HLWYM HEmails

From: MaryLynn Musgrove [mmusgrove@cnwra.swri.edu]
Sent: Tuesday, March 07, 2006 11:26 AM
To: Stuart Stothoff
Attachments: comparisons_DOE-RW-0583.wpd

Stu,

Here is my listing of everything wrong with the comparative data cited in the DOE report.

I'll check with Gordon and plan to forward it on to Randy, if you have nothing to add, in prep for today's telecom.

mlm

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Hearing Identifier: HLW_YuccaMountain_Hold_EX
Email Number: 1282

Mail Envelope Properties (002d01c64203$c6d87f10$5dc8a281)

Subject:
Sent Date: 3/7/2006 11:25:41 AM
Received Date: 3/7/2006 11:26:54 AM
From: MaryLynn Musgrove

Created By: mmusgrove@cnwra.swri.edu

Recipients:
"Stuart Stothoff" <sstothoff@cnwra.swri.edu>
Tracking Status: None

Post Office: cnwra.swri.edu

Files	**Size**	**Date & Time**
MESSAGE	455	3/7/2006 11:26:54 AM
comparisons_DOE-RW-0583.wpd	54078	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

To: Gordon Wittmeyer
From: MaryLynn Musgrove
Date: 2/27/2006
RE: Further assessment of DOE/RW-0583, focusing on comparative recharge estimates in West Texas, New Mexico, and Arizona

As noted by S. Stothoff in the Technical Assessment of this document (February 22, 2006), there are some numerical discrepancies in the infiltration values cited in the report. I have been reviewing in greater detail the studies presented in the DOE/RW-0583 for comparison with USGS INFIL model results. What follows is a listing of some discrepancies and observations of data presented in DOE/RW-0583's Figure 4-4 ("Comparison of Recharge Estimates for the Southwestern United States (Texas, New Mexico, and Arizona) With Yucca Mountain Net Infiltration Rate Estimates"). While many of these observations are minor and/or of debatable significance, they are numerous. I note them below as thoroughly as possible for reference in further evaluation of this report.

On page 19, the report notes that data plotted in Figure 4-4 comes from multiple published sources, as detailed in Appendix H, Table H-3. While studies presented in Table H-3 provide values for recharge that are generally representative of numerous studies in the arid and semiarid southwestern U.S., they are by no means a comprehensive list. The selection is, in my opinion, lacking, when one considers numerous studies readily available in the literature addressing recharge in the desert southwest. Several of the studies noted on Table H-3 are not recent, or are based on old data or very simplistic estimations, and may have been succeeded by subsequent work, which is not noted in Table H-3. Several of the cited studies are compilations of previous work, which are not individually cited in Table H-3. Several of the studies noted in Table H-3 make reference to and compare their results with other studies (e.g., Scanlon, 1991, Table 1; Wilson and Guan, Table 2), which are not subsequently included in Table H-3. While Table H-3 points to these other studies in some cases (e.g., in the "Notes" column of Table H-3), they are not considered in Figure 4-4 for comparison purposes, though they may be viable comparative estimates.

● **Scanlon et al. (1999):** Table H-3 selectively includes recharge data from this study. Table H-3 lists a recharge range of 0.02 to 0.05 mm/year for inter-drainage areas. The correct range for interdrainage areas is 0.02 to 0.06 (Scanlon et al., 1999, Table 2). Table H-3 notes that higher values were found in local depressions and that these areas represent only 1% of the study area. The higher values noted for the localized topographic depressions for recharge are 1.5 to 13.4 mm/year, with a mean flux of ~10 mm/year. Table H-3 also does not include results for drainage areas, which range from 0.23 to 3.8 mm/year. Although the drainage and depression areas represent small portions of the study area, their recharge values are orders of magnitude higher and thus, require consideration as they may have a marked impact on total recharge flux.

Also, it should be noted that in Scanlon et al. (1999) the range of 0.02 to 0.06 represents 8 values, which themselves are mean values, each of which encompasses a larger range of fluxes; i.e., the total range of fluxes for interdrainage areas is 0.01 to 0.36 mm/year. While these recharge/flux values are still small, noting the range, rather than just the mean, may better account for potential spatial variability. All values noted above exclude runon, which may also

impact net infiltration in specific environments (inclusion for Scanlon et al, 1999 study would increase estimates of water flux by about an order of magnitude).

● **Scanlon (1991):** Table H-3 lists a recharge range of 0.03 to 0.27 mm/year as the range for interstream areas, but does not include the total recharge range noted in Scanlon (1991), which is 0.01 to 0.7 mm/year. This larger range includes ephemeral stream areas as well as interstream areas. The author notes the sensitivity of recharge rates to geomorphic setting. Similarly as noted for the Scanlon et al. (1999) reference above, although ephemeral streams may represent a small portion of the study area, their higher recharge rates should be considered as they may impact total recharge flux.

● **Wood et al. (1997):** The importance of the spatial variability of recharge associated with different geomorphic settings is also called out in the Wood et al. (1997) paper. Wood et al. (1997) results suggests that 60-80% of the 11 mm/year recharge flux is through macropores, 15-35% occurs by interstitial recharge through the basin floors, and only 5% of the total recharge occurs via interstitial or matrix recharge between the basin floors (which represents about 95% of the area). A clarification to the Wood and Sanford (1995) and Wood et al. (1997) entry on table H-3: the noted value of 2% for recharge as a function of precipitation applies to a precipitation value of 485 mm/year, which is the specific value for the northern half of the Southern High Plains, within the noted range of 330 to 560 mm/year.

● **Gates et al. (1980):** Gates et al. (1980) is a study of groundwater availability in basins in westernmost Texas. It is not a study specifically estimating recharge, but rather provides some estimates based on limited water budget estimates, where recharge is assumed to be ~1% of precipitation. The report's introductory material (page 10, section "General Ground-Water Hydrology) notes that "recharge cannot be estimated accurately over most of westernmost Texas because few data are available on the location of recharge areas and on the amounts of precipitation and streamflow on or above the recharge areas. However, some rough relations between drainage area, precipitation, and recharge can be used to obtain order of magnitude estimates." The paper continues, based on these rough relations to estimate recharge values equal to 1% for seven subregions within the region, providing values for recharge in acre-feet based on estimated MAP values and area of the subregion. For the first subregion considered, the northern Hueco bolson, the value of 1% compares well to a previously determined estimate by Meyers (1976). While seven subregions are called out in Gates et al. (1980), only four are noted in Table H-3 (N. Hueco, Presidio-Redford, Green River, and Red Light Draw). Three precipitation (MAP) values are provided in Table H-3 for Ysleta, Pecos River, and the Davis Mountains, which are not directly comparable to the recharge regions noted in Table H-3.

● **Stephens and Knowlton (1986):** Table H-3 lists precipitation for this study as 200 mm/year; the value noted in the paper for the November 1982 through May 1984 study period is 179 mm/year. Table H-3 notes a range of recharge values of 7-36.6 mm/year for pressure head data, and 37-97 mm/year for water content data. Stephens and Knowlton (1986), however, note that there was a period during which the neutron moisture probe was malfunctioning and they question resulting high recharge calculations for water content data (e.g. 97 mm/year) as a

possible result of error associated with neutron probe measurements. In both their abstract and summary they do not include this data and instead present a high recharge value of 37 mm/year.

● **Shurbaji et al. (1995):** This reference is mis-cited in Table H-3. The correct citation, as noted on page 19 of the report, is Shurbaji and Campbell (1997). The field in Table H-3 for "%" is empty, but should be 0.1 to 0.6%.

● **Wilson and Guan (2004):** This citation, as noted in Table H-3 compares values for 5 different methods of assessing recharge with values that range from 15 to 132 mm/year for the Sandia Mountains, Albuquerque Basin, New Mexico. Table H-3 refers the reader to Table 2 of that citation. The cited reference is a summary paper reviewing mountain-block hydrology and mountain-front recharge and makes no assessments of recharge. Rather, Table 2 of that study lists results of other independent studies of mountain front recharge. Of the multiple studies listed, 3 specifically address the different methods for the noted area (Anderholm, 2000; Tiedeman et al., 1998; Sanford et al., 2000). It is these studies that data presented in Table H-3 is from, as listed in Wilson and Guan (2004). These are noted individually as follows:

- Sanford et al. (2000): This citation is an extended abstract within a proceedings volume of a USGS workshop. The abstract describes the status of a groundwater flow model of the Middle Rio Grande Basin of central New Mexico. The study uses the inverse modeling code UCODE, and water levels are simulated using MODFLOW. The model is calibrated using inverse methods and carbon-14 and water level data is used to provide additional constraints on the results. The authors not that their estimates for basin-margin and tributary recharge are considerably lower than in previous models and present an argument for why their values may be more accurate (e.g., previous models do not account for runoff entering the Rio Grande, or ET of runoff once it enters the subsurface). The citation lists total recharge as 18,000 acre-feet/year, and compares this value with Tiedeman et al. (1998), with a total recharge value of 113,000 acre-feet/year (much higher), and Anderholm (2000), with a comparable value. Wilson and Guan (2004) convert these values to mm/year and percentage of precipitation in their Table 2. Sanford et al. (2000) note that the model suggests recharge to the basin was 5-6 times higher during the last glacial maximum.

- Anderholm (2000): Currently, I am only able to locate the abstract for this USGS WRI publication. The correct citation is Anderholm (2001) - the year is incorrectly cited by Wilson and Guan (2004). The study uses chloride mass balance and water-yield regression methods to estimate recharge for the Middle Rio Grande Basin. From the abstract, the study estimates recharge of 11 thousand acre-feet/year using the chloride mass balance method, and recharge of 36 and 38 thousand acre-feet/year using two water-yield regression equations. Recharge ranged from 0.7 to 15% of MAP and is correlated generally with altitude (higher recharge at higher elevation). Wilson and Guan (2004) convert these values to mm/year in their Table 2.

-Tiedeman et al. (1998): Currently I am only able to locate the abstract for this USGS WRI publication. The study calibrates the numerical flow model for the Middle Rio Grande Basin using a nonlinear least-squares regression technique. Six different basin subsurface configurations are considered, with one yielding the most optimal estimates. Although the value is not listed in the abstract, it is presumably the value of 132 mm (26% of precipitation) listed in Wilson and Guan (2004) Table 2 (though Tiedeman et al., 1998, may have presented the value in acre-feet/year).

● **Coes and Pool (2005):** Table H-3 lists a recharge range of 2 to 60 mm/year for basin floor infiltration. The Coes and Pool study determines infiltration rates for both ephemeral stream channels (its main focus) as well as basin floor areas between ephemeral stream channels. Values for ephemeral stream channels are not included in Table H-3, which lists only the results of basin floor areas. Coes and Pool (2005) estimate ephemeral stream channel annual recharge values represent 12-19% of total recharge during the study area. Although the ephemeral streams only flow a few days per year, their contribution to MAI is, thus, a significant contributor to total recharge.

● **Lopes and Hoffmann (1997):** Table H-3 does not include values for recharge (mm/year) but only percentage of precipitation (as 1-3%) and notes "assumed percentage for input to analysis." Lopes and Hoffman (1997), however provide a table of estimate recharge rates for 3 different porosities and for 6 different time periods. The values for the youngest (i.e., modern) waters range from 2,500 to 3,500 acre-feet/year. The authors compare this value to a previous study (Eychaner, 1983) which estimates recharge of 4,800 acre-feet/year. Recharge values are estimated to have been 4 times greater during glacial periods. Using an area of 104 sq. miles for the Shonto area (as listed in Lopes and Hoffman, Table 7), these values convert to 11, 16, and 22 mm/year recharge, which slightly exceeds the 1-3% range of precipitation estimated in Table H-3 (using precipitation values of 457 mm in the Shonto area, recharge values would be ~ 2.4 to 3.5%, and 5% of precipitation for the Eychaner study).

● **SPPA (2002):** SPPA (2002) is a report prepared by S. S. Papadopulos and Associates, Inc. to characterize the available water supply for the Rio Grande and La Jencia Basins for the New Mexico Interstate Stream Commission as a first step in developing a regional water plan. The report does not independently determine recharge, but rather collects and presents recharge estimates for sub-areas within the study area based on previous studies. The cited precipitation value in Table H-3 is for Socorro, NM, close to the Rio Grande portion of the study area. Table H-3 does not cite precipitation as reported in SPPA (2002) for Magdalena (11.74 inches/year), which is closer to the La Jencia basin. Table H-3 cites several earlier studies applying different methods to estimate recharge for the Rio Grande basin as listed (the reported values do not include recharge reported in SPPA (2002) for the La Jencia basin):

- The Maxey-Eakin method (Maxey and Eakin, 1949): as noted in Table H-3, based on the Maxey-Eakin relationship to the study area, recharge =3% of MAP for both the Rio Grande and La Jencia basins. The value of 7.1 mm/year reported on table H-3 is for the Rio Grande basin, but not for the La Jencia basin (where, based on the precipitation value reported in SPPA (2002) for Magdalena (11.74 inches/year), recharge = 8.6 mm/year).
- Table H-3 lists the Hearne-Dewey regression analysis method: SPPA (2002) cites this method and determined values as described in Roybal (1991) based on the method described in Hearne and Dewey (1988). Roybal (1991) recharge estimates are 2,900 and 16,700 acre-feet/year for 2 sub-areas of the Rio Grande basin (as reported in Table 2 of the SPPA report). The range of 1.8 to 2.1% cited in Table H-23 is from SPPA's Table 3 (cited as Hearne and Dewey, 1988). The value reported by the SPPA report (Table 7) citing Roybal (1991) for the La Jencia basin is 4,600 acre-feet/year.
- The chloride mass balance method results of 0.7 to 0.9% for two sub-areas cited in Table H-3 are values from Anderholm (2001), as reported in SPPA (2002). This is the same

USGS Water Resources Investigation that is cited above under the entry for Wilson and Guan (2004).

Table H-3 does not cite additional recharge values reported in SPPA (2002) from Waltemeyer (1994), also listed in SPPA's Table 3, which are notably higher estimates of 5.5 to 9% of annual precipitation for the two sub-areas of the Rio Grande basin. The SPPA (2002) report notes that the alternate regression method developed by Waltemeyer uses annual precipitation rather than winter precipitation and "is postulated by Anderholm to be better suited for this southern area of the basin where snowmelt is less significant component of recharge." As reported in SPPA (2002), however, Anderholm further "notes that the estimate of 9 percent for the Abo sub-area may not be valid due to the fact that the drainage area size is outside of the range used to develop the model."

● **Boghici (1999) and Ashworth (1990):** Table H-3 cites these two reports together for the Trans-Pecos region of west Texas. The listed precipitation value (241-338 mm/year) is from Boghici (1999). With respect to recharge estimates, the Boghici (1999) report, however, simply cites (pg. 25) the Ashworth (1990) report: "Previous research estimated the effective recharge to the Cenozoic Pecos Alluvium aquifer in the study area to be approximately 67,800 acre-feet per year (Ashworth, 1990, p. 43). This amount represents the safe yield or usable water available on a perennial basis from the aquifer and is based on the results of a seepage study performed along the Pecos River prior to extensive groundwater development in the area (Grover et al., 1922)".

Ashworth (1990) is noted on Table H-3, but is not included in the references in DOE/RW-0583. Ashworth (1990) notes that the recharge value of 67,800 acre-feet/year is a combination of natural recharge from precipitation and artificial recharge via irrigation return flow. As noted above, Ashworth (1990) uses methodology to determine recharge based on a seepage study along the Pecos River conducted in 1918, which is based on a water balance between discharge and recharge. This yields 31,000 acre-feet of recharge. The remainder of the total 67,800 acre-feet of recharge is estimated to result from artificial recharge mechanisms (irrigation-water seepage).

● **Winograd (1981)**: Though not noted on Figure 4-4, Figure 4-1 includes a value from Winograd (1981) for estimated recharge of 2 mm/year for 120 mm/year precipitation in alluvium at the Nevada Test site. Referring to Winograd (1981), however, clarifies that this value is for downward vadose water velocity, not flux. Winograd's computation of velocity is based on the maximum flux number from Winograd and Thordarson of 65 acre-feed/year ($8.4\text{-}0 \times 10^4$ m^3) through an area of 18×10^8 ft^2), which yields a value of 0.47 mm/year.

<u>References discussed herein and not included in DOE/RW-0583</u>

Anderholm, S. K., 2001, Mountain-front recharge along the eastern side of the Middle Rio Grande
Basin, central New Mexico, U.S. Geological Survey Water-Resources Investigations Report 00-4010, 36 p.

Ashworth, J. B., 1990, Evaluation of ground-water resources in parts of Loving, Pecos, Reeves, Ward, and Winkler counties, Texas, Texas Water Development Board, Report 317, 51 p.

Grover, N. C., Gray, G. A., and Ellsworth, C. E., 1922, Surface Water Supply of the United States and Hawaii, Part 8, Western Gulf of Mexico basins, 1918, U.S. Geological Survey Water Supply Paper 478, 106 p.

Hearne, G. A., and J.D., Dewey, 1988, Hydrologic Analysis of the Rio Grande north of Embudo, New Mexico, Colorado and New Mexico: U.S. Geological Survey Water-Resources Investigation Report 86-4113, 244 p.

Meyer, W. R., 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 Investigation 58-75, 36 p.

Roybal, F.E., 1991, Groundwater Resources of Socorro County, New Mexico, U.S. Geological Survey Water Resources Investigations Report 89-4083, 103 p.

Sanford, W. E., Plummer, L. N., McAda, D. P., Bexfield, L. M., and Anderholm, S. K., 2000, Estimation of hydrologic parameters for the ground-water model of the Middle Rio Grande Basin using carbon-14 and water-level data, p. 4-6, *in* Cole, J. C. (ed.),U.S. Geological Survey Middle Rio Grande Basin Study-Proceedings of the Forth Annual Workshop, Albuquerque, New Mexico, February 15-16, 2000, U.S. Geological Survey Open-File Report 00-488, 51 p.

Tiedeman, C. R., Kernodle, J. M., and McAda, D. P., 1998, Application of nonlinear-regression methods to a ground-water flow model of the Albuquerque Basin, New Mexico, U.S. Geological Survey Water Resources Investigation Report 98-4172, 90 p.

Winograd, U. J., and Thordarson, W., 1975, Hydrogeologic and hydrochemical framework, South-Central Great Basin, Nevada-California with special reference to the Nevada Test Site, U.S. Geological Survey Professional Paper 712-c.