STATEWIDE WATER ASSESSMENT: RECHARGE DATA COMPILATION AND RECHARGE AREA IDENTIFICATION FOR THE STATE OF NEW MEXICO

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ABSTRACT

The rate and distribution of groundwater recharge to New Mexico's aquifers is the least understood aspect of the state's water budget. Despite a history of precise and distributed measurements quantifying surface water flow, water table elevations, precipitation amounts, as well as current models that describe evapotranspiration, a statewide assessment of recharge has not previously been attempted. While recharge estimates and studies of recharge processes have been conducted, the effort to date has been on the basin scale, or by county and water-planning region. With a long-term goal of estimating groundwater recharge on a statewide scale, this study has compiled existing recharge estimates throughout the state and constructed a recharge-area map. We have compiled over one hundred recharge estimates made in New Mexico, many of which are from academic and government studies. A geographic information system (GIS) layer was created to display locations of recharge and water resource planning studies. Data are displayed in a format that contains the study citation, location (individual basins, counties, and water planning regions), recharge estimate, methodology, and a link to the original work. To map recharge areas, a GIS-based distributed-parameter soil-water-balance model, the Evapotranspiration and Recharge Model (ETRM) was developed to simulate recharge using gridded precipitation, reference evapotranspiration, geology, vegetation cover, and soils data as inputs. Results show high recharge in the mountainous areas of the state, which typically have thinner soils, lower temperatures, and higher rates of precipitation than the lowlands.

Keywords: Recharge, groundwater, evapotranspiration, precipitation, soil water balance, distributed parameter model

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JUSTIFICATION OF WORK PERFORMED

Groundwater recharge is the least understood component of the New Mexico state water budget. Despite a long history of systematic stream gauging, water-table elevation monitoring, and precipitation measurements, along with a burgeoning evapotranspiration (ET) measurement effort, large-scale estimation of recharge in New Mexico has not been undertaken. Groundwater recharge defines a limit for the availability of water for humans and ecosystems, therefore estimating recharge for the state of New Mexico is critical for effective water resource management. However, estimating recharge is difficult in New Mexico, where the extremely heterogeneous topography and sporadic precipitation complicate recharge calculations. Efforts in New Mexico to date have typically employed methods of partitioning precipitation into a recharge fraction based on precipitation intensity, by stream base-flow estimates, or by completing water mass-balance calculations with recharge defined as the remainder of other measured components of the water budget. In order to understand the water resources of New Mexico, accurate and large-scale estimation methods must be developed. The benefits of more extensive and accurate recharge estimates include enabling federal, state, and municipal organizations to plan for a sustainable use of groundwater resources as extraction increases and the groundwater system reacts to climate change.

The overall goal of this study is to estimate groundwater recharge for the entire state as part of the Water Resources Research Institute (WRRI) Statewide Water Assessment. Ultimately, this statewide recharge estimate will be presented along with other components of the state water balance on an interactive map that can be accessed on the Internet. Estimates will be updated on an regular basis and will be based on the best and latest data available. It is important to note that this project will likely take three to four years to complete.

This report describes the results of the first year of this study. The objectives of this study were to:

1) Compile existing recharge estimates from different hydrogeologic studies over the last fifty or so years, and present them in a table and on an interactive map.
2) Construct a New Mexico recharge area map within a geographic information systems (GIS) framework by combining several individual layers containing spatial data that can help to determine where groundwater recharge likely takes place (Figure 1). These spatial data sets include a digital elevation model (DEM), precipitation rates, potential ET rates, regional geology, vegetation cover, and soils.

These objectives were achieved.

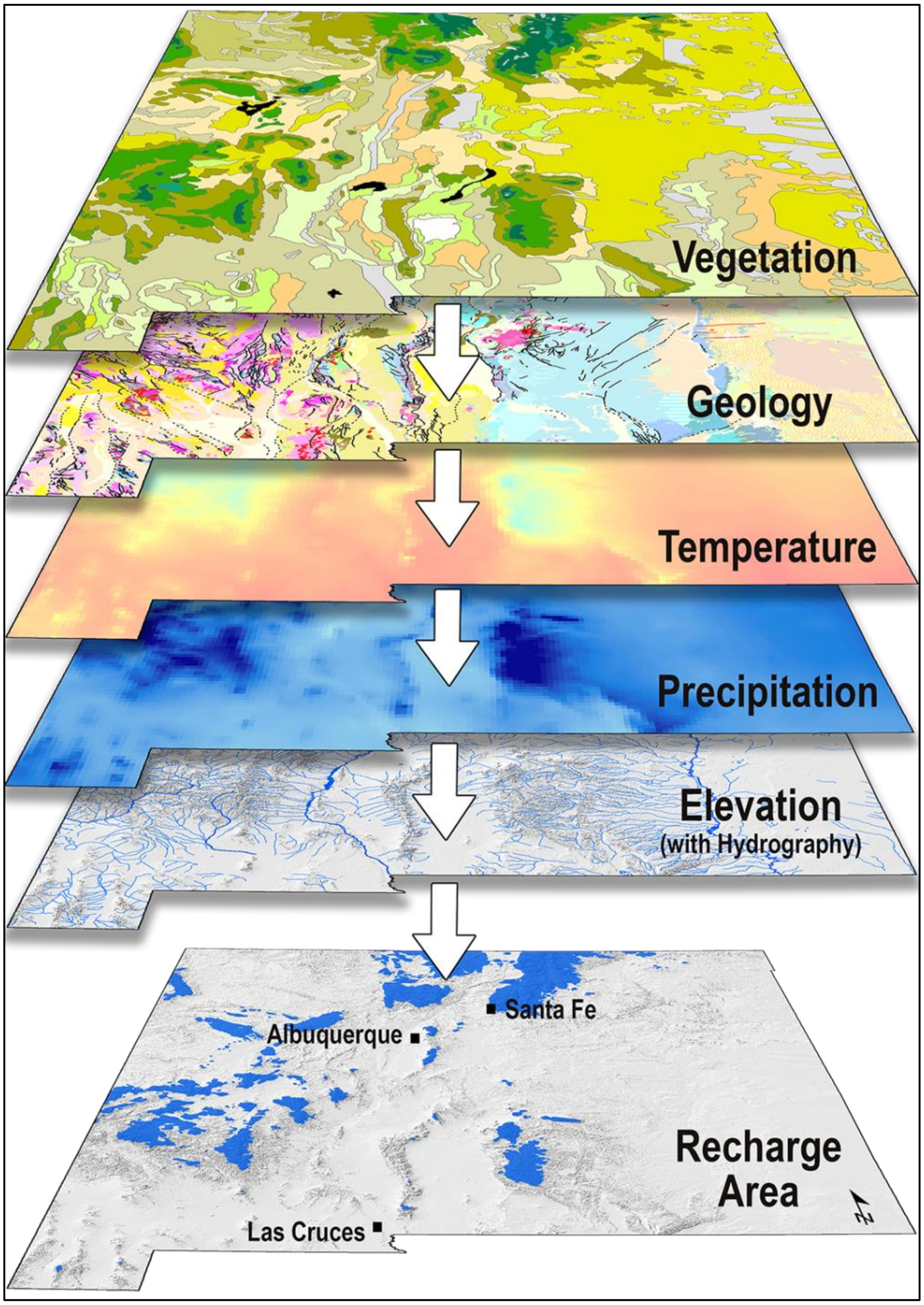

Figure 1. The New Mexico recharge-area map integrates several existing spatial data sets, including elevation, precipitation, temperature (proxy for potential ET), geology, and vegetation.

METHODS

Compilation of recharge estimates

The compilation of previously conducted recharge estimates consists of around 130 individual estimates ranging in geographic scale from entire Water Resource Planning Regions (WRPRs) to small basins, geologic formations, and individual mountain slopes. The data were found through a review of New Mexico-related water studies. The principal source of recharge estimates were the Water-Resource Investigation Reports published by the United States Geological Survey (USGS), many of which are computational models of groundwater flow. The New Mexico Office of the State Engineer (OSE) has documents posted online pertaining to each of New Mexico's 16 WRPRs, many of which estimate the components of the water budget over the entire region, including recharge. These reports have typically been completed by private industry consultants.

The data pertaining to recharge was compiled in tabular form, associated to geographic points, and converted to a "layer" in GIS. Each layer represents a feature type that can be represented geographically on a map in point, line, or polygon form. Each study location was included in the tabular data and was then converted to a point layer in a GIS. A base map of New Mexico and the outlying headwaters of inflowing rivers from other states was created. The purpose of the base map is simply to orient the viewer to where the points are located with familiar geographic features of New Mexico. The points layer on the map shows each study. Using ArcGIS software, the viewer simply chooses the Identify Selection tool from the toolbar and clicks on any point. This displays a window in which the information from the tabulated recharge data is shown.

Groundwater recharge potential map

Identification of potential recharge areas statewide was completed using the Evapotranspiration and Recharge Model (ETRM), which was developed specifically for this purpose. The soil layer is the interface between the atmosphere and the groundwater system, and mediates the transfer of water between the surface and subsurface. Precipitation that does not become runoff is stored temporarily before it eventually recharges the groundwater system or is lost to the atmosphere as ET. Treating soil as a reservoir in a mathematical model allows for calculation of the water balance over large areas using ET, deep drainage (recharge), and runoff to account for losses that balance water inputs by precipitation and run-on. In the arid and semi-arid southwest United States, Flint and Flint (2007) and Hevesi (2003) employed soil water balance (SWB) to estimate regional recharge rates using a model framework that was first developed to characterize recharge at a proposed high-level nuclear waste disposal site at Yucca Mountain, Nevada. This method incorporates many of the physical parameters controlling recharge: soil water storage capacity, vegetative cover, underlying geology, and meteorological conditions controlling the energy and water available for ET and precipitation. The Evapotranspiration and Recharge Model (ETRM) has been developed to estimate diffuse recharge and ET over New Mexico by employing a similar technique. The ETRM is a spatially distributed model; rather than estimating recharge at a specific point, the model uses gridded (raster) data that covers the entire state. The aforementioned inputs to the SWB are represented by individual cells that are continuous over the state and limited in spatial detail by the resolution of the grid.

The ETRM is designed to solve the following soil water balance on a daily time step (modified from Allen et al., 2005):

$$D_i = D_{i-1} + RO + ET + R - P$$

where D_i and D_{i-1} is soil water depletion on the current and previous day, respectively, RO is runoff, ET is evapotranspiration, R is recharge, and P is precipitation. All terms are reported as depth of water in millimeters. Soil-water depletion is a convenient parameter with which the water accounting is carried from day to day. At any cell in the model extent, maximum soil water capacity is estimated based on the STATSGO statewide soil survey (Schwarz and Alexander, 1995); the depletion term represents the depth of water that could be added by precipitation to the soil before runoff and recharge begin. If depletion is zero, the soil is at field capacity. When the soil water balance is calculated, depletion from the previous day plus water loss from runoff, ET, and recharge defines a new soil depletion at each cell. Only when the soil depletion is negative (during prolonged or intense precipitation events) does recharge occur.

ET is calculated using the dual-crop-coefficient method after Allen and others (2005) and the daily National Land Data Assimilation System reference ET layer (Cosgrove et al., 2003). The reference ET is the rate of ET that would occur in a crop of well watered alfalfa, of 70 cm height, according to that day’s local meteorological conditions. Runoff in the ETRM is caused by precipitation in excess of the maximum rate of recharge, which is controlled by the saturated hydraulic conductivity of the underlying rock or unconsolidated material. While runoff contributes to focused recharge, an important pathway for recharge in the state, the ETRM currently only estimates in-place recharge and does not consider recharge by runoff that becomes surface-water flow. Daily precipitation data is provided by the Parameter-Regression and Independent Slopes Model (PRISM) at an 800 m resolution (Daly et al., 1998). Data from the year 2000 was found to be close to the 33 year precipitation normal in New Mexico and was used to generate a potential recharge map.

PRINCIPAL FINDINGS

Figure 2 shows the New Mexico and headwaters base map, along with the locations of the different studies throughout the state that estimated groundwater recharge rates. Overall, academic studies have generally focused on the conceptual basis for estimating or modeling recharge (Mattick et al., 1987; Rau, 1986; Scanlon, 1991; Stone and McGurk 1985), while the USGS and OSE have focused on quantifying the components of the water budget for modeling or planning purposes (Anderholm, 1994; Hearne, 1985; Kernodle, 1996; McAda and Wasiolek, 1988). The compilation revealed that the majority of estimates were made in the vicinity of the middle Rio Grande Valley, the slopes of the Jemez Mountains, and the Sacramento Mountains/Pecos Slope aquifer (Figure 2). This is most likely due to the fact that most scientific institutions and human population centers are in proximity to these areas.

It was found that the methodology used to estimate recharge varied greatly from study to study. There are many methods that can be employed for groundwater recharge studies. The simplest and most commonly used is the water balance/mass balance method, where the outputs from a system (i.e., evaporation, transpiration, exfiltration to streams) are subtracted from the inputs to the system (i.e., precipitation, stream loss, and underflow) and the remainder is accounted for as recharge (McAda, 1984; Spiegel and Baldwin, 1963; Wasiolek, 1995, Weeden and Maddock, 1999). This method has the advantage of being calculated remotely without

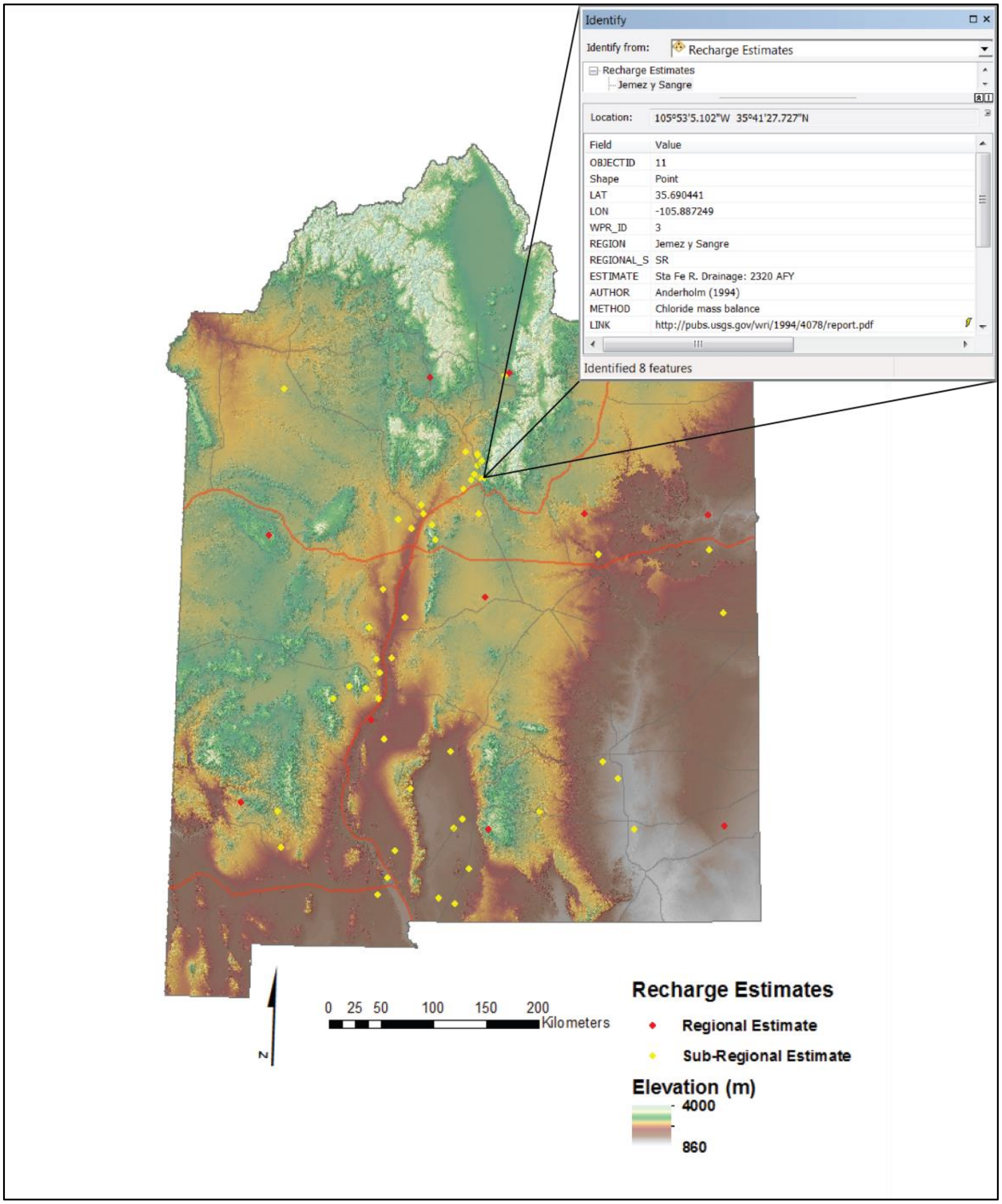

Figure 2. New Mexico and headwaters base map shows recharge estimate study points throughout the state. Selection of a point displays a window with pertinent information.

making field measurements of recharge through other means, though the recharge estimate is entirely dependent on the accuracy of other water-budget components.

Another common method that has been used in New Mexico is the Maxey-Eakin method. Maxey and Eakin (1949) postulated that precipitation is proportional to recharge in semiarid regions and that with increasing precipitation over an area, an increasing proportion of that water infiltrates to become groundwater. This rough estimate is considered a good “first approximation” and has much precedent in the literature and use in the southwestern United States, so it is often the method employed when a large area needs to be analyzed (Daniel B. Stephens and Associates, 2003a, 2003b, 2005a, 2005b, 2007; Frenzel, 1992). The disadvantage is that this method assumes homogeneous conditions over a large surface area.

Both the water-balance, and Maxey-Eakin, approaches are often incorporated into more nuanced methods of recharge estimation that are documented in this compilation, especially in the many groundwater modeling efforts conducted by the USGS over the past 30 years (Orr and Risser, 1992; Roybal, 1989; Waltemeyer, 2001). Modeled recharge estimates are common, though their existence is owed in great part to the need of recharge quantification during the process of model parameterization. Less-often-employed but more scientifically rigorous methods include chloride mass balance, stream-loss calculations, long-term aquifer tests, and Darcy calculations (Anderholm, 1994: Hearne, 1985; Frenzel 1985, Stephens and Knowlton, 1986). In any case, since there is no method of measuring groundwater recharge directly aside from very expensive point measurements using lysimeters (a method typically employed at agricultural sites); recharge estimates rely heavily on measurement of other components of the water budget.

As the ETRM is still in development, the model results were interpreted as relative recharge potential across the state (Figure 3). Areas were delineated based on the modeled propensity for recharge. It was found that the potential recharge is highest in the mountains, especially the Black and San Francisco Ranges of Catron and Grant counties; the Organ Mountains of Doña Ana County; the Sacramento Mountains of Otero and Lincoln counties; the Jemez and Brazos Mountains of Rio Arriba County; and the Sangre de Cristo Mountains of Taos, Colfax, Mora, San Miguel, and Santa Fe counties. Most of the state (76%) has a very low potential for recharge, 22% has a low potential, and a very small portion of the state has moderate or high potential for recharge (1.2% and 0.8%, respectively).

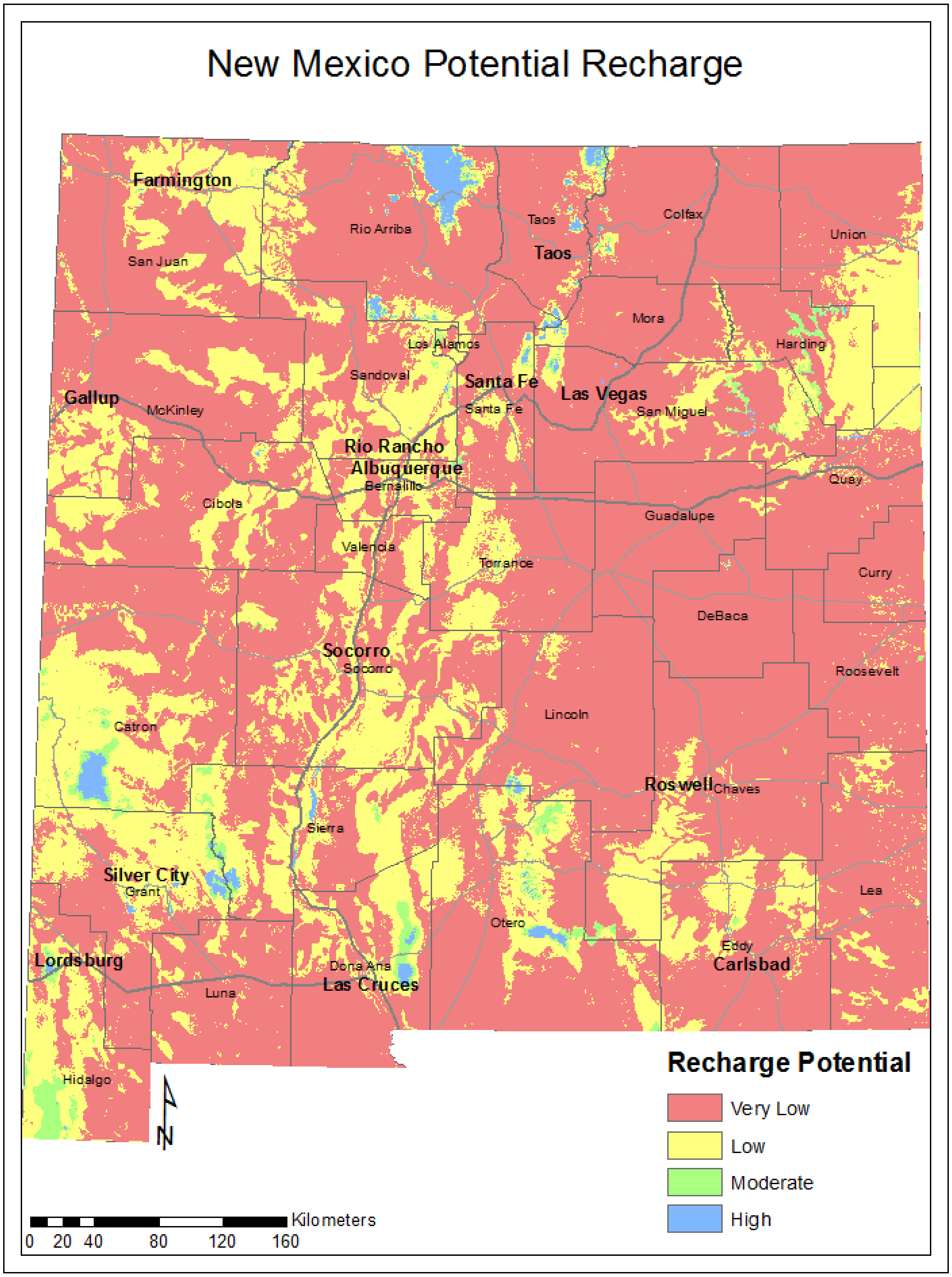

Figure 3. Groundwater recharge potential over the state of New Mexico, according to the Evapotranspiration and Recharge Model. Red indicates unlikely recharge, green and blue represent high recharge potential.

DISCUSSION

While recharge estimates have been made over the essentially the entire state (Appendix I), the techniques used at the water resource planning region scale have been first order approximations based on disparate techniques involving unrealistic physical assumptions. The most common WRPR-wide estimation technique is the modified Maxey-Eakin approach, which was has been found to produce results within 50 percent of independent estimates (Avon and Durbin, 1994). Smaller scale estimates have been made using a wide variety of techniques. This disparity in technique and geographic coverage makes estimating statewide recharge based on existing work in the literature difficult.

Recharge across the state appears to correlate strongly with elevation. High recharge in mountainous areas is indicated by the ETRM and is expected; high altitude ranges cause air masses to rise and cool, causing precipitation (the orographic effect). Soils also tend to be thin in the mountains where the work of erosion is rapid and loose material tends to be washed quickly downwards into valleys. Thin soils are quickly saturated during precipitation and thus cause higher recharge. Low recharge potential is predicted by the ETRM at low elevations and in areas with thick soils. This is expected, as low areas have high barometric pressures and temperatures, which allow atmospheric water to remain in the vapor phase rather than condensing and precipitating. Thick soils tend to host vegetation with deep roots that can effectively drain the soil layer of water for long periods of time after precipitation events, preventing water from percolating through the root zone to become recharge.

The ETRM makes several significant assumptions that ignore certain physical realities. First, the model does not account for water that recharges after having run off the place where it initially fell as precipitation. Second, the model treats the soil layer as a one-dimensional space; unsaturated and saturated-zone lateral flow is not accounted for. Third, the ETRM doesn't attempt to model the unsaturated zone between the soil layer and the aquifer; once water has passed through the soil, it is immediately considered recharge. This is a particularly significant assumption in the Southwest United States, where the unsaturated zone can be hundreds of meters in thickness and travel times through it could be from years to millennia (Flint and Flint, 2004). Though the ETRM uses high-resolution precipitation data, the soils data has been converted from a 1:250,000 scale map, while the reference ET data is a raster grid of 12 km cells. The low resolution of soils and reference ET data neglect the fine-scale variability associated with the topography of New Mexico and result in ET estimates that, while constrained by the water and energy balance, do not reflect this high spatial heterogeneity.

The ETRM provides quantified recharge estimates, yet the results are presented qualitatively as relative recharge potential. This is because the model does not have continuous soil data coverage over the state, the model does not account for focused recharge generated by runoff, and the simulation used data from just one year. There are several large soil-data gaps, especially in the north around the Jemez Mountains, and in and around the lower ranges of the south. These gaps cause the ETRM to fail and were thus given 5 mm of soil manually. The ETRM simulated only the year 2000, which was found to have near normal total precipitation statewide. It would be expected that precipitation, while normal for the state, would have varied from the 30 year normal locally. For these reasons, the results are presented qualitatively, to indicate the propensity for in-place recharge anywhere in the state, while not seeking to quantify the recharge that year. The classification of “Very Low”, “Low”, “Moderate”, and “High” recharge potential is somewhat arbitrary, as the threshold between classes of potential recharge was applied manually to best show the geographic pattern statewide.

FUTURE WORK

Future work on recharge estimation in New Mexico will include improvements to the ETRM and the field collection of water samples that will be analyzed for chloride concentration to estimate recharge in the mountains and assess the performance of the ETRM. The reference ET layer upon which the ETRM relies to control the energy budget must be adjusted to the topography of the state to realistically represent changes in ET due to changing elevation, aspect, shading, and slope. The soils data used to model the soil layer water storage and depletion in the ETRM must be improved by replacing the STATSGO coverage with the latest National Resources Conservation Service SSURGO soils survey. Chloride concentrations found by lab analysis of mountain spring water will be used to perform chloride-mass-balance calculations, an established technique to estimate recharge using groundwater samples. With the completion of future modeling and point-scale recharge estimates, statewide recharge amounts can be quantified.

SUMMARY

Using a GIS framework, existing recharge estimates made within New Mexico were compiled and mapped, and a soil-water-balance model was used to identify potential recharge areas in the state. Over 130 recharge estimates were found. Review of recharge estimation techniques revealed that the methods to estimate recharge over large areas were rough first-order approximations, and efforts to estimate recharge on a smaller scale were made using disparate techniques. A soil-water-balance model that uses soils, precipitation, reference ET, geology, and vegetation to model water mass balance transfer at the atmosphere/subsurface interface simulated daily conditions over one year to identify likely recharge areas. The model shows the expected result, most in-place groundwater recharge occurs in mountainous terrain, where low temperatures, high precipitation, and thin soils allow high recharge rates. Further development of soil water balance modeling is recommended to quantify in-place recharge and analyze possible methods for quantifying focused recharge in New Mexico.

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-- Mora-San Miguel-Guadalupe Regional Water Plan. 2005b. *Prepared for the Tierra y Montes Soil and Water Conservation District and the Mora-San Miguel-Guadalupe Regional Water Planning Steering Committee, June 2005 Sec. 7 p. 8.*
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See Appendix II for recharge estimate references.

APPENDIX I. REGIONAL AND SUB-REGIONAL RECHARGE ESTIMATES BY WATER PLANNING REGION (WPR)

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
1	NE New Mexico	R	247000 AFY	DBS&A (2007) Sec. 5 p. 52	Modified Maxey-Eakin Recharge coefficient of 0.025	http://www.ose.state.nm.us/Planning/RWP/Regions/NorthNM/07_NE_Sect_5.pdf
1	NE New Mexico	SR	3118 AFY: Curry County	Stone and McGurk (1985)	Chloride Mass Balance (CMB), recharge coefficient based on soil	https://nmgs.nmt.edu/publications/guidebooks/downloads/36/36_p0331_p0335.pdf
1	NE New Mexico	SR	1114 AFY: Quay County	Stone and McGurk (1985)	Chloride Mass Balance (CMB), recharge coefficient based on soil	https://nmgs.nmt.edu/publications/guidebooks/downloads/36/36_p0331_p0335.pdf
2	San Juan	R	141000 AFY	Kernodle (1996)	Steady state simulation	http://pubs.er.usgs.gov/publication/wri954187
2	NE New Mexico	SR	Eastern NM (Ogallala): 0.028-1.24 cm/yr	Stone (1990) in Scanlon (1991)	Chloride Mass Balance	in http://www.sciencedirect.com/science/article/pii/0022169491901355
3	Jemez y Sangre	R	3840 AFY	Anderholm (1994) p. 46	Chloride mass balance	http://pubs.usgs.gov/wri/1994/4078/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	Sta Fe R. Drainage: 2320 AFY	Anderholm (1994) p. 46	Chloride mass balance	http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	Tesuque R. Drainage: 690 AFY	Anderholm (1994) p. 46	Chloride mass balance	http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	R. Hondo Drainage: 830 AFY	Anderholm (1994) p. 46	Chloride mass balance	http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	East of Rio Grande: 7400 AFY	Hearne (1985) p. 25	simulations based on streamflow estimates of Reiland (1975)	http://pubs.usgs.gov/wsp/2205/report.pdf
3	Jemez y Sangre	SR	Sta. Fe R. Drainage: 2070	Hearne (1985) p. 25	simulations based on streamflow estimates of Reiland (1975)	http://pubs.usgs.gov/wsp/2205/report.pdf
3	Jemez y Sangre	SR	Pojoaque R. Drainage: 2250 AFY	Hearne (1985) p. 25	simulations based on streamflow estimates of Reiland (1975)	http://pubs.usgs.gov/wsp/2205/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	R. Chupadero Drainage: 390 AFY	Hearne (1985) p. 25	simulations based on streamflow estimates of Reiland (1975)	http://pubs.usgs.gov/wsp/2205/report.pdf
3	Jemez y Sangre	SR	Tesuque R. Drainage: 1800 AFY	Hearne (1985) p. 25	simulations based on streamflow estimates of Reiland (1975)	http://pubs.usgs.gov/wsp/2205/report.pdf
3	Jemez y Sangre	SR	R. En Medio: 890 AFY	Hearne (1985) p. 25	simulations based on streamflow estimates of Reiland (1975)	http://pubs.usgs.gov/wsp/2205/report.pdf
3	Jemez y Sangre	SR	Galisteo Cr.: 3600 AFY	Kernodle, McAda, Thorne (1995)	Mass balance involving precipitation, evaporation, and surface runoff	http://pubs.usgs.gov/wri/1994/4251/report.pdf
3	Jemez y Sangre	SR	Sta Fe River Drainage: 4000 AFY	Kernodle, McAda, Thorne (1995)	Mass balance involving precipitation, evaporation, and surface runoff	http://pubs.usgs.gov/wri/1994/4251/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	0.28"/yr	Lee Wilson and Associates (1978)	streamflow and existing literature examination	https://nmgs.nmt.edu/publications/guidebooks/downloads/30/30_p0293_p0298.pdf
3	Jemez y Sangre	SR	Nambe-Pojoaque Drainage: 2700 AFY	Lee Wilson and Associates (1978)	streamflow and existing literature examination	https://nmgs.nmt.edu/publications/guidebooks/downloads/30/30_p0293_p0298.pdf
3	Jemez y Sangre	SR	Tesuque R. Drainage: 1500 AFY	Lee Wilson and Associates (1978)	streamflow and existing literature examination	https://nmgs.nmt.edu/publications/guidebooks/downloads/30/30_p0293_p0298.pdf
3	Jemez y Sangre	SR	Sta Fe R. Drainage: 3500	Lee Wilson and Associates (1978)	streamflow and existing literature examination	https://nmgs.nmt.edu/publications/guidebooks/downloads/30/30_p0293_p0298.pdf
3	Jemez y Sangre	SR	32020 AFY	McAda and Wasiolek (1988)	based on precipitation infiltration coefficient of (0.05-0.5) varying according to precipitation differences over the study area	http://pubs.er.usgs.gov/publication/wri874056

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	Pojoaque R. Drainage: 2250 AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Mountain front recharge in Sta. F. R. Basin: 5390 AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Mountain front recharge in Pojoaque Basin: 6080 AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Mountain stream channel recharge to Sta. F. R. Basin: 5430 AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	Mountain stream channel recharge to Pojoaque Basin: 5900AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Mountain stream channel recharge A. de los Chamisos: 1010 AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Mountain stream channel recharge A. Hondo: 510 AFY	McAda and Wasiolek (1988)	estimates based on streamflow estimates of Reiland (1975)	http://pubs.er.usgs.gov/publication/wri874056

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	Grand Total: 32020 AFY	McAda and Wasiolek (1988)	based on precipitation infiltration coefficient of (0.05-0.5) varying according to precipitation differences over the study area	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Total Direct Recharge: 7700 AFY	McAda and Wasiolek (1988)	based on precipitation infiltration coefficient of (0.05-0.5) varying according to precipitation differences over the study area	http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	Stream channel recharge to A. Hondo: 13 AF (2000), 200 AF (2001), 0 AF (2002)	Moore (2007)	inverse modeling of infiltration using flow gauges spaced 2km apart	http://pubs.usgs.gov/pp/pp1703/f/
3	Jemez y Sangre	SR	0.57"/yr	Spiegel and Baldwin (1963)	Water mass balance technique.	http://pubs.usgs.gov/wsp/1525/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	Ancha Fm: 0.5"/yr	Spiegel and Baldwin (1963)	water mass balance	http://pubs.usgs.gov/wsp/1525/report.pdf
3	Jemez y Sangre	SR	La Cienega: 0.7"/yr	Spiegel and Baldwin (1963)	water mass balance	http://pubs.usgs.gov/wsp/1525/report.pdf
3	Jemez y Sangre	SR	stream channel recharge Sta Fe R.: 1.7cfs over 2.5 mi reach above La Bajada	Thomas et. Al. (2000) in McAda and Wasiolek (1988)	measure loss of flow, 745 observed, and assumed [(0.02-0.08) by (flow)= evaporation]	in http://pubs.er.usgs.gov/publication/wri874056
3	Jemez y Sangre	SR	MFR to Tesuque A. of Espanola B.: 14700 AFY	Wasiolek (1995)	from NMOSE water budgets (0.13)(annual precipitation)	in http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	Mountain Front Recharge: 9200 AFY	Wasiolek (1995)	Simulation using water balance method;	in http://pubs.usgs.gov/wri/1994/4078/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
3	Jemez y Sangre	SR	9200 AFY	Wasiolek (In Press)	water balance method from Toendle and Leaf (1980)	in http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	MFR R. en Medio: 1710 AFY	Wasiolek (In Press)	water balance method from Toendle and Leaf (1980)	in http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	MFR Tesuque Cr. Dranaige: 1530 AFY	Wasiolek (In Press)	water balance method from Toendle and Leaf (1980)	in http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	MFR Sta. Fe R. Drainage: 4170 AFY	Wasiolek (In Press)	water balance method from Toendle and Leaf (1980)	in http://pubs.usgs.gov/wri/1994/4078/report.pdf
3	Jemez y Sangre	SR	MFR Little Tesuque Cr. Drainage: 1790 AFY	Wasiolek (In Press)	water balance method from Toendle and Leaf (1980)	in http://pubs.usgs.gov/wri/1994/4078/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
4	SW New Mexico	SR	3932 AFY Stream Channel Reacharge between Feywood and Spaulding	Cuddy and Keyes (2011) p. 3	Measurement of flow-loss	http://www.ose.state.nm.us/Pub/pub_reports.php#C
4	SW New Mexico	R	224000 AFY	DBS&A (2005a) Sec. 7 p. 8	Precipitation infiltration coefficient estimate	http://www.ose.state.nm.us/Planning/RWP/Regions/SouthwestNM/7_WtrBudgets.pdf
4	SW New Mexico	SR	76000 AFY Upper Mimbres Basin from Mountain Front Runoff, Stream Infiltration and Underflow	Hanson et al (1994) p. 40	Analysis of mountain-front runoff (Hearne and Dewey (1988), infiltration from streams and springs (flow loss),and underflow (bedrock constriction gauged, Darcy calculation)	http://pubs.er.usgs.gov/publication/wri944011

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
4	SW New Mexico	SR	Mimbres Basin above 1500 m: 0.2153 mm/yr	Odunmbaku et al. (2014) NMGS Spring Meeting	Chloride Mass Balance	https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=303
5	Tularosa - Sacramento - Salt Basins	SR	MFR near Holloman AFB: 3300 AFY	Burns and Hart (1987) p. 17	Recharge coefficient of 20% from Garza and McLean (1997)	http://pubs.er.usgs.gov/publication/wri864324
5	Tularosa - Sacramento - Salt Basins	R	75000 AFY	Livingston and Shoemaker (2003)	Surplus Precipitation Estimate	http://ci.alamogordo.nm.us/Assets/IntraInterNET/articles+and+info/articles/FINAL+Alamogordo+40-Year+Plan+2005-2045+11-22-06.pdf
5	Tularosa - Sacramento - Salt Basins	SR	North: 8300 AFY	Livingston and Shoemaker (2003)	Surplus Precipitation Estimate	http://ci.alamogordo.nm.us/Assets/IntraInterNET/articles+and+info/articles/FINAL+Alamogordo+40-Year+Plan+2005-2045+11-22-06.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
5	Tularosa - Sacramento - Salt Basins	SR	Central: 5800 AFY	Livingston and Shoemaker (2003)	Surplus Precipitation Estimate	http://ci.alamogordo.nm.us/Assets/IntraInterNET/articles+and+info/articles/FINAL+Alamogordo+40-Year+Plan+2005-2045+11-22-06.pdf
5	Tularosa - Sacramento - Salt Basins	SR	South: 60500 AFY	Livingston and Shoemaker (2003)	Surplus Precipitation Estimate	http://ci.alamogordo.nm.us/Assets/IntraInterNET/articles+and+info/articles/FINAL+Alamogordo+40-Year+Plan+2005-2045+11-22-06.pdf
5	Tularosa - Sacramento - Salt Basins	R	67900 AFY	Mamer et al (2014)	Darcy Flow calculations (mean elev. Of each basin)(av. Annual rainfall)(0.089 recharge)	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/551-575/562/OFR_562.pdf
5	Tularosa - Sacramento - Salt Basins	SR	North: 4600 AFY	Mamer et al (2014)	Darcy Flow calculations (mean elev. Of each basin)(av. Annual rainfall)(0.089 recharge)	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/551-575/562/OFR_562.pdf
5	Tularosa - Sacramento - Salt Basins	SR	Central: 4300 AFY	Mamer et al (2014)	Darcy Flow calculations (mean elev. Of each basin)(av. Annual rainfall)(0.089 recharge)	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/551-575/562/OFR_562.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
5	Tularosa - Sacramento - Salt Basins	SR	South: 60000 AFY	Mamer et al (2014)	Darcy Flow calculations (mean elev. Of each basin)(av. Annual rainfall)(0.089 recharge)	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/551-575/562/OFR_562.pdf
5	Tularosa - Sacramento - Salt Basins	SR	Tularosa Basin: 3000 AFY	Rau (1986)	Darcy Flow approximation based on several aquifer tests	in https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/551-575/562/OFR_562.pdf
5	Tularosa - Sacramento - Salt Basins	SR	Hueco Bolson: 14600 AFY	Sayre and Livingston (1945)	Recharge coefficient of 25% of precipitation from the Organ and Franklin mountains	http://pubs.er.usgs.gov/publication/wsp919
5	Tularosa - Sacramento - Salt Basins	R	45300 AFY	Waltemeyer (2001)	Basin Climatic Characteristics Model	http://pubs.er.usgs.gov/publication/wri014013
5	Tularosa - Sacramento - Salt Basins	SR	North from Runoff: 4300 AFY (calculated by Mamer et al (2014)	Waltemeyer (2001)	Basin Climatic Characteristics Model	http://pubs.er.usgs.gov/publication/wri014013

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
5	Tularosa - Sacramento - Salt Basins	SR	South from stream runoff: 40300	Waltemeyer (2001)	Basin Climatic Characteristics Model	http://pubs.er.usgs.gov/publication/wri014013
5	Tularosa - Sacramento - Salt Basins	SR	Central from stream runoff: 640 AFY	Waltemeyer (2001)	Basin Climatic Characteristics Model	http://pubs.er.usgs.gov/publication/wri014013
6	NW New Mexico	R	3700 AFY	Frenzel (1992) p. 30	30% of "San Juan" Method of Hearne and Dewey (1988)	http://pubs.er.usgs.gov/publication/wri914099
7	Taos	R	83000 AFY	DBS&A (2008) Sec. 7 p. 30	Modified Maxey-Eakin Recharge Estimate	http://www.ose.state.nm.us/Planning/RWP/Regions/taos/7-TaosWaterBudget.pdf
8	Mora - San Miguel - Guadalupe	R	179500 AFY	DBS&A (2005b) Sec. 7 p. 6	Modified Maxey-Eakin Recharge Estimate	http://www.ose.state.nm.us/Planning/RWP/Regions/Mora-SanMiguel/MSMG-7-WaterBudget.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
9	Colfax	R	2930 AFY Mountain Front Recharge	DBS&A (2003a) p. 7-13	Estimated 5% annual precipitation infiltration into mountain front areas	http://www.ose.state.nm.us/Planning/RWP/Regions/colfax/colfax_vol1.pdf
10	Lower Pecos Valley	R	142000 AFY	Balleau Groundwater, Inc. (2001) p. 84	Based on water balance	http://www.ose.state.nm.us/Planning/RWP/Regions/pecos/pecos_vol2_regplan.pdf
10	Lower Pecos Valley	SR	Roswell Artesian Basin: 165000 AFY	Fiedler and Nye (1933) p. 253	Calculation based on total discharges from wells	http://pubs.er.usgs.gov/publication/wsp639
10	Lower Pecos Valley	SR	Pecos Slope aquifer: 14190-28380 AFY (infiltration est)	Newton et al. (2012)	Calculation based on estimate of (0.05-0.10%) precipitation infiltration	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/526-550/543/OFR543_june12_LR.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
10	Lower Pecos Valley	SR	Pecos Slope aquifer: 43230 AFY (CMB)	Newton et al. (2012)	Chloride mass balance method	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/526-550/543/OFR543_june12_LR.pdf
10	Lower Pecos Valley	SR	Pecos Slope aquifer: 43230 AFY (CMB)	Newton et al. (2012)	Chloride mass balance method	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/526-550/543/OFR543_june12_LR.pdf
10	Lower Pecos Valley	SR	Pecos Slope aquifer: 14190-28380 AFY (infiltration est)	Newton et al. (2012)	Calculation based on estimate of (0.05-0.10%) precipitation infiltration	https://geoinfo.nmt.edu/publications/openfile/downloads/OFR500-599/526-550/543/OFR543_june12_LR.pdf
10	Lower Pecos Valley	SR	Central Roswell Basin Carbonate Aquifer: 124000 AFY	Rehfelt and Gross (1982)	Numerical Simulation	http://www.wrri.nmsu.edu/publish/techrpt/abstracts/abs142.html

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
10	Lower Pecos Valley	SR	Pecos Basin: 67000 AFY	Risser (1987)	Base flow plus evaporation losses	http://pubs.er.usgs.gov/usgspubs/wri/wri854291
10	Lower Pecos Valley	SR	Pecos R. D. from R. Hondo to Dayton: 40000 AFY	Theis (1937)	Water Budget Method	http://adsabs.harvard.edu/abs/1937TrAGU..18..564T
10	Lower Pecos Valley	SR	Pecos R. D. from R. Hondo to Dayton: 40000 AFY	Theis (1937)	Water Budget Method	http://adsabs.harvard.edu/abs/1937TrAGU..18..564T
11	Lower Rio Grande	SR	11100 AFY Mountain Front Recharge Mesilla Basin	Frenzel et al (1992) p. 22	Water budget analysis	http://pubs.er.usgs.gov/publication/pp1407C

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
11	Lower Rio Grande	SR	5600 AFY Hueco Basin via Tularosa Basin	Meyer (1976)	Digital model simulating effects of pumping	http://pubs.er.usgs.gov/publication/wri7558
11	Lower Rio Grande	SR	5600 AFY Hueco Basin via Tularosa Basin	Meyer (1976)	Digital model simulating effects of pumping	http://pubs.er.usgs.gov/publication/wri7558
11	Lower Rio Grande	SR	4300 AFY	Orr and Risser (1992)	3% annual recharge of precipitation in the mountains	http://pubs.er.usgs.gov/publication/wri914082
11	Lower Rio Grande	SR	4300 AFY Mountain Recharge	Orr and Risser (1992)	3% annual recharge of precipitation in the mountains	http://pubs.er.usgs.gov/publication/wri914082
11	Lower Rio Grande	SR	5200 AFY Jornada Del Muerto Basin	Shomaker and Finch (1996)	Multilayer groundwater flow model	in http://www.ose.state.nm.us/Pub/HydrologyReports/HR-01-06.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
11	Lower Rio Grande	SR	3800 AFY Mountain Front Recharge San Andres Mtns	Shomaker and Finch (1996)	Multilayer groundwater flow model	in http://www.ose.state.nm.us/Pub/HydrologyReports/HR-01-06.pdf
11	Lower Rio Grande	SR	12967 AFY Mountain Front Recharge Mesilla Basin	Weeden and Maddock (1999)	Water budget analysis	http://www.hwr.arizona.edu/simulation-groundwater-flow-rincon-valley-area-and-mesilla-basin-new-mexico-and-texas-0
11	Lower Rio Grande	SR	12967 AFY Mountain Front Recharge Mesilla Basin	Weeden and Maddock (1999)	Water budget analysis	http://www.hwr.arizona.edu/simulation-groundwater-flow-rincon-valley-area-and-mesilla-basin-new-mexico-and-texas-0

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
12	Middle Rio Grande	R	11000 + 36000 AFY	Anderholm (2001) p.34	Chloride mass balance/ water yield regression analysis (estimates mountain front recharge to be 0.007-0.15 total annual precipitation)	http://pubs.usgs.gov/wri/2000/4010/report.pdf
12	Middle Rio Grande	SR	Sandia Range to Los Pinos: 11000 AFY	Anderholm (2001) p.34	Chloride mass balance	http://pubs.usgs.gov/wri/2000/4010/report.pdf
12	Middle Rio Grande	SR	Sandia Range to Los Pinos: 36000-38000 AFY	Anderholm (2001) p.34	Water yield regression analysis (two analyses)	http://pubs.usgs.gov/wri/2000/4010/report.pdf
12	Middle Rio Grande	SR	Subsurface flow from Espanola Basin to MRGB: 8800 AFY	Frenzel (1995)	Analytical results from a long-term aquifer test	http://pubs.er.usgs.gov/publication/wri954091

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
12	Middle Rio Grande	SR	East Front MRGB from A. Tonque to Los Pinos: 36000 AFY	Hearne and Dewey (1988)	Water-yield regression method	in http://pubs.usgs.gov/wri/wri02-4200/
12	Middle Rio Grande	SR	East Front MRGB from A. Tonque to Los Pinos: 36000 AFY	Hearne and Dewey (1988)	Water-yield regression method	in http://pubs.usgs.gov/wri/wri02-4200/
12	Middle Rio Grande	SR	Albuquerque Basin (Cochiti to San Acacia): 280300 AFY	Kernodle (1998)	Revision of steady- state simulation of Kernodle (1995)	http://pubs.er.usgs.gov/publication/ofr96209
12	Middle Rio Grande	SR	Albuquerque Basin from tributaries and MFR: 130000	Kernodle et al (1986)	Simulation of groundwater flow in Albuquerque Basin	http://pubs.er.usgs.gov/publication/wri864194

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
12	Middle Rio Grande	R	110000 AFY (RWP 3+12)	Kernodle, McAda, Thorne (1995)	Simulation of groundwater flow in Albuquerque Basin	http://pubs.usgs.gov/wri/1994/4251/report.pdf
12	Middle Rio Grande	SR	A. Tonque to Los Pinos: 72000 AFY	Kernodle, McAda, Thorne (1995)	Simulation of groundwater flow in Albuquerque Basin	http://pubs.usgs.gov/wri/1994/4251/report.pdf
12	Middle Rio Grande	SR	Jemez R. North of R. Salado: 12800 AFY	Kernodle, McAda, Thorne (1995)	Simulation of groundwater flow in Albuquerque Basin	http://pubs.usgs.gov/wri/1994/4251/report.pdf
12	Middle Rio Grande	SR	Abo Arroyo: 1300 AFY	Nimmo et al. (2001) in McAda and Barroll (2002)	Darcian Steady-State Centrifugal Method	in http://pubs.usgs.gov/wri/wri02-4200/
12	Middle Rio Grande	R	61400 AFY	Plummer et al. (2004)	simulations using MODFLOW, MODPATH, and UCODE	in http://riogrande.nmt.edu/outside/courses/hyd558/downloads/Set_19_SedBasins/CaseStudy-Middle_Rio_Gran.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
12	Middle Rio Grande	SR	R. Puerco: 3600 AFY	Plummer et al. (2004)	simulations using MODFLOW, MODPATH, and UCODE	in http://riogrande.nmt.edu/outside/courses/hyd558/downloads/Set_19_SedBasins/CaseStudy-Middle_Rio_Gran.pdf
12	Middle Rio Grande	SR	Abo A.:1000 AFY	Plummer et al. (2004)	simulations using MODFLOW, MODPATH, and UCODE	in http://riogrande.nmt.edu/outside/courses/hyd558/downloads/Set_19_SedBasins/CaseStudy-Middle_Rio_Gran.pdf
12	Middle Rio Grande	SR	R. Jemez: 260 AFY	Plummer et al. (2004)	simulations using MODFLOW, MODPATH, and UCODE	in http://riogrande.nmt.edu/outside/courses/hyd558/downloads/Set_19_SedBasins/CaseStudy-Middle_Rio_Gran.pdf
12	Middle Rio Grande	SR	Eastern Mountain-Front Recharge: 8400 AFY	Plummer et al. (2004)	simulations using MODFLOW, MODPATH, and UCODE	in http://riogrande.nmt.edu/outside/courses/hyd558/downloads/Set_19_SedBasins/CaseStudy-Middle_Rio_Gran.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
12	Middle Rio Grande	SR	Abo Arroy stream channel recharge: 650-17000 AFY	Stewart-Deaker et al (2007)	Analytical results from a long-term aquifer test	in http://riogrande.nmt.edu/outside/courses/hyd558/downloads/Set_19_SedBasins/CaseStudy-Middle_Rio_Gran.pdf
12	Middle Rio Grande	R	139000 AFY	Thorn et al. (1993)	Analytical results from a long-term aquifer test	http://www.ose.state.nm.us/water-info/NMWaterPlanning/regions/MiddleRioGrande/History/HH-Changes-March2004Version.pdf
12	Middle Rio Grande	SR	Mountain-front recharge + tributary stream channel recharge: 139000 AFY	Thorn et al. (1993)	Analytical results from a long-term aquifer test	http://www.ose.state.nm.us/water-info/NMWaterPlanning/regions/MiddleRioGrande/History/HH-Changes-March2004Version.pdf
12	Middle Rio Grande	R	90000 AFY	Tiedeman et al. (1998) in Kernodle et al (1995)	Non-linear regression modeling applied to flow estimates of Kernodel et al (1995)	in http://pubs.usgs.gov/wri/1994/4251/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
12	Middle Rio Grande	SR	East Front MRGB from A. Tonque to Los Pinos: 36000-49000 AFY	Tiedeman et al. (1998) in Kernodle et al (1995)	Non-linear regression modeling applied to flow estimates of Kernodel et al (1995)	in http://pubs.usgs.gov/wri/1994/4251/report.pdf
13	Estancia Basin	R	37000 AFY	Corbin Consulting (1999) p E-3	Water level data analysis	http://www.ose.state.nm.us/Planning/RWP/Regions/estancia/Estancia-Plan-book1.pdf
14	Rio Chama	R	124390 AFY	La Calandria Associates, Inc. (1995)	Based on Waltemeyer and Kernodle (1992) (Correlates recharge with infiltration coefficient and winter precipitation)	http://www.ose.state.nm.us/Planning/RWP/Regions/RioArriba/6-Water-Budget.pdf
15	Socorro - Sierra	R	196917 AFY	DBS&A (2003b) App. F3 p. 2	Modified Maxey-Eakin Recharge Estimate	http://www.ose.state.nm.us/Planning/RWP/Regions/Socorro-Sierra/Volume-2/Appendix-F3.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
15	Socorro - Sierra	SR	Ladron Pk.: 1300 AFY	Kernodle, McAda, Thorne (1995)	Simulation of groundwater flow in Albuquerque Basin	http://pubs.usgs.gov/wri/1994/4251/report.pdf
15	Socorro - Sierra	SR	Magdalena Mtns SE: 3620 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf
15	Socorro - Sierra	SR	Magdalena Mtns SW: 2900 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf
15	Socorro - Sierra	SR	San Mateo Mtns NE: 4340 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf
15	Socorro - Sierra	SR	Ridge W of Bosque del Apache: 724 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf
15	Socorro - Sierra	SR	Socorro Peak: 2900 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
15	Socorro - Sierra	SR	Lemitar Mtns: 724 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf
15	Socorro - Sierra	SR	E. Socorro Basin: 1450 AFY	Roybal (1989)	Mountain front recharge method of Hearne and Dewey (1988)	pubs.usgs.gov/wri/1989/4083/report.pdf
15	Socorro - Sierra	SR	5200 AFY Jornada Del Muerto Basin	Shomaker and Finch (1996)	Multilayer groundwater flow model	in http://www.ose.state.nm.us/Pub/HydrologyReports/HR-01-06.pdf
15	Socorro - Sierra	SR	Socorro: 0.9-4.7 cm/yr	Stephens et al. (1986)	Darcy calculations	onlinelibrary.wiley.com/doi/10.1029/WR022i006p00881/abstract;jsessionid=42061A607BAC7C67642709A8EAAC1FBC.f01t02
15	Socorro - Sierra	SR	Ladron Pk.: 1300 AFY	Tiedeman et al. (1998) in Kernodle et al (1995)	Non-linear regression modeling applied to flow estimates of Kernodel et al (1995)	in http://pubs.usgs.gov/wri/1994/4251/report.pdf

WPR	REGION	REGIONAL (R) SUB-REGIONAL (S)	ESTIMATE	AUTHOR	METHOD	LINK
16	Lea County	R	75000 AFY	Dugan and Cox (1994) p.11, NM OSE Sec. 6 p. 9	Water level data analysis	http://pubs.usgs.gov/wri/1994/4157/report.pdf, http://www.ose.state.nm.us/Planning/RWP/Regions/leacounty/6-WaterResources.pdf
16	Socorro - Sierra	SR	Socorro: 0.1cm/yr	Mattick, Daval, and Phillips (1987)	Chloride Mass Balance	wrri.nmsu.edu/publish/techrpt/tr220/tr220.pdf
16	Lea County	R	37500 AFY	McAda (1984)	Water budget analysis	http://pubs.er.usgs.gov/publication/wri844062
16	Socorro - Sierra	SR	Socorro: 3.7 cm/yr	Stephens et al. (1986)	Darcy and soil moisture probe	http://onlinelibrary.wiley.com/doi/10.1029/WR022i006p00881/pdf

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