7. Water Budget

A water budget is an accounting of the input and output volumes of water for the different components of the hydrologic cycle and for a specified hydrologic system. The hydrologic cycle is a continuous set of processes through which water evaporates from the oceans to the atmosphere, falls on the land, and eventually flows back to the oceans. The part of the hydrologic cycle that is of most relevance to water planning is the fate of precipitation, which will partition to the following components:

- Some precipitation that falls on land seeps (infiltrates) into the ground to become soil moisture, part of which is taken up by plant roots and returned to the atmosphere through the process of transpiration. It is difficult to separate this transpiration from evaporation off land surfaces, so they are typically combined into a single term known as evapotranspiration.

- Precipitation that is not intercepted or infiltrated flows across the land surface and through channels, from which it may be diverted for various consumptive uses or used to fill reservoirs, where it is stored until used or evaporated.

- When soil moisture storage capacity is exceeded, recharge to groundwater occurs. Groundwater may reside in storage until withdrawn from a well or, where physical conditions allow, it may discharge into springs, streams or lakes or flow to other groundwater basins.

The hydrologic cycle is thus a complex movement of water through several subsystems. A hydrologic budget is a quantification of the amounts of water moving in and out of a specified subsystem of the overall hydrologic cycle.

For a given region, the overall hydrologic budget can be expressed by the following equation (Viessman and Lewis, 1996):

$$P - R - G - E - T = \Delta S$$

Where P = precipitation

R = surface runoff

G = groundwater flow to and from other basins

E = evaporation

T = transpiration

ΔS = change in aquifer storage

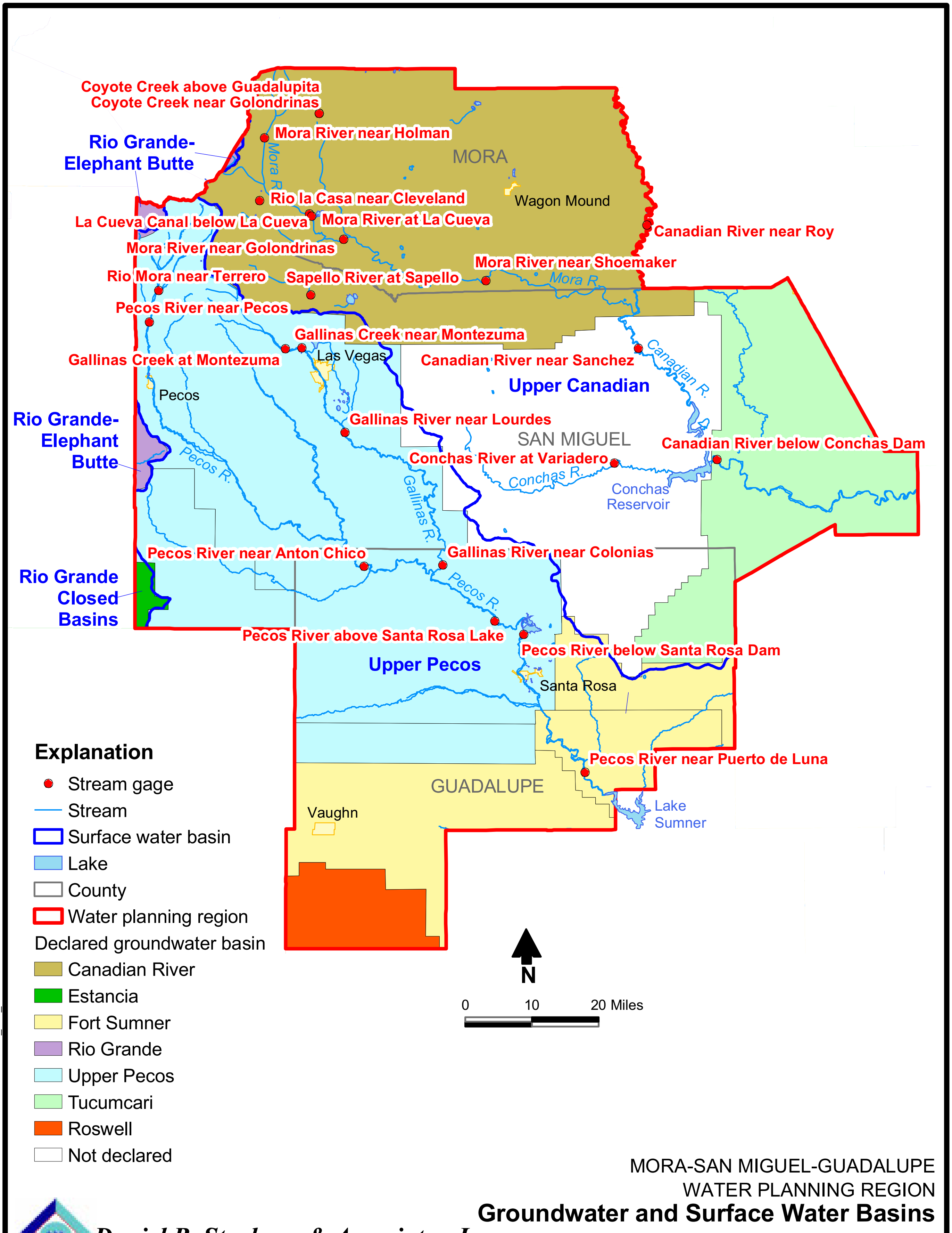
Except for precipitation, subsets of these parameters apply differently to budgets computed above or below the surface. For example, losses to infiltration from the surface are realized as an input to the subsurface (groundwater) system, and losses from subsurface discharges are sometimes realized as an input to the surface system. It is therefore convenient to view surface water systems and groundwater systems as separate, interconnected subsystems of the hydrologic cycle.

Groundwater budgets can be developed more accurately for individual systems with hydrologic boundaries as compared to basins with subsurface groundwater flow between basins. The Mora-San Miguel-Guadalupe Water Planning Region covers a very large area based on political (county line) boundaries and contains two major stream systems, parts of seven declared groundwater basins, and additional groundwater resources in undeclared areas. Separate water budgets were developed for each administrative (declared) groundwater basin, and surface water budgets were prepared for the Pecos and Canadian River Basins.

In addition, although the water budgets presented in this section provide a broad overview of the supply and demand in each of the basins shown in Figure 7-1, it should not be used as an indicator of availability of supply to meet demand in individual localities, as that ability depends on water rights, infrastructure, and proximity to surface water and/or groundwater supplies.

7.1 Surface Water Budget

Surface water budgets were prepared for the two principal perennial streams in the planning region: the Pecos River and the Canadian River.



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MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION
Groundwater and Surface Water Basins

Daniel B. Stephens & Associates, Inc.
3-17-05
JN WR02.0036

Figure 7-1

7.1.1 Surface Water Budget Terms and Methodologies

Surface water budget analyses rely heavily on estimates of components instead of actual measurements. Although precipitation and streamflow are measurable water sources, they are typically measured at only a few locations. Evaporation, evapotranspiration by plants, infiltration, return flows, and spring and seep discharges are generally not measured directly and are therefore usually estimated. Consequently, surface water budget calculations generally have a high degree of uncertainty and should be used with considerable caution.

7.1.1.1 Inflow Components

Inflow sources for surface water include surface inflow, spring or stream gain, and return flow from municipal and irrigation uses.

Runoff from rain and snowmelt provides ***surface inflow*** to a stream. This is the volume of water that flows into streams from the precipitation that has not been intercepted or evaporated from non-riparian vegetation.

The estimated precipitation volume for the entire planning region is 7,340,000 acre-feet (based on the precipitation contours in Figure B-8), but the vast majority of this inflow does not become streamflow, due to upland evapotranspiration and other factors. Non-riparian evapotrans-piration, which is likely the largest output component of the water budget, can exceed 90 percent of precipitation in some watersheds (Brooks et al., 1991), and measurements in the Los Alamos, New Mexico area showed that non-riparian evapotranspiration losses were between 75 and 87 percent of total precipitation (Gray, 1997). In addition, about 10 to 20 percent of precipitation is intercepted such that it wets and adheres to aboveground objects (generally vegetation) and is subsequently returned to the atmosphere through evaporation, and in areas with dense forests, such evaporation may be as much as 25 percent of total annual precipitation (Viessman and Lewis, 1996).

Accordingly, the water budget discussed herein is based on the amount of surface water that flows into the planning region. In the Mora-San Miguel-Guadalupe water budget, this inflow component was comprised of gaged stream discharges from the two main drainages in the planning region. The stream discharges are the median values for the period 1950 through

2002, as presented in Section 5.2.1, with the annual yields corrected for the number of irrigated acres upstream of the gage site.

Spring/stream gain is inflow from springs and seeps and is calculated as the increased flow volume between an upstream and a downstream gage, adjusted for irrigation diversions, reservoir evaporation, change in reservoir storage, and riparian evapotranspiration for the reach. The spring/stream gain reflects (1) water that is discharged from the aquifer and (2) inflow from ungaged tributaries. Because the water budget is based on median flows from 1950 through 2002 and diversions (and change in reservoir storage for Conchas Lake) for 1999, rather than median evaporation and diversions, the stream gain estimates are highly uncertain. However, diversions in 1999 do represent average conditions.

For some uses, a portion of the diverted flow is not consumptively used and returns to a water body; the returned water is called ***return flow***. Return flow from irrigation with surface water is assumed to return directly to the stream and is calculated using the procedures of Wilson et al. (2003), which are described in Section 7.2.1.1. Return flow from municipal users discharged directly to streams was estimated to be about 66 percent of diversions for the City of Las Vegas (Wilson et al., 2003).

7.1.1.2 Outflow Components

Outflows are comprised of surface water depletions and flow past the New Mexico state line. Outflows due to ***surface water diversions*** include:

- *Public and domestic use.* Diversions from surface water and return flows were obtained from Wilson et al. (2003) for the year 2000. The net depletions to surface water from groundwater pumping for communities adjacent to the stream system were also included in this outflow component of the surface water budgets.

- *Commercial use.* Commercial water use was based on the depletions for 2000 (Wilson et al., 2003), which reflect current commercial uses. Commercial surface water use in the planning region occurred only in San Miguel County in 2000, for the golf courses and Conchas Lake State Park.

- *Livestock use.* Livestock depletions are based on year 2000 estimates (Wilson et al., 2003). Based on the 2000 data, all livestock surface water use in Mora County was assumed to be in the Canadian River basin, and the surface water used for livestock purposes in San Miguel and Guadalupe Counties was assumed to be from the Pecos River Basin.

- *Mining, industrial and power uses.* Essentially no surface water is used for these purposes in the planning region, and they were therefore not included in the surface water budget.

- *Irrigation use:* Estimates of the amount of water diverted for irrigation are based on the agricultural use by county and river basin for 1999 from the OSE water use report (Wilson et al., 2003). Where the location of the irrigation was identified, the diversions were weighted based on OSE's geographic information system (GIS) coverage of irrigated acres in the Pecos River Basin. Irrigation locations identified by Martinez (1990) were used to assign the distribution of irrigation diversions reported by Wilson et al. (2003) as "scattered" in the Canadian River Basin.

Stream loss into the groundwater is the amount of water that is lost from a stream and recharges the aquifer. This component is estimated similarly to stream gain, by subtracting flow at an upstream gage from flow at the next downstream gage and adjusting for irrigation diversions and returns, riparian evapotranspiration, and reservoir evaporation within that reach.

Average annual ***reservoir evaporation*** for Santa Rosa and Conchas Lakes was calculated using USACE (2005) data and the Quay County 40-year water plan (Barnes, 2004) evaporation estimate for the lake. Average annual evaporation from Conchas Lake was calculated as the evaporation in 1999, an average year, in order to compare with gage data and diversions for the Arch Hurley Conservancy District. Average annual evaporation from Santa Rosa Lake was calculated as the median annual evaporation from 1983 (the first complete year of evaporation data after Santa Rosa Dam was constructed) to 2000. Evaporation from Storrie Lake and other storage ponds for the City of Las Vegas was based on a 1990 estimate by OSE.

Evapotranspiration (water lost from plants, such as transpiration through tree leaves) is based on the riparian acreage within the reach between gages. The evapotranspiration estimate is based on riparian acreage for the reaches analyzed on the two main rivers in the planning region and available data for riparian evapotranspiration rates in New Mexico. Because this evapotranspiration is based on estimated rather than measured rates, there is considerable uncertainty in the estimate.

Surface outflow from the planning region is based on stream gage data for the downstream reaches in the two main rivers, the Pecos and the Canadian.

7.1.2 Summary of Surface Water Budgets

Two surface water budgets for the planning region were prepared: one for the Pecos River basin and one for the Canadian River basin. For each of these two basins, two annual water budgets were prepared: one representing an average water supply and demand year and one representing a drought year.

7.1.2.1 Average Surface Water Budget

The average annual surface water budget results for both the Pecos and Canadian River basins are presented in Tables 7-1 and 7-2. Inflows are comprised primarily of gaged stream discharges from these two main drainages and inflows from gaged tributaries. The stream discharges are the median annual water yields for the period 1950 through 2002, corrected for the upstream irrigated acreages. The Gallinas, a gaged tributary to the Pecos River, has significant demands for municipal and irrigation uses and is chronically short in meeting those demands. Other tributaries to the Pecos River are not gaged, and no detail is available on the water budgets. Details on three gaged tributaries to the Canadian River are included in the Canadian River water budget.

The estimated average precipitation volume for the entire planning region is 7,342,000 acre-feet (based on the precipitation contours in Figure B-8), but the vast majority of this inflow does not show up as streamflow due to upland evapotranspiration and other factors; therefore, the water

Table 7-1. Pecos River Water Budget for Median Conditions (1950-2002)

Component of Flow	Stream/Tributary in Pecos River Basin (ac-ft/yr)		
	Pecos	Gallinas	Total Basin
Surface water inflows			
Stream inflow from gaged flow [a]	72,672	10,500	83,172
Stream gain from ungaged tributaries or groundwater (calc)	100,976	9,655	110,631
Irrigation return flow	10,447	5,830	16,277
Return flow from Las Vegas WWTP	NA	1,576	1,576
Water released from storage [b]	NE	0	0
Total inflows	184,095	27,561	211,656
Surface water depletions and outflows			
Public water supply	517	2,387	2,904
Irrigated agriculture	16,628 [c]	10,736	27,364
Livestock	144	0	144
Riparian ET [d]	8,599	1,599	10,198
Reservoir evaporation [e]	16,751	2,740	19,491
Stream loss to groundwater	15,382	0	15,382
Water to storage	NE	0	0
Gaged flow out	135,600	---	135,600
Total outflows	193,621	17,462	211,083

[a] Gaged inflows adjusted for irrigation depletions above gage based on 1999 water use data and median flows. Gage values from USGS Median for period 1950-2002.
[b] Release from Storrie included in annual supply.
[c] Irrigation on Cow Creek, Tres Hermanos Creek, and Tecolote Creek, ungaged tributaries to the Pecos River (total 2174.85 acres), are not included here.
[d] Riparian ET calculated by DBS&A using Rio Grande reach 1 average for cottonwood, cottonwood bosque, willows and salt cedar ET (2.94 ft/yr)
[e] Reservoir evaporation for Santa Rosa is median for period 1983 through 2000.

ac-ft/yr = Acre-feet per year
NA = Not applicable
NE = Not estimated
WWTP = Wastewater treatment plant
ET = Evapotranspiration
--- = Outflow from the Gallinas does not leave the Pecos Basin (it goes into the Pecos River)

Table 7-2. Canadian River Water Budget for Median Conditions (1950-2002)

Component of Flow	Stream/Tributary in Canadian River Basin (ac-ft/yr)				
	Canadian [a]	Mora / Coyote	Sapello	Conchas [b]	Total Basin
Surface Water Inflows					
Stream inflow from gaged flow [c]	29,558	35,197	16,469	4,509	85,733
Stream gain from ungaged tributaries or groundwater (calc)	107,112	0	0	0	107,112
Irrigation return flow	1,845	15,234	2,927	0	20,006
Total inflows	138,351	50,431	19,396	4,509	212,851
Surface Water Depletions and Outflows					
Public water supply	105	139	0	0	244
Commercial supply	164	0	0	0	164
Irrigated agriculture [d]	3,414	28,514	7,810 [e]	0	39,738
Livestock	288	0	0	0	288
Riparian ET [f]	4,452	4,802	280	388	9,922
Reservoir evaporation	44,021	NA	1367	0	45,388
Stream loss to groundwater	0	838	0	0	838
Arch Hurley diversions [b]	95,955	NA	NA	NA	95,955
Water to storage	14,929	NA	NA	NA	14,929
Canadian River Below Conchas Dam (1937-1971)	5,384	--	--	--	5,384
Total outflows	168,712	34,293	9,457	388	212,850

[a] Canadian River diversions applied to irrigation water budget for the Canadian River (rather than tributary, assuming Wilson would have identified a tributary or labeled as "scattered").
[b] Conchas Reservoir values and Arch Hurley Diversions based on year 1999 (Barnes, 2004)
[c] Gaged inflows adjusted for irrigation depletions above gage based on 1999 water use data and median flows
[d] Irrigation in Mora County based on total withdrawals and depletions reported by Wilson et al. (2003) for 1999 and distributed based on Martinez (1990). Irrigation in San Miguel County based on Wilson et al. (2003) for 1999, which shows diversions for Sapello River of 7,810 ac-ft and Canadian River of 3,414 ac-ft, unspecified location.
[e] Martinez (1990) shows all Sapello River irrigation above Sapello gage; thus Wilson's diversions for Sapello are applied to above the Sapello gage.
[f] Riparian ET estimated only for reaches downstream of stream gages.

ac-ft/yr = Acre-feet per year
NA = Not applicable
ET = Evapotranspiration
--- = Outflow from tributaries does not leave the Canadian River Basin (it goes into the Canadian River)

budget discussed herein is based on the amount of surface water available in the two main drainages in the planning region, as determined from stream gage records.

As discussed in Section 4, several apportionment actions (i.e., the Hope Decree and Interstate Compacts) limit the amount of irrigated acreage and consumptive use in the Pecos River basin, with the remaining flows are intended for downstream users. Consequently, the result of inflows minus depletions shown on the Pecos River budget (Table 7-1) does not represent excess water for the planning region, but rather the average amount of water that flows downstream to other users.

7.1.2.2 Representative Drought Year Surface Water Budget

Annual surface water budget results for a representative drought year are presented in Tables 7-3 and 7-4. The year 2000 was picked as a representative drought year because streamflow at regional gaging stations for that year are close to the 10th percentile annual water yield values over the 53-year analysis period from 1950 through 2002 (Q_{10} in Table 5-5, where Q_{10} is the yield below which 10 percent of all the annual water yields fall). Accordingly, inflows in the drought year water budget are composed of the water yields recorded by regional gaging stations in 2000. Outflows are comprised of surface water depletions reported by the OSE (Wilson et al., 2003) and the USACE (2005):

- Depletions for public, domestic, livestock, and commercial use were based on OSE-reported depletions in the year 2000 for their respective categories. As with the average surface water budget, mining, industrial, and power uses are not included in the water budget because no water use was reported by the OSE in the planning region for these categories from 1975 through 2000.

- The OSE-reported irrigation depletion for the year 2000 is based on 1999 data because 2000 was a drought year and OSE water use reports are meant to represent average conditions. The average diversions and depletions were also used for the drought period to show the demand on the system when supply is low. Where the average demand clearly exceeds supply, as it did on Coyote Creek, irrigation demand was reduced to match the supply.

Table 7-3. Pecos River Water Budget for Drought Conditions

Component of Flow	Stream/Tributary in Pecos River Basin (ac-ft/yr)		
	Pecos	Gallinas	Total Pecos River
Surface Water Inflows			
Stream inflow from gaged flow [a]	32,461	4,403	36,864
Stream gain from ungaged tributaries, inflow from groundwater (calc)	80,811	5,317	86,128
Irrigation return flow	10,447	1,560	12,007
Return flow from Las Vegas WWTP	NA	1,576	1,576
Water released from storage [b]	NE	0	0
Total inflows	123,719	12,856	136,576
Surface Water Depletions and Outflows [c]			
Public water supply	517	2,387	2,904
Irrigated agriculture	16,628 [d]	2,766	19,394
Livestock	144	0	144
Riparian ET [e]	8,599	1,599	10,198
Reservoir evaporation [f]	12,888	2,740	15,628
Stream loss to groundwater	0	0	0
Water to storage	0	0	0
Gaged flow out	87,888	---	87,888
Total outflows	126,664	9,492	136,156

[a] Gage values from USGS 10th percentile (1950-2002); inflows adjusted for irrigation depletions above gage based on 1999 water use data and 10th percentile flows.
[b] Release from Storrie included in annual supply.
[c] Demand values from Wilson et al. (2003) for 1999, except where supply is insufficient to meet demands.
[d] Irrigation on Cow Creek, Tres Hermanos Creek, and Tecolote Creek, ungaged tributaries to the Pecos River (total 2,174.85 acres), are not included here.
[e] Riparian ET calculated by DBS&A using Rio Grande average for cottonwood, cottonwood bosque, willows and salt cedar ET (2.94 ft/yr)
[f] Reservoir evaporation for Santa Rosa is based on year 2000. Changes in storage in Santa Rosa Reservoir not estimated.

ac-ft/yr = Acre-feet per year
WWTP = Wastewater treatment plant
NA = Not applicable
ET = Evapotranspiration
--- = Outflow from the Gallinas does not leave the Pecos Basin (it goes into the Pecos River)

Table 7-4. Canadian River Water Budget for Drought Conditions

Component of Flow	Stream/Tributary in Canadian River Basin (ac-ft/yr)				
	Canadian [a]	Mora / Coyote	Sapello	Conchas [b]	Total Basin
Surface Water Inflows					
Stream inflow from gaged flow [c]	8,894	15,515	6,476	1,499	32,384
Stream gain from ungaged tributaries or groundwater (calc)	30,464	5,639	0	0	36,103
Irrigation return flow	1,845	14,411	2,927	0	19,183
Water from storage	85,024	NA	NA	NA	85,024
Total inflows	126,227	35,565	9,403	1,499	172,694
Surface Water Depletions and Outflows					
Public water supply	105	139	0	0	244
Commercial supply	164	0	0	0	164
Irrigated agriculture [d]	3,414	27,000 [e]	7,810 [f]	0	38,224
Livestock	288	0	0	0	288
Riparian ET [g]	4,452	4,802	226 [h]	388	9,868
Reservoir evaporation	28,550	NA	1,367	NA	29,917
Stream loss to groundwater	0	0	0	0	0
Arch Hurley diversions [b]	92,519	NA	NA	NA	92,519
Water to storage	0	NA	NA	NA	0
Canadian River Below Conchas Dam (1937-1971)	1,600	---	---	---	1,600
Total outflows	131,092	31,941	9,403	388	172,824

[a] Canadian River diversions applied to irrigation water budget for the Canadian River (rather than tributary, assuming Wilson would have identified a tributary or labeled as "scattered").
[b] Conchas Reservoir values and Arch Hurley Diversions based on year 2000 (Barnes, 2004)
[c] Gaged inflows adjusted for irrigation depletions above gage based on 1999 water use data and 10th percentile flows
[d] Irrigation in Mora County based on total withdrawals and depletions reported by Wilson et al. (2003) for 1999 and distributed based on Martinez (1990). Irrigation in San Miguel County based on Wilson et al. (2003) for 1999, which shows diversions for Sapello River of 7,810 ac-ft and Canadian River of 3,414 ac-ft, unspecified location.
[e] Irrigation on Coyote Creek reduced to not exceed available supply in 2000.
[f] Martinez (1990) shows all Sapello River irrigation above Sapello gage; thus Wilson's diversions for Sapello are applied to above the Sapello gage.
[g] Riparian ET estimated only for reaches downstream of stream gages.
[h] Riparian ET estimate on Sapello reduced to not exceed supply.

ac-ft/yr = Acre-feet per year
NA = Not applicable
ET = Evapotranspiration
--- = Outflow from tributaries does not leave the Canadian River Basin (it goes into the Canadian River)

- Annual reservoir evaporation for the year 2000 was calculated from daily evaporation data collected by the USACE (2005) for Santa Rosa and Conchas Lakes. Storrie Lake evaporation for 2000 was obtained from Wilson et al. (2003). As in the average surface water budget, it was assumed that evaporation from other, smaller reservoirs and lakes in the planning region was negligible.

- Riparian evapotranspiration was estimated based on GIS coverage and available data for riparian evapotranspiration rates in New Mexico. This value may decrease in a drought year due to plants shutting down or dying back from lack of available water; however, available data are insufficient to accurately estimate drought year riparian evapotranspiration.

Again, because of the various apportionment actions on the Pecos River (Section 7.1.2), the total of inflows minus depletions shown on the drought year budget for the Pecos River Basin (Table 7-3) does not represent excess water for the planning region, but rather the average amount of water that flows to users downstream.

7.1.3 Discussion of Surface Water Budgets

Details on the assumptions and methods for developing the water budgets in Tables 7-1 through 7-4 are included in Appendix G. Tables G-1 and G-2 (Appendix G) show the balance in each gaged reach from upstream to downstream in the Pecos and Canadian Rivers and their tributaries.

7.1.3.1 Pecos River Basin

As shown in Tables 7-1 and 7-3, whereas the Pecos River supply is sufficient to meet demands under both median and drought conditions, demands on the Gallinas River appear to exceed native supply at the upstream Gallinas near Montezuma gage under both the median and drought conditions. However, a stream gain of about 9,000 ac-ft/yr is estimated between the Gallinas near Montezuma and the Gallinas near Colonias (at the confluence with the Pecos River) gages, resulting in a net inflow to the Pecos River from the Gallinas even in drought conditions, and if this gain is closer to the upstream section on the Gallinas, then supply could meet demand. A seepage study conducted by the USGS in September of 1977 shows that the Gallinas River gains and loses throughout the reach between Montezuma and the confluence with the Pecos (Section 5.2.1.2).

It may also be that the Storrie Lake Irrigation Project is able to take advantage of irrigation return flows within its system, which would result in sufficient supply under median conditions. While the surface water supply during the irrigation season (March through September) is about 75 percent of the annual flow in the Gallinas River, it is assumed that the storage in Storrie Lake allows the irrigators to take advantage of the full annual flow in a median year.

A comparison of the water rights on the Gallinas River with the available supply shows that the water supply is not sufficient under either median or drought conditions to fulfill all the water rights on the river. The water rights on the Gallinas are defined by the decreed acéquia acreage listed by Martinez (1990) as active, (3,367.2 acres), a duty of 1.5 acre-feet per acre, and a conveyance efficiency of 70 percent, along with the Storrie Project water rights of 17,568.77 ac-ft/yr (accounting for a conveyance efficiency of 70 percent on a duty of 12,298.14 ac-ft/yr) (Table 4-2). Other inflow and outflow components are described under Section 7.1.1, summarized in Table 7-5, and shown in Figure 7-2.

This comparison of supply to water rights assumes that the irrigation return flow is available for diversion for irrigation, which may be the case for part of the irrigated lands but may overstate the overall available supply. The analysis also assumes that water stored in Storrie Lake allows the irrigators to use their full annual supply; without this storage, only 75 percent of the annual supply would be available during the irrigation season (March through September). A better understanding of the flow in locations where stream gains occur and at each diversion point would improve the understanding of the water budget on the Gallinas River.

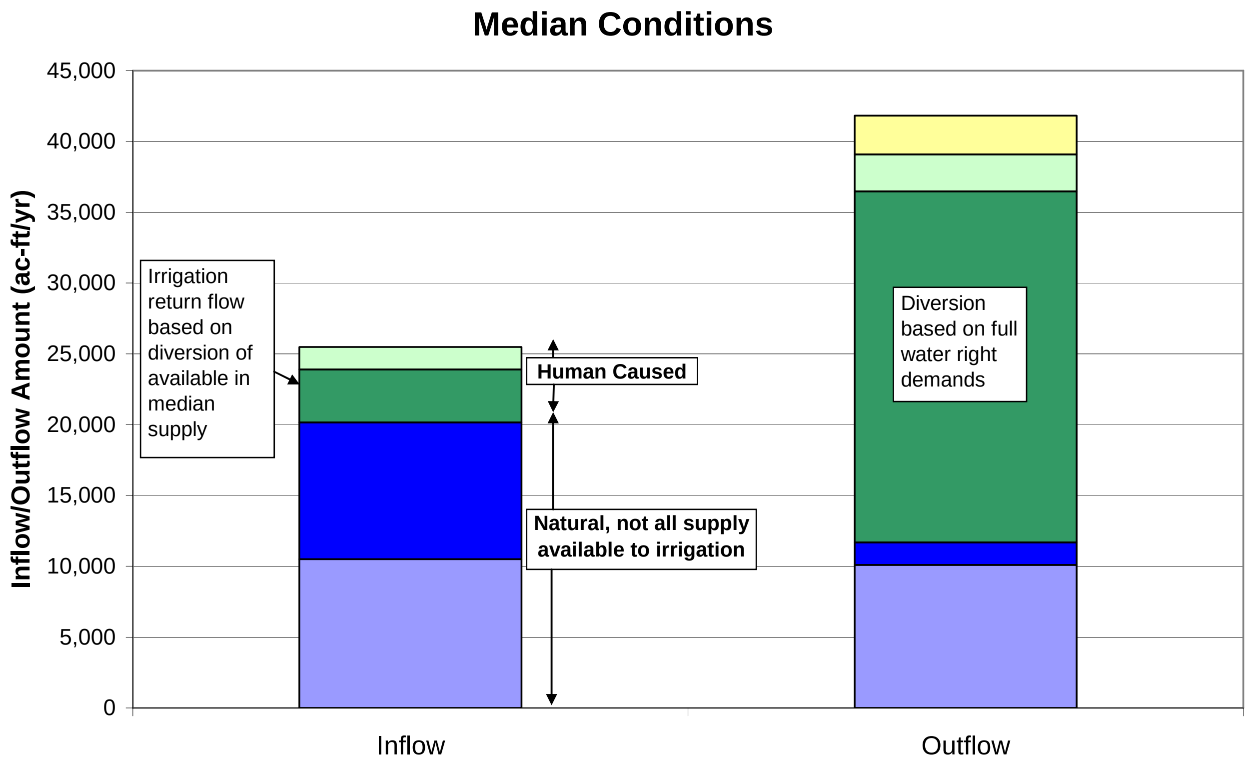
Table G-1 (Appendix G) attempts to show the balance in the river as the inflows and outflows occur. To keep the calculated river flow positive, much less Storrie Project water is diverted than the decreed amount, under both median and drought conditions. The outflow in the Gallinas near Colonias is 10,100 acre-feet and 3,365 acre-feet for median and drought conditions respectively, indicating that the stream is gaining from groundwater inflow.

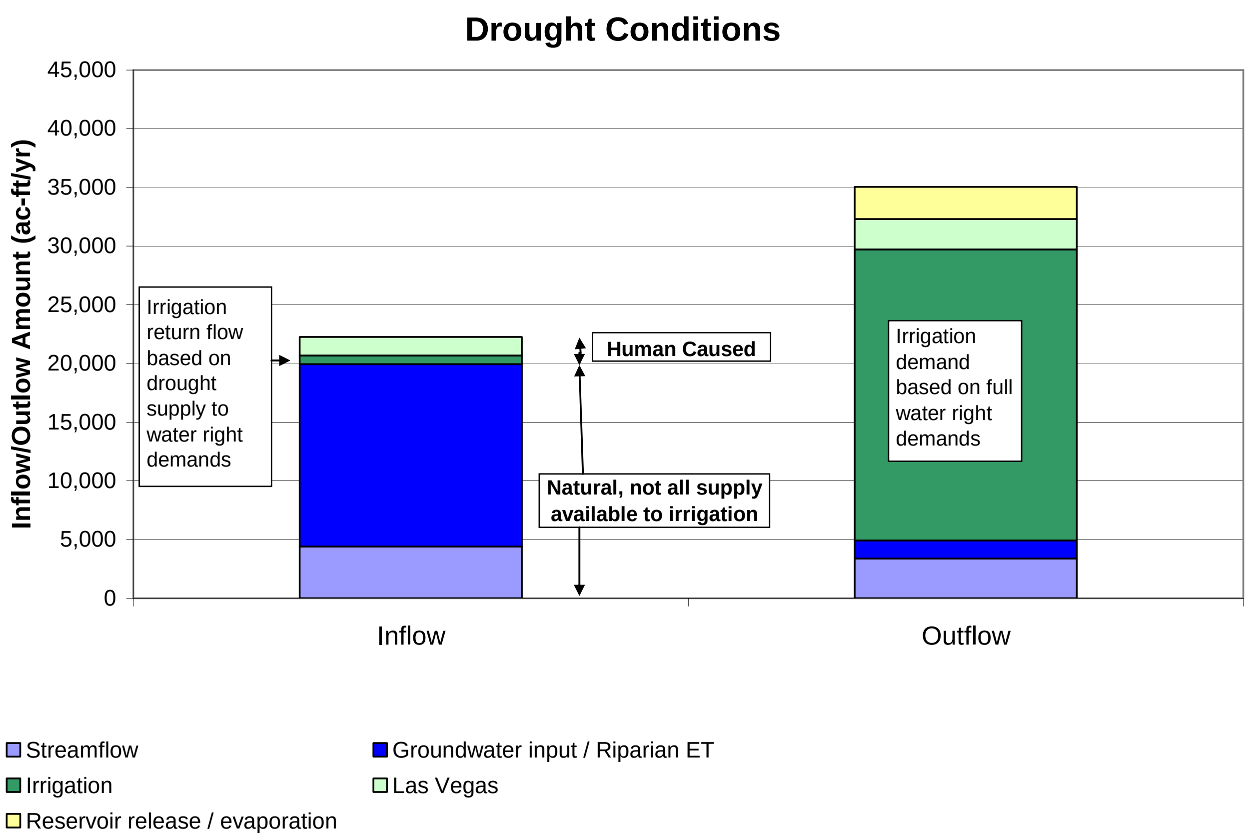
Table 7-5. Comparison of Water Supply to Water Rights on the Gallinas River

Component of Flow	Inflow (ac-ft/yr)	Outflow/ Water Rights (ac-ft/yr)	Explanation
Median Conditions			
Natural			
Streamflow	10,500	10,100	Median (1950-2002) gaged inflow and outflow
GW input/riparian ET	9,655	1,599	Calculated stream gain, riparian ET
Total natural	20,155	11,699	
Human-caused			
Irrigation	3,750	24,784	Storrie Right of 17,569 acre-feet plus irrigation with duty of 1.5 on 3,367.2 acres (not included in Storrie Project), conveyance efficiency of 70% and a total project efficiency of 30% (Wilson et al., 2003)
Las Vegas	1,576	2,600	Water right diversion and return flows estimated by Wilson et al., 2003
Reservoir release/ evaporation	0	2,740	Reservoir releases included in annual supply Wilson et al., 2003
Total human-caused	5,326	30,124	
Drought Conditions			
Natural			
Streamflow	4,403	3,365	10th percentile flow (1950-2002) gaged inflow and outflow
GW input/riparian ET	5,317	1,559	Calculated stream gain, riparian ET
Total natural	9,720	4,924	
Human-caused			
Irrigation	750	24,784	Storrie Right of 17,569 acre-feet plus irrigation with duty of 1.5 on 3,367.2 acres (not included in Storrie Project), conveyance efficiency of 70% and a total project efficiency of 30% (Wilson et al., 2003)
Las Vegas	1,576	2,600	Water right diversion and return flows estimated by Wilson et al., 2003
Reservoir release/ evaporation	0	2,740	Reservoir releases included in drought supply Wilson et al., 2003
Total human-caused	2,326	30,124	

ac-ft/yr = Acre-feet per year

GW = Groundwater
ET = Evapotranspiration





MORA-SAN MIGUEL-GUADALUPE
WATER PLANNING REGION

Water Rights and Supply on the Gallinas River

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7/1/05

Figure 7-2

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7.1.3.2 Canadian River Basin

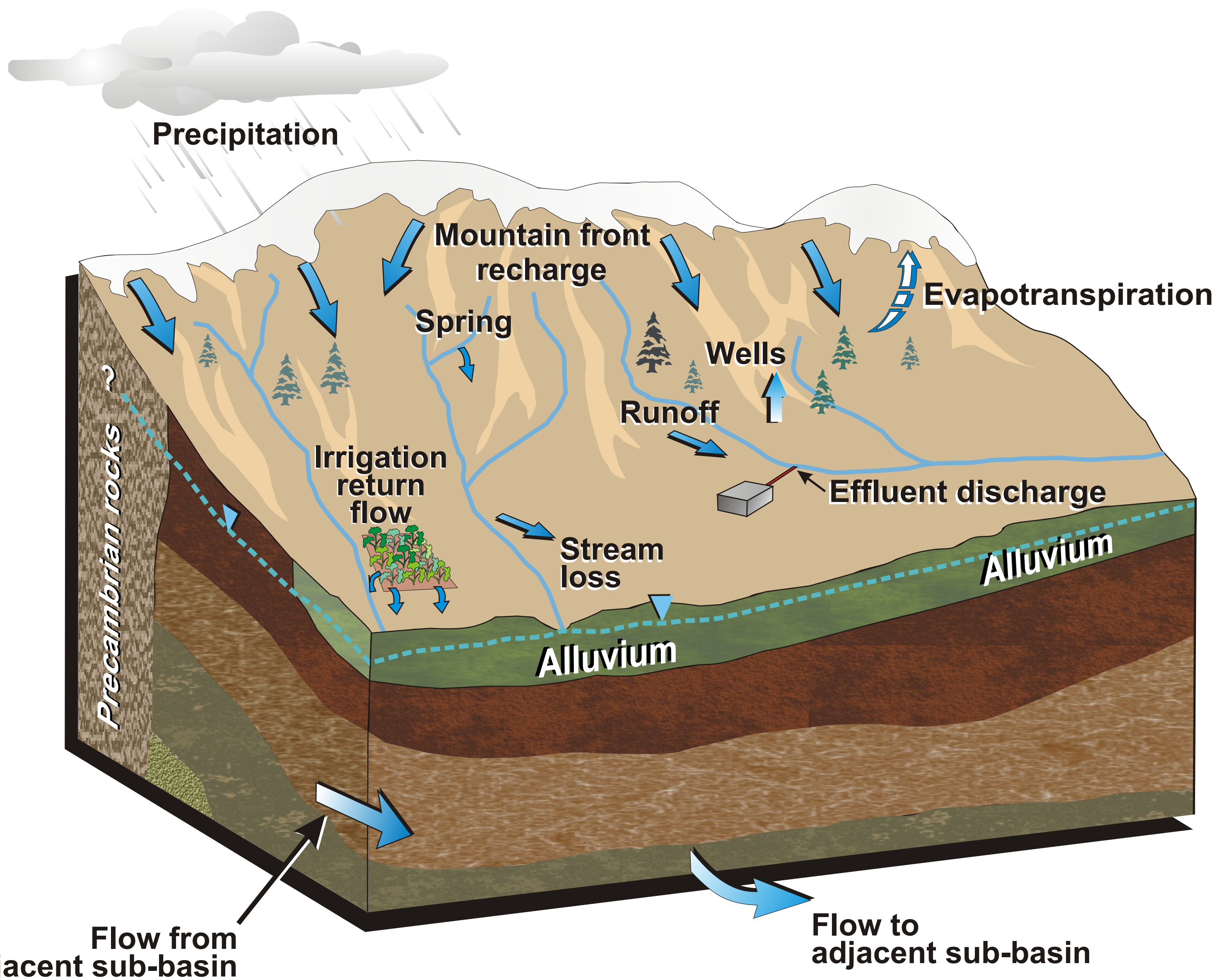
The Canadian River system appears to meet demands under median conditions. However, under drought conditions, the inflow to Coyote Creek is insufficient to meet demand, as represented by the 1999 diversions, and therefore, no inflow to Mora Creek is estimated from Coyote Creek. Additionally, no inflow from the Sapello River is calculated under drought conditions as reservoir evaporation and riparian evapotranspiration consume all flow measured at an upstream gage (Sapello River near Sapello). Under drought conditions the Canadian River provides insufficient supply in Conchas Reservoir for the Arch Hurley Irrigation District (in Quay County); during the recent drought years, for example, only 16 percent of average demands were filled in 2002 and no diversions at all occurred in 2003. The water budgets presented here do not reflect the available supply during the irrigation season. About 84 percent of the flow in the Mora River occurs during the irrigation season and about 49 percent of the flow on Coyote Creek occurs during the irrigation season.

7.2 Groundwater Budget

Historically, groundwater has provided most of the domestic and livestock water supply needs throughout the water planning area, but only about half of the public and commercial water supply and only 2 percent of the irrigation demands. While the demands on groundwater have been estimated by the OSE (Wilson et al., 2003), the natural components of flow are not well understood for the planning region. DBS&A has calculated recharge for each of the administrative groundwater basins as defined by the OSE, but little else is known. While the groundwater budgets are incomplete, they do clarify areas for which data are needed.

7.2.1 Groundwater Budget Terms and Methodology

The groundwater budget components consist of the inflow components of recharge, stream loss, sub-flow from adjacent basins, and return flow from municipal, mining, or irrigation uses. The outflow components consist of pumping from municipal, commercial, domestic, irrigation, industrial, livestock, mining, and power generation wells, evapotranspiration, springs, and sub-flow to other basins. Figure 7-3 is a schematic showing the water budget components.



Not to Scale

MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Water Budget Components

Figure 7-3

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A groundwater budget is the balance between inflow and outflow:

- If the total inflow and outflow components are equal, groundwater levels will not rise or fall.
- If outflow is greater than the inflow, groundwater levels will decline and the volume of water in storage will decrease.
- If inflow is greater than outflow, groundwater levels will rise and the volume of water in storage will increase.

In other words, where the change in storage is negative, water levels in the basin are dropping and where the value is positive, water levels are rising. It is possible for water levels to be dropping in one location and rising in another within the same basin. Unfortunately, the USGS, which is the primary agency that monitors aquifer levels, has only one well in the planning region with a long-term period of record and only a few wells with shorter periods of record (Section 5.3).

Where the water budget components are poorly understood, the difference between inflow and outflow components may be a result of error in the knowledge of the basin rather than an indication of changes in groundwater storage. Because all of the water budgets for the planning region are so poorly understood, the net differences between calculated inflows and outflows are not presented.

The procedures used to estimate the inflow and outflow components for the Mora-San Miguel-Guadalupe groundwater budgets are discussed in Sections 7.2.1.1 and 7.2.1.2.

7.2.1.1 Inflow Components

Recharge consists of the addition of water to an aquifer by infiltration, either directly into the aquifer or indirectly by way of another rock formation. Recharge as estimated herein is the natural recharge from precipitation that infiltrates to the water table. Artificial recharge, which occurs when water is injected through wells or spread over permeable surfaces for the purpose of recharging an aquifer, is considered part of the return flow component described below. The method of estimating recharge is described in Section 5.3.4.

Stream loss represents the recharge to the aquifer by seepage from streams and is calculated as described in Section 7.1.1.2. Establishing the average annual losses to groundwater in a losing reach requires records from stream gaging stations in appropriate locations with sufficient periods of record. Such losses vary from day to day and year to year depending on the amount of precipitation. Stream losses were estimated for a reach on the Mora River in the Canadian Basin and a reach along the Pecos River and are presented in Tables 7-1 through 7-4.

Sub-flow from adjacent basins is the water that flows underground across basin boundaries. No estimates of this inflow component are available for any of the basins in the planning region. In general, groundwater is flowing east and south in the planning region, from the Sangre de Cristo Mountains toward the plains.

As discussed in Section 7.1.1.1, ***return flow*** is that portion of flow diverted for some uses that is not consumptively used and returns to a water body. In general, all commercial uses are assumed to be fully depleted, and return flow from self-supplied domestic wells is not included in the water budgets. The water budgets do include, as applicable, estimates of return flow to groundwater from municipal/industrial and irrigation uses, based on OSE estimates of return flow and irrigation efficiencies (Wilson et al., 2003):

- The OSE estimate assumes that 50 percent of municipal/industrial uses are returned to the groundwater system unless metered. This is a very general estimate for water budgeting purposes. Specific return flow analyses are required by OSE for individual water rights applications.

- The estimates of irrigation return flow are based on a combination of conveyance losses and estimated irrigation efficiencies, which differ from basin to basin but range in the planning region from 45 percent for flood irrigation to 85 percent for drip irrigation. For example, an irrigation water right of 1,000 acre-feet with a system conveyance efficiency of 60 percent and an on-farm efficiency of 70 percent will lose 400 acre-feet before it reaches the farm and 30 percent of the remaining 600 acre-feet (180 acre-feet), for a total return flow of 580 acre-feet. All return flow from irrigation with groundwater diversions is assumed to return to groundwater.

7.2.1.2 Outflow Components

The estimates of ***well diversions*** for municipal, commercial, irrigation, industrial, livestock, mining, and power uses were all derived from OSE's water use report for 2000 (Wilson et al., 2003), as described in Section 6.1. Diversions from domestic wells were estimated by subtracting the population served by public water systems from the total county population and multiplying the remainder by an average per capita demand (Section 6.1).

The ***evapotranspiration*** component of the water budget is the discharge of groundwater through the roots of trees or other vegetation that taps the aquifer directly; therefore, evapotranspiration of groundwater occurs only where the depth to water is shallow. No estimates of evapotranspiration are available for any of the groundwater basins in the planning region.

Discharge to springs and streams occur where the groundwater level intersects the ground surface or the elevation of a stream. Discharge to springs can either be directly measured, where a spring issues at a single location, or can be estimated in the same way that stream losses are estimated, by evaluating the water budget on a stream system using stream gages. The latter method was used in this study, recognizing that the lack of estimates of flow from ungaged tributaries may result in an overestimation of spring flow. Outflow to springs and streams was estimated for the Canadian River and the Gallinas River in the Pecos Basin.

Sub-flow out of a basin is the water that flows underground out of a basin boundary. No estimates of sub-flow out of the basins in the planning region were available.

7.2.2 Summary of Basin Groundwater Budgets

Table 7-6 summarizes the groundwater budgets for seven administrative groundwater basins and one undeclared area in the planning region. In developing these budgets, the man-induced components were estimated, but many of the natural components, such as evapotranspiration, sub-flow out of the basins, and spring and stream gain, were not estimated.

Table 7-6. Summary of Estimated Groundwater Budget Components for Administrative Basins in the Mora-San Miguel-Guadalupe Region

Component	Flow Amount (ac-ft/yr)								
	Canadian	Estancia	Ft. Sumner	Not Declared	Rio Grande	Roswell	Tucumcari	Upper Pecos	Total
Inflow									
Recharge [a]	65,339	320	11,882	17,865	3,559	2,477	11,517	66,523	179,480
Stream loss	838	NE	NE	NE	NE	NE	NE	15,382	16,220
Flow from adjacent basins	NE	NE	NE	NE	NE	NE	NE	NE	NE
Return flow M&I	129	0	120	0	0	0	10	480	740
Return flow mining	0	0	0	0	0	0	0	0	0
Return flow irrigation	10	0	130	0	0	0	0	370	510
Total inflow	66,315	320	12,130	17,865	3,560	2,480	11,525	82,755	196,950
Outflow									
Municipal wells	305	0	240	0	0	0	0	1,010	1,560
Commercial (self-supplied)	6	0	10	0	0	0	70	130	220
Domestic wells (self-supplied)	633	0	30	10	0	4	10	1,210	1,900
Irrigation wells	50	0	310	0	0	0	0	880	1,240
Industrial (self-supplied)	0	0	0	0	0	0	0	0	0
Livestock (self-supplied)	150	0	130	100	0	20	80	340	820
Mining (self-supplied)	0	0	0	0	0	0	0	0	0
Power (self-supplied)	0	0	0	0	0	0	0	0	0
Evapotranspiration	NE	NE	NE	NE	NE	NE	NE	NE	NE
Springs/stream gain	74,000	NE	NE	NE	NE	NE	NE	NE	74,000
Sub flow out	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total outflow	75,140	0	720	110	0	20	160	3,570	79,720

[a] Based on more conservative, alternate estimate

ac-ft/yr = Acre-feet per year
NE = Not estimated
M&I = Municipal and industrial

The primary output components of the simple groundwater budget constructed here are depletions from pumping wells for the year 2000 for the aforementioned uses (Section 7.2.1.2), summarized in Table 6-1 and briefly described below:

- In the year 2000, all of the domestic water supply (1,900 acre-feet) and about half of the public water supply (groundwater depletions of 820 acre-feet) were from groundwater. Together, these two uses made up 56 percent of measured total groundwater depletions.

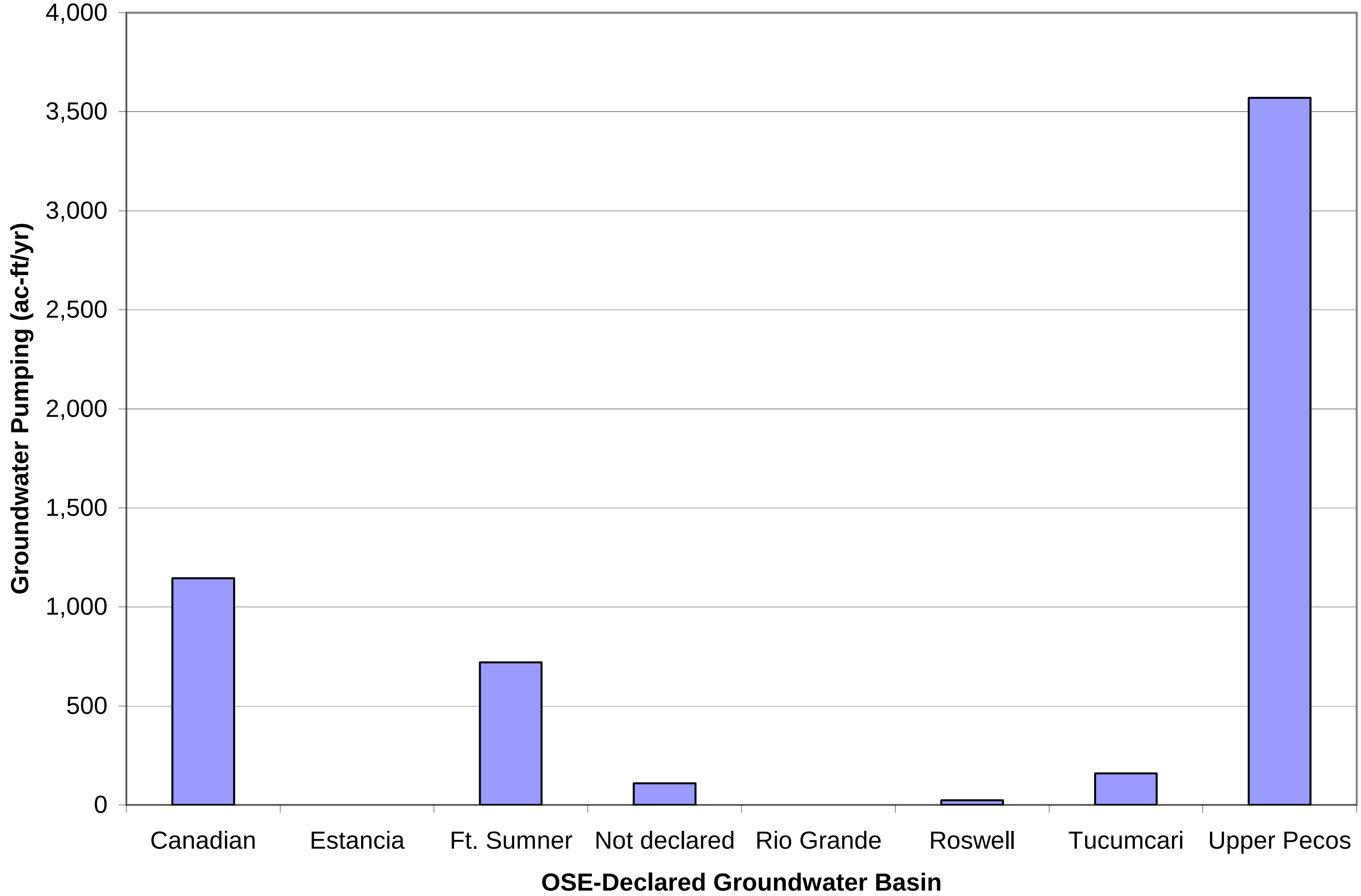
- Also in 2000, groundwater supplied 820 acre-feet, or 61 percent, of the total livestock needs. This 820 acre-feet comprised 21 percent of the total recorded groundwater depletions.

- Irrigation accounted for 19 percent of all groundwater depletions in the planning region in 2000. However, groundwater supplied only 2 percent of all irrigation depletions (surface and groundwater) in the region in the same year.

- The remaining 5 percent of tabulated groundwater depletions in 2000 were for commercial uses.

Figure 7-4 shows the total amount of pumping from each basin. The Upper Pecos Basin has by far the greatest amount of groundwater diversions, approaching 3,500 ac-ft/yr, whereas no diversions are estimated for the Estancia or Rio Grande Basins, which actually have a few domestic and stock wells.

Although not determined by the OSE, groundwater discharge to evapotranspiration can be estimated for areas with a depth to groundwater of 20 feet or less, based on the fact that phreatophyte trees typically have rooting depths of about 33 feet (Bouwer, 1978) and phreatophyte shrubs commonly root to a depth of 10 feet. A depth to groundwater map for the planning region was developed by WRRI (Figure B-6 in Appendix B), but available data did not allow for a contour interval sufficient to identify the 20-foot depth-to-water interval; therefore, groundwater discharge due to evapotranspiration was not estimated for the planning region.



MORA-SAN MIGUEL-GUADALUPE WATER PLANNING REGION

Groundwater Pumping

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7/1/05

Figure 7-4

The primary input component of the groundwater budget is recharge. As discussed in Section 5.3.4, recharge for each declared basin in the planning region was estimated based on modified Maxey-Eakin calculations. The estimated average recharge for the groundwater basins within the planning region is about 178,000 ac-ft/yr.

A comparison of the year 2000 groundwater depletions with the estimated average groundwater recharge indicates that recharge is much more than the recent OSE-reported rate of groundwater withdrawals due to man-induced mechanisms. This observation suggests that additional groundwater usage could perhaps be developed; however, impacts to surface water must be offset to maintain compliance with the interstate compacts on the Pecos and Canadian Rivers.

In addition, recharge rates will be reduced during drought years, when lower snowpack yields and lessened rainfall produce reduced amounts of runoff available for recharge. If drought conditions persist over a prolonged period, the current rate of groundwater use in the planning region will likely result in mining of the groundwater resources in some localities.

As shown in Table 7-6, more information on the amount of evapotranspiration, stream losses and gains, and subflow in and out of each basin is needed to obtain a better understanding of the water budgets. Return flow estimates could be improved by measuring surface diversions and canal losses. Detailed water level maps could help define the flow regimes in each basin, and greater coverage by the USGS to monitor water level changes is thus necessary to better understand the condition of the groundwater in this planning region.