Appendix 3C
Water Supplies in the Colorado WAM

Region F
Water Planning Group

Freese and Nichols, Inc.
LBG-Guyton Associates, Inc.
Alan Plummer Associates, Inc.

TECHNICAL MEMORANDUM

To: Region F Water Planning Group

From: Jon S. Albright – Freese and Nichols, Inc.

Re: Water Supplies from the Colorado WAM

Date: March 8, 2005
Revised May 19, 2005
Revised December 19, 2005

Existing Surface Water Supplies

Surface water from reservoirs provides most of the municipal water supply in Region F. Run-of-the-river water rights are used primarily for irrigation. Table 1 shows information regarding the 15 major Colorado Basin reservoirs in Region F. Figure 1 shows the location of these reservoirs.

All surface water supplies are derived from Water Availability Models (WAMs) developed by the Texas Commission on Environmental Quality (TCEQ). The TWDB requires the use of the Full Authorization Run (Run 3) of the approved TCEQ WAM for each basin as the basis for water availability in regional water planning[1]. Three WAM models are available in Region F: the Colorado WAM, which covers most of the central and eastern portions of the region, and the Rio Grande WAM, which covers the Pecos Basin, and the Brazos WAM. This memorandum focuses on supplies from the Colorado WAM.

[1] Texas Water Development Board: Exhibit B Guidelines for Regional Water Plan Development, July 2002.

Table 1
Major Colorado Basin Reservoirs in Region F

Reservoir Name	Stream	County(ies)	Water Right Number(s)	Priority Date	Permitted Conservation Storage (Acre-Feet)	Permitted Diversion (Acre-Feet per Year)	Owner	Water Rights Holder(s)
Lake J. B. Thomas	Colorado River	Borden and Scurry	CA-1002	08/05/1946	204,000	30,050	CRMWD	CRMWD
Lake Colorado City	Morgan Creek	Mitchell	CA-1009	11/22/1948	29,934	5,500	TXU	TXU
Champion Creek Reservoir	Champion Creek	Mitchell	CA-1009	04/08/1957	40,170	6,750	TXU	TXU
Oak Creek Reservoir	Oak Creek	Coke	CA-1031	04/27/1949	30,000	10,000	City of Sweetwater	City of Sweetwater
Lake Coleman	Jim Ned Creek	Coleman	CA-1702	08/25/1958	40,000	9,000	City of Coleman	City of Coleman
E. V. Spence Reservoir	Colorado River	Coke	CA-1008	08/17/1964	488,760	38,573	CRMWD	CRMWD
Lake Winters/ New Lake Winters	Elm Creek	Runnels	CA-1095	12/18/1944	8,347	1,755	City of Winters	City of Winters
Lake Brownwood	Pecan Bayou	Brown	CA-2454	09/29/1925	114,000	29,712	Brown Co. WID	Brown Co. WID
Hords Creek Lake	Hords Creek	Coleman	CA-1705	03/23/1946	7,959	2,240	COE	City of Coleman
Lake Ballinger / Lake Moonen	Valley Creek	Runnels	CA-1072	10/04/1946	6,850	1,000	City of Ballinger	City of Ballinger
O. H. Ivie Reservoir	Colorado River	Coleman, Concho and Runnels	A-3866 P-3676	02/21/1978	554,340	113,000	CRMWD	CRMWD
O. C. Fisher Lake	North Concho River	Tom Green	CA-1190	05/27/1949	119,000	80,400	COE	Upper Colorado River Authority
Twin Buttes Reservoir	South Concho River	Tom Green	CA-1318	05/06/1959	186,000	29,000	U.S. Bureau of Reclamation	City of San Angelo
Lake Nasworthy	South Concho River	Tom Green	CA-1319	03/11/1929	12,500	25,000	City of San Angelo	City of San Angelo
Brady Creek Reservoir	Brady Creek	McCulloch	CA-1849	09/02/1959	30,000	3,500	City of Brady	City of Brady
Total					*1,871,860*	*358,500*		

Table 2 compares the firm yield of the 15 Colorado Basin reservoirs in Region F used in the 1997 State Water Plan[2], the 2001 Region F Plan[3], and from the Colorado WAM[4]. Table 3 compares run-of-the river supplies from the 2001 Region F Plan to the Colorado WAM. (In most cases, the run-of-the-river supplies from the 2001 Region F Plan are identical to those used in the 1997 Water Plan.) The supplies derived using the WAM are very different from those assumed in previous plans. Supplies from reservoirs are about 54 percent of that assumed in the 2001 Region F Plan. Run-of-the-river supplies are about 25 percent of the supplies in the previous plan. The reason for this change is because previous studies made significantly different assumptions about the operation of water rights in the Colorado Basin. The WAM assumes that priority of diversion and storage determines water availability regardless of the type of right or purpose of use. Previous water plans assumed that reservoir supplies were not subject to priority calls. It is unknown why run-of-the-river supplies are so much less with the WAM, largely because the source of these numbers is not well documented in the previous studies. However, we can speculate that these supplies were not modeled as thoroughly as in the current WAM.

Description of TCEQ WAM Program

TCEQ developed the water availability models specifically "to determine whether water would be available for a newly requested water right or amendment."[5] Although several different scenarios, referred to as "runs," were part of the original WAM program, the agency retained only two runs for use in processing permits:

- *Full Authorization (Run 3)* where all water rights are assumed to use their full permitted amount. There are no return flows unless they are specified in a water right (100% reuse). This scenario is used to evaluate new permanent water rights or amendments.

[2] Texas Water Development Board, Final 1997 Water Plan Allocations from MADNESS model, 1998.
[3] Freese and Nichols, Inc. et al.: Region F Regional Water Plan, prepared for the Region F Regional Water Planning Group, January 2001.
[4] R.J. Brandes Company et al.: Water Availability Modeling for the Colorado/Brazos-Colorado Basin, prepared for the Texas Natural Resources Conservation Commission, December 2001.
[5] Texas Commission on Environmental Quality: "Water Availability Models," available online at http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/wam.html#files

Table 2
Comparison of Firm Yields of Region F Reservoirs from the 1997 State Water Plan, the 2001 Region F Plan, and the Colorado Water Availability Models
(Values in Acre-Feet per Year)

Reservoir Name	Yield from 1997 State Water Plan [a]	Yield from 2001 Region F Plan [a]	WAM Firm Yield [b]
Lake J. B. Thomas	151,800 [c]	9,900	780 [d]
E. V. Spence Reservoir		38,776	
O. H. Ivie Reservoir		96,169	86,110 [e]
Lake Colorado City	5,500	4,550	0
Champion Creek Reservoir	5,000	4,081	0
Oak Creek Reservoir	4,800	5,684	0
Lake Coleman	7,090	8,822	30
Lake Winters/ New Lake Winters	1,160	1,407	0
Lake Brownwood	31,400	41,800	40,612 [e]
Hords Creek Lake	1,200	1,425	0
Lake Ballinger / Lake Moonen	1,600	3,566	40
O. C. Fisher Lake	13,200	2,973	0
Twin Buttes Reservoir	31,400	8,900	50 [d]
Lake Nasworthy	500	7,900	
Brady Creek Reservoir	3,100	2,252	10
Total	*257,750*	*238,205*	*127,632*

a 1997 and 2001 Water Plan yields are for year 2000 sediment conditions
b WAM yields are for original sediment conditions except where noted
c Individual yields not reported for Thomas, Spence or Ivie in the 1997 State Water Plan
d Individual yields not computed in the Colorado WAM report
e WAM yield using year 2000 sediment conditions at reservoir

Table 3
Comparison of Run-of-the-River Colorado Basin Supplies from 2001 Plan to Supplies from the Water Availability Models [a]
(Values in Acre-Feet per Year)

County	2001 Plan Supplies	WAM Supplies	Change
Andrews	125	0	-125
Borden	89	0	-89
Brown	3,256	778	-2,478
Coke	275	48	-227
Coleman	2,326	31	-2,295
Concho	727	263	-464
Ector	1,800	23	-1,777
Howard	24	0	-24
Irion	1,980	580	-1,400
Kimble	3,502	1,488	-2,014
Martin	550	0	-550
Mason	0	0	0
McCulloch	550	128	-422
Menard	3,792	3,238	-554
Midland	1,400	0	-1,400
Mitchell	235	15	-220
Reagan	0	0	0
Runnels	5,500	771	-4,729
Schleicher	0	0	0
Scurry	1,170	69	-1,101
Sterling	0	48	48
Sutton	475	8	-467
Tom Green	15,839	3,454	-12,385
Total	*43,615*	*10,942*	*-32,673*

a Does not include unpermitted supplies for livestock or diverted water from chloride control projects

- *Current Conditions (Run 8)* where water rights are assumed to be used at current levels. Return flows are set at current levels as well. This scenario is used to process temporary permits and amendments, usually referred to as "term" permits.

TCEQ staff maintains these two runs, updating them as new water rights applications are received. In this memorandum, all references to the WAM refer to Run 3 unless otherwise stated. TWDB requires the use of Run 3 to determine availability in the regional water plans.**Error! Bookmark not defined.**

The WAM program uses the Water Rights Analysis Package (WRAP), a computer model developed by Dr. Ralph Wurbs of Texas A&M University. The WRAP model is specifically designed to model river basins using priority analysis.

There are several assumptions that need to be kept in mind when interpreting the results of the WAM models:

- Priority is the determining factor when allocating available water
- Storing water in a reservoir is given the same importance as diverting water for use
- All water rights divert and store water at their full authorized amounts
- Instream flow requirements apply not only to the original water right, but also to all water rights junior to the original water right
- Return flows from either surface water or groundwater sources are not available unless specifically required by a water right.

Each of these assumptions is discussed in more detail below.

Priority Determines Availability

Water availability in Texas is determined by the *prior appropriation doctrine*, or "first in time is first in right."[6] In times of shortage, water is distributed based upon the priority date of the water right. In older rights, the priority date of a right corresponds to the time that the water was first used for a beneficial purpose. In more recent rights the priority date corresponds to the date that the application for water use was deemed administratively complete by TCEQ. In Texas, both the right to divert and the right to store water are assigned a priority date. Many rights have multiple priority dates for diversion or storage of water.

In the WAM model each water right diverts and stores water according to its priority date. The water rights with the most senior priority divert first and downstream flows are reduced accordingly. If all flows downstream have been taken by senior water rights, then an upstream junior water right can no longer divert even if there is flow in the

[6] Texas Water Code §11.027

stream at the upstream junior water right's point of diversion. This prevents upstream junior water rights from causing a shortage downstream.

Although this allocation of water determined by priority follows current state law, it is not the way that the Colorado Basin has functioned historically. Water right holders have historically diverted and impounded streamflow as it was available to them. Water use is reported by water right holders on the honor system. Only in times of shortage may some junior water right holders be instructed to cease diversion in order to allow water to flow to downstream water rights. Because of budget, staffing and other constraints, TCEQ, the agency that regulates water diversions, is reluctant to enforce the priority of water rights unless a watermaster program has been established. Priority has not historically determined the day-to-day operation of the Colorado Basin.

Priority operation can be in direct conflict with efficient operation of some of the major water supplies in the Colorado Basin. For example, in the WAM Lake Thomas and Spence Reservoir both pass water downstream to Ivie Reservoir even though those reservoirs are all owned by the Colorado River Municipal Water District (CRMWD). If this type of operation was used for these reservoirs, the water would need to be pumped back uphill to CRMWD customers at considerably higher expense than pumping the water from Spence Reservoir or Lake Thomas. Lake Thomas has better water quality than either Spence Reservoir or Ivie Reservoir, so priority operation of the system would cause degradation of water quality for CRMWD customers.

Storing Water is Given the Same Importance as Diverting Water for Use

The WAM models assume that the right to store water has the same weight as the right to divert water. For senior rights with storage, the model assumes that junior water rights can only divert if there is enough water to both completely satisfy a senior water right's diversion amount *and* fill all of the senior water right's empty storage. This occurs even if a senior water right does not need to store the full amount of water to make its diversion reliable. If there is not enough water to fulfill both diversion and storage

requirements of senior water rights, junior water rights must either use their own stored water or, if no storage is available, the junior water right will experience a shortage.

In actual practice, upstream junior water rights have historically impounded and diverted water even when a downstream senior reservoir is not full. Inflows are only passed when water is not needed, an upstream reservoir is full, or a downstream water right has made a priority call on inflows into a reservoir. Normally, a senior water right does not make a priority call unless a shortage is likely some time in the near future. A reservoir that is down by a few feet seldom qualifies as an imminent shortage.

In developing the WAM program, TCEQ recognized that giving storage the same weight as diversion "embodies what is perhaps the letter of the law conflicting with reality."[7] In the legal environment required for permit processing, it makes sense to assume that the right to store water has the same weight as the right to divert water. However, from a practical standpoint, this assumption is in conflict with the way that any river basin has been operated.

Diversion and Storage at Authorized Amounts

The Full Authorization run (Run 3) assumes that every water right in the basin stores and diverts water at the maximum amount authorized by its water right. There are no adjustments for storage capacity that has been lost due to accumulation of sediment in older reservoirs. For example, the authorized storage for Lake Nasworthy is 12,500 acre-feet. The 1993 survey of the reservoir shows a conservation storage of 10,108 acre feet[8], or a loss of about 18 percent of the storage volume of the reservoir. The City of San Angelo has dredged Lake Nasworthy, restoring much of the lost storage.

There are also no adjustments for water rights that authorize diversions in excess of the potential water supply from the reservoir. An example is O.C. Fisher Lake (CA

[7] Texas Natural Resources Conservation Commission: WAM Resolved Technical Issue #4 Conservation Storage Protection, January 1999. Available online at http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/resolve.html#storage.
[8] Texas Water Development Board: Volumetric Survey of Lake Nasworthy, prepared for the City of San Angelo, December 1993.

1190), which authorizes 80,400 acre-feet per year diversion from 80,400 acre-feet of storage. The authorized diversion greatly exceeds the ability of the reservoir to supply water.

Instream Flow Requirements Apply to All Junior Water Rights

Instream flow requirements are minimum flows that must be maintained in the stream before a water right can divert or store water. Diversions by a water right may not cause flows to go below the minimum flow requirements. If flows are below the instream flow requirement, a water right cannot divert or store water (although a water right with storage can use stored water until it is exhausted). In more recent water rights, instream flow requirements are primarily designed to protect fish and wildlife habitats or bay and estuary inflows. In older water rights, instream flow requirements were designed to protect downstream senior water rights. If instream flow requirements are imposed, they are normally part of the special conditions of a water right permit.

TCEQ has assumed that instream flow requirements have the same priority as the associated water right. TCEQ also has elected to impose these requirements to every upstream junior water right even if that water right has no instream flow requirements. When modeling priority rights, this assumption is required to prevent diversions by upstream junior water rights from impacting the reliability of downstream senior water rights by causing flows to drop below the instream flow requirement[9]. However, in the real world this type of operation would be difficult to enforce. Upstream junior water rights holders are probably not aware of the special conditions of other water rights in the basin, and it would be difficult to prove which water right caused an impact on a senior right and to what extent that impact occurred.

The most significant instream flow requirements in the Colorado WAM are the target and critical flows in the LCRA Water Management Plan. The Water Management

[9] Texas Natural Resources Conservation Commission: WAM Resolved Technical Issue #3 Streamflow Reservations Associated with Permits, January 1999. Available online at http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/resolve.html#streamflow.

Plan itself does not specify a priority for these instream flow requirements. However, in its order upholding the LCRA Water Management Plan, TCEQ determined that the target and critical flows were part of the full amount of water appropriated to LCRA in its water rights for the Highland Lakes. In the WAM, both the target and critical instream flow requirements are assigned a 1926 priority date (the same as the Highland Lake storage) and apply to all water rights upstream with a priority after 1926. After all rights with priorities senior to 1926 divert, if there is not enough flow in the lower basin to meet these instream flow requirements, all water rights with junior priority dates must stop diverting or storing water, including water rights above the Highland Lakes.

No Return Flows

Return flows consist of either surface water or groundwater that is returned to a stream after first being used for a beneficial purpose. Most return flows consist of treated municipal sewage effluent, although other water discharged into a stream can be considered return flows as well. The Full Authorization run does not include return flows unless the water right permit specifies a volume of water that must be returned to the stream after being used. There are two reasons why TCEQ elected not to consider return flows when evaluating new permits. The first reason is that there is nothing in most water rights permits or in state law that compels either the generation or the discharge of wastewater. Use does not necessarily imply the generation of wastewater, and what wastewater is generated can be disposed of by means other than discharge to a stream. The second reason is that wastewater reuse will be widespread in the future. Therefore permanent water rights should not be granted assuming a specific level of flow originating as return flows from other water rights except on a temporary or contingent basis.

The most significant impact of this assumption in the Colorado WAM is associated with the reduction in: (1) the yield of reservoirs, (2) reliability of run-of-river water rights, and (3) flows available to meet instream flow and freshwater inflow needs associated with the LCRA Water Management Plan. Currently, the return flows from the

Austin metropolitan area are approximately 100,000 acre-feet per year. During low-flow periods, these return flows are a significant part of the flow in the lower Colorado River. If these flows are not available, upstream inflows that could have otherwise been diverted or stored by upstream water rights must be released or passed through to meet these requirements.

Impacts of Assumptions used in the Colorado WAM

Figures 2 and 3 illustrate the impact of the assumptions used in the Colorado WAM on water availability in Region F. Figure 2 is a graph of the variation in unappropriated flow at the confluence of the Concho and Colorado Rivers as a function of the priority date. The confluence is in the pool of Ivie Reservoir, just upstream from Freese Dam. The horizontal axis represents the priority date of each water right in the Colorado WAM. The vertical axis represents the percentage of total naturalized flow over the 59-year simulation period available for appropriation at each priority date. The WAM model appropriates water to each water right in priority order. As the model appropriates water, some of the naturalized flows at the confluence will be diverted and used upstream, while other portions of the flow will be reserved for use by water rights downstream. Water rights with priority dates of 1899 or earlier have no impact on water availability at the confluence. Water rights with a priority date of 1900 have the first impact on water availability at the confluence, reducing available flows by about 2 percent. The most significant change in available flows occurs in 1926. At this priority date, almost 50 percent of the total naturalized flows at the confluence are allocated to meet instream flow requirements associated with the LCRA water rights, and to fill storage in the Highland Lakes and Ivie Reservoir. (The Colorado WAM allows Ivie Reservoir to impound water at the same priority date as Lake Buchanan to model the impact of Ivie Reservoir on the firm yield of the Highland Lakes system as outlined in the LCRA Water Management Plan.) Note that by the end of the simulation period, only about 2 percent of the total flow at the confluence remains unappropriated. This does not mean that only

Figure 2
Percentage of Total Naturalized Flow Available at the Confluence of the Concho and Colorado Rivers by Priority Date

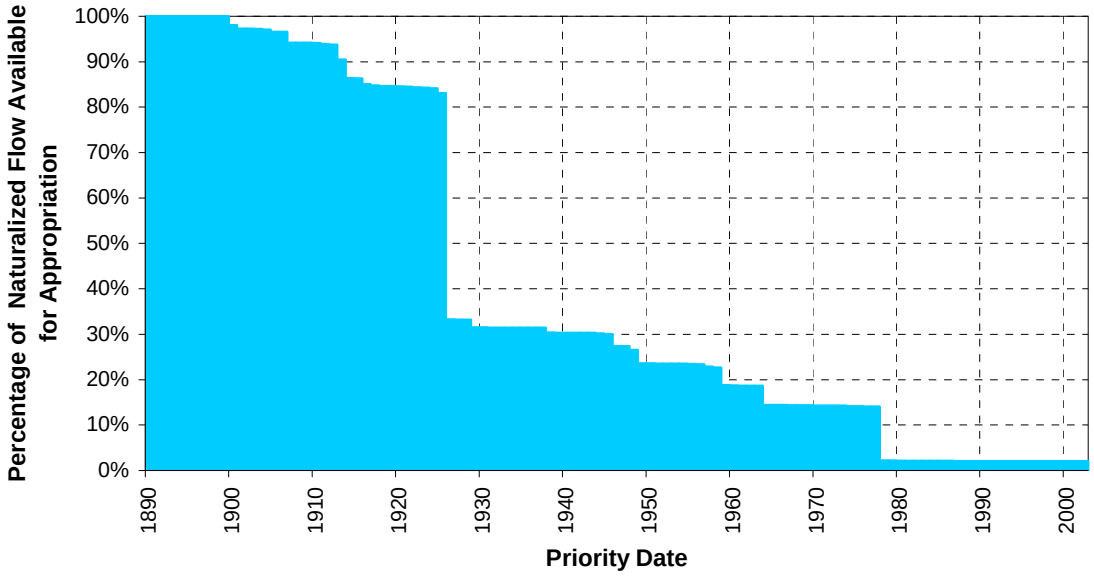
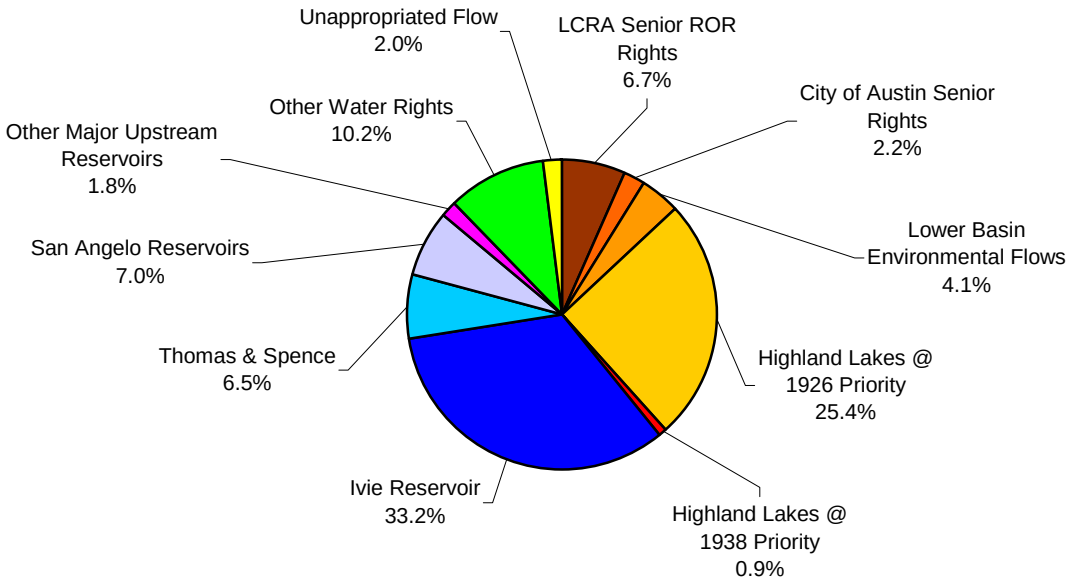


Figure 3
Distribution of Flows at the Colorado and Concho River Confluence



2 percent of the flow remains at the confluence. A significant portion of the flow has been reserved for downstream water rights and flows past the confluence.

Figure 3 shows the distribution of total naturalized flows at the confluence of the Colorado and Concho Rivers as a function of water rights. About 48% of the total flow is allocated to reservoirs upstream of the confluence, with the largest share going to Ivie Reservoir. Almost 40% of the flows at the confluence are reserved by senior water rights owned by LCRA, the City of Corpus Christi and the City of Austin. Over 25% of the flow at the confluence is used to fill storage in the Highland Lakes, which occurs at a 1926 priority date. Over 4% of the total flow is used to meet instream flow and bay and estuary requirements in the lower basin. About 2 percent of the total flow remains unappropriated.

Conclusions

Colorado WAM Run 3 is required by the TWDB for use in regional water planning. The Colorado WAM has significantly lower supplies for Region F than have been used in previous water plans. In many ways, the lower supplies are largely the results of the assumptions used in the Colorado WAM. Because of these assumptions, any water right with a priority date junior to 1926 will have essentially no yield. These assumptions are in conflict with the way that the basin has historically been operated.

The recent drought in most of Region F indicates that reliable supplies can be obtained from most reservoir sources in the region. In order to have a more realistic picture of supplies from these reservoirs, the Colorado WAM will need to be modified to subordinate senior downstream rights to reservoirs in Region F. This will be a complex analysis, and it will be difficult to evaluate this as a water management strategy following TWDB rules. However, since Region F is contractually obligated to use WAM Run 3 it will be necessary to either consider subordination or develop unnecessary strategies to meet the needs that result from the WAM.