Depletion of Aquifer Levels in the Lower Rio Grande

New Mexico
Supercomputing Challenge
Final Report
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EXECUTIVE SUMMARY

The aquifers of New Mexico are an important source of water for both agricultural and residential use. Due to a swelling population and warming climate, these aquifers are becoming increasingly stressed. As more and more people are forced to draw water from the aquifer, it is being drained at a significantly faster rate that it is being recharged.

Our goal is to model the strain of increasing population and decreasing water availability on the Mesilla Aquifer in southern New Mexico. The city of Las Cruces is located on the aquifer, which will provide a source for population data associated with the depletion of the aquifer. Other variables in our model will include precipitation, amount of water entitled to farmers, and the water level of the Rio Grande.

With our model, we hope to make a fairly accurate projection of how the aquifer level will fluctuate in the future. This model will also demonstrate the connection between population, temperature, precipitation, and changing aquifer levels.

This is a very relevant problem to the state of New Mexico, because as our water resources are decreasing, it is important to be able to explain what is causing the depletion of water resources, how the trend will continue, and what we can do to stop it.

INTRODUCTION

A. Objective

Through this project, we hope to accurately model the fluctuation of the Mesilla Aquifer so that we can find the correlation between population, temperature, precipitation, and the decreasing aquifer levels. Through doing this, we hope to predict how this trend will continue, and manipulate the variables to calculate the best way to stop the rapid drainage of the Mesilla Aquifer.

B. Purpose

We chose this project because our decreasing access to water in New Mexico is a very significant problem that is affecting not only surrounding communities, but also our community and the environment.

C. Hypothesis

We predict that as population increases and Rio Grande water allotment decreases, the amount of water being drawn from the wells will increase, and the aquifer level will decrease. Based on other calculations and studies the aquifer level should drop approximately 25 feet in about 90 years.

D. Background

a. Theory

Aquifers are bodies of groundwater that are used to supply water for various uses. As surface water moves across Earth's crust, seeps through the ground, and is filtered and cleaned by this process. It eventually reaches the main aquifer, and is pumped back to the surface through several wells. [18]

In an aquifer, the hydraulic head is the elevation of the water at a specific point plus the pressure head. Pressure head is gauge pressure divided by the density of water times the acceleration of gravity. In groundwater, head determines how the water will flow, as it travels from higher to lower head. The head is measured in units of length using a piezometer, which measures the elevation water in a tube, rises when the tube is inserted into an aquifer. [15]

h=Hydraulic head (length unit)

$$\boldsymbol{h = \psi + z}$$

ψ=Pressure head

$$\boldsymbol{\psi = P/\rho g}$$

P=gauge pressure

ρ=density of the water

g=gravitational acceleration

z=elevation at piezometer

The primary calculation in our model is based on Darcy's Law, which calculates the rate of water flow between two points. This is demonstrated in Figure 1. [4]

$$\mathbf{Q = K\ A\ [H1\text{-}H2]\ /L}$$

Q=groundwater flow rates

[H1-H2] = head1 minus head2

K=hydraulic conductivity

A=Area

L=length

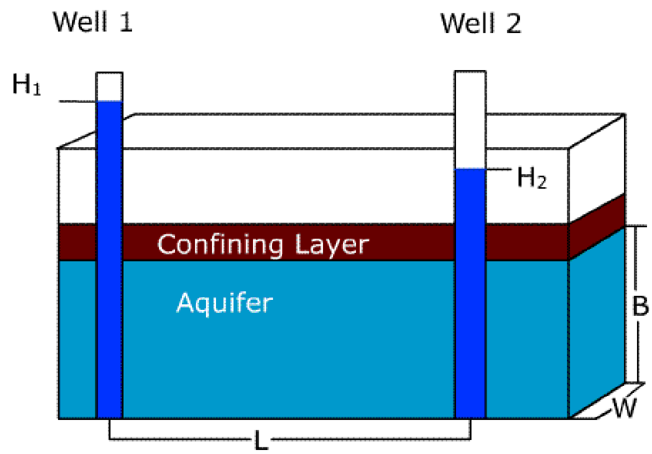


Figure 1 The flow rate of an aquifer can be found using Darcy's law, which relates change in head, hydraulic conductivity, area and length. [15]

The other equation that controls groundwater flow involves the conservation of water. The change in volume of water in an aquifer equals the change in head times the storage coefficient. Darcy's Law and conservation of water, put together, become The Diffusion Equation as shown in figure 2.

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)+W=S_S\frac{\partial h}{\partial t} \quad (1)$$

where

K_{xx}, K_{yy}, and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T);
h is the potentiometric head (L);
W is a volumetric flux per unit volume representing sources and/or sinks of water, with W<0.0 for flow out of the ground-water system, and W>0.0 for flow in (T^{-1});
S_s is the specific storage of the porous material (L^{-1}); and
t is time (T).

Figure 2 The Diffusion Equation is used to calculate the conservation of water. [2]

b. Area of Interest

The Mesilla aquifer stretches from southern New Mexico into Northern Mexico. The aquifer is surrounded by mountain ranges, and provides water for Las Cruces, NM and Dona Ana County. It is primarily recharged through crop irrigation and well as run-off and precipitation. [7]

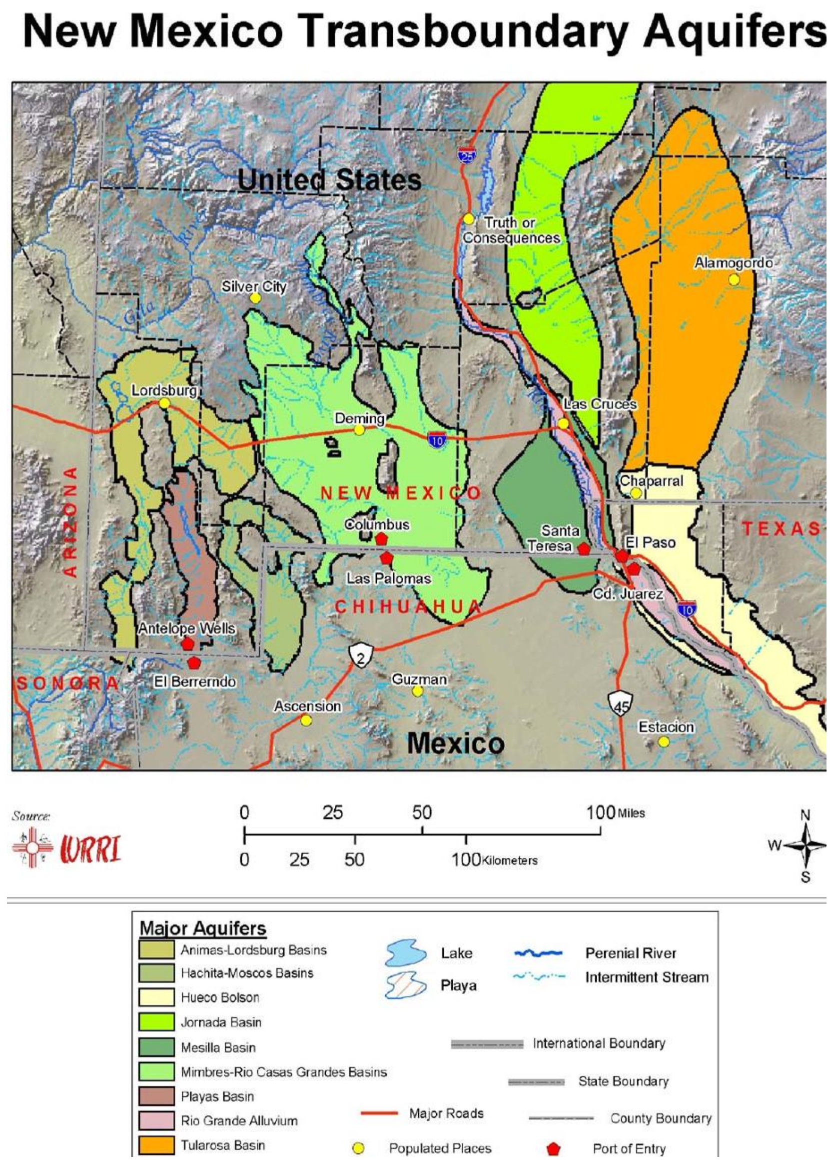


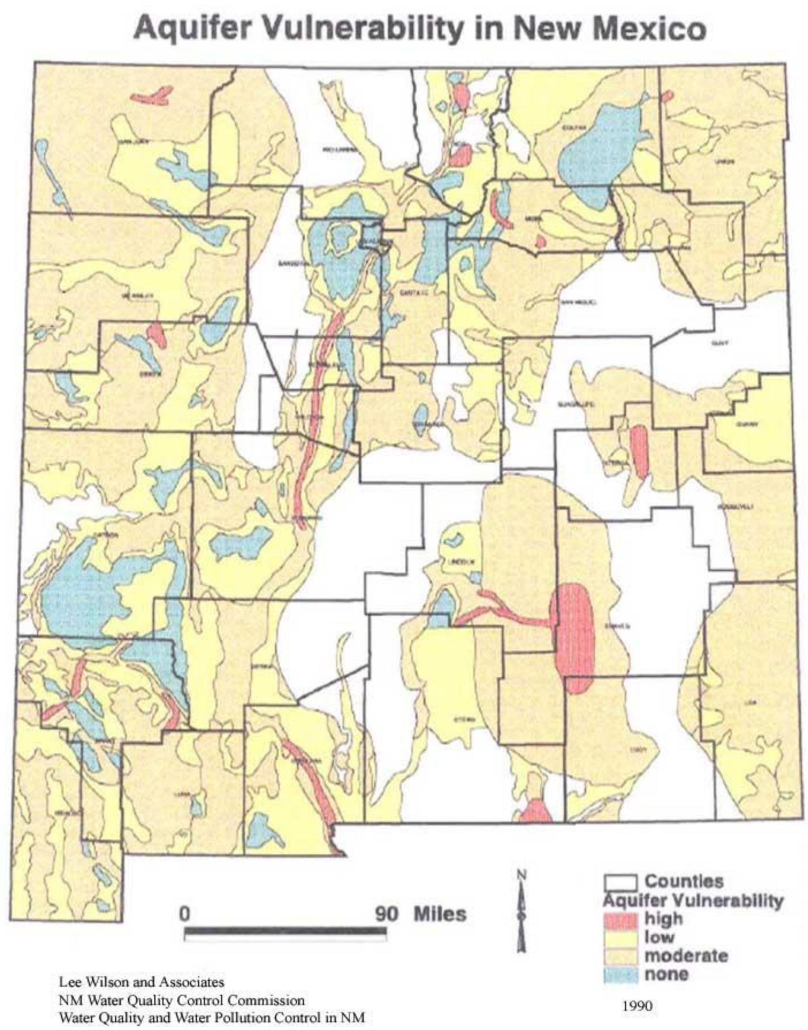
Figure 3 The Mesilla Basin in southeast New Mexico stretches into northern Mexico and provides water for Dona Ana County. [8]

Due to recent water litigation, New Mexico now has less access to water from the Rio Grande, so more and more water is being pulled from the aquifers to compensate for our limited surface water sources. This, along with steadily increasing population and temperate, has caused the Mesilla Basin to be drained at a significantly faster rate than it is being recharged. [17]

Another variable contributing to the dropping aquifer level is the increased number of pecan crops in New Mexico. More and more farmers are growing pecan trees, as pecans are very profitable product. Unfortunately, they also consume large amounts of water, and are contributing to the rapid rate of aquifer drainage. [9]

According to **Figure 2**, the Mesilla Basin is in an area of moderate to high aquifer vulnerability, which also contributes to the fluctuation in aquifer level. This area is prone to a dry climate and very little water.

Figure 4 The Mesilla Basin is in an area of high aquifer vulnerability. [19]



DESCRIPTION

A. Model

To model our project, we used Groundwater Vista 5, a graphical user interface that uses MODFLOW (modeling system) to calculate groundwater flow and groundwater head over time. MODFLOW is a finite difference modeling system that uses Darcy's Law plus the conservation of mass to do this. The equation you get when you incorporate conservation of mass into Darcy's law is called the diffusion equation, which is a second-degree differential equation. A finite difference model solves differential equations by splitting the domain into blocks and applying the simplified equation.

Groundwater Vistas creates the input files that MODFLOW uses, in a graphical interface and interprets the results on a grid, visually. The grid represents an aerial view of a river valley. Above the grid, there is a cross section of the aquifer under the river valley. Each cell of the grid begins with a starting head. The grid can have multiple layers and the sizes of each cell can be changed. Time is divided into stress periods. Each stress period is equivalent to a certain number of years.

Through the program, properties including hydraulic conductivity, daily recharge, porosity and multiple others can be manipulated to affect rate of flow according to Darcy's Law. Hydraulic conductivity is the ease at which water can move through the aquifer. Boundary conditions describe the conditions of the edges of the aquifer and the forces being applied to the aquifer. Examples of these conditions are wells, which pump water, the river, which is constantly flowing and controls the head next to it, and drains, which divert overflowing water when the aquifer reaches surface level. [5]

In the model we created of the Mesilla aquifer, there are two layers. One is from the elevation of 2000 ft to 3900 ft and the other is from 3900 ft to 4020 ft. We set the starting head of across all of the aquifer to 4000 ft. There are 33 rows and 40 columns with each cell's area ranging from ¼ of a square mile to 1 mile. The area of the cell gets smaller around the city of Las Cruses and along the inner part of the aquifer.

Our model has 91 stress periods ranging from 1940 through 2030. Our first stress period in 1940 is a steady-state stress period, where the model continues to run until it finds equilibrium. This represents the time before humans started farming and pumping water from the aquifer. In the next 10 stress periods that lead up to 1950 represent, the city of Las Cruces growing. Farming occurred using primarily river water appose to irrigation wells. In 1950 people began pumping water for farming because of a severe drought and Las Cruces continued to grow. The model runs through 2011 using historical data, and continues through 2030 using extrapolated data. [12]

We set up two hydraulic conductivity zones with one for the inner aquifer and one for the outer aquifer. A hydraulic conductivity zone is a zone where the hydraulic conductivity of the aquifer is the same. In the inner aquifer zone the hydraulic conductivity for water moving side to side was set to 100, but for water moving up and down the hydraulic conductivity was set to 10. In the outer aquifer zone the hydraulic conductivity was set to 5 for water flowing in all directions. In the porosity section, we set the specific yield for the whole aquifer to 0.15 and the storage constant to 0.001.

In our model we created a recharge zone near the river where the farming is occurring with an excluded square that accounts for Las Cruces. The two sources of recharge are from water leaking from canals that divert water from the Rio Grande and water that the crops do not absorb. From the data we have gathered, we know that there are 60,000 acres of farmed land in the Mesilla Valley, the allotted water from the Rio Grande (in acre ft per acre), and the total water needed (in acre ft per acre.) The water leaking from the canals is 90% of the allotted water. Next we had to convert it into feet per day by dividing it by 365. The crops do not absorb about 1/3 of the water. To calculate this part of the recharge you take the total amount of water applied divided by 3 to get the recharge per year. Then we divided that by 365 to get recharge per day. To get total recharge we added both of these numbers together. We did these calculations on an excel spreadsheet so it was easy to copy the formulas for the rest of the years (see tables 1-3 in appendix.) For the years going into the future, we kept the irrigated areas and the total water needed the same. We copied the allotment data from roughly the last 20 years, but changed lowered all values above two to two to take into account the recent litigation with Texas. We put all of the recharge data in a separate excel spreadsheet and imported into Groundwater Vistas in a comma-delimited file.

In our model we created a river going straight down the right-hand side of the aquifer. We set the elevation of the river to 4000 ft and the river bottom to 3995 ft. We set the width of the river to 100 and the length to 5000 in each cell. We set the thickness of the riverbed to 10 and the hydraulic conductivity of the riverbed to 10. The river maintains the same elevation across the whole aquifer. We also created a system of drains that are at the elevation of the ground and drain excess surface water into the river. [16]

In this model we created two different sets of pumping wells. The first set is composed of the irrigation wells, which are all on the inner aquifer and the other set is composed of the wells surrounding Las Cruces. In our model we had to reduce the number of wells because if we had been true to life there would be too many wells to easily add to our model. We reduced the number of irrigation wells to 50 and the Las Cruces pumping wells to 4. These numbers were chosen because they are easy to work with and approximately proportional to the number of wells in reality.

To find the irrigation pumping data first we had to subtract the water that was allotted to farmers from the Rio Grande from the total amount of water needed to come up with the amount of water that the farmers pumped. To turn this number into a volume you multiply it by 60,000 (the amount of famed area) so the data is now in Acre-feet per year. The model only uses data in cubic ft/ day and to do that conversion, you multiply the volume in Acre-feet per year by 119. Then we divided this number by 50 to get the amount of pumping per well. We put all of this data in another spreadsheet and imported it in the same way we imported the recharge data(see table 3 in appendix). [16]

We already had the data for the total amount of water that the city of Las Cruces pumped, but we still had to convert into cubic feet per day, so we multiplied the number by 119 (the conversion factor between acre feet per year and cubic feet per year.) The next thing we had to do was divide that number by four to get the pumping per well (there are four pumping wells for Las Cruces in our model.) To calculate the pumping in the future we had to calculate the rate between population and pumping by dividing the amount of pumping by the population of Las Cruces. We only had the population projects for the county of Las Cruces, which Is Donna Ana County. To find the projections of just Las Cruces we made another rate between the populations of Donna Ana County and Las Cruces. We multiplied the projections of Donna Ana County by this rate to find the projections for Las Cruces. Next we multiplied this projection by the rate between pumping and population to get the projection total pumping of Las Cruces. We had to divide that number by 4 to put the pumping data over 4 wells.

We used data for irrigation pumping as well as Las Cruces pumping going through 2011. The Las Cruces pumping data was acquired from the Office of the State Engineer (OSE). [7]

B. Scope

The primary limitation of our model was the fact that we were not able to model the river was flowing year round, when in reality it only flows for a portion of the year. Having the river flow year round would change the amount of water depletion during the time period when the river was dry. Another limitation was the fact that we couldn’t have the immense number of wells drawing from the aquifer in our model, so we had to create fewer wells to produce the same result.

RESULTS

Through manipulating various aspects of the program, we were able to produce a fairly accurate representation of the depletion of the Mesilla Aquifer. In our model, we input various independent variables including pumping rates for wells, recharge rate, hydraulic conductivity, porosity and storage. The program then calculated the change in hydraulic head over time. The data produced by the model provides the hydraulic head for every cell in each stress period.

Data is presented on the grid with contour lines showing change in hydraulic head level across the aquifer. Data is also depicted using hydrographs that are created with data collected by monitor wells, which measure hydraulic head, but do not pump water. Hydrographs show the fluctuation of head over time from a certain point in the model.

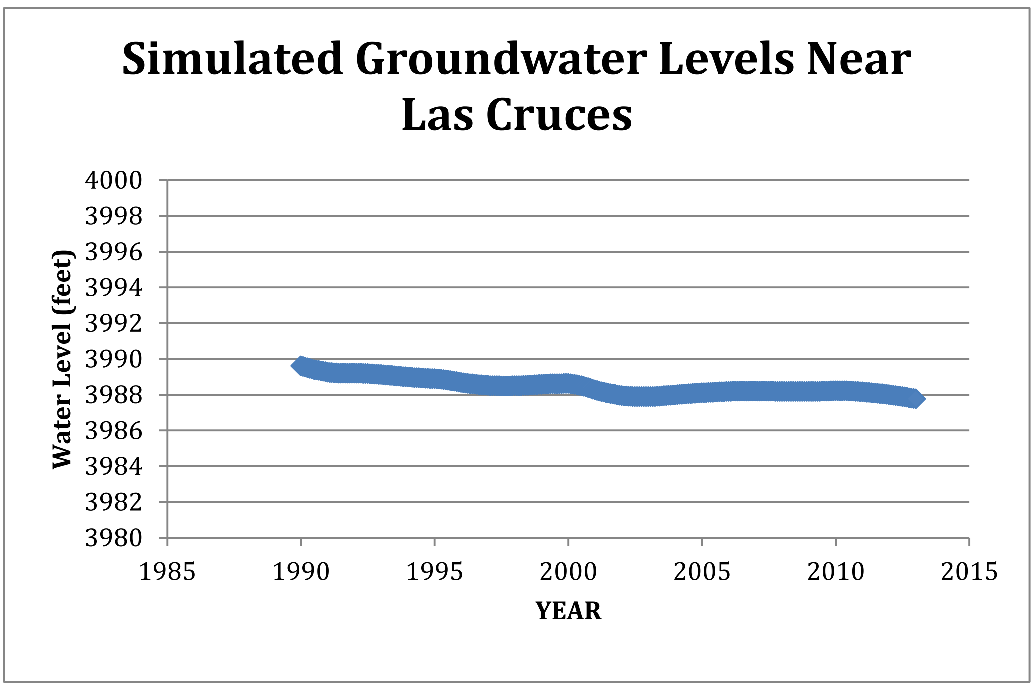


Figure 5
Hydrograph from 1990-present near Las Cruces simulated by our model showing the aquifer level dropping approximately four feet in just over ten years.

Figure 6 A hydrograph created by a piezometer near Las Cruces from 1990-present illustrating a trend that our model was able to produce fairly accurately. [15]

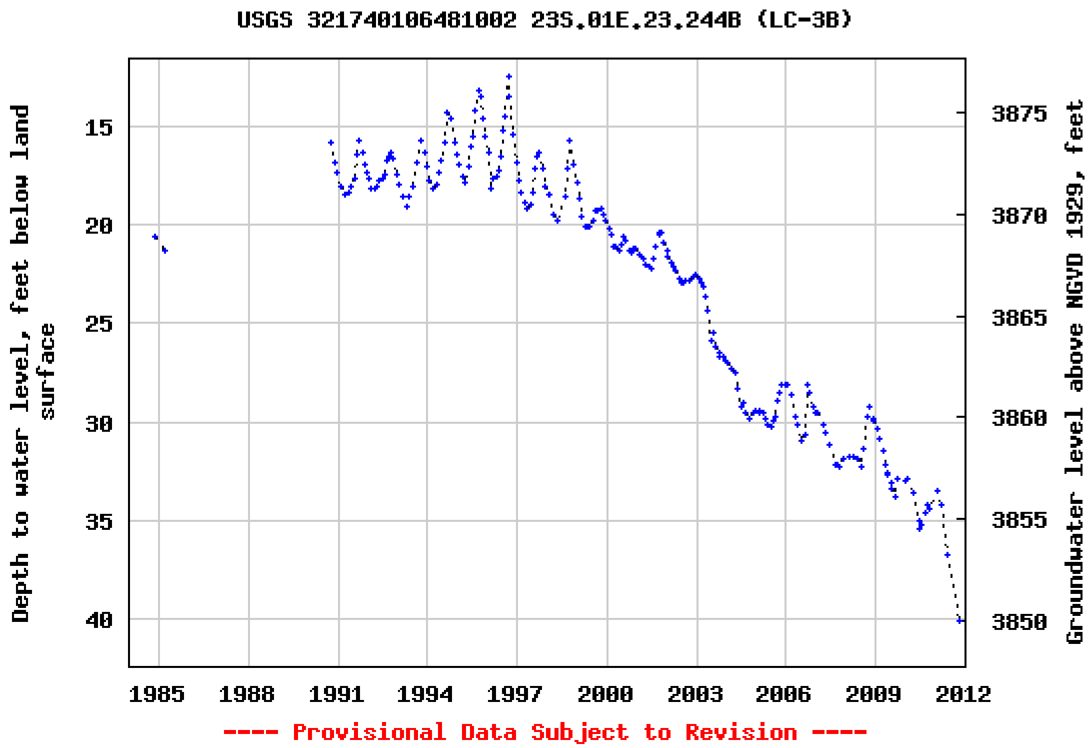
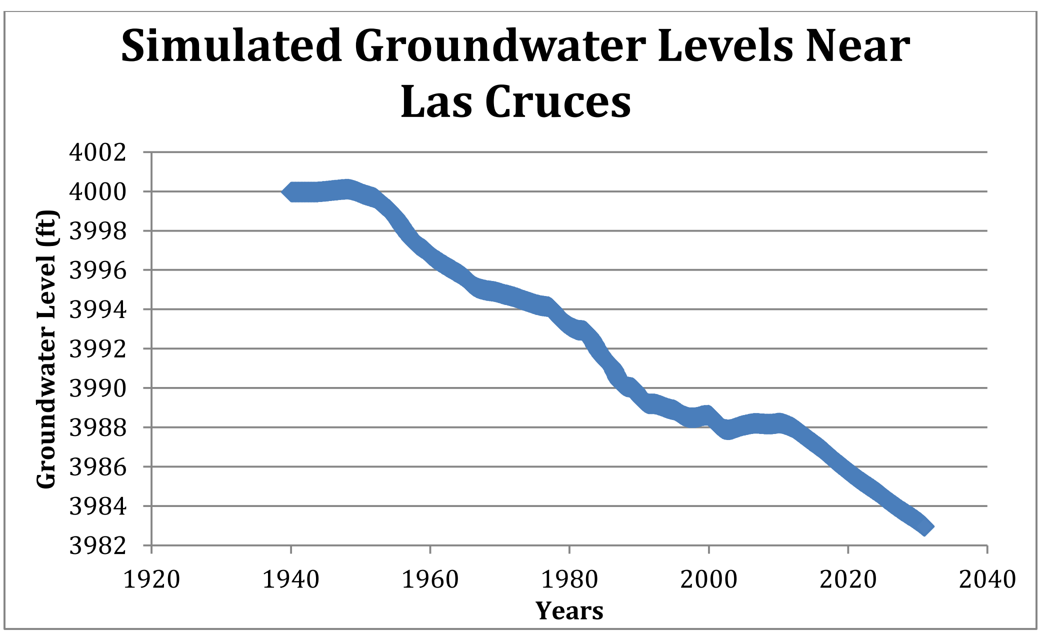


Figure 7 Hydrograph from 1940-2030 near Las Cruces, simulated by our model showing decreasing aquifer level projected into the future.



To generate accurate results, we had to modify a majority of the properties such as storage, porosity, and hydraulic conductivity because the data gathered did not include these values.

From this process, we learned how highly volatile New Mexico aquifers are and how rapidly hydraulic head is decreasing. We also learned about the relevance of differential equations in many different applications.

CONCLUSION

A. Analysis

From our results, we were able to verify our hypothesis, because as population increased and Rio Grande water allotment decreased, the aquifer level decreased as well. Our model provided fairly accurate results that matched other studies done of the area. The hydrographs produced in our model have the same general curve compared to hydrographs created by piezometers. However the hydrographs created by piezometers have a steeper decrease in water elevation starting in the 1990s. Our hydrographs don't lose as much in the 1990s, but start to lose more in later years. Our hydrographs showed the same water elevation at the present as the piezometers', but ours had a different rate of change.

Since our results were semi-accurate, we continued the same general trend, predicting future hydraulic head. This leads us to believe that the data we produced for the next 20 years will be similarly accurate, unless there is an uncalculated change in population, amount of farmed land or water allotment.

The alarming rate that the hydraulic head of the Mesilla basin is dropping is a cause for concern, because it provides water for many different uses. It is important to be more conscious of our water consumption and conserve our water resources. From our model, we learned that the greatest factor contributing to the depletion of the aquifer is the continuous growth of Las Cruces and increased water demand.

Our most significant achievement was semi-accurately modeling the past 70 years of aquifer level fluctuation. This achievement demonstrated the verity of our model and indicated that we had successfully modeled the Mesilla Basin.

B. Future Developments

In the future, we could expand on our model to make it more accurate. We increased the number of stress periods to two per year, and then we can model the fluctuation in the amount of water in the river and how it affects the aquifer. This would help calibrate the model to more accurately calibrate our model to the actual results from the piezometers. We could also explore the production of various crops and the amount of water they need to grow, and how this changes the aquifer’s hydraulic head.

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APENDIX

Appendix A. Data

Table 1:

Year	Population of Dona Ana County	Annual Growth Data	Las Cruces Population	EBID allotment (acre-feet/acre)	Irrigated acreage in Mesilla	Farm Delivery Requirements (acre-feet/acre)	Crop consumption of irrigation water
1940-2002				3.00	60000	3.0	2.6
2003				0.67	60000	4.0	2.6
2004				0.67	60000	4.0	2.6
2005				3.00	60000	4.0	2.6
2006				1.17	60000	4.0	2.6
2007				2.00	60000	4.0	2.6
2008				3.00	60000	4.0	2.6
2009				2.50	60000	4.0	2.6
2010	215,828	1.02	95366	2.00	60000	4.0	2.6
2011	219950.1073	1.02	97187	0.33	60000	4.0	2.6
2012	224150.9429	1.02	99043	2.00	60000	4.0	2.6
2013	228432.0105	1.02	100935	2.00	60000	4.0	2.6
2014	232794.8423	1.02	102863	2.00	60000	4.0	2.6
2015	237,241	1.02	104827	2.00	60000	4.0	2.6
2016	240995.8469	1.02	106487	0.33	60000	4.0	2.6
2017	244810.1223	1.02	108172	1.85	60000	4.0	2.6
2018	248684.7668	1.02	109884	2.00	60000	4.0	2.6
2019	252620.7358	1.02	111623	1.50	60000	4.0	2.6
2020	256619	1.02	113390	2.00	60000	4.0	2.6
2021	260130.003	1.01	114941	2.00	60000	4.0	2.6
2022	263689.0428	1.01	116514	2.00	60000	4.0	2.6
2023	267296.7766	1.01	118108	1.75	60000	4.0	2.6
2024	270953.8705	1.01	119724	0.80	60000	4.0	2.6
2025	274661	1.01	121362	2.00	60000	4.0	2.6
2026	278024.4106	1.01	122848	2.00	60000	4.0	2.6
2027	281429.0084	1.01	124352	2.00	60000	4.0	2.6
2028	284875.2979	1.01	125875	2.00	60000	4.0	2.6
2029	288363.7895	1.01	127417	1.25	60000	4.0	2.6
2030	291895	1.01	128977	0.75	60000	4.0	2.6

Table 2:

Year	City of Las Cruces GW pumping (acre-feet)	demand	Volume of allotment	seepage	Four wells in Las Cruces	Pumping (acre-feet/year)	Pumping (cubic feet/year)
1940	347	180000	180000	162000	10350.96958	0	0
1941	580	180000	180000	162000	17300.4701	0	0
1942	931	180000	180000	162000	27778.1551	0	0
1943	931	180000	180000	162000	27778.1551	0	0
1944	931	180000	180000	162000	27778.1551	0	0
1945	931	180000	180000	162000	27778.1551	0	0
1946	931	180000	180000	162000	27778.1551	0	0
1947	931	180000	180000	162000	27778.1551	0	0
1948	1621	180000	180000	162000	48345.74539	0	0
1949	2151	180000	180000	162000	64151.58434	0	0
1950	2151	180000	180000	162000	64151.58434	0	0
1951	2234	180000	105000	94500	66633.22167	75000	8925000
1952	3735	180000	150000	135000	111402.6918	30000	3570000
1953	3735	180000	114000	102600	111402.6918	66000	7854000
1954	4644	180000	30000	27000	138512.9193	150000	17850000
1955	5587	180000	25200	22680	166630.7633	154800	18421200
1956	5587	180000	23400	21060	166630.7633	156600	18635400
1957	5587	180000	70200	63180	166630.7633	109800	13066200
1958	5793	180000	240000	216000	172784.0941	0	0
1959	7250	180000	210000	189000	216232.9759	0	0
1960	7250	210000	195000	175500	216232.9759	15000	1785000
1961	7493	210000	147000	132300	223477.8913	63000	7497000
1962	7902	210000	195000	175500	235679.9745	15000	1785000
1963	7993	210000	120000	108000	238385.2722	90000	10710000
1964	8050	210000	19800	17820	240089.0601	190200	22633800
1965	8948	210000	111000	99900	266888.6058	99000	11781000
1966	8139	210000	150000	135000	242751.6104	60000	7140000
1967	7962	210000	90000	81000	237476.1273	120000	14280000
1968	7777	210000	120000	108000	231942.6333	90000	10710000
1969	8447	210000	180000	162000	251930.0808	30000	3570000
1970	8636	210000	180000	162000	257567.3898	30000	3570000
1971	8636	210000	105000	94500	257567.3898	105000	12495000
1972	8626	210000	48000	43200	257271.975	162000	19278000
1973	8880	210000	180000	162000	264835.2055	30000	3570000
1974	9276	210000	180000	162000	276667.066	30000	3570000
1975	9276	210000	180000	162000	276667.066	30000	3570000
1976	9276	240000	180000	162000	276667.066	60000	7140000
1977	11359	240000	75000	67500	338779.7536	165000	19635000
1978	10904	240000	45000	40500	325197.5411	195000	23205000

1979	10925	240000	180000	162000	325837.2249	60000	7140000
1980	10967	240000	180000	162000	327087.5854	60000	7140000
1981	10473	240000	180000	162000	312349.6673	60000	7140000
1982	13273	240000	180000	162000	395853.9653	60000	7140000
1983	14845	240000	180000	162000	442742.9798	60000	7140000
1984	14557	240000	180000	162000	434164.0442	60000	7140000
1985	14777	240000	180000	162000	440730.0605	60000	7140000
1986	17941	240000	180000	162000	535078.6477	60000	7140000
1987	15433	240000	180000	162000	460292.4573	60000	7140000
1988	14995	240000	180000	162000	447230.7601	60000	7140000
1989	18156	240000	180000	162000	541497.2832	60000	7140000
1990	16902	240000	180000	162000	504103.8485	60000	7140000
1991	15722	240000	180000	162000	468916.5149	60000	7140000
1992	16595	240000	180000	162000	494942.9355	60000	7140000
1993	16699	240000	180000	162000	498052.0894	60000	7140000
1994	16513	240000	180000	162000	492503.9564	60000	7140000
1995	17637	240000	180000	162000	526008.8434	60000	7140000
1996	17117	240000	180000	162000	510522.2366	60000	7140000
1997	16497	240000	180000	162000	492017.3803	60000	7140000
1998	15921	240000	180000	162000	474839.9028	60000	7140000
1999	16361	240000	180000	162000	487973.5001	60000	7140000
2000	19167	240000	180000	162000	571654.3458	60000	7140000
2001	18197	240000	180000	162000	542731.5458	60000	7140000
2002	17179	240000	180000	162000	512370.457	60000	7140000
2003	15969	240000	40200	36180	476288.3134	199800	23776200
2004	15500	240000	40200	36180	462287.5	199800	23776200
2005	15500	240000	180000	162000	462287.5	60000	7140000
2006	15500	240000	70000	63000	462287.5	170000	20230000
2007	15500	240000	120000	108000	462287.5	120000	14280000
2008	15500	240000	180000	162000	462287.5	60000	7140000
2009	15229	240000	150000	135000	454204.925	90000	10710000
2010	16116	240000	120000	108000	480659.7	120000	14280000
2011	16000	240000	20000	18000	477200	220000	26180000
2012	16737	240000	120000	108000	499195.3083	120000	14280000
2013	17057	240000	120000	108000	508729.4588	120000	14280000
2014	17383	240000	120000	108000	518445.7024	120000	14280000
2015	17715	240000	120000	108000	528347.5169	120000	14280000
2016	17995	240000	19800	17820	536709.7479	220200	26203800
2017	18280	240000	111000	99900	545204.3291	129000	15351000
2018	18569	240000	120000	108000	553833.3553	120000	14280000
2019	18863	240000	90000	81000	562598.9543	150000	17850000
2020	19162	240000	120000	108000	571503.2876	120000	14280000
2021	19424	240000	120000	108000	579322.4661	120000	14280000
2022	19690	240000	120000	108000	587248.6249	120000	14280000
2023	19959	240000	105000	94500	595283.2275	135000	16065000
2024	20232	240000	48000	43200	603427.7578	192000	22848000

2025	20509	240000	120000	108000	611683.7197	120000	14280000
2026	20760	240000	120000	108000	619174.2025	120000	14280000
2027	21014	240000	120000	108000	626756.4114	120000	14280000
2028	21272	240000	120000	108000	634431.4695	120000	14280000
2029	21532	240000	75000	67500	642200.514	165000	19635000
2030	21796	240000	45000	40500	650064.6956	195000	23205000

Table 3:

Year	Total recharge per year	Las Cruces	On farm recharge (ft/year)	On farm recharge (ft/day)	Seepage recharge (ft/year)	Seepage recharge (ft/day)	Total Recharge (ft/day)	Pumpage (cubic ft/day)	Pumpage per well (cubic ft/day)
1940	60000	41403.87833	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1941	60000	69201.88042	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1942	60000	111112.6204	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1943	60000	111112.6204	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1944	60000	111112.6204	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1945	60000	111112.6204	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1946	60000	111112.6204	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1947	60000	111112.6204	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1948	60000	193382.9816	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1949	60000	256606.3374	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1950	60000	256606.3374	1	0.002739726	2.7	0.00739726	0.010136986	0	0
1951	60000	266532.8867	1	0.002739726	1.575	0.004315068	0.007054795	8925000	178500
1952	60000	445610.7672	1	0.002739726	2.25	0.006164384	0.00890411	3570000	71400
1953	60000	445610.7672	1	0.002739726	1.71	0.004684932	0.007424658	7854000	157080
1954	60000	554051.6772	1	0.002739726	0.45	0.001232877	0.003972603	17850000	357000

1955	60000	666523.0531	1	0.002739726	0.378	0.001035616	0.003775342	18421200	368424
1956	60000	666523.0531	1	0.002739726	0.351	0.000961644	0.00370137	18635400	372708
1957	60000	666523.0531	1	0.002739726	1.053	0.002884932	0.005624658	13066200	261324
1958	60000	691136.3764	1	0.002739726	3.6	0.009863014	0.01260274	0	0
1959	60000	864931.9037	1	0.002739726	3.15	0.008630137	0.011369863	0	0
1960	70000	864931.9037	1.167	0.003196347	2.925	0.008013699	0.011210046	1785000	35700
1961	70000	893911.5652	1.167	0.003196347	2.205	0.006041096	0.009237443	7497000	149940
1962	70000	942719.8981	1.167	0.003196347	2.925	0.008013699	0.011210046	1785000	35700
1963	70000	953541.0888	1.167	0.003196347	1.8	0.004931507	0.008127854	10710000	214200
1964	70000	960356.2404	1.167	0.003196347	0.297	0.000813699	0.004010046	22633800	452676
1965	70000	1067554.423	1.167	0.003196347	1.665	0.004561644	0.007757991	11781000	235620
1966	70000	971006.4416	1.167	0.003196347	2.25	0.006164384	0.009360731	7140000	142800
1967	70000	949904.5092	1.167	0.003196347	1.35	0.00369863	0.006894977	14280000	285600
1968	70000	927770.5332	1.167	0.003196347	1.8	0.004931507	0.008127854	10710000	214200
1969	70000	1007720.323	1.167	0.003196347	2.7	0.00739726	0.010593607	3570000	71400
1970	70000	1030269.559	1.167	0.003196347	2.7	0.00739726	0.010593607	3570000	71400
1971	70000	1030269.559	1.167	0.003196347	1.575	0.004315068	0.007511416	12495000	249900
1972	70000	1029087.9	1.167	0.003196347	0.72	0.001972603	0.00516895	19278000	385560
1973	70000	1059340.822	1.167	0.003196347	2.7	0.00739726	0.010593607	3570000	71400
1974	70000	1106668.264	1.167	0.003196347	2.7	0.00739726	0.010593607	3570000	71400
1975	70000	1106668.264	1.167	0.003196347	2.7	0.00739726	0.010593607	3570000	71400
1976	80000	1106668.264	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1977	80000	1355119.015	1.333	0.003652968	1.125	0.003082192	0.00673516	19635000	392700
1978	80000	1300790.164	1.333	0.003652968	0.675	0.001849315	0.005502283	23205000	464100

1979	80000	1303348.9	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1980	80000	1308350.342	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1981	80000	1249398.669	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1982	80000	1583415.861	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1983	80000	1770971.919	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1984	80000	1736656.177	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1985	80000	1762920.242	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1986	80000	2140314.591	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1987	80000	1841169.829	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1988	80000	1788923.04	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1989	80000	2165989.133	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1990	80000	2016415.394	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1991	80000	1875666.059	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1992	80000	1979771.742	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1993	80000	1992208.357	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1994	80000	1970015.825	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1995	80000	2104035.374	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1996	80000	2042088.946	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1997	80000	1968069.521	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1998	80000	1899359.611	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
1999	80000	1951894	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
2000	80000	2286617.383	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
2001	80000	2170926.183	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
2002	80000	2049481.828	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800

2003	80000	1905153.254	1.333	0.003652968	0.603	0.001652055	0.005305023	23776200	475524
2004	80000	1849150	1.333	0.003652968	0.603	0.001652055	0.005305023	23776200	475524
2005	80000	1849150	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
2006	80000	1849150	1.333	0.003652968	1.05	0.002876712	0.00652968	20230000	404600
2007	80000	1849150	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2008	80000	1849150	1.333	0.003652968	2.7	0.00739726	0.011050228	7140000	142800
2009	80000	1816819.7	1.333	0.003652968	2.25	0.006164384	0.009817352	10710000	214200
2010	80000	1922638.8	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2011	80000	1908800	1.333	0.003652968	0.3	0.000821918	0.004474886	26180000	523600
2012	80000	1996781.233	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2013	80000	2034917.835	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2014	80000	2073782.81	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2015	80000	2113390.068	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2016	80000	2146838.992	1.333	0.003652968	0.297	0.000813699	0.004466667	26203800	524076
2017	80000	2180817.317	1.333	0.003652968	1.665	0.004561644	0.008214612	15351000	307020
2018	80000	2215333.421	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2019	80000	2250395.817	1.333	0.003652968	1.35	0.00369863	0.007351598	17850000	357000
2020	80000	2286013.15	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2021	80000	2317289.864	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2022	80000	2348994.5	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2023	80000	2381132.91	1.333	0.003652968	1.575	0.004315068	0.007968037	16065000	321300
2024	80000	2413711.031	1.333	0.003652968	0.72	0.001972603	0.005625571	22848000	456960
2025	80000	2446734.879	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2026	80000	2476696.81	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600

2027	80000	2507025.645	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2028	80000	2537725.878	1.333	0.003652968	1.8	0.004931507	0.008584475	14280000	285600
2029	80000	2568802.056	1.333	0.003652968	1.125	0.003082192	0.00673516	19635000	392700
2030	80000	2600258.783	1.333	0.003652968	0.675	0.001849315	0.005502283	23205000	464100