Recharge Rates for the Major Aquifers

The attached table contains recharge rates for 8 major aquifer including the Carrizo-Wilcox, Gulf Coast, High Plains, Edwards-Trinity, Trinity, Seymour, Cenozoic Pecos Alluvium, and Hueco-Mesilla Bolson aquifers. Recharge rates for the Edwards aquifer can be found in Slattery et al., 1998 and in annual reports published by the Edwards Aquifer Authority (e.g. EAA, 2000). Recharge data were compiled from reports published by the Texas Water Development Board, U.S. Geological Survey, and other publications. The table lists the study areas (counties or general area), underlying aquifers, recharge rates (units of mm/yr, inches/yr, or total recharge in acre-feet/yr), data sources, and techniques used to estimate recharge. Additional notes are provided in some cases. The full reference citations are listed separately.

The main techniques for estimating recharge are Darcy's law, groundwater modeling, and baseflow discharge. Darcy's Law is widely applied in the confined sections of the Carrizo-Wilcox and Gulf Coast aquifers. Groundwater modeling is used in most aquifers. Baseflow discharge is used primarily in the Trinity, Edwards-Trinity, Seymour, and Cenozoic Pecos Alluvium aquifers. Environmental tracers so far have only been used to a limited (chloride mass balance, tritium, and carbon-14).

Estimates of recharge rates in the Carrizo-Wilcox aquifer range from 0.1 to 5.8 in/yr. The higher recharge rates occur in the sandy portions of the aquifer (i.e. Simsboro and Carrizo units). Recharge rates are generally lower in the Gulf Coast aquifer, ranging from 0.0004 to 2 in/yr. In both the Carrizo-Wilcox and Gulf Coast aquifers, higher recharge rates are in upland areas with sandy soils. Regional recharge rates in the High Plains aquifer, outside irrigated areas, are generally low (0.004 to 1.7 in/yr) whereas playa-focused recharge rates are much higher (0.5 to 8.6 in/yr). Irrigated areas also have fairly high recharge rates (0.6 to 11 in/yr). Recharge rates in the Trinity and Edwards-Trinity aquifer generally range from 0.1 to 2 in/yr. The Seymour aquifer has recharge rates that range from 1 to 2.5 in/yr. Recharge rates for the Hueco-Mesilla Bolson and the Cenozoic Pecos Alluvium are represented as total recharge along mountain fronts and valley floors.

Major Aquifer	Location (County/Area)	Aquifer	Recharge rate (mm/yr)	Recharge rate (in/yr)	Total recharge (af/yr)	Reference	Technique	Notes
Carrizo Wilcox	Atascosa, Frio	Carrizo sand	45.7	1.8		Alexander and White, 1966	^{14}C, Darcy's Law	
	Sabine, San Augustine	undifferentiated	50.8	2.0		Anders, 1967	Darcy's Law	
	Sabine, San Augustine	undifferentiated	25.4	1.0		Anders, 1967	baseflow discharge	
	Camp, Franklin, Morris, Titus	Carrizo Wilcox			12,000	Broom et al., 1965	baseflow discharge	
	Harrison	Cypress	7.9	0.3	15,000	Broom and Meyers, 1966	Darcy's Law	
	Harrison	Cypress	7.9	0.3	40,000	Broom and Meyers, 1966	baseflow discharge	
	Wood	Carrizo	12.7	0.5	3,000	Broom, 1968	Darcy's Law	
	Freestone	Calvert Bluff sands	100	3.9		Dutton, 1990	soil water budget	
	Bastrop, Lee, Milam	Simsboro, Carrizo	51 - 102	2.0 - 4.0		Dutton, 1999	groundwater modeling	
	Bastrop	Carrizo, Wilcox sand	38	1.5		Follett, 1981	Darcy's Law	
	Winter Garden area	undifferentiated	5 - 127	0.2 - 5.0		Guyton & Assoc. and HDR, 1998	modeling, water budget	
	Bastrop, Lee, Milam, Robertson, Halls, Falls, Limestone, Freestone, Navarro	Carrizo, Simsboro	76 - 127	3.0 - 5.0		Harden, 2000	groundwater modeling	
	Bastrop, Lee, Milam, Robertson, Halls, Falls, Limestone, Freestone, Navarro	Calvert Bluff, Hooper,	12.7	0.5		Harden, 2000	groundwater modeling	
	Bexar	Hooper, Simsboro, Calvert Bluff	45.7	1.8		HDR Engineering Inc., 2000	groundwater modeling	
	Winter Garden area	undifferentiated			100,000	Klemt et al., 1976	groundwater modeling	
	Atascosa	Carrizo	147	5.8		Opfel and Elder, 1978	neutron probe logging	
	Rusk	Carrizo	<25.4	< 1.0		Sandeen, 1987	Darcy's Law	
	Navarro	Carrizo Wilcox	12.7	0.5		Thompson, 1972	estimate	
	Caldwell, Bastrop, Lee, Milam, Robertson, Limestone, Freestone	undifferentiated	25.4	1.0		Thorkildsen and Price, 1991	groundwater modeling	
	Bastrop, Lee, Fayette	undifferentiated	25.4	1.0		Thorkildsen et al., 1989	groundwater modeling	
	Atascosa, Bexar, Dimmit, Frio, Gonzales, Guadalupe, Medina, Uvalde, Wilson, Zavala	undifferentiated			25,000	Turner et al., 1960	Darcy's Law	
	Rains, Van Zandt	Carrizo Wilcox	3	0.1	5,000	White, 1973	Darcy's Law	
Gulf Coast	Matagorda, Wharton	Beaumont, Chicot, Evangeline	0 - 10	0.0 - 0.4		Dutton and Richter, 1990	groundwater modeling	
	Duval, Jim Wells	Evangeline	1.5	0.1		Groschen, 1985	groundwater modeling	
	Aransas, Bee, Brooks, Calhoun, De Witt, Duval, Goliad, Hidalgo, Jackson, Jim Hogg, Jim Wells, Karnes, Kenedy, Kleberg, Lavaca, Live Oak, McMullen, Nueces, Refugio, San Patricio, Starr, Victoria, Webb, Willacy	Chicot, Evangeline, Jasper	0.01 - 3.0	0.0004 - 0.12		Hay, 1999	groundwater modeling	
	Colorado, Lavaca, Wharton	Chicot, Evangeline	30 - 34	1.2 - 1.3		Loskot et al., 1982	Darcy's Law	
	Jim Wells	Evangeline	<2.5	< 0.1		Mason, 1963	Darcy's Law	
	Gulf Coast					Muller and Price, 1979	groundwater modeling	
	Brooks	Evangeline			5,600	Myers and Dale, 1967	Darcy's Law	
	Harris, Montgomery, Walker	Chicot, Evangeline	< 152.4	< 6.0		Noble et al., 1996	Tritium	
	Montgomery	Chicot,	43.2	1.7		Popkin, 1971	Transmission	
	Gulf Coast		18.8 (0 - 152)	0.7 (0.0 - 6.0)		Ryder, 1988	groundwater modeling	
	Washington	Jasper, Evangeline, Catahoula,	17.8	0.7		Sandeen, 1972	base flow discharge	

Major Aquifer	Location (County/Area)	Aquifer	Recharge rate (mm/yr)	Recharge rate (in/yr)	Total recharge (af/yr)	Reference	Technique	Notes
	Nueces, San Patricio				5,400	Shafer, 1968	Darcy's Law	
	Polk	Jasper and Evangeline	50.8	2.0		Tarver, 1968	Darcy's Law	
	Gulf Coast		0 - 16.8	0.0 - 0.7		Williamson et al., 1990	groundwater modeling	

Major Aquifer	Location (County/Area)	Aquifer	Recharge rate (mm/yr)	Recharge rate (in/yr)	Total recharge (af/yr)	Reference	Technique	Notes
High Plains		Southern	0.6 - 2	0.02 - 0.08		Brown and Signor,	Darcy's Law	regional
		Southern	13	0.5		Cronin, 1961	Darcy's Law	regional
			13 - 38	0.5 - 1.5		Dugan et al., 1994	water budget	regional
		Central	3.6 - 42.7	0.1 - 1.7		Dutton et al., 2000	groundwater modeling	regional
	Armstrong, Carson, Collingsworth, Donley, Gray, Hansford, Hemphill, Hutchinson, Lipscomb, Ochiltree, Potter, Roberts, Wheeler		152	6.0		Gould, 1906	observation	regional
	Lea Co., New Mexico		20.6	0.8		Havens, 1966	water budget	regional
			76 - 102	3.0 - 4.0		Johnson, 1901	observation	regional
		Central, Southern	4.8	0.2		Klemt, 1981	neutron probe logging	regional
		Central, Southern	2.8 - 5.1	0.1 - 0.2		Klemt, 1981	neutron probe logging	nonirrigated
		Central, Southern	15 - 279 (irrigated)	0.6 - 11.0		Klemt, 1981	neutron probe logging	irrigated
		Central, Southern	5.1 (1.5 - 20)	0.2 (0.06 - 0.8)		Knowles et al., 1984	groundwater modeling	regional
	Dallam, Hartley		16 - 24	0.6 - 0.9		Luckey and Becker, 1999	groundwater modeling	sand dunes
	Sherman Moore, Hansford, Hutchinson, Ochiltree, Lipscomb		1.6 - 2.1	0.06 - 0.08		Luckey and Becker, 1999	groundwater modeling	low permeability soils
		Southern	3.3 (2.5-25.4)	0.13 (0.1 - 1.0)		Luckey et al., 1986	groundwater modeling	regional
		Central	3.8 (1.5-	0.14 (0.06 -		Luckey et al., 1986	groundwater modeling,	regional
	Carson, Potter		205.5	8.1		Mullican et al., 1994	gw modeling	playa
	Carson, Potter		6.00	0.2		Mullican et al., 1994	gw modeling	Blackwater Draw
	Armstrong, Carson, Donley, Gray, Hemphill, Hutchinson, Potter, Randall, Roberts, Wheeler		9.00	0.4		Mullican et al., 1997	groundwater modeling	Ogallala outcrop area
	Armstrong, Carson, Donley, Gray, Hemphill, Hutchinson, Potter, Randall, Roberts, Wheeler		219.00	8.6		Mullican et al., 1997	groundwater modeling	playas Blackwater Drav
	Lubbock		41 (13 - 82)	1.6 (0.5 - 3.2)		Nativ, 1988	Tritium	playa
	Carson, Potter		60 - 100	2.4 - 3.9		Scanlon and	Chloride mass balance	playa
	Carson, Potter		0.1 - 4	0.004 - 0.16		Scanlon and Goldsmith, 1997	Chloride mass balance	interplaya
		Southern	71.1 (15.2-139.7)	2.8 (0.6 - 5.5)		Stovall et al., 2000	groundwater modeling	regional
		Central, Southern	3.2 - 17.0	0.1 - 0.7		Theis, 1937	Darcy's law	regional
			24	0.9		U.S. Bur. Reclamation, 1982		regional
		Central, Southern	2.5	0.1		Wood and Osterkamp, 1984	literature	regional
		Central, Southern	40	1.6		Wood and Osterkamp, 1984	literature	playa annulus
		N. half of Southern	11	0.4		Wood and Sanford, 1995	Chloride mass balance	regional
	Lynn		77	3.0		Wood et al., 1997	tritium	playa

Major Aquifer	Location (County/Area)	Aquifer	Recharge rate (mm/yr)	Recharge rate (in/yr)	Total recharge (af/yr)	Reference	Technique	Notes
Trinity	Kendall		33	1.3		Ashworth, 1983	baseflow discharge	Comfort and Spring Branch on Guadalupe 1940 - 1960
	Bandera, Blanco, Comal, Gillespie, Hays, Kendall, Kerr, Medina, and Travis		38.1 (1.8 in 1956; - 116.8 in 1975)	1.5 (0.07 - 4.6)		Bluntzer, 1992	baseflow discharge	
	Dallas, Kaufman, Parker, Tarrant		111.8	4.4		Dutton et al., 1996	Cross section groundwater model	
	Bell, Brown, Callahan, Comanche, Cook, Coryell,		1.0 to 7.6	0.04 - 0.3		Dutton et al., 1996	groundwater modeling	
	Callahan, Comanche, Coryell, Eastland, Erath, Falls, Hamilton, Hill, Lampasas, Limestone, McLennan, Milam, Mills, Somervell, Williamson		30.5	1.2		Klemt et al., 1975	assumed	
	Bandera, Bexar, Comal, Gillespie, Hays, Kendall, Kerr, Travis		55.9	2.2		Kuniansky and Holligan, 1994	groundwater modeling	
	Bandera, Blanco, Gillespie, Kendall, Kerr		53 - 152	2.1 - 6.0		Kuniansky, 1989	baseflow	1974 - 1977
	Kendall		55.9	2.2		Mace et al., 2000	baseflow	Comfort and Spring Branch on Guadalupe, 1940 - 1997
	Bandera, Bexar, Comal, Gillespie, Hays, Kendall, Kerr, Travis		34.5	1.4		Mace et al., 2000	groundwater modeling	
	Kendall		38.1	1.5		Reeves, 1967	baseflow	
	Kerr		25.4	1.0		Reeves, 1969	baseflow	
Seymour	Haskell, Knox		55.9	2.2		Harden and Associates, 1978	water budget	
	Hardeman		25.4	1.0		Maderak, 1972	Darcy's Law	
	Baylor		66	2.6		Preston, 1978	baseflow	
	Jones		45.7	1.8		Price, 1978	baseflow	
	Wilbarger		63.5	2.5		Willis and Knowles, 1953	baseflow	
Hueco-		Hueco Bolson			5,640	Meyer, 1976	groundwater modeling	mountain-front
Mesilla		Mesilla Valley			18,000	Leggat et al., 1962	Darcy's Law	
Bolson		Mesilla Valley			3,547	Frenzel et al., 1992	empirical	mountain-front
Cenozoic Pecos	Reeves				10,000 - 50,000	Ogilbee and Osborne, 1962	baseflow	
Alluvium								
Edwards -	Kinney		35.6	1.4		Bennett and Sayre, 1962	baseflow	
Trinity	Crockett		7.6	0.3		Iglehart, 1967	baseflow	
	Real		50.8	2.0		Long, 1958	baseflow	
	Kerr		25.4	1.0		Reeves, 1969	baseflow	

REFERENCES FOR AQUIFER RECHARGE RATES

Alexander, W.H., and White, D.E., 1966, Ground-water resources of Atascosa and Frio Counties, Texas: Texas Water Development Board Report 32, 99 p.

Anders, R.B., 1967, Ground-water resources of Sabine and San Augustine Counties, Texas: Texas Water Development Board Report 37, 115 p.

Ashworth, J.B., 1983, Ground-water availability of the Lower Cretaceous formations in the Hill Country of south-central Texas: Texas Department of Water Resources Report 273, 173 p.

Bennett, R.R., and Sayre, A.N., 1962, Geology and ground water resources of Kinney County, Texas: Texas Board of Water Engineers Bulletin B6216, 163 p.

Bluntzer, R.L., 1992, Evaluation of ground-water resources of the Paleozoic and Cretaceous aquifers in the Hill Country of Central Texas: Texas Water Development Board Report 339, 130 p.

Broom, M.E., 1968, Ground-water resources of Wood County, Texas: Texas Water Development Board Report 79, 84 p.

Broom, M.E., Alexander, W.H., Jr., and Myers, B.N., 1965, Ground-water resources of Camp, Franklin, Morris, and Titus Counties, Texas: Texas Water Development Board Bulletin 6517, 153 p.

Broom, M.E., and Myers, B.N., 1966, Ground-water resources of Harrison County, Texas: Texas Water Development Board Report, 27, 73 p.

Brown, R.F., and Signor, D.C., 1973, Artificial recharge experiments and operations on the Southern High Plains of Texas and New Mexico: U.S. Geological Survey Water Resources Investigations 10-73, 54 p.

Cronin, J.G., 1961, A summary of the occurrence and development of ground water in the Southern High Plains of Texas: Texas Board of Water Engineers Bulletin 6107, 104 p.

Dugan, J.T., McGrath, T., and Zelt, R.B., 1994, Water level changes in the High Plains aquifer - predevelopment to 2002: U.S. Geological Survey Water Resource Investigation Report 94-4027, 56 p.

Dutton, A.R., 1990, Vadose-zone recharge and weathering in an Eocene sand deposit, East Texas, U.S.A.: Journal of Hydrology, v. 114, p. 93-108.

Dutton, A.R., 1999, Groundwater availability in the Carrizo Wilcox aquifer in Central Texas - numerical simulations of 2000 through 2050 withdrawal projections: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 256, 53 p.

Dutton, A.R., Mace, R.E., Nance, H.S., and Blum, M., 1996, Geologic and hydrogeologic framework of regional aquifers in the Twin Mountains, Paluxy, and Woodbine Formations near the SSC site, North-Central Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for Texas National Research Laboratory Commission under contract no. IAC(92-93)-0301, 141 p.

Dutton, A.R., Reedy, A.R., and Mace, R.E., 2000, Saturated thickness in the Ogallala Aquifer in the Panhandle Water Planning Area - Simulation of 2000 through 2050 withdrawal projections: The University of Texas at Austin, Bureau of Economic Geology, Technical Completion Report, 36 p.

Dutton, A.R., and Richter, B.C., 1990, Regional geohydrology of the Gulf Coast aquifer in Matagorda and Wharton Counties, Texas: Development of a numerical model to estimate the impact of water-management strategies: The University of Texas at

Austin, Bureau of Economic Geology, final technical report prepared for the Lower Colorado River Authority, 116 p.
Edwards Aquifer Authority, 2000, Edwards Aquifer Authority Hydrogeologic Data Report for 1999: San Antonio, 89 p.
Follett, C.R., 1981, Ground-water resources of Bastrop County, Texas: Texas Water Development Board Report. 109, 146 p.
Frenzel, P.F., Kaehler, C.A., and Anderholm, S.K., 1992, Geohydrology and simulation of ground-water flow in the Mesilla Basin, Dona Ana County, New Mexico and El Paso County, Texas: U.S. Geological Survey Professional Paper P 1407C, p. c1-c105.
Gould, C.N., 1906, The geology and water resources of the eastern portion of the Panhandle of Texas: U.S. Geological Survey Water Supply and Irrigation Paper No. 154, 64 p.
Groschen, G.E., 1985, Simulated effects of projected pumping on the availability of freshwater in the Evangeline aquifer in an area southwest of Corpus Christi, Texas: U.S. Geological Survey, Water Resources Investigations Report 85-4182, 103 p.
Guyton, L.B.G. & Associates and HDR Engineering Inc., 1998, Interaction between ground water and surface water in the Carrizo-Wilcox aquifer: Report prepared for Texas Water Development Board, variously paginated.
Harden, R.W., 2000, Carrizo-Wilcox ground water flow model and simulation results: draft report prepared for Brazos G Regional Water Planning Group, variously paginated.
Harden, R.W. and Assoc., 1978, The Seymour Aquifer, Ground-water quality and availability in Haskell and Knox counties, Texas: Texas Department of Water Resources Report 226, 261 p.
Havens, J.S., 1966, Recharge studies on the High Plains in northern Lea County, New Mexico: U.S. Geological Survey 1819-F, 52 p.
Hay, R., 1999, A numerical groundwater flow model of the Gulf Coast aquifer along the South Texas Gulf Coast: Corpus Christi, Texas A&M, M.Sc., 47 p.
HDR Engineering, Inc., 2000, Preliminary feasibility options to deliver ALCOA/CPS groundwater to Bexar County: technical report prepared for San Antonio Water Systems, variously paginated.
Iglehart, H.H., 1967, Occurrence and quality of ground water in Crockett County, Texas: Texas Water Development Board Report 47, 150 p.
Johnson, W.D., 1901, The High Plains and their utilization: U.S. Geological Survey 21st Annual Report, 1890-1900, pt. 4, p. 601-741.
Klemt, W.R., Perkins, R.D., and Alvarez, H.J., 1975, Ground-water resources of part of Central Texas with emphasis on the Antlers and Travis Peak Formations: Texas Water Development Board Report 195, 63 p.
Klemt, W., Duffin, G., and Elder, G., 1976, Ground water resources of the Carrizo aquifer in the Winter Garden Area of Texas: Texas Water Development Board Report 210, v.1, 30 p.
Klemt, W.B., 1981, Evaluating the ground-water resources of the High Plains of Texas, neutron probe measurements of deep soil moisture as an indication of aquifer recharge rates: Texas Department of Water Resources LP-142, 31 p.
Knowles, T.R., Nordstrom, P., and Klemt, W.B., 1984, Evaluating the ground-water resources of the High Plains of Texas: Texas Department of Water Resources Report 288, 119 p.

Kuniansky, E.L., 1989, Precipitation, streamflow, and base flow in west-central Texas, December 1974 through March 1977: U.S. Geological Survey Water-Resources Investigation Report 88-4218, 2 sheets.

Kuniansky, E.L., and Holligan, K.Q., 1994, Simulations of flow in the Edwards-Trinity aquifer system and continuous hydraulically connected units, west-central Texas: U.S. Geological Survey Water-Resources Investigations Report 93-4039, 40 p.

Leggat, E.R., Lowery, M.E., and Hood, J.W., 1962, Ground-water resources of the lower Mesilla Valley, Texas and New Mexico: Texas Water Commission Bulletin 6203, 195 p.; republished 1963, U.S. Geological Survey Water-Supply Paper 1660-AA, p. AA1-AA49.

Long, A.T., Jr., 1958, Ground-water geology of Real County, Texas: Texas Board of Water Engineers Bulletin B 5803, 46 p.

Loskot, C.L., Sandeen, W.M., and Follett, C.R., 1982, Ground-water resources of Colorado, Lavaca, and Wharton Counties, Texas: Texas Department of Water Resources Report 270, 240 p.

Luckey, R.L., and Becker, M.F., 1999, Hydrogeology, water use, and simulation of flow in the High Plains aquifer in northwestern Oklahoma, southeastern Colorado, southwestern Kansas, northeastern New Mexico, and northwestern Texas: Water-Resources Investigations Report 99-4104, 68 p.

Luckey, R.R., Gutentag, E.D., Heimes, F.J., and Weeks, J.B., 1986, Digital simulation of ground-water flow in the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1400-D, 57 p.

Mace, R.E., Chowdhury, A.H., Anaya, R., and Way, S.C., 2000, A numerical groundwater flow model of the Upper and Middle Trinity Aquifer, Hill Country Area: Final Report, Texas Water Development Board, 169 p.

Maderak, M.L., 1972, Ground-water resources of Hardeman county, Texas: Texas Water Development Board Report 161, 44 p.

Mason, C.C., 1963, Availability of ground water from the Goliad Sand in the Alice Area, Texas: Texas Water Development Board Bulletin 6301, 107 p.

Meyer, 1976, Digital model for simulated effects of ground-water pumping in the Hueco Bolson, El Paso area, Texas, New Mexico, and Mexico: U.S. Geological Survey Water-Resources Investigations Report 58-75, 31 p.

Muller, D.A., and Price, R.D., 1979, Ground-water availability in Texas, estimates and projections through 2030: Texas Department of Water Resources Report 238, 77 p.

Mullican, W.F., III, Fryar, A.E., and Johns, N.D., 1994, Vertical transport of contaminants through perched aquifers to the Ogallala aquifer, Pantex Plant area, Southern High Plains, Texas, *in* Dutton, A.R., ed., Toxic Substances and the Hydrologic Sciences: Austin, TX, American Institute of Hydrology, p. 547-562.

Mullican, W.F.III, Johns, N.D., and Fryar, A.E., 1997, Playas and recharge of the Ogallala aquifer on the Southern High Plains of Texas–An examination using numerical techniques: The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations No. 242, 72 p.

Myers, B.N., and Dale, O.C., 1967, Ground-water resources of Brooks County, Texas: Texas Water Development Board Report 61, 85 p.

Nativ, R., 1988, Hydrogeology and hydrochemistry of the Ogallala Aquifer, Southern High Plains, Texas Panhandle and Eastern New Mexico: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 177, 64 p.

Noble, J.E., Bush, P.W., Kasmarek, M.C., and Barbie, D.L., 1996, Estimated depth to the water table and estimated rate of recharge in outcrops of the Chicot and Evangeline aquifers near Houston, Texas, U.S. Geological Survey, Water Resources Investigations Report 96-4018, 19 p.

Ogilbee, W., and Osborne, F.L., Jr., 1962, Ground-water resources of Haskell and Knox Counties, Texas: Texas Board of Water Engineers Bulletin B6209, 174 p.

Opfel, W.J., and Elder, G.R., 1978, Results of an infiltration study on the Carrizo sand outcrop in Atascosa County, Texas: Texas Department of Water Resources LP-61, 35 p.

Popkin BP (1971) Groundwater resources of Montgomery County, Texas. Texas Water Development Board Report 136, 143 p.

Preston, R.D., 1978, Occurrence and quality of groundwater in Baylor county, Texas: Texas Department of Water Resources Report 218, 101 p.

Price, R.D., 1978, Occurrence, quality, and availability of ground water in Jones county, Texas: Texas Department of Water Resources Report 215, 224 p.

Reeves, R.D., 1969, Ground-water resources of Kerr County, Texas: Texas Water Development Board Report 102, 58 p.

Reeves, 1967, Ground-water resources of Kendall County, Texas: Texas Water Development Board Report 60, 100 p.

Ryder, P., 1988, Hydrogeology and predevelopment flow in the Texas Gulf Coast aquifer systems: U.S. Geological Survey 87-4248, 109 p.

Sandeen, W.M., 1972, Ground-Water Resources of Washington County, Texas: Texas Water Development Board Report 162, 111 p.

Sandeen, W.M., 1987, Ground-water resources of Rusk County, Texas: Texas Water Development Board Report 297, 121 p.

Scanlon, B.R., and Goldsmith, R.S., 1997, Field study of spatial variability in unsaturated flow beneath and adjacent to playas: Water Resources Research, v. 33, p. 2239-2252.

Shafer, G.H., 1968, Ground-water resources of Nueces and San Patricio Counties, Texas: Texas Water Development Board Report 73, 129 p.

Slattery, R.N., Patton, J.T., and Brown, D.S., 1998, Recharge to and discharge from the Edwards Aquifer in the San Antonio Area, Texas, 1997: USGS FAQ sheet http://tx.usgs.gov/reports/district/98/01.

Stovall, J., Rainwater, K., and Frailey, S., 2000, Groundwater modeling for the Southern High Plains: final report submitted to Llano Estacado Regional Water Planning Group, variously paginated.

Tarver, G.R., 1968, Groundwater resources of Polk County, Texas: Texas Water Development Board Report 82, 109 p.

Theis, C.V., 1937, Amount of ground-water recharge in the Southern High Plains: American Geophysical Union, Transactions, 18th Annual Meeting, p. 564-568.

Thompson, G.L., 1972, Ground-water resources of Navarro County, Texas: Texas Water Development Board Report 160, 63 p.

Thorkildsen, D., and Price, R.D., 1991, Ground-water resources of the Carrizo-Wilcox aquifer in the Central Texas Region: Texas Water Development Board Report 332, 46 p.

Thorkildsen, D., Quincy, R., and Preston, R., 1989, A digital model of the Carrizo-Wilcox aquifer within the Colorado River Basin of Texas: Texas Water Development Board Report LP-208, 58 p.

Turner, S.F., Robinson, T.W., White, W., Outlaw, D., and George, W.O., 1960, Geology and Ground-water resources of the Winter Garden District Texas, 1948: U.S. Geological Survey Water Supply Paper 1481. 223 p.

U.S. Bureau of Reclamation, 1982, Llano Estacado playa lake water resources study, appraisal report, in U.S. Bureau of Reclamation, Llano Estacado playa lake water resources study, a special investigation, variously paginated.

White, D.E., 1973, Ground-water resources of Rains and Van Zandt Counties, Texas: Texas Water Development Board Report 169, 80 p.

Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf Coast aquifer systems, south central United States--A preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 89-4071, 124 p.

Willis, G.W., and Knowles, D.B., 1953, Ground-water resources of the Odell Sand Hills, Wilbarger County, Texas: Texas Board of Water Engineers Bulletin 5418, 54 p.

Wood, W.W., and Osterkamp, W.R., 1984, Recharge to the Ogallala aquifer from playa lake basins on the Llano Estacado (an outrageous proposal?), *in* Whetstone, G.A., ed., Proceedings, Ogallala Aquifer Symposium II: Texas Tech University Water Resources Center, p. 337-349.

Wood, W.W., Rainwater, K.A., and Thompson, D.B., 1997, Quantifying macropore recharge: examples from a semi-arid area: Ground Water, v. 35, no. 6, p. 1097-1106.

Wood, W.W., and Sanford, W.E., 1995, Chemical and isotopic methods for quantifying ground-water recharge in a regional, semiarid environment: Ground Water, v. 33, p. 458-468.