	—	—	—	—
Hill	—	—	—	—	—	—
Hunt	—	—	—	—	—	—
Johnson	—	—	—	—	—	—
Kaufman	—	—	—	—	—	—
Lamar	122	122	517	395	324%	Yes
Lampasas	—	—	—	—	—	—
Limestone	—	—	—	—	—	—
McLennan	—	—	—	—	—	—
Milam	—	—	—	—	—	—
Mills	—	—	—	—	—	—
Navarro	—	—	—	—	—	—
Red River	13	13	84	71	546%	Yes
Rockwall	—	—	—	—	—	—
Somervell	—	—	—	—	—	—
Tarrant	148	149	171	23	16%	Yes
Taylor	0	0	0	0	0%	No
Travis	—	—	—	—	—	—
Williamson	—	—	—	—	—	—

1. Existing Drawdowns are from Shi (2018).
2. Values greater than five feet are highlighted.
3. Values greater than five percent are highlighted.
4. A desired future condition is violated only when drawdown change is greater than both five feet and five percent at the same time.

Table 8 Comparison of Simulated Drawdowns by Model with Desired Future Conditions of Trinity Aquifer by Counties in Upper Trinity Groundwater Conservation District.

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance?[4]
			Paluxy			
Hood (outcrop)	5	5	5	0	0%	No
Hood (downdip)	—	—	—	—	—	—
Montague (outcrop)	—	—	—	—	—	—
Montague (downdip)	—	—	—	—	—	—
Parker (outcrop)	5	5	5	0	0%	No
Parker (downdip)	1	1	1	0	0%	No
Wise (outcrop)	—	—	—	—	—	—
Wise (downdip)	—	—	—	—	—	—
			Glen Rose			
Hood (outcrop)	7	7	7	0	0%	No
Hood (downdip)	28	27	31	3	11%	No
Montague (outcrop)	—	—	—	—	—	—
Montague (downdip)	—	—	—	—	—	—
Parker (outcrop)	10	10	10	0	0%	No
Parker (downdip)	28	28	37	9	32%	Yes
Wise (outcrop)	—	—	—	—	—	—
Wise (downdip)	—	—	—	—	—	—
			Twin Mountains			
Hood (outcrop)	4	4	4	0	0%	No
Hood (downdip)	46	46	51	5	11%	No

County	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance?[4]
Montague (outcrop)	—	—	—	—	—	—
Montague (downdip)	—	—	—	—	—	—
Parker (outcrop)	1	1	1	0	0%	No
Parker (downdip)	46	46	63	17	37%	Yes
Wise (outcrop)	—	—	—	—	—	—
Wise (downdip)	—	—	—	—	—	—
Antlers						
Hood (outcrop)	—	—	—	—	—	—
Hood (downdip)	—	—	—	—	—	—
Montague (outcrop)	18	18	21	3	17%	No
Montague (downdip)	—	—	—	—	—	—
Parker (outcrop)	11	11	14	3	27%	No
Parker (downdip)	—	—	—	—	—	—
Wise (outcrop)	34	35	42	8	24%	Yes
Wise (downdip)	142	142	168	26	18%	Yes

1. Existing Drawdowns are from Shi (2018).
2. Values greater than five feet are highlighted.
3. Values greater than five percent are highlighted.
4. A desired future condition is violated only when drawdown change is greater than both five feet and five percent at the same time.

Table 9 **Comparison of Simulated Drawdowns by Model with Desired Future Conditions (DFCs)of Trinity and Woodbine Aquifers by Groundwater Conservation Districts (GCDs).**

Groundwater Conservation District	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment [2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Woodbine						
Central Texas GCD	—	—	—	—	—	—
Clear Water GCD	—	—	—	—	—	—
Middle Trinity GCD	—	—	—	—	—	—
North Texas GCD	278	251	534	256	92%	Yes
Northern Trinity GCD	7	6	7	0	0%	No
Post Oak Savanah GCD	—	—	—	—	—	—
Prairielands GCD	39	35	61	22	56%	Yes
Red River GCD	204	201	457	253	124%	Yes
Saratoga UWCD	—	—	—	—	—	—
Southern Trinity GCD	6	6	7	1	17%	No
Upper Trinity GCD (outcrop)	—	—	—	—	—	—
Upper Trinity GCD (subcrop)	—	—	—	—	—	—
Paluxy						
Central Texas GCD	—	—	—	—	—	—
Clear Water GCD	19	19	19	0	0%	No
Middle Trinity GCD	6	6	7	1	17%	No
North Texas GCD	671	671	1,213	542	81%	Yes
Northern Trinity GCD	101	101	122	21	21%	Yes
Post Oak Savanah GCD	—	—	—	—	—	—
Prairielands GCD	35	35	82	47	134%	Yes

Groundwater Conservation District	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment [2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Red River GCD	699	699	1,807	1,108	159%	Yes
Saratoga UWCD	—	—	—	—	—	No
Southern Trinity GCD	35	35	39	4	11%	No
Upper Trinity GCD (outcrop)	5	5	5	0	0%	No
Upper Trinity GCD (subcrop)	1	1	1	0	0%	No
Glen Rose						
Central Texas GCD	2	2	2	0	0%	No
Clear Water GCD	83	83	85	2	2%	No
Middle Trinity GCD	27	27	29	2	7%	No
North Texas GCD	341	341	993	652	191%	Yes
Northern Trinity GCD	148	148	217	69	47%	Yes
Post Oak Savanah GCD	212	212	216	4	2%	No
Prairielands GCD	126	126	193	67	53%	Yes
Red River GCD	283	283	1,414	1,131	400%	Yes
Saratoga UWCD	1	1	1	0	0%	No
Southern Trinity GCD	133	133	146	13	10%	Yes
Upper Trinity GCD (outcrop)	8	8	8	0	0%	No
Upper Trinity GCD (subcrop)	28	28	36	8	29%	Yes
Twin Mountains						
Central Texas GCD	—	—	—	—	—	—
Clear Water GCD	—	—	—	—	—	—
Middle Trinity GCD	6	6	6	0	0%	No
North Texas GCD	569	569	1,192	623	109%	Yes
Northern Trinity GCD	315	315	409	94	30%	Yes

Groundwater Conservation District	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment [2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Post Oak Savanah GCD	—	—	—	—	—	—
Prairielands GCD	142	142	183	41	29%	Yes
Red River GCD	377	377	1,369	992	263%	Yes
Saratoga UWCD	—	—	—	—	—	—
Southern Trinity GCD	—	—	—	—	—	—
Upper Trinity GCD (outcrop)	3	3	3	0	0%	—
Upper Trinity GCD (subcrop)	46	46	59	13	28%	Yes
Travis Peak						
Central Texas GCD	16	16	16	0	0%	—
Clear Water GCD	300	294	297	-3	-1%	—
Middle Trinity GCD	88	88	92	4	5%	—
North Texas GCD	—	—	—	—	—	—
Northern Trinity GCD	—	—	—	—	—	—
Post Oak Savanah GCD	345	344	348	3	1%	No
Prairielands GCD	258	261	360	102	40%	Yes
Red River GCD	269	269	1,181	912	339%	Yes
Saratoga UWCD	6	6	6	0	0%	No
Southern Trinity GCD	471	468	488	17	4%	No
Upper Trinity GCD (outcrop)	—	—	—	—	—	—
Upper Trinity GCD (subcrop)	—	—	—	—	—	—
Hensell						
Central Texas GCD	7	7	7	0	0%	No
Clear Water GCD	137	137	138	1	1%	No
Middle Trinity GCD	72	72	75	3	4%	No

Groundwater Conservation District	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
North Texas GCD	—	—	—	—	—	—
Northern Trinity GCD	—	—	—	—	—	—
Post Oak Savanah GCD	229	229	231	2	1%	No
Prairielands GCD	190	190	262	72	38%	Yes
Red River GCD	—	—	—	—	—	—
Saratoga UWCD	1	1	1	0	0%	No
Southern Trinity GCD	220	220	234	14	6%	Yes
Upper Trinity GCD (outcrop)	—	—	—	—	—	—
Upper Trinity GCD (subcrop)	—	—	—	—	—	—
Hosston						
Central Texas GCD	20	20	20	0	0%	No
Clear Water GCD	330	330	333	3	1%	No
Middle Trinity GCD	111	111	116	5	5%	No
North Texas GCD	—	—	—	—	—	—
Northern Trinity GCD	—	—	—	—	—	—
Post Oak Savanah GCD	345	345	349	4	1%	No
Prairielands GCD	289	290	398	109	38%	Yes
Red River GCD	—	—	—	—	—	—
Saratoga UWCD	11	11	11	0	0%	No
Southern Trinity GCD	542	542	564	22	4%	No
Upper Trinity GCD (outcrop)	—	—	—	—	—	—
Upper Trinity GCD (subcrop)	—	—	—	—	—	—
Antlers						
Central Texas GCD	—	—	—	—	—	—

Groundwater Conservation District	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment [2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Exceedance ?[4]
Clear Water GCD	—	—	—	—	—	—
Middle Trinity GCD	10	10	10	0	0%	No
North Texas GCD	290	293	403	113	39%	Yes
Northern Trinity GCD	148	149	171	23	16%	Yes
Post Oak Savanah GCD	—	—	—	—	—	—
Prairielands GCD	—	—	—	—	—	—
Red River GCD	304	304	782	478	157%	Yes
Saratoga UWCD	—	—	—	—	—	—
Southern Trinity GCD	—	—	—	—	—	—
Upper Trinity GCD (outcrop)	24	25	29	5	21%	No
Upper Trinity GCD (subcrop)	142	142	168	26	18%	Yes

1. Existing Drawdowns are from Shi (2018).
2. Values greater than five feet are highlighted.
3. Values greater than five percent are highlighted.
4. A desired future condition is violated only when drawdown change is greater than both five feet and five percent at the same time.

Table 10 Comparison of Simulated Drawdowns by Model with Desired Future Conditions of Trinity and Woodbine Aquifers by Groundwater Management Area 8.

Aquifer	Desired Future Conditions (DFCs, feet)	Existing Drawdowns[1] (feet)	Drawdowns after Region D Pumping Adjustment (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[2] (feet)	Drawdown Change from DFCs after Region D Pumping Adjustment[3] (%)	Does Region D Pumping Adjustment Cause DFCs Violation?[4]
Woodbine	146	136	316	170	117%	Yes
Paluxy	144	144	290	146	101%	Yes
Glen Rose	116	116	236	120	104%	Yes
Twin Mountain	313	313	575	262	84%	Yes
Travis Peak	177	177	246	69	39%	Yes
Hensell	118	118	139	21	18%	Yes
Hosston	206	206	235	29	14%	Yes
Antlers	177	177	350	173	98%	Yes

1. Existing Drawdowns are from Shi (2018).
2. Values greater than five feet are highlighted.
3. Values greater than five percent are highlighted.
4. A desired future condition is violated only when drawdown change is greater than both five feet and five percent at the same time.

Table 11 Optimal amount of groundwater available that meets desired future conditions with an error tolerance of five percent or five feet, whichever is greater, for the Trinity and Woodbine aquifers.

County	Aquifer	River Basin	Simulated Pumping in Region D in Acre-Feet Per Year (Total Pumping that is compatible with the modeled available groundwater)					
			2020	2030	2040	2050	2060	2070
Delta	Trinity	Sulphur	56	56	56	56	56	56
Hunt	Trinity	Sabine	213	213	213	213	213	213
Hunt	Woodbine	Sabine	344	343	344	343	344	343
Hunt	Trinity	Sulphur	3	3	3	3	3	3
Hunt	Woodbine	Sulphur	165	165	165	165	165	165
Hunt	Trinity	Trinity	0	0	0	0	0	0
Lamar	Trinity	Red	0	0	0	0	0	0
Lamar	Woodbine	Red	22	22	22	22	22	22
Lamar	Trinity	Sulphur	8	8	8	8	8	8
Lamar	Woodbine	Sulphur	62	62	62	62	62	62
Red River	Trinity	Red	52	52	52	52	52	52
Red River	Woodbine	Red	251	251	251	251	251	251
Red River	Trinity	Sulphur	234	233	234	233	234	233

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October 23, 2019

Mr. Ron Ellis
Texas Water Development Board
1700 North Congress Avenue
Austin, TX 78711-3231

Subject: Revised Request for Review of Groundwater Availability in Region D for Draft Recommended Water Management Strategies

Dear Mr. Ellis:

This memorandum is a follow-up to the original May 24, 2019 memorandum submitted on behalf of the North East Texas Regional Water Planning Group (NETRWPG / Region D) detailing the proposed methodology for determining groundwater availability in Region D, and the subsequent August 27, 2019 response to that memo provided by the Texas Water Development Board (TWDB) providing a technical review of that proposed methodology.

Objective

The objective of this memorandum is to specify the exact quantities that have been identified by Region D as being potentially available (pending TWDB approval) for use as a source for draft recommended water management strategies for water users with identified projected needs within Region D.

Background

As there are no groundwater conservation districts (GCDs) within Region D, the NETRWPG has wished to exercise the right to refine the groundwater availability estimates to determine if the Modeled Available Groundwater (MAG) volumes estimated by the TWDB are appropriate for the purposes of the 2021 Region D Water Plan. The first May 24, 2019 submittal on behalf of the NETRWPG identified two county-aquifer-basin locations recommended to be increased based on a local hydrogeologic assessment on available information, as well as provided estimates on maximum availability to be applied to identified needs for future water management strategies (WMSs). At that time, the evaluation of feasible WMSs was underway, but was not at a point where recommended and alternative WMSs had been identified, thus the use of estimated maximums by the NETRWPG at that time.

In response to that memorandum, the above referenced August 27, 2019, memorandum from TWDB was provided to the NETRWPG. The TWDB memorandum presented the TWDB's model-based review of the proposed availabilities to determine whether they are physically compatible with desired future conditions (DFCs) for relevant aquifers in GCDs in co-located groundwater management areas (GMAs). Alternative volumes proffered by TWDB as maximum availabilities for select county-aquifer-basins were then presented in the memorandum.

Status

The present work of the NETRWPG is in the development and identification of recommended and alternative water management strategies, which will be incorporated into the Initially Prepared Plan (IPP) to be submitted by March, 2020. As it is roughly five (5) months until the submittal of the IPP, the "recommended" and "alternative" strategies discussed herein represent the best available information at present as to the representation of these strategies for the purposes of the 2021 Region D Plan. It should be noted that these are thus draft representations of these strategies; however, as TWDB rules (357.32(d)(2)) require that TWDB review the proposed availabilities and determine whether they are physically compatible with the desired future conditions for relevant aquifers in GCDs in the co-located GMAs, this memo is submitted to initiate the final component of TWDB's review of groundwater availability for the North East Texas region.

Analysis

With the analyses of existing supplies in the region complete, and with draft recommended and alternative[1] water management strategies identified, the consultant team for the NETRWPG has performed a comparative analysis to identify the extent of availabilities identified as exceeding the MAGs and the TWDB's modeled maximum availabilities by county-aquifer-basin. Table 1 below presents the list of draft recommended and alternative WMSs that when compiled by similar county-aquifer-basin location may potentially exceed the present MAGs for the respective county-aquifer-basin. Presented in Table 2 are the individual sums of these strategies by county-aquifer-basin.

Using output from DB22, the NETRWPG has identified the remaining amount of MAG after accounting for allocations to existing WUG supplies, as shown in Table 3. These amounts, in effect, show how much MAG remains available for potential utilization as a source for potential WMSs.

Table 4 presents the results of a comparison between the recommended and alternative WMS amounts (by county-aquifer-basin as identified in Table 2) to the remaining MAGs after allocations have been made for existing supplies. The amounts presented in Table 4 represent the amounts (by county-aquifer-basin) in exceedance of the MAG. There are eight (8) county-aquifer-basins where the combined total recommended WMS amounts exceed the present MAG by a total amount of 6,453 ac-ft/yr in 2020 and 8,392 ac-ft/yr in 2070. The majority of these overages occurs in the portion of the Carrizo-Wilcox Aquifer-in the Sulphur River Basin in Hopkins County and the portion of the Nacatoch Aquifer in the Sulphur River Basin in Red River County. No overage occurs in the portion of the Queen City Aquifer in the Cypress River Basin in Camp County.

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[1] It is noted that TWDB's review is focused upon recommended WMSs and the associated availability amounts for such strategies. Alternative WMSs are identified herein for informational purposes only, as they represent the present draft status of potentially feasible strategies that at a later date may be considered/discussed. These Alternative WMSs are *not* requested for TWDB review and approval at this time.

Table 1 Draft Recommended and Alternative Water Management Strategies Potentially Exceeding MAG and Increased Availabilities Identified by TWDB (August 27, 2019 memorandum)

County	Entity	Recommendation (ac-ft/yr) by Decade						Strategy	Supply Source		
		2020	2030	2040	2050	2060	2070		Groundwater	County	Basin
CAMP	LIVESTOCK CAMP	3,962	3,962	3,962	3,962	3,962	3,962	DRILL NEW WELLS	QUEEN CITY AQUIFER	CAMP	CYPRESS
HOPKINS	IRRIGATION HOPKINS	4,627	4,627	4,516	4,240	4,052	3,696	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR
HOPKINS	LIVESTOCK HOPKINS	1,068	1,090	1,140	1,143	1,196	1,219	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR
HOPKINS	MILLER GROVE WSC	8	16	23	29	40	52	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR
HOPKINS	MINING HOPKINS	227	283	360	444	533	639	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR
HUNT	COMMERCE	0	0	22	377	856	1,561	DRILL NEW WELLS	NACATOCH AQUIFER	HUNT	SULPHUR
HUNT	HICKORY CREEK SUD	116	293	461	462	461	462	USE EXISTING WELL PRODUCTION CAPACITY BEYOND MAG	WOODBINE AQUIFER	HUNT	SULPHUR
HUNT	LIVESTOCK HUNT	2	2	2	2	2	2	DRILL NEW WELLS	TRINITY AQUIFER	HUNT	SABINE
HUNT	MINING HUNT	73	64	35	19	7	0	DRILL NEW WELLS	TRINITY AQUIFER	HUNT	SABINE
HUNT	WEST TAWAKONI	90	0	0	0	0	0	DRILL NEW WELLS	TRINITY AQUIFER	HUNT	SABINE
RED RIVER	IRRIGATION RED RIVER	2,057	2,057	2,057	2,057	2,057	2,057	DRILL NEW WELLS	NACATOCH AQUIFER	RED RIVER	SULPHUR
RED RIVER	IRRIGATION RED RIVER	185	185	185	185	185	185	DRILL NEW WELLS	TRINITY AQUIFER	RED RIVER	SULPHUR
RED RIVER	LIVESTOCK RED RIVER	174	173	174	173	174	173	DRILL NEW WELLS	TRINITY AQUIFER	RED RIVER	SULPHUR
TITUS	LIVESTOCK TITUS	275	334	379	425	517	560	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS

County	Entity	Recommendation (ac-ft/yr) by Decade						Strategy	Supply Source		
		2020	2030	2040	2050	2060	2070		Groundwater	County	Basin
VAN ZANDT	CANTON	100	100	100	100	100	100	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE
VAN ZANDT	SOUTH TAWAKONI WSC	38	0	0	0	0	0	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE
ALTERNATIVE WMS											
WOOD	COUNTY-OTHER, WOOD	8,716	9,751	10,285	14,121	20,856	32,060		CARRIZO-WILCOX AQUIFER	WOOD	SABINE
HOPKINS	BRINKER WSC	0	0	0	12	47	83	DRILL NEW WELLS	CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR

Table 2 Sum of WMS Amounts by County-Aquifer-Basin

Source Name	Source County	Source Basin	DRAFT WMS SUPPLY (AC-FT/YR)					
			2020	2030	2040	2050	2060	2070
RECOMMENDED WMSs								
QUEEN CITY AQUIFER	CAMP	CYPRESS	3,962	3,962	3,962	3,962	3,962	3,962
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	5,930	6,016	6,039	5,856	5,821	5,606
NACATOCH	HUNT	SULPHUR	0	0	22	377	856	1,561
WOODBINE	HUNT	SULPHUR	116	293	461	462	461	462
TRINITY AQUIFER	HUNT	SABINE	165	66	37	21	9	2
NACATOCH	RED RIVER	SULPHUR	2,057	2,057	2,057	2,057	2,057	2,057
TRINITY AQUIFER	RED RIVER	SULPHUR	359	358	359	358	359	358
CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS	275	334	379	425	517	560
CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE	138	100	100	100	100	100
ALTERNATIVE WMSs								
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	5,930	6,016	6,039	5,868	5,868	5,689
CARRIZO-WILCOX AQUIFER	WOOD	SABINE	8,716	9,751	10,285	14,121	20,856	32,060

Table 3 Modeled Available Groundwater Remaining after Allocation to Existing Supplies

Source Name	Source County	Source Basin	MAG REMAINING AFTER EXISTING SUPPLY ALLOCATIONS (AC-FT/YR)					
			2020	2030	2040	2050	2060	2070
RECOMMENDED WMSs								
QUEEN CITY AQUIFER	CAMP	CYPRESS	4,170	4,170	4,014	4,014	4,014	4,014
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	2,048	2,048	2,048	2,048	2,048	2,048
NACATOCH	HUNT	SULPHUR	0	0	0	0	0	0
WOODBINE	HUNT	SULPHUR	20	20	20	20	20	20
TRINITY AQUIFER	HUNT	SABINE	0	0	0	0	0	0
NACATOCH	RED RIVER	SULPHUR	179	180	181	181	181	181
TRINITY AQUIFER	RED RIVER	SULPHUR	65	65	65	65	65	65
CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS	1,587	878	239	0	0	0
CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE	0	0	0	0	0	0
ALTERNATIVE WMSs								
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	2,048	2,048	2,048	2,048	2,048	2,048
CARRIZO-WILCOX AQUIFER	WOOD	SABINE	5,583	5,495	5,397	5,340	5,266	5,164

Table 4 Total WMS Amount over MAG by County-Aquifer-Basin

Source Name	Source County	Source Basin	TOTAL AMOUNT RECOMMENDED OVER MAG (AC-FT/YR)					
			2020	2030	2040	2050	2060	2070
RECOMMENDED WMSs								
QUEEN CITY AQUIFER	CAMP	CYPRESS	0	0	0	0	0	0
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	3,882	3,968	3,991	3,808	3,773	3,558
NACATOCH	HUNT	SULPHUR	0	0	22	377	856	1,561
WOODBINE	HUNT	SULPHUR	96	273	441	442	441	442
TRINITY AQUIFER	HUNT	SABINE	165	66	37	21	9	2
NACATOCH	RED RIVER	SULPHUR	1,878	1,877	1,876	1,876	1,876	1,876
TRINITY AQUIFER	RED RIVER	SULPHUR	294	293	294	293	294	293
CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS	0	0	140	425	517	560
CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE	138	100	100	100	100	100
		TOTAL	**6,453**	**6,577**	**6,901**	**7,342**	**7,866**	**8,392**
ALTERNATIVE WMSs								
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	3,882	3,968	3,991	3,820	3,820	3,641
CARRIZO-WILCOX AQUIFER	WOOD	SABINE	3,133	4,256	4,888	8,781	15,590	26,896

Although the amounts above exceed the MAG, it is again noted that the TWDB's August 27, 2019 memorandum presents alternative volumes as maximum availabilities for select county-aquifer-basins that remain physically compatible with DFCs for relevant aquifers in GCDs in co-located GMAs. These maximums identified by TWDB, in a number of instances, represent an increase in modeled availability that achieves these objectives. These increases above the MAG identified by TWDB are presented in Table 5.

Table 5 Increase in Modeled Availability above MAG Identified by TWDB (August 27, 2019 Memorandum)

Source Name	Source County	Source Basin	TOTAL AMOUNT RECOMMENDED OVER MAG (AC-FT/YR)					
			2020	2030	2040	2050	2060	2070
RECOMMENDED WMSs								
QUEEN CITY AQUIFER	CAMP	CYPRESS	0	0	0	0	0	0
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	3,991	3,991	3,991	3,820	3,820	3,670
NACATOCH	HUNT	SULPHUR	0	0	0	0	0	0
WOODBINE	HUNT	SULPHUR	0	0	0	0	0	0
TRINITY AQUIFER	HUNT	SABINE	213	213	213	213	213	213
NACATOCH	RED RIVER	SULPHUR	0	0	0	0	0	0
TRINITY AQUIFER	RED RIVER	SULPHUR	109	108	109	108	109	108
CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS	2,019	1,952	2,055	1,967	1,825	1,860
CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE	139	139	134	131	131	128
ALTERNATIVE WMSs								
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	3,991	3,991	3,991	3,820	3,820	3,670
CARRIZO-WILCOX AQUIFER	WOOD	SABINE	0	0	0	0	0	0

Results of a comparison between the WMS amounts exceeding the MAG (by county-aquifer-basin as shown in Table 4) to the increases in availabilities identified by the TWDB (as shown in Table 5) are shown in Table 6, which depicts the WMS amounts in excess of the increased availabilities identified by TWDB by county-aquifer-basin.

Table 6 WMS Amounts above Increased Availabilities Identified by TWDB

Source Name	Source County	Source Basin	EXCEEDANCE OF WMS ABOVE ADDITIONAL AVAILABILITY IDENTIFIED BY TWDB (AC-FT/YR)					
			2020	2030	2040	2050	2060	2070
RECOMMENDED WMSs								
QUEEN CITY AQUIFER	CAMP	CYPRESS	0	0	0	0	0	0
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	0	0	0	0	0	0
NACATOCH	**HUNT**	**SULPHUR**	**0**	**0**	**22**	**377**	**856**	**1,561**
WOODBINE	**HUNT**	**SULPHUR**	**96**	**273**	**441**	**442**	**441**	**442**
TRINITY AQUIFER	HUNT	SABINE	0	0	0	0	0	0
NACATOCH	**RED RIVER**	**SULPHUR**	**1,878**	**1,877**	**1,876**	**1,876**	**1,876**	**1,876**
TRINITY AQUIFER	**RED RIVER**	**SULPHUR**	**185**	**185**	**185**	**185**	**185**	**185**
CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS	0	0	0	0	0	0
CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE	0	0	0	0	0	0
ALTERNATIVE WMSs								
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	0	0	0	0	0	0
CARRIZO-WILCOX AQUIFER	WOOD	SABINE	3,133	4,256	4,888	8,781	15,590	26,896

Based on the results shown in Table 6, there are four (4) county-aquifer-basins (shown in bold) where the draft recommended strategies exceed the total groundwater availability identified by the MAG when incorporating the additional amounts identified by TWDB in its' August 27, 2019 memorandum. The totals (by county-aquifer-basin) of the remaining recommended strategies (non-bold) are within the total amounts of available groundwater supply when reflecting both the MAGs plus the additional amounts identified by TWDB. Thus, the recommended strategies within the non-bold county-aquifer-basins shown in Table 6 are physically compatible with the DFCs for relevant aquifers in GCDs in the co-located GMAs.

The aforementioned analyses performed on behalf of the NETRWPG identifies eight (8) county-aquifer-basins wherein the total recommended WMSs exceed the present respective MAGs (Table 4). When the additional amounts identified by TWDB's analysis from its' August 27, 2019, memorandum are included in the comparison, the total amounts for recommended WMSs exceed the total available groundwater in four (4) county-aquifer-basins (Table 6).

Focusing upon the identified WMSs in Table 1, it is thus noted that the Camp County Livestock WMS (located in the Queen City Aquifer, Camp County, Cypress Creek Basin) is found to be within the MAG, which necessitates no further review. For the remaining strategies identified in Table 1 that are located in the below county-aquifer-basins, these WMSs are found to be within the total available groundwater supply when considering both the MAG and the additional availability identified by TWDB in its' August 27, 2019, memorandum:

1. Hopkins County, Carrizo-Wilcox Aquifer, Sulphur River Basin.
2. Hunt County, Trinity Aquifer, Sabine River Basin.
3. Titus County, Carrizo-Wilcox Aquifer, Cypress Creek River Basin.
4. Van Zandt County, Carrizo-Wilcox Aquifer, Sabine River Basin.

Based on the analyses by TWDB and the evaluation documented herein, the WMSs identified in Table 1 located in the above enumerated county-aquifer-basins are physically compatible with the DFCs for relevant aquifers in GCDs in the co-located GMAs. If necessary, the amounts for these enumerated county-aquifer-basins that are above the MAG (as identified in Table 4) can be interpreted as being part of the requested review and approval to the TWDB from the NETRWPG, although it is noted that these results are within the amounts previously identified by TWDB.

There are four (4) remaining instances where recommended WMSs have amounts that exceed the total available groundwater when adding the MAGs with the additional availabilities identified by TWDB. Those four recommended WMSs are shown in Table 7 below by county-aquifer-basin, along with their respective amounts in exceedance of the total available groundwater. Note that the amounts shown in Table 7 are exceedances, and do not represent the total amount of the recommended WMS (which can be found in Table 1). A portion of the Hickory Creek SUD's recommended WMS is met by the existing MAG in Hunt County, Woodbine Aquifer, Sulphur Basin. Similarly, a portion of the Red River County Irrigation recommended WMS for the Sulphur River Basin is met by the existing MAG for the Red River County, Nacatoch Aquifer, Sulphur River Basin. Portions of the recommended amount for Red River County Irrigation in the Sulphur River Basin are met by both the remaining MAG for the Red River County, Trinity Aquifer, Sulphur River Basin, as well as additional availability amounts identified by the TWDB for that county-aquifer-basin.

A local hydrogeologic assessment of the available information base has been performed by the Region D consultant team (attached hereto). The results of this assessment applicable to the four county-aquifer-basins are summarized in the notes in Table 7.

Table 7 Recommended WMS Amounts in Exceedance of the MAG and the Additional Availability Identified by TWDB

WUG	County	Aquifer	Basin	Recommended Amount in Exceedance[2] of Additional Availability identified by TWDB (ac-ft/yr)						NOTE
				2020	2030	2040	2050	2060	2070	
COMMERCE	HUNT	NACATOCH	SULPHUR	0	0	22	377	856	1,561	Past maximum historic pumping exceeds the identified 2070 needs
HICKORY CREEK SUD	HUNT	WOODBINE	SULPHUR	96	273	441	442	441	442	Use of full production capacity from existing system
IRRIGATION_ RED RIVER_ SULPHUR	RED RIVER	NACATOCH	SULPHUR	1,878	1,877	1,876	1,876	1,876	1,876	Based on a relatively low average annual water level decline and the potential for high-productivity wells in the portion of the Nacatoch Aquifer located in the Sulphur River Basin in Red River County, it has been determined that the future projected needs can likely be met with additional irrigation wells.
IRRIGATION_ RED RIVER_ SULPHUR	RED RIVER	TRINITY	SULPHUR	185	185	185	185	185	185	Assessment did not identify sufficient available data to determine potential productivity; however, since there is little to no current production from this portion of the Trinity Aquifer, it has been determined that sufficient source availability is likely to meet the projected needs

[22] Remaining portion of recommended amount is within the total available amount identified by the MAG in addition to the available amount identified by TWDB in its' August 27, 2019 memorandum.

Request for TWDB Review

The amounts presented in Table 7, along with the supporting documentation, are recommended for the TWDB's review and possible approval to be used in addition to the additional amounts identified by the TWDB in its August 27 2019 memorandum. If approval is necessary for all amounts above the MAG, Table 4 represents the total amount of recommended WMS availability identified above the MAG by county-aquifer-basin for TWDB review.

The NETRWPG and its' consultant team appreciate the TWDB's efforts in support of these analyses, as they represent the first attempt at a Regional Water Planning Group identifying groundwater availability for planning purposes since there are no GCDs located within the region. It is the intent of this memorandum to document milestones of significance to the process as they have occurred to date, in the hope that such documentation will assist in refining the process for future rounds of planning.

If there are any questions whatsoever, please feel free to contact us at your convenience. We truly appreciate the opportunity to work with you and your staff on the planning process.

Sincerely,

CAROLLO ENGINEERS, INC.

Tony L. Smith, P.E.
Associate Vice President
Water Resources

TLS:ckt

Enclosures: WSP Local Hydrogeological Assessment

cc: Mr. Walt Sears
Mr. James Beach
Mr. David K. Harkins

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November 1, 2019

Mr. Ron Ellis
Texas Water Development Board
1700 North Congress Avenue
Austin, TX 78711-3231

Subject: Addendum to Revised Request of Groundwater Availability in Region D for Draft Recommended Water Management Strategies

Dear Mr. Ellis:

This is an addendum to the October 23, 2019 memorandum submitted on behalf of the North East Texas Regional Water Planning Group (NETRWPG / Region D) regarding Groundwater Availability in Region D for Draft Water Management Strategies.

The attached table reflects the original Modeled Available Groundwater (MAG) amounts, total groundwater availabilities identified by TWDB that are physically compatible with desired future conditions for aquifers in GCDs in co-located groundwater management areas, and lastly the total groundwater availability identified by Region D for the specific aquifer, county and basin splits requested for review and approval by the TWDB. There are a total of nine splits with amounts identified above their current respective MAGs. Of these, there are five (5) splits that are higher than the availabilities identified in the August 27, 2019, memorandum from TWDB provided to the NETRWPG; however, two of these splits are within the Nacatoch Aquifer, a non-relevant aquifer for the purposes of regional water planning. Thus, there are three (3) identified splits remaining that are in relevant aquifers that exceed the availabilities identified by TWDB in its' August 27, 2019, memorandum, namely:

1. Woodbine Aquifer, Lamar County, Red River Basin;
2. Woodbine Aquifer, Hunt County, Sulphur River Basin; and
3. Trinity Aquifer, Red River County, Sulphur River Basin.

The supporting documentation for the Woodbine Aquifer, Lamar County, Red River Basin split's availability (i.e. No. 1 above), was submitted as part of the original May 24, 2019, memorandum submitted on behalf of the NETRWPG to Region D. Supporting documentation for the remaining splits was submitted in the revised request submitted in the NETRWPG's October 23, 2019, memorandum and supporting documentation.

We appreciate your staff's input in presenting this request in a manner that best facilitates TWDB's review of the groundwater availabilities identified herein. If there is anything we can do to assist further, please feel free to contact me at your convenience.

Sincerely,

Tony L. Smith, P.E.
Associate Vice President

TLS
Enclosures: Attached Table

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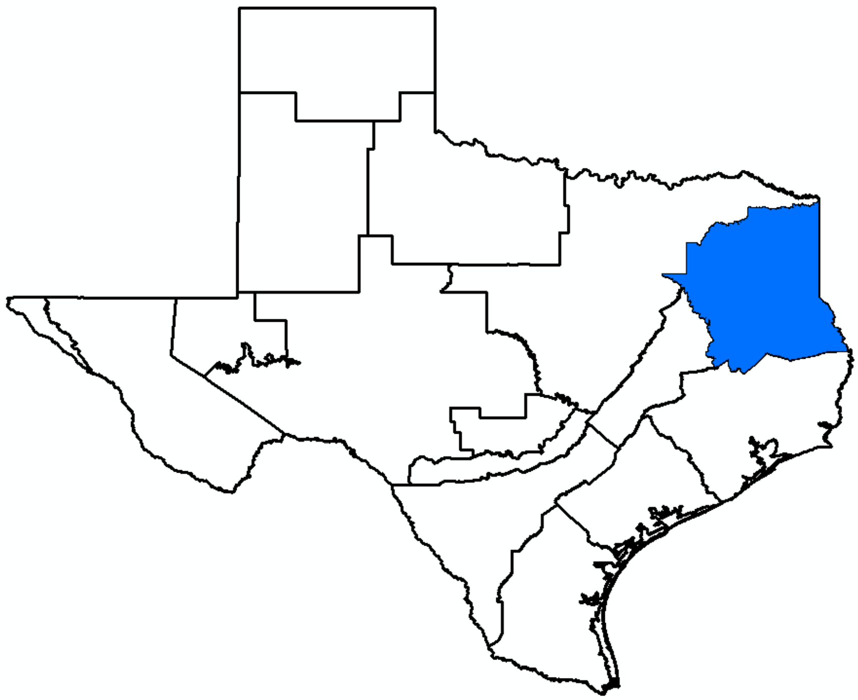
Summary of Groundwater Availabilities

Source Name	Source County	Source Basin	Original Modeled Available Groundwater (MAG)						Total Availability Identified from August 27, 2019, TWDB Review						Groundwater Source Availability Requested by Region D for Review by the TWDB					
			2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
WOODBINE	LAMAR	RED	0	0	0	0	0	0	22	22	22	22	22	22	60	60	60	60	60	60
CARRIZO-WILCOX AQUIFER	HOPKINS	SULPHUR	3,237	3,237	3,237	3,237	3,237	3,237	7,228	7,228	7,228	7,057	7,057	6,907	7,119	7,205	7,228	7,045	7,010	6,795
NACATOCH	HUNT	SULPHUR	491	491	491	491	491	491	491	491	491	491	491	491	491	491	513	868	1,347	2,052
WOODBINE	HUNT	SULPHUR	165	165	165	165	165	165	165	165	165	165	165	165	261	438	606	607	606	607
TRINITY AQUIFER	HUNT	SABINE	0	0	0	0	0	0	213	213	213	213	213	213	165	66	37	21	9	2
NACATOCH	RED RIVER	SULPHUR	1,047	1,047	1,047	1,047	1,047	1,047	1,047	1,047	1,047	1,047	1,047	1,047	2,925	2,924	2,923	2,923	2,923	2,923
TRINITY AQUIFER	RED RIVER	SULPHUR	125	125	125	125	125	125	234	233	234	233	234	233	419	418	419	418	419	418
CARRIZO-WILCOX AQUIFER	TITUS	CYPRESS	7,215	7,064	6,834	6,786	6,735	6,634	9,234	9,016	8,889	8,753	8,560	8,494	7,215	7,064	6,974	7,211	7,252	7,194
CARRIZO-WILCOX AQUIFER	VAN ZANDT	SABINE	4,629	4,629	4,456	4,397	4,397	4,270	4,768	4,768	4,590	4,528	4,528	4,398	4,767	4,729	4,556	4,497	4,497	4,370

Attachment 2

GMA 11 Technical Memorandum 20-05
Draft 1

Base Simulation for Joint Planning with Updated Groundwater Availability Model for the Sparta, Queen City, and Carrizo-Wilcox Aquifers



Prepared for:
Groundwater Management Area 11

Prepared by:
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December 30, 2020

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Appendices

1.0 Introduction and Background

1.1 Updated Groundwater Availability Model

Panday and others (2020) completed an update of the Groundwater Availability Model that corrected some of the identified limitations of the previous Groundwater Availability Model identified in Hutchison (2017a, 2017b, and 2017c). Of note is that the updated model does not result in rising groundwater levels due to a combination of recharge conceptualization problems and restrictions to the movement of groundwater from outcrop areas to downdip areas. The improvements were documented in example predictive runs of the updated Groundwater Availability Model documented in appendices in Panday and others (2020).

The final version of the updated Groundwater Availability Model was delivered to the Texas Water Development Board on December 11, 2020. The simulation described in this draft Technical Memorandum uses the delivered version of the updated Groundwater Availability Model, which differs slightly from the version used in Hutchison (2017a, 2017b, and 2017c). These differences are mostly with aquifer hydraulic conductivity values.

1.2 Updated Regional Water Plan Groundwater Availability

Technical Memorandum 20-03 documented the groundwater availability values developed by Region D and Region I that are comparable to the modeled available groundwater values from the 2016 round of joint planning by Groundwater Management Area 11. Most of the modeled available groundwater values for county-river basin units are the same as the groundwater availability values in the regional plans. This base simulation uses the regional water plans availability numbers as the basis for future pumping assumptions.

2.0 Model Files

2.1 Files Unchanged from Final Calibrated Model

Files that contain model input parameters related to the model grid and aquifer parameters were the same files used in the final calibrated model. Names of the files used in the base simulation are shown in Table 1.

Table 1. Predictive Simulation Files Unchanged from Final Calibrated Model

File Name	Description
pred.dis	Spatial discretization
pred.ims	Solver parameters
pred.npf	Node property flow (aquifer parameters)
tr58-g_final_model_gwv_L2top_newK._kx	Horizontal hydraulic conductivity
tr58-g_final_model_gwv_L2top_newK._kz	Vertical hydraulic conductivity
tr58-g_final_model_gwv_L2top_newK._ss	Specific storage
tr58-g_final_model_gwv_L2top_newK._sy	Specific yield

2.2 Files for Control of Simulation (NAM and OC6 Packages)

The NAM files were updated with the new names of the simulation files (*mfsim.nam* and *predbase.nam*). The output control file (*predbase.*oc6) was updated to reflect additional stress periods as documented below.

2.3 Time Discretization and Storage (TDIS and STO Packages)

The predictive simulation was run for the period 2014 to 2080, a total of 67 annual stress periods. The TDIS file from the final calibrated model was modified to reflect 67 annual stress periods and named *pred.tdis.* Initially, the simulation was specified with a single time step in each stress period. This caused numerical problems and resulted in non-convergence of the solution. Through trial and error, the final number of time steps that resulted in solution convergence with a reasonable run time (about 40 minutes) using a TSMULT value of 1.2 were:

- Stress Period 1: 10 time steps
- Stress Period 2: 5 time steps
- Stress Period 3: 3 time steps
- Stress Period 4: 2 time steps
- Stress Periods 5 to 67: 1 time step

The final calibrated model for storage was modified to reflect the change in the number of stress periods (all transient) and renamed *pred.sto*.

2.4 Initial Conditions (IC6 Package)

The initial conditions file was renamed and updated (*pred.ic6*). The update was open and close a file of 2013 heads that were extracted from the final calibrated model with the FORTRAN pre-processor *geteoy2013.exe*. The source code for the pre-processor is presented in Appendix A.

2.5 Simulated Pumping (WEL Package)

The simulated pumping for the base predictive scenario is based on the regional planning groups groundwater availability values as documented in Technical Memorandum 20-03 and the calculated factors that convert 2011 pumping from the final calibrated model as documented in Technical Memorandum 20-04. The FORTRAN pre-processor *makebasewel.exe* was written to develop the input file. The source code for the pre-processor is presented in Appendix B.

The pre-processor:

- Reads the updated grid file (documented in Technical Memorandum 20-01)
- Reads the pumping factor file (documented in Technical Memorandum 20-04)
- Reads the text header and footer of the final calibrated model WEL file (12 lines)
- Reads the historic pumping from 2011 (documented in Technical Memorandum 20-04)
- Calculates the base predictive scenario pumping using the factors for county-river basin units
- Writes updated pumping values for each location
- Adds pumping in the eight cells in San Augustine County-Sabine River Basin unit (note that the regional planning group listed 3 AF/yr in this unit while the final calibrated model had no wells in this unit)
- Writes the final footer line of text

Please note that all areas outside of Groundwater Management Area 11 and all areas in Groundwater Management Area 11 outside of Regions D and I were assigned a factor of one (i.e. pumping in 2011 was assumed for all future pumping without change).

2.6 Evapotranspiration (EVT Package)

The evapotranspiration file from the calibrated model was modified to include only the initial steady-state period for all stress periods in the predictive simulation. Inspection of the final calibrated model input file shows that the same evapotranspiration parameters were used for each stress period of the calibrated model (1980 to 2013). The modified file was named *pred.evt*.

2.7 General Head Boundaries (GHB Package)

General head boundaries were implemented in the calibrated model to simulate the effects of overlying formations that are not formally part of the model domain. The general head boundary file from the calibrated model was modified to include only the initial steady-state stress period for all stress periods in the predictive scenario. Inspection of the calibrated model input file shows that the same general head boundary parameters are used in each stress period of the calibration period (1980 to 2013). The modified file was named *pred.ghb*.

2.8 Recharge (RCH Package)

The recharge input file of the calibrated model contains the cell-by-cell recharge amounts for each stress period of the calibrated model (1980 to 2013). Recharge was implemented by defining a steady-state recharge (applied to stress period 1) and applying a stress period-specific factor to increase or decrease the recharge for each stress period. The first stress period of recharge was extracted and used for all stress periods in the predictive simulation. The modified recharge file was named *pred.rch.*

2.9 River (RIV Package)

The calibrated model simulated surface water-groundwater interactions with the River (RIV) package. Inspection of the input file yielded the conclusion that RIV head values changed slightly for each stress period. River conductance and bottom elevations remained the same in all stress periods. The calibrated model first stress period input data was extracted and used for all stress periods in the predictive simulation. The modified file was named *pred.riv*.

3.0 Results

3.1 Pumping

One of the features of MODFLOW 6 is the ability to dynamically reduce pumping during a simulation if the saturated thickness decreases to the point that the input pumping rate for a well cannot be sustained. This contrasts with older versions of MODFLOW where a cell would go dry and pumping would be reduced to zero for the remainder of the simulation.

As described above, the input pumping was specified to equal the groundwater availability values developed by Region D and Region I, which were based, in part, on the results of the old GAM and the modeled available groundwater based on simulations with the old GAM. However, as noted earlier, the groundwater conservation districts in Groundwater Management Area 11 had identified limitations of the previous Groundwater Availability Model (Hutchison, 2017a, 2017b, and 2017c). Of note is that the old GAM exhibited rising groundwater levels due to a combination of recharge conceptualization problems and restrictions to the movement of groundwater from outcrop areas to downdip areas.

The output pumping from the simulation was extracted from the cell-by-cell output file using the FORTRAN post-processor *getpump.exe*. The source code for the post-processor is presented in Appendix C.

The post-processor:

- Reads the updated grid file
- Reads the number of time steps in each stress period
- Reads a list of 70 county-river basin units with codes
- Reads the final calibration cbb file
- Convert pumping from cubic feet per day to acre-feet per year
- Incrementally add acre-feet per year values if final time step to aquifer pumping totals
- Writes pumping total summary files for each county-river basin unit

The output pumping was organized into county-river basin units for comparison with the regional water plan availability values used as input. Table 2 presents the results for the Sparta Aquifer. Table 3 presents the results for the Queen City Aquifer. Table 4 presents the results for the Carrizo-Wilcox Aquifer.

Table 2. Output Pumping Summary - Sparta Aquifer

County	River Basin	2011 Pumping (AF/yr)	GW Availability (AF/yr)	2014 Simulated Pumping (AF/yr)	2080 Simulated Pumping (AF/yr)
Anderson	Neches	14	344	223	149
Anderson	Trinity	32	272	222	198
Angelina	Neches	331	371	371	371
Cherokee	Neches	228	359	359	359
Houston	Neches	225	477	477	477
Houston	Trinity	560	977	973	973
Nacogdoches	Neches	266	365	365	365
Sabine	Sabine	648	160	11	11
Sabine	Neches	12	37	37	37
San Augustine	Sabine	0	3	3	3
San Augustine	Neches	23	163	164	164
Trinity	Neches	19	154	153	153
Total		**2,358**	**3,682**	**3,358**	**3,260**

Table 3. Output Pumping Summary - Queen City Aquifer

County	River Basin	2011 Pumping (AF/yr)	GW Availability (AF/yr)	2014 Simulated Pumping (AF/yr)	2080 Simulated Pumping (AF/yr)
Anderson	Neches	423	11,828	11,724	11,430
Anderson	Trinity	303	7,274	6,533	5,514
Angelina	Neches	96	1,093	1,094	1,094
Camp	Cypress	58	4,306	1,704	1,637
Cass	Sulphur	150	3,010	737	635
Cass	Cypress	449	35,499	20,767	15,935
Cherokee	Neches	1,094	23,211	10,555	8,975
Gregg	Cypress	41	1,359	973	495
Gregg	Sabine	187	5,625	3,062	2,005
Harrison	Cypress	216	7,762	4,775	3,099
Harrison	Sabine	180	2,310	634	543
Henderson	Neches	602	12,067	11,128	10,629
Henderson	Trinity	159	0	159	158
Houston	Neches	63	2,043	2,046	2,046
Houston	Trinity	186	258	214	214
Marion	Cypress	172	15,407	8,466	7,453
Morris	Cypress	119	9,469	4,487	3,433
Nacogdoches	Neches	329	2,985	2,969	2,958
Rusk	Sabine	11	18	15	15
Rusk	Neches	15	40	40	39
Smith	Sabine	333	28,343	24,421	13,016
Smith	Neches	890	30,692	29,605	20,528
Titus	Cypress	1	144	65	60
Upshur	Cypress	829	19,642	7,572	6,447
Upshur	Sabine	614	7,749	6,252	6,013
Van Zandt	Neches	266	4,791	3,555	2,475
Wood	Cypress	102	986	869	815
Wood	Sabine	1,710	9,060	6,138	5,818
Total		**9,598**	**246,971**	**170,559**	**133,479**

Table 4. Output Pumping Summary - Carrizo-Wilcox Aquifer

County	River Basin	2011 Pumping (AF/yr)	GW Availability (AF/yr)	2014 Simulated Pumping (AF/yr)	2080 Simulated Pumping (AF/yr)
Anderson	Neches	2,143	23,335	23,303	21,979
Anderson	Trinity	3,479	5,753	5,354	5,067
Angelina	Neches	25,214	27,591	27,592	27,592
Bowie	Sulphur	3,230	9,872	9,668	9,662
Camp	Cypress	1,323	4,050	3,997	3,770
Cass	Sulphur	856	2,864	775	775
Cass	Cypress	2,895	15,159	12,856	12,856
Cherokee	Neches	9,617	20,933	20,672	15,379
Franklin	Sulphur	202	2,021	883	477
Franklin	Cypress	454	7,765	6,404	5,586
Gregg	Cypress	274	862	863	729
Gregg	Sabine	2,959	7,179	6,850	5,412
Harrison	Cypress	2,462	6,183	4,749	4,635
Harrison	Sabine	2,113	4,851	4,702	4,469
Henderson	Neches	3,582	6,036	5,987	3,991
Henderson	Trinity	4,014	0	3,790	3,226
Hopkins	Sulphur	1,521	7,228	3,708	2,116
Hopkins	Cypress	102	313	313	294
Hopkins	Sabine	1,124	2,842	2,778	2,517
Houston	Neches	1,468	22,488	1,720	1,720
Houston	Trinity	5,139	3,806	634	634
Marion	Cypress	1,834	2,726	1,967	1,967
Morris	Sulphur	273	402	401	401
Morris	Cypress	1,013	2,166	2,161	2,154
Nacogdoches	Neches	17,949	24,181	21,171	20,880
Panola	Sabine	5,184	8,370	4,957	4,957
Rains	Sabine	700	1,839	1,584	1,462
Rusk	Sabine	3,355	9,068	8,897	6,989
Rusk	Neches	3,958	11,769	8,939	7,114
Sabine	Sabine	1,822	3,249	1,030	1,029
Sabine	Neches	254	356	355	355
San Augustine	Sabine	197	290	290	288
San Augustine	Neches	2,342	1,149	304	304
Shelby	Sabine	5,095	8,317	3,869	3,702
Shelby	Neches	496	2,577	2,577	2,577
Smith	Sabine	3,538	13,246	12,941	7,936
Smith	Neches	12,618	22,705	22,410	17,592
Titus	Sulphur	584	2,838	2,479	2,084
Titus	Cypress	1,299	7,252	6,790	5,497
Trinity	Neches	32	269	266	266
Trinity	Trinity	1	0	1	1
Upshur	Cypress	4,416	5,442	5,441	5,122
Upshur	Sabine	1,273	1,689	1,690	1,551
Van Zandt	Sabine	2,779	4,767	3,801	3,352
Van Zandt	Neches	1,198	4,317	4,095	2,635
Van Zandt	Trinity	910	1,384	1,251	1,095
Wood	Cypress	320	2,053	1,870	930
Wood	Sabine	5,556	19,404	18,931	16,971
Total		**153,167**	**342,956**	**288,066**	**252,097**

Please note that, in general, the historic pumping (defined by the high pumping in 2011 during drought conditions) is lower than the groundwater availability values. Also, please note that, in general, pumping at the input amounts (groundwater availability) are not possible given the dynamic reduction due to decreased saturated thickness. Finally, please note that the first year of the simulation (2014) has higher pumping than the last year of the simulation (2080). In summary, as saturated thickness declines, pumping declines. However, simulated 2080 pumping is higher than the 2011 pumping.

The differences in the total pumping in GMA 11 are presented graphically in Figure 1 for the Sparta Aquifer, Figure 2 for the Queen City Aquifer, and Figure 3 for the Carrizo-Wilcox Aquifer.

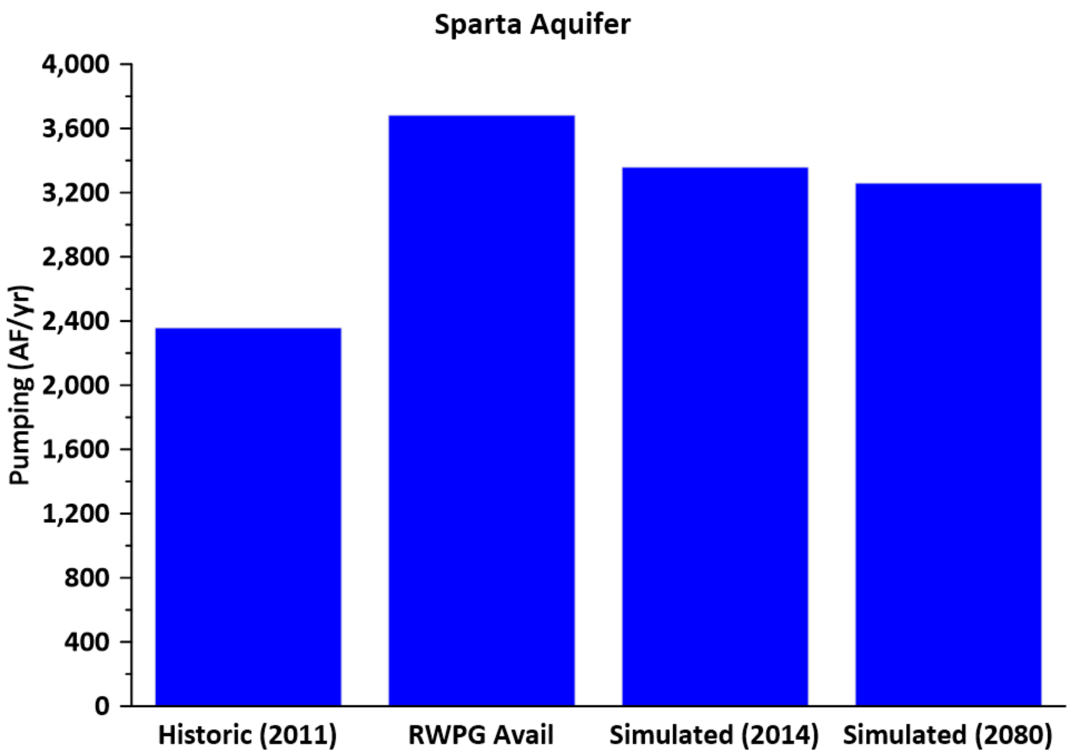

Figure 1. Total GMA 11 Pumping - Sparta Aquifer

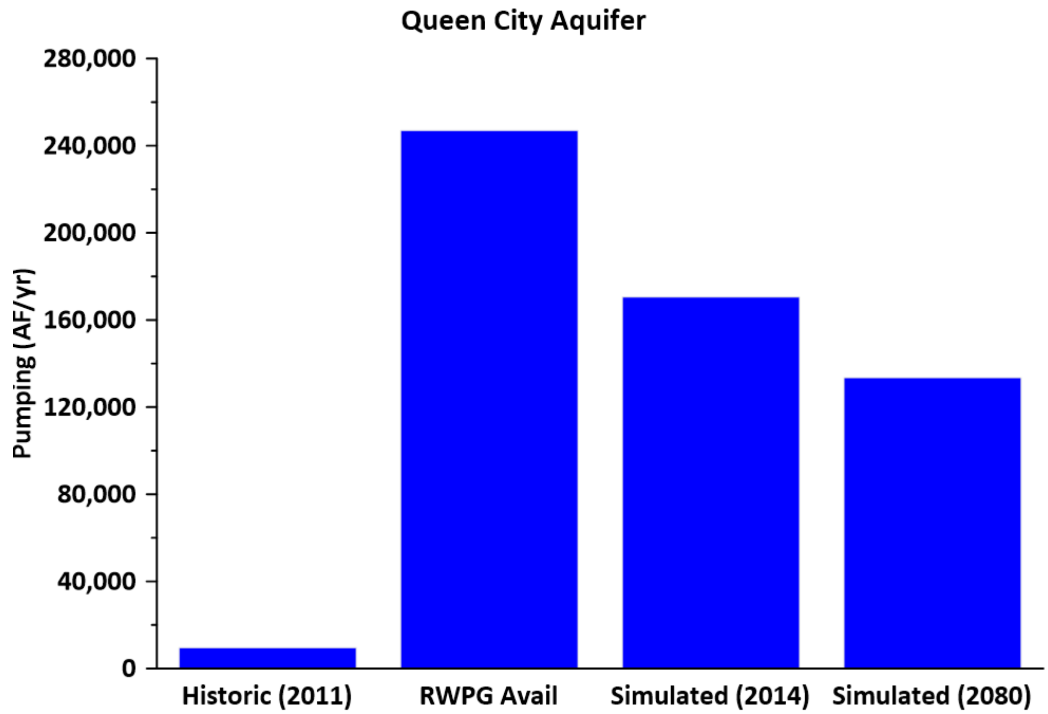

Figure 2. Total GMA 11 Pumping - Queen City Aquifer

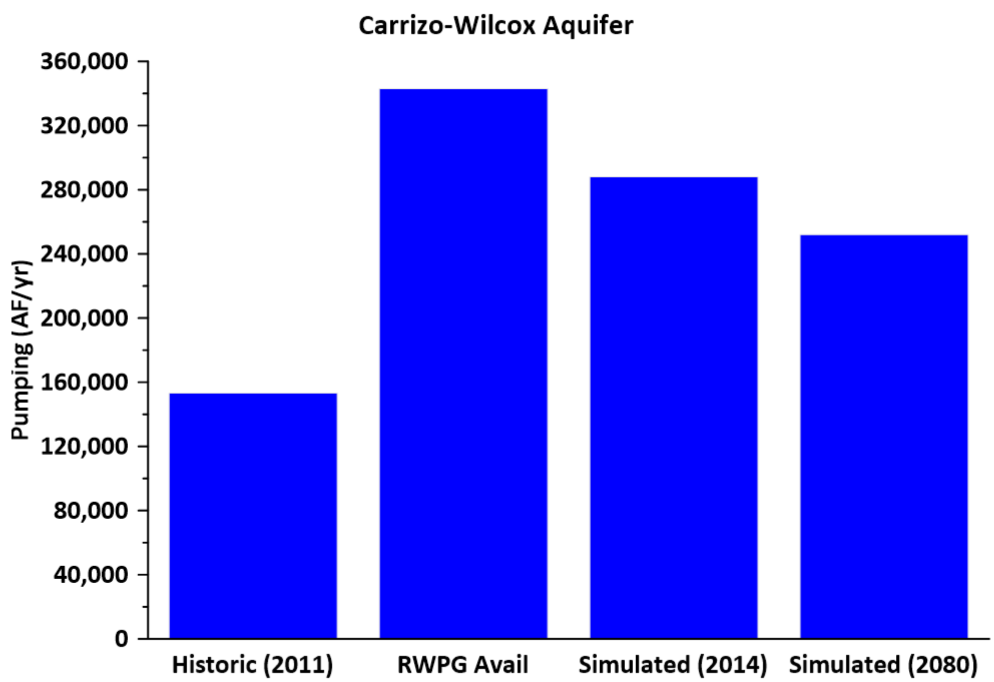

Figure 3. Total GMA 11 Pumping - Carrizo-Wilcox Aquifer

3.2 Average Drawdown (2013 to 2080)

Average drawdown from 2013 to 2080 for each county-model layer unit and for each county-aquifer unit was calculated using the FORTRAN post-processor *getdd.exe*. Source code for the post-processor is presented in Appendix D.

The post-processor:

- Reads a list of counties in GMA 11
- Reads the updated grid file
- Counts the cells in each county-layer unit
- Writes summary tables with total cell count for each county-layer unit
- Reads the final calibrated model hds file
- Calculates drawdown
- Sums drawdowns
- Calculates average drawdown for each county-layer unit (drawdown sum divided by number of cells)
- Calculates average drawdown for the Carrizo-Wilcox Aquifer (layers 6 to 9)
- Reads a list of file names for output for each county
- Writes annual drawdowns for each county
- Writes a summary file for 2080 drawdowns by layer
- Writes a summary file for 2080 drawdowns by aquifer

Table 5 presents the drawdown from 2013 to 2080 for each county-aquifer unit.

Table 5. Average Drawdown (2013 to 2080) for Each County-Aquifer Unit in GMA 11

County	Sparta Aquifer	Queen City Aquifer	Carrizo-Wilcox Aquifer
Anderson	32	47	158
Angelina	6	28	68
Bowie			12
Camp		13	88
Cass	72	36	80
Cherokee	7	34	181
Franklin			109
Gregg		52	115
Harrison		46	27
Henderson		38	109
Hopkins			66
Houston	3	12	87
Marion	129	33	33
Morris		43	80
Nacogdoches	7	22	74
Panola			21
Rains			17
Rusk	26	17	89
Sabine	1	3	9
SanAugustine	2	7	22
Shelby	18	12	17
Smith	157	149	275
Titus		9	69
Trinity	5	18	57
Upshur	10	32	155
VanZandt		88	57
Wood	9	17	127

3.3 Groundwater Budget (Pumping Impacts)

A groundwater budget is an accounting of all inflow components, all outflow components, and storage changes for a given area over a specified time period. For purposes of this analysis, the groundwater budget of the calibrated model (1980 to 2013) is compared to the groundwater budget of the base predictive simulation (2014 to 2080) to assess the source of the increased pumping simulated in the base predictive simulation.

When pumping is increased, the initial response is storage reduction. However, over an extended period, pumping will induce inflow and capture natural outflow. The pumping increases associated with the predictive simulation are discussed above. This analysis provides insight as to the source of that increased pumping.

The defined area is GMA 11 as defined in the updated grid file. The updated grid file (documented in Technical Memorandum 20-01) includes a GMA column that was used to create a zone file for zone budget. Each cell was assigned a zone number based on the GMA designation. Layer 1 cells (alluvial cells) were reclassified as zone 1, and cells outside of Texas were reclassified as zone 2. GMAs that border GMA 11 include GMA 8, GMA 12, and GMA 14.

The groundwater budget for GMA 11 was extracted from the cell-by-cell output files of the calibrated model and the base predictive scenario using the program ZONEBUDGET for MODFLOW 6 obtained from the US Geological Survey.

The results for the calibrated model were saved in the Excel file *zbgmacalib.xlsx*, and the results for the base predictive simulation were saved in the Excel file *zbgmapredbase.xlsx*. A summary of the groundwater budgets for the two time periods is presented in Table 6.

Table 6. Groundwater Budget Summary for GMA 11

	1981 to 2013 Average (AF/yr)	2014 to 2080 Average (AF/yr)	Difference (AF/yr)
Inflow			
Recharge	235,475	235,341	-134
Overlying Formations	3,221	6,193	2,973
Alluvium	0	144,707	144,707
Outside Texas	0	3,412	3,412
GMA 8	13	13	0
GMA 12	4,968	13,754	8,785
GMA 14	4,981	13,871	8,890
Total Inflow	248,657	417,290	168,633
Outflow			
Pumping	129,718	393,637	263,919
Evapotranspiration	73,198	33,008	-40,190
Alluvium	45,624	0	-45,624
Outside Texas	542	0	-542
Total Outflow	249,081	426,645	177,564
Model Storage			
Confined	-143	-1,117	-974
Unconfined	-281	-8,238	-7,956
Total Model Storage	-424	-9,355	-8,931
Inflow-Outflow	-424	-9,355	-8,931
Model Error	0	0	0

Please note that the predictive scenario simulates average pumping that is over 250,000 AF/yr above the historic period. The differences in other components are useful to understand the source of the increased pumping and are summarized in Table 7.

Table 7. Summary of Sources of Increased Pumping

	AF/yr	Percentage of Pumping Increase
Pumping Increase	263,919	100
Induced Inflow		
Overlying Formations	2,973	1.13
Alluvium	190,331	72.12
Outside Texas	3,954	1.50
GMA 8	0	0.00
GMA 12	8,785	3.33
GMA 14	8,890	3.37
Captured Outflow		
Evapotranspiration	40,190	15.23
Reduced Storage		
Confined	974	0.37
Unconfined	7,956	3.01
Recharge Difference	-134	-0.05

Based on these results, 72 percent of the increased pumping is derived from the alluvium, and ultimately, from surface water. About 15 percent of the pumping is from decreased evapotranspiration. Only about 3 percent of the pumping is sourced from groundwater storage.

4.0 Discussion of Results

Limitations associated with the old GAM resulted in an underprediction of average drawdowns due to the issues of recharge and the inability of water to move from the outcrop areas to the downdip areas of the aquifers. The updated GAM has corrected these limitations.

The pumping associated with the previous round of joint planning and the groundwater availability in the Region D and Region I water plans cannot be sustained with the assumed geographic distribution of pumping used in the predictive scenario. If this round of joint planning were to adopt desired future conditions based on this predictive scenario, the modeled available groundwater values would be less than the current groundwater availability values in the regional plans. This would not be an arbitrary reduction, nor a reduction based on regulation. This would, however, reflect the results of an updated and improved groundwater model to make such predictions.

Due to the timing of the release of the updated GAM and the approaching deadline for GMA 11 to propose a desired future condition, and due to budget considerations of the groundwater conservation districts in GMA 11, it is not feasible to develop simulations that would increase the amount of pumping by changing the geographic distribution of pumping. This task would be appropriate to consider as part of the next round of joint planning (i.e. in 2026).

5.0 References

Hutchison, W.R., 2017a. Desired Future Condition Explanatory Report: Carrizo-Wilcox/Queen City/Sparta Aquifers for Groundwater Management Area 11. Report submitted to Texas Water Development Board, January 24, 2017, 445p.

Hutchison, W.R., 2017b. Use of Predictive Simulation Results from Scenario 4 in Desired Future Conditions for Sparta, Queen City, and Carrizo-Wilcox Aquifer. GMA 11 Technical Memorandum 16-02. Report submitted to Groundwater Management Area 11. January 24, 2017, 15p.

Hutchison, W.R., 2017c. Initial GAM Simulations for Sparta, Queen City and Carrizo-Wilcox Aquifers. GMA 11 Technical Memorandum 15-01. Report submitted to Groundwater Management Area 11. January 21, 2017, 109p.

Panday, S., Rumbaugh, J., Hutchison, W.R., Schorr, S., 2020. Numerical Model Report: Groundwater Availability Model for the Northern Portion of the Queen City, Sparta, and Carrizo-Wilcox Aquifers. Final Report prepared for Texas Water Development Board, Contact Number #1648302063. 198p.

Appendix A

Source Code for *geteoy2013.exe*

```fortran
! geteoy2013.exe
!
! reads binary hds file from calibrated model run
! returns final sp file for predictive run initial heads (End-of-Year 2013 heads)
!
! Declare arrays
!
double precision hds(34,637536 )
integer*4 kstp,kper,nodes
double precision pertim,totim,tb,gd,te,st
character*16 text

! read calibrated model hds file
! write header file as qc check

open (1,file='tr58_g_final.hds',form='binary')
open (2,file='header.dat')
100 read (1,end=199) kstp,kper,pertim,totim,text,nodes,i1,i2
write ( 2, 110 ) kstp,kper,pertim,totim,text,nodes,i1,i2
110 format (2i10,2f15.4,1x,a16,1x,3i10)
read (1) (hds(kper,n),n=1,nodes)
go to 100
199 continue

! write last stress period/last time step heads to eoy file for use in predicitve runs

open (3,file='eoy2013.dat' )
do 300 n=1,nodes
write (3,312) hds(34,n)
312 format (f15.4)
300 continue

stop
end
```

Appendix B

Source Code for *makebasewel.exe*

```
! makebasewel.exe
!
! read updated grid file
! read pumping factor file
! read text for WEL file
! write WEL file leading text lines (12 lines)
! read historic pumping
! calculate pred scen pumping using factor for county-river basin unit
! write updated pumping for predictive scenario
! write final text for WEL file

! declare arrays

dimension il(637536),icounty(637536),ibn(637536),igcd(637536)
dimension igma(637536),nodesa(8)
dimension pumpfac(3,70),ic(70),irb(70)
character*40 text,txtw(13)

! read grid file

open (1,file='updatedgrid.dat')
do 100 k=1,637536
read (1,*) kk,ac,ir,icol,il(k),icounty(k),ibn(k),igcd(k),igma(k),ib,iaq2
100 continue

! read pumping factor file

open (2,file='2011fac.dat')
do 200 k=1,70
read (2,*) text,ic(k),text,irb(k),(pumpfac(iaq,k),iaq=1,3)
200 continue

! read text from MF6 WEL file
! write first 12 lines to predictive simulation file

open (3,file='weltext.dat')
open (31,file='predbase.wel')
do 300 k=1,13
read (3,310) txtw(k)
310 format (a40)
300 continue
do 301 k=1,12
write (31,310) txtw(k)
301 continue

! read historic pumping
```

```fortran
! calculate predictive simulation pumping with factors

open (4,file='2011pumpout.dat')
do 400 kk=1,53189
read (4,*) isp,iyr,text,node,cfd,afd
fac=1.0
do 401 k=1,70
if (ic(k).eq.icounty(node).and.irb(k).eq.ibn(node)) then
if (il(node).eq.2) fac=pumpfac(1,k)
if (il(node).eq.4) fac=pumpfac(2,k)
if (il(node).gt.5) fac=pumpfac(3,k)
end if
401 continue
if (fac.lt.0) fac=1.0
cfd2=cfd*fac
write (31,410) node,cfd2
410 format (i10,e15.5)
400 continue

! Add 3 AF/yr to San Augustine-Sabine in Sparta Aquifer
!  (no hisotric pumping but RWPG has availability)

nodesa(1)=326840
nodesa(2)=327562
nodesa(3)=328170
nodesa(4)=328904
nodesa(5)=329565
nodesa(6)=329566
nodesa(7)=329567
nodesa(8)=330258
tafy=-3
cafy=tafy/8
cfd=cafy*43560/365
do 500 in=1,8
write (31,410) nodesa(in),cfd
500 continue

! write final line for WEL file

write (31,310) txtw(13)

stop
end
```

Appendix C

Source Code for *getpump.exe*

```
! getpump.exe
!
! Read updated grid file
! Read number of time steps in each stress period
! Read list of 70 county-river basin units with codes
! Read calibration cbb file
! Convert cfd to afy
! Incrementally add afy of final time step to aquifer pumping totals
! Write pumping totals summary files for each county-river basin unit

! declare arrays

dimension id1(637536),id2(637536)
character*16 text,txt1id1,txt2id1,txt1id2,txt2id2,auxtxt(400)
character*40 cn(70),rbn(70)
double precision delt,pertim,totim
double precision data(4338894),data2d(4,4338894)
dimension
il(637536),icounty(637536),ibn(637536),igcd(637536),igma(637536),ib(637536),iaq(637
536)
dimension itsnum(67)
dimension pump(67,3,8,27)
dimension ic1(70),ic2(70),irb1(70),irb2(70)
dimension spinp(2,70),qcinp(2,70),cwinp(2,70)

! read grid file

open (2,file='updatedgrid.dat')
do 200 k=1,637536
read (2,*) kk,ac,ir,ic,il(k),icounty(k),ibn(k),igcd(k),igma(k),ib(k),iaq(k)
200 continue

! read list of number of time steps for each stress period

open (21,file='tsnum.dat')
do 201 isp=1,67
read (21,*) itsnum(isp)
201 continue

! read list of county-river basin units and codes
! read county-river basin output filenames

open (31,file='avail2011compare.csv')
read (31,*) text
do 300 k=1,70
read (31,*) ic1(k),ic2(k),cn(k),irb1(k),irb2(k),rbn(k),x1,x2,x3,x4,x5,x6
```

```
spinp(1,k)=x1
spinp(2,k)=x2
qcinp(1,k)=x3
qcinp(2,k)=x4
cwinp(1,k)=x5
cwinp(2,k)=x6
300 continue

! read cbb file

open (4,file='predbase.cbb',form='binary')
open (5,file='header.dat')

kk=0
400 read (4,end=499) kstp,kper,text,ndim1,ndim2,nd3
kk=kk+1
ndim3=-nd3
read (4) imeth,delt,pertim,totim
write (5,410) kstp,kper,text,ndim1,ndim2,ndim3,imeth,delt,pertim,totim
write (*,490) kper,kstp
490 format ('+',2x," Stress Period ",i3,2x," Time Step ",i3)
410 format (2i10,1x,a16,1x,4i10,3f15.4)

if (imeth.eq.1) read (4) (data(j),j=1,ndim1)

if (imeth.eq.6) then
read (4) txt1id1
read (4) txt2id1
read (4) txt1id2
read (4) txt2id2
read (4) ndat
read (4) (auxtxt(n),n=1,ndat-1)
read (4) nlist
if (ndat.eq.1) write (5,411) txt1id1,txt2id1,txt1id1,txt2id2,ndat,nlist
if (ndat.eq.2) write (5,412) txt1id1,txt2id1,txt1id1,txt2id2,ndat,nlist,auxtxt(1)
411 format (4a16,i10,i10)
412 format (4a16,i10,i10,a16)
read (4) ((id1(n),id2(n),(data2d(i,n),i=1,ndat)),n=1,nlist)

! pumping in position 4
! convert pumping to AFY and sum for each county-model layer unit

if (kk.eq.4) then
do 420 n=1,nlist
if (data2d(1,n).ne.0.and.kstp.eq.itsnum(kper)) then
pumpaf=-data2d(1,n)*365/43560
```

```
do 430 kcrb=1,70
if (icounty(id1(n)).eq.ic2(kcrb).and.ibn(id1(n)).eq.irb2(kcrb)) then
if (il(id1(n)).eq.2)
pump(kper,1,irb1(kcrb),ic1(kcrb))=pump(kper,1,irb1(kcrb),ic1(kcrb))+pumpaf
if (il(id1(n)).eq.4)
pump(kper,2,irb1(kcrb),ic1(kcrb))=pump(kper,2,irb1(kcrb),ic1(kcrb))+pumpaf
if (il(id1(n)).gt.5)
pump(kper,3,irb1(kcrb),ic1(kcrb))=pump(kper,3,irb1(kcrb),ic1(kcrb))+pumpaf
end if
430 continue
end if
420 continue
end if

end if
if (kk.eq.8) kk=0
goto 400
499 continue

! write summary files

open (51,file='pumpsp.dat')
open (52,file='pumpqc.dat')
open (53,file='pumpcw.dat')
do 500 k=1,70
write (51,510)
ic2(k),irb2(k),spinp(1,k),spinp(2,k),pump(1,1,irb1(k),ic1(k)),pump(67,1,irb1(k),ic1(k))
write (52,510)
ic2(k),irb2(k),qcinp(1,k),qcinp(2,k),pump(1,2,irb1(k),ic1(k)),pump(67,2,irb1(k),ic1(k))
write (53,510)
ic2(k),irb2(k),cwinp(1,k),cwinp(2,k),pump(1,3,irb1(k),ic1(k)),pump(67,3,irb1(k),ic1(k))
510 format (2i10,4f10.0)
500 continue

stop
end
```

Appendix D

Source Code for *getdd.exe*

```
! getdd.exe

! reads list of counties
! reads grid file
! counts cells in each county-layer unit
! writes summary table with total cell count for each county-layer
! read calibrated model hds file

! declare arrays

dimension icount(10,27),iclist(27)
dimension sumdd(10,27,1980:2080),avgdd(10,27,1980:2080)
dimension sumcwdd(27,1980:2080),avgcwdd(27,1980:2080)
dimension icn(637536),il(637536)
character*30 county(27),txt
double precision hds(1980:2080,637536)
dimension dd(1980:2080,637536)
integer*4 kstp,kper,nodes
double precision pertim,totim,tb,gd,te,st
character*16 text
character*30 gma11county(27),gma11fn(27)
dimension icngma11(27)

! read list

open (1,file='GMA11CountyNamNum.csv')
read (1,*) text
do 100 k=1,27
read (1,*) county(k),iclist(k)
100 continue

! read grid file and count

open (2,file='updatedgrid.dat')
do 200 nn=1,637536
read (2,*) kk,carea,ir,ic,il(nn),icn(nn),ibn,igcd,igma,ib,iaq
do 201 ic=1,27
if (iclist(ic).eq.icn(nn)) then
icount(il(nn),ic)=icount(il(nn),ic)+1
icount(10,ic)=icount(10,ic)+1
end if
201 continue
200 continue

! write cell count summary file

```

```
open (3,file='cellcount.dat')
do 300 k=1,27
write (3,310) k,iclist(k),county(k),(icount(ilay,k),ilay=1,10)
310 format (2i10,2x,a15,2x,10i7)
300 continue

! read calibrated model hds file and fill hds array

open (4,file='tr58_g_final.hds',form='binary')
open (5,file='headercal.dat')
400 read (4,end=499) kstp,kper,pertim,totim,text,nodes,i1,i2
iyr=kper+1979
write (5,410) kstp,kper,iyr,pertim,totim,text,nodes,i1,i2
410 format (3i10,2f15.4,1x,a16,1x,3i10)
read (4) (hds(iyr,n),n=1,nodes)
goto 400
499 continue

! read predicitve run hds file and fill hds array

open (6,file='predbase.hds',form='binary')
open (7,file='headerpred.dat')
600 read (6,end=699) kstp,kper,pertim,totim,text,nodes,i1,i2
iyr=kper+2013
write (7,710) kstp,kper,iyr,pertim,totim,text,nodes,i1,i2
710 format (3i10,2f15.4,1x,a16,1x,3i10)
read (6) (hds(iyr,n),n=1,nodes)
goto 600
699 continue

! calculate drawdown

do 800 iyr=1980,2080
do 801 nn=1,637536
dd(iyr,nn)=hds(2013,nn)-hds(iyr,nn)
801 continue
800 continue

! sum dd

do 900 ic=1,27
do 901 iyr=1980,2080
do 902 nn=1,637536
if (iclist(ic).eq.icn(nn)) then
sumdd(il(nn),ic,iyr)=sumdd(il(nn),ic,iyr)+dd(iyr,nn)
sumdd(10,ic,iyr)=sumdd(10,ic,iyr)+dd(iyr,nn)
```

```
if (il(nn).gt.5) sumcwdd(ic,iyr)=sumcwdd(ic,iyr)+dd(iyr,nn)
end if
902 continue
901 continue
900 continue

! calculate avgdd (layer)

do 1000 ilay=1,10
do 1001 ic=1,27
do 1002 iyr=1980,2080
avgdd(ilay,ic,iyr)=-9999
if (icount(ilay,ic).gt.0) avgdd(ilay,ic,iyr)=sumdd(ilay,ic,iyr)/icount(ilay,ic)
1002 continue
1001 continue
1000 continue

! calculate avgdd (Carrizo-Wilcox)


do 1010 ic=1,27
   do 1011 iyr=1980,2080
cwcount=icount(6,ic)+icount(7,ic)+icount(8,ic)+icount(9,ic)
avgcwdd(ic,iyr)=sumcwdd(ic,iyr)/cwcount
1011 continue
1010 continue


! read gma 11 county list and file names

open (11,file='GMA11ddfile.csv')
read (11,*) text
do 1100 ic=1,27
read (11,*) gma11county(ic),icngma11(ic),gma11fn(ic)
1100 continue

! write gma 11 drawdowns

do 1200 ic=1,27
open (12,file=gma11fn(ic))
do 1201 iyr=1980,2080
write (12,1210) gma11county(ic),iyr,(avgdd(ilay,ic,iyr),ilay=1,10),avgcwdd(ic,iyr)
1210 format (a20,1x,i10,11f10.2)
1201 continue
close (12)
1200 continue
```

```
! write summary file of 2080 drawdowns - layer

open (13,file='dd2080sumlayer.dat')
iyr=2080
do 1300 ic=1,27
write (13,1310) gma11county(ic),iyr,(avgdd(ilay,ic,iyr),ilay=1,10)
1310 format (a20,1x,i10,10f10.0)
1300 continue

! write summary file of 2080 drawdown - aquifer

open (14,file='dd2080sumaquifer.dat')
iyr=2080
do 1400 ic=1,27
write (14,1410) gma11county(ic),iyr,avgdd(2,ic,iyr),avgdd(4,ic,iyr),avgcwdd(ic,iyr)
1410 format (a20,1x,i10,3f10.0)
1400 continue


stop
end
```