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Methods and Data Sources for Annual Water-Table Maps Prepared for the Albuquerque Bernalillo County Water Utility Authority

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OPEN-FILE REPORT

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A groundwater monitoring well at the ABCWUA Bear Canyon Recharge Project. *Photo by Rowan Hannan, ABCWUA*

INTRODUCTION

The residents of the Albuquerque metropolitan area rely in part on groundwater for domestic, municipal, and industrial use. An understanding of changes in groundwater levels and groundwater storage in the aquifer is necessary to achieve groundwater management goals set by the Albuquerque Bernalillo County Water Utility Authority (referred to here as the Water Authority; ABCWUA, 2016). Periodic manual and continuous automatic water-level measurements in wells and maps of the water-level elevation surface, or water table, derived from these data are essential tools for understanding the groundwater resources of the region.

This report describes the methods used and the sources of data for water-table maps of the Albuquerque area that have been prepared by the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) for the Water Authority annually since 2020. The text of this report largely repeats what is present in Rawling 2023a, 2023b, and 2024. The maps prepared annually following the winter 2022–2023 time period will refer to this report for an explanation of the methods and procedures used in the analysis. This document will be updated annually as necessary to clarify and explain any changes in these procedures and methods. The data used in each year's map will be compiled in a spreadsheet and released with the map.

Changes in the water level and the amount of groundwater in storage in the aquifer since the predevelopment time period are presented with each year's water-table map. Predevelopment is defined by the map of Bexfield and Anderholm (2000) and represents conditions prior to 1961.

The water-level surface and changes since predevelopment are also presented in terms of water-level management criteria defined by the Water Authority (ABCWUA, 2016), shown in the block diagram in Figure 1. Referring to this diagram, the range of water-level elevations from 50 to 250 ft of drawdown relative to predevelopment conditions is defined as the "working reserve." The fuel gauge on the left in the diagram (F for full to E for empty) pertains to the water level relative to the base of the working reserve, the 250-ft drawdown level. The 50 ft of aquifer below the working reserve is referred to as the "safety reserve." The base of the safety reserve, at 300 ft of drawdown relative to predevelopment, is a conservative estimate of when irreversible compaction effects will start to occur in the aquifer. The diagram also shows the management level of 110 ft of drawdown, a target average value drawdown for wells used by the Water Authority.

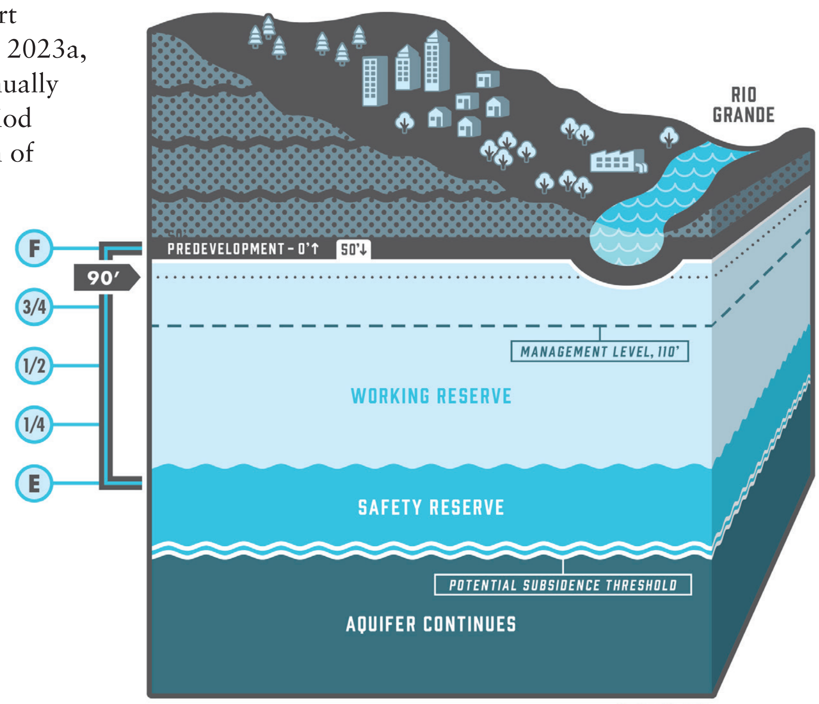

Figure 1. Block diagram illustrating water management criteria for the Water Authority (ABCWUA, 2016). See text for definitions and elevation thresholds.

METHODS

Periodic manual measurements and continuous water-level data collected from wells are used to map the winter water-level surface within the producing zone of the upper Santa Fe Group aquifer in the Albuquerque region. Winter is defined as November 1 through March 1. Standard methods, as described in Falk et al. (2011) and Galanter and Curry (2019), are used to acquire these data in the field.

Water-level data in the Albuquerque area are collected by the U.S. Geological Survey (USGS), NMBGMR, and staff at Kirtland Air Force Base (KAFB), Sandia National Laboratories (Sandia), Bernalillo County (BernCo), and the City of Albuquerque (CABQ). All available data from November 1 to March 1 (the "time window") are compiled and reviewed. These compiled datasets vary in the number and location of wells sampled from year to year, the types of information recorded, and the formatting of the reported data. Water-level elevations are calculated for USGS and NMBGMR data using the elevation of the wellhead and the measured depth to water relative to the ground surface. Reported water-level elevations are used for data from other sources. Some of the wells are in very dense clusters that were installed for specific monitoring purposes. These include the 174 wells monitored by KAFB at the Bulk Fuels Facility in southeast Albuquerque and several groups of wells monitored by CABQ at the Albuquerque railyard and several closed landfill sites. When numerous measurements are present at these well clusters in the time window, the clustered data are downsampled to 10 or fewer measurements (<2.5 wells/km^2) by evenly sampling the measured wells based on the northing coordinate of the well locations. Water-level measurements flagged as being affected by pumping or other conditions that can affect the static water level are removed.

The Albuquerque region wells are located across an area larger than the extent of the study area boundary shown on the maps (Fig. 2). Calculations and interpolations are performed across this larger area, and the results are clipped to the extent shown in the maps, which is the extent of previous water-level maps prepared by Falk et al. (2011) and Galanter and Curry (2019). This process reduces the influence of artifacts caused by edge effects in the interpolations and produces maps that are spatially consistent and directly comparable with previous work.

To produce a water-table map of the production zone of the aquifer, described by Falk et al. (2011) as "…the interval of the aquifer, about 300 feet below land surface to 1,100 feet or more below land surface, in which production wells generally are screened," all single isolated wells are considered. Collocated wells (well nests) are also present, with two to six wells in each nest. The deeper well of a nested pair (two wells) is selected, and the second-deepest well is selected from nests with three to six wells. When multiple measurements exist for a single well, the highest (shallowest) water level for each well during the time window is retained.

An important methodological difference of this series of maps from the earlier work of Bexfield and Anderholm (2000), Falk et al. (2011), and Galanter and Curry (2019) is the treatment of the water-level elevation in the production zone of the aquifer along the course of the Rio Grande, which transects the study area and is hydrologically connected to the shallow aquifer system. Bexfield and Anderholm (2000) characterized the groundwater elevation at the river by using the elevation of the riverbed digitized from topographic maps. The riverbed elevation points were limited to the resolution of the contour interval at the river (10 ft) and change over time as the channel morphology changes. In addition, riverside drains below the river level can cause the groundwater levels to be beneath the riverbed, so this approach does not account for gaining or losing reaches along the river.

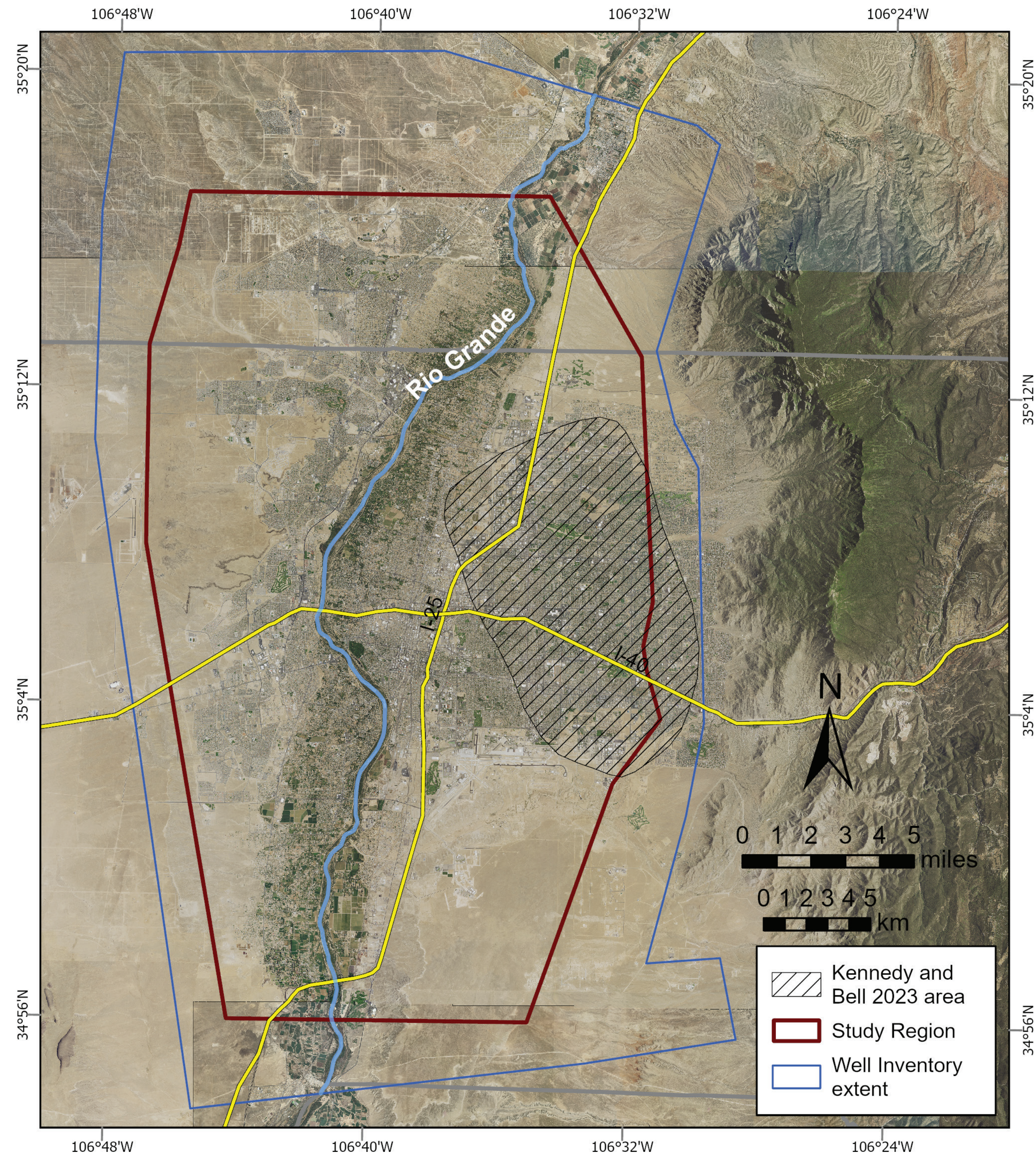

Figure 2. Study area for the annual water-table maps. The spatial extent of the wells inventoried each year is shown in blue. The analysis region of Kennedy and Bell (2023) is shown in gray.

Falk et al. (2011) and Galanter and Curry (2019) calculated the head difference between shallow and deeper wells at five piezometer nests near the river and linearly interpolated this difference along the course of the river. The difference in groundwater levels between the shallow, river-connected aquifer and the deeper production zone at the five wells varied from 1 to 38 ft from south to north (Galanter and Curry, 2019), with the deeper well always having the lower level. Rawling (2023a) attempted this approach and found it to be unreliable because only three well nests had data for the winter 2019–2020 period. The method produced an unreasonable trend of estimated water-level elevations when interpolated along the length of the river.

The method adopted by Rawling (2023a, 2023b, 2024) involves selecting wells within 750 m of the centerline of the Rio Grande and assigning water levels at those wells to adjacent points along the river centerline. Groundwater levels along the river reach are then modeled with a linear curve fit to the water levels at the projected well points. The modeled curve is used to assign groundwater levels to points along the river centerline at 1 km intervals from south to north across the study area. This produces a smooth variation in water-level elevations derived from groundwater measurements and is not dependent on uncertain land- and/or river-surface elevations in the vicinity of the river or the details of the surface water—shallow groundwater interactions between the river, riverside drains, and the aquifer (Alex Rinehart, personal communication, 2021).

The standard geostatistical method of regression kriging (Hengl et al., 2007) is implemented with the gstat package in R (R Core Team, 2019) to interpolate water levels between the water-level measurement points and river points. The regional water-level elevation trend is modeled with third-order polynomial fit to the easting and northing coordinates of the wells and river points. The spatial covariance structure of the residuals from this surface (the variogram) is fit with an appropriate variogram model. The residuals are interpolated using spatial kriging on a 200-m grid. The interpolated residuals are then added to the polynomial trend surface, resulting in the water-level surface for the time period of interest.

It is important to recognize that for the water-level surface, and the subsequent maps derived from it, the accuracy of the interpolated surface depends on the locations of the data (i.e., wells and interpolation points along the Rio Grande). This is quantified by the kriging variance. Results are most reliable where data are abundant (low variance) and least reliable where data are scarce (high variance). Any conclusions drawn by comparing water-level maps in different years must take into account the variation in the spatial distribution and density of the wells used to generate the maps because these change from year to year. Apparent differences between maps in different years, such as details of the geometry of the water-level surface, are as much a function of data distribution and density as they are related to actual water-level changes in the aquifer. This emphasizes the great importance of a consistent well network that can be measured annually within the winter time window (November 1–March 1).

Subtracting the water-level surface from a 10-m resolution digital elevation model results in the depth-to-water map. The map of water-level change is based on the interpolation of predevelopment water-level contours to raster surfaces using the Topo to Raster tool in ArcGIS 10.7.1 (Esri, 2019; Fig. 1), followed by raster math operations.

The map of water-level change since predevelopment can be used to estimate the storage change in the aquifer since predevelopment. This is a straightforward calculation of the net volume change from the water-level changes multiplied by the specific yield. It must be viewed with caution because the result is highly dependent on the value for specific yield, which must be assumed in this case. A value of 0.2 is used in these calculations, consistent with previous work (McAda and Barroll, 2002; Rinehart et al., 2016). Specific yield varies in space, with depth, and with lithology (Cederstrand and Becker, 1998; Kennedy and Bell, 2023). The calculation is also dependent on the accuracy of the predicted water-level changes, which are themselves dependent on the spatial density of the data as revealed by the kriging variance map.

Kennedy and Bell (2023) used repeat microgravity measurements, measured water-level changes, and reported groundwater pumping data to estimate the specific yield and map its spatial variation over a part of the Albuquerque metropolitan area. The extent of their study is shown in gray in Figure 2. At four individual well sites, they calculated specific yield values ranging from 0.1 to 0.22. They interpolated these point results across their study area, which resulted in mapped specific yield values ranging from 0.05 to 0.4, with a mean standard deviation of 0.098 for the estimates. If the analysis area of Kennedy and Bell (2023) were larger and coincided with the boundaries of the maps in this series, their mapped specific yield values could be used to improve the storage change estimates calculated in this work. Nevertheless, it is encouraging that the single value of 0.2 used in this work is consistent with both the point and mapped specific yield estimates of Kennedy and Bell (2023).

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