**SOAH DOCKET NO. 952-19-0705**

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| **APPLICATION OF LOWER** | **§** | **BEFORE THE STATE OFFICE** |
| **COLORADO RIVER AUTHORITY** | **§** | |
| **FOR OPERATING AND TRANSPORT** | **§** | **OF** |
| **PERMITS FOR EIGHT WELLS IN** | **§** | |
| **BASTROP COUNTY, TEXAS** | **§** | **ADMINISTRATIVE HEARINGS** |

# GM EXHIBIT 11

## DIRECT TESTIMONY OF WILLIAM R. HUTCHISON, Ph.D., P.E., P.G.

***on behalf of***

**THE GENERAL MANAGER OF**
**LOST PINES GROUNDWATER CONSERVATION DISTRICT**

**SUBMITTED ON JULY 26, 2019**

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## GLOSSARY OF ACRONYMS AND DEFINED TERMS

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|---|---|
| DFC | Desired Future Condition, as defined by Texas Water Code section 36.108(d) |
| Donnelly Report | The District hydrogeologist's report dated April 6, 2018 |
| Draft Permit | The General Manager's draft operating and transport permit for the LCRA Applications dated August 20, 2018 |
| GAM | Groundwater Availability Model approved by the Texas Water Development Board |
| Old GAM | 2004 Central Queen City-Sparta GAM |
| New GAM | 2018 Central Carrizo-Wilcox GAM |
| GMA | Groundwater Management Area |
| LCRA | Lower Colorado River Authority |
| LCRA Applications | LCRA's applications for 8 operating and transport permits for 8 proposed wells in Bastrop County, Texas submitted to LPGCD during February 2018 |
| LPGCD or District | Lost Pines Groundwater Conservation District |
| TWDB | Texas Water Development Board |

## LIST OF EXHIBITS

| Exhibit | Description |
|---|---|
| GM EXHIBIT 11 | Direct Testimony of William R. Hutchison, Ph.D., P.E. P.G. |
| GM EXHIBIT 12 | William R. Hutchison, Ph.D., P.E. P.G. Resume |
| GM EXHIBIT 13 | Expert Report of William R. Hutchison, Ph.D., P.E., P.G. prepared on behalf of the General Manager of the Lost Pines Groundwater Conservation District (model runs and reference materials used for this report provided to the parties via online sharefile site) |

## I. WITNESS INTRODUCTION AND QUALIFICATIONS

**Q. Please state your name and business address.**

A. My name is William R. Hutchison and my business mailing address is 9305 Jamaica Beach, Jamaica Beach, Texas 77554.

**Q. On whose behalf are you testifying in this proceeding?**

A. I am filing testimony on behalf of the Lost Pines Groundwater Conservation District ("District").

**Q. By whom are you employed and in what position?**

A. I am self-employed as an Independent Groundwater Consultant.

**Q. How long have you been self-employed in this capacity?**

A. I started undertaking independent consulting projects with my own business in 2012.

**Q. Please describe generally your work as an independent consultant.**

A. I am a practicing hydrogeologist and engineer. My work includes consulting with mostly public and governmental entities on projects involving groundwater resources.

**Q. Please describe your educational background and professional affiliations.**

A. I graduated from the University of California, Davis with a Bachelor of Science degree in Soil and Water Science in 1980. I received a Master of Science from the University of Arizona in Hydrology in 1983 and earned a Ph.D. from the University of Texas at El Paso in 2006 in Environmental Science and Engineering.

I am a member of the American Society of Civil Engineers, the International Association of Hydrogeologists, the National Groundwater Association, and an associate member of the Texas Alliance of Groundwater Districts.

**Q. Please describe your professional experience.**

A. I have over 35 years of professional experience. From 1983 to 2001, I was employed by various consulting firms or worked as an independent consultant in California and Arizona. From 2001 to 2009, I was employed by El Paso Water Utilities in El Paso, Texas. From 2009 to 2012, I was the Director of the Groundwater Resources Division of the Texas Water Development Board. From 2011 to 2012, I was employed by LBG-Guyton in Austin, Texas. Since 2012, I have been an independent consultant, currently based in Jamaica Beach, Texas.

**Q. Are you a licensed professional geoscientist in Texas?**

A. Yes. I am a licensed professional geoscientist (geology) in Texas. My registration number is 286.

**Q. When did you first become a licensed professional geoscientist in Texas?**

A. I received my license to practice as a professional geoscientist in 2003.

**Q. Is your registration currently in good standing with the Texas Board of Professional Geoscientists?**

A. Yes.

**Q. Are you required to participate in continuing education to maintain your good standing with the Texas Board of Professional Geoscientists?**

A. I am.

**Q. What types of continuing education do you commonly participate in for your geoscientist license?**

A. I regularly attend technical presentations related to various issues in hydrogeology and water resources. I also undertake self-directed study that involves reading and reviewing technical hydrogeology and earth-science literature. I have also prepared and presented the results of my own research and technical work, and I have attended and participated in professional conferences related to the earth sciences. Finally, I have attended short courses and instructional seminars.

**Q. Are you a licensed professional engineer in Texas?**

A. Yes. I am a licensed professional engineer in Texas. My registration number is 96287. I have been licensed since 2005 as a Geological Engineer, and since 2012 as a Civil Engineer. My engineering firm (No. 14526) has been licensed since 2012.

**Q. Is your registration currently in good standing with the Texas Board of Professional Engineers?**

A. Yes.

**Q. Are you required to participate in continuing education to maintain your good standing with the Texas Board of Professional Engineers?**

A. I am.

**Q. What types of continuing education do you commonly participate in for your engineering license?**

A. I regularly attend technical presentations and have undertaken self-study related to hydrology and hydrogeology. I have also prepared and presented the results of my own research and technical work, and I have attended and participated in professional conferences related to groundwater resources. Finally, I have attended short courses and instructional seminars.

**Q. Please describe your experience with groundwater resources in the Carrizo-Wilcox Aquifers.**

A. I have completed consulting assignments for Groundwater Management Area (GMA) 11 and 13. I am also the principal hydrogeologist for a team of consultants for the Texas Water Development Board updating the groundwater availability models for the northern and southern portions of the Carrizo-Wilcox Aquifer. I am also currently completing a consulting assignment for the Rusk County Groundwater Conservation District.

As the consultant for GMAs 11 and 13 (the northern and southern portions of the Carrizo-Wilcox Aquifer), I assisted the groundwater conservation districts in the process of developing Desired Future Conditions, or DFCs. As part of that process I used the existing Queen-City Sparta Groundwater Availability Models or "GAM" developed for the Texas Water Development Board, for the relevant aquifers including the Carrizo-Wilcox. It was during this process that needed improvements to the models were identified. Subsequently, the Texas Water Development Board (TWDB) awarded contracts to update and improve the northern and southern Carrizo-Wilcox GAMs to the consulting team that I am a part of.

The current work for the Rusk County Groundwater Conservation District involves comparing the results of the simulations used to develop the desired future conditions adopted in GMA 11 with actual monitoring data.

**Q. Have you provided expert testimony in the past?**

A. Yes. I have testified in the following cases:

- In 1992, I testified as an expert witness in a groundwater rights case in San Benito County, California.

- In 1993, I testified as an expert witness before the California State Water Resources Control Board regarding the Los Angeles Department of Water and Power Water Rights in the Mono Basin.
- In 1999, I testified as an expert witness before the California State Water Resources Control Board regarding the request of the City of San Luis Obispo to raise the height of the dam that forms Santa Margarita Lake (aka Salinas Reservoir).
- In 2016, I testified as an expert witness at a mandamus hearing filed against the Middle Pecos Groundwater Conservation District by Republic Water Company of Texas, LLC in Fort Stockton, Texas.

Although I have not yet testified, I have been disclosed as an expert witness and completed an expert report for the State of Texas in the Texas, New Mexico, and Colorado litigation regarding the Rio Grande Compact of 1938.

**Q. Are you being paid for your work as an expert?**

A. I am.

**Q. Your fees as an expert in this case are not related to, and you do not have, any financial interest in the outcome of this case, correct?**

A. I have no financial interest in the outcome of this case.

**Q. Is GM EXHIBIT 12 a true and correct copy of your resume?**

A. Yes.

**Q. Does GM EXHIBIT 12 include a current list of your past and current consulting assignments and publications?**

A. Yes.

**[DISTRICT GM OFFERS GM EXHIBIT 12]**

## II. SUMMARY OF TESTIMONY

**Q. Please summarize your testimony.**

A. My testimony addresses the technical components that apply to groundwater management. I will cover the reliability of the model used to evaluate impacts to groundwater systems, impacts to overlying and underlying formations from groundwater production, impacts to surface water, subsidence, LCRA's requested phased approach, the effect on existing water resources and permit holders, and responses to LCRA witnesses and the Protestants' witnesses. I also refer to and rely on a report that I prepared at the direction of the District evaluating impacts to water resources on a district-wide basis from the proposed production.

**Q. What information have you reviewed and relied upon for your testimony.**

A. I have relied upon and reviewed the following information:

- My education and studies in groundwater hydrology;
- My professional experience as a groundwater hydrologist;
- LCRA's applications;
- The Administrative Record filed in this proceeding;
- Written pre-filed testimonies submitted by other parties in this proceeding and exhibits attached to those testimonies;
- Documents produced in discovery in this proceeding;
- The District's Rules and Management Plan, and Texas Water Code, Chapter 36; and
- All materials referenced in and provided with the Hutchison Report.

## III. OVERVIEW OF WORK PERFORMED

**Q. How have you gained knowledge of the facts in this case?**

A. I am familiar with District geology and hydrogeology from past professional work involving the Carrizo-Wilcox (which includes the Simsboro). I am familiar with the GAM from past professional work, including working at the TWDB, researching, and consulting. I initially reviewed the LCRA Applications and Mr. Andy Donnelly's April 6, 2018 Memorandum on his review of the LCRA Applications, and the General Manager's Draft Permit. I obtained copies of the GAMs from the Texas Water Development Board and reviewed those. I obtained and reviewed the specific model files provided by INTERA (LCRA witnesses), and extracted results from those model runs as developed in my associated report, Expert Report for the General Manager of the Lost Pines Groundwater Conservation District (the "Hutchison Report"). A true and correct copy of this report can be found at DISTRICT EXHIBIT GM 13.

**[DISTRICT GM OFFERS GM EXHIBIT 13]**

## IV. RELIABILITY OF THE GAM

**Q. What is a Groundwater Availability Model?**

A. A Groundwater Availability Model, or GAM, is a computer-based, three-dimensional numerical groundwater flow model that is designed to simulate the dynamics of the groundwater flow for a specific area in Texas. As part of state water planning, TWDB developed GAMs for all major and most minor aquifers in Texas. For the area around the District, the Central Queen City-Sparta GAM, has been used since its development in 2004 (the "Old GAM"). In 2018, the TWDB updated the model and is called the Central Carrizo-Wilcox GAM. As described in the Hutchison Report (GM EXHIBIT 13), the new GAM (completed in 2018) has ten model layers (the "New GAM"). The major and minor aquifers that are explicitly included in the model are the Sparta, Queen City, and Carrizo-Wilcox aquifers. The GAMs incorporate available information on aquifer structure, hydrostratigraphy, hydraulic properties, stream flow, and recharge estimates. Both GAMS were calibrated against actual measured water level data and from a modeling standpoint, the calibration was deemed acceptable by TWDB when the GAM was adopted. The Hutchison Report also explains that the calibration of the New GAM is better than the Old GAM in Bastrop County, and that impacts from production in Bastrop County may occur in Lee County. This is not surprising because the TWDB continues to assess and refine the GAMs, which the districts are required to consider in developing their DFCs.

**Q. Please briefly describe how the GAM is developed.**

A. TWDB initiates the process by deciding which area of Texas will be covered and the aquifer or aquifers that will be included in the GAM. Some GAMs include multiple aquifers, while others include only a single aquifer. The GAMs are then either developed by TWDB technical staff or by consulting firms that contract with the TWDB. The developers of the model collect information from existing studies of the aquifers, including maps, drillers logs, sub-surface geologic data, water levels, water quality data, well pumping records, stream and spring flows, and results from other computer models. The developers use this information to design the basic architecture of the system, i.e., thickness and depth of aquifer formations and lateral boundaries. This information is also used to develop estimates of the various aquifer parameters, e.g., hydraulic conductivity and recharge, and to develop a conceptual model of the system, which is basically a mental and idealized image of the structure and function of the aquifer(s) that the developers will use to guide development of the actual computer model. The actual computer model is a set of computer files, mostly ASCII text files, that contain all the information necessary to represent the structure and function of the aquifer(s).

Once the computer files are prepared and the model is run, the model results are checked against actual data in a process called calibration. Typically, the comparisons include groundwater elevations and, if appropriate, surface water flows. In the calibration process, the model is run for a period of time that represents a historic period that has a significant amount of measured data; preferably a period that was before considerable well pumping has occurred. Various aquifer parameters and inputs, such as hydraulic conductivity values and recharge amounts, are then adjusted to improve the match to real-world data. The final step in the development process is documentation of the model. The attached Hutchison Report includes citations for the documentation of the Old GAM and the New GAM and briefly discusses the calibration of the two models in Bastrop County.

**Q. What is the GAM used for?**

A. When the GAM process started in about 2000, TWDB's stated purpose was to create a tool for state and regional water planners and groundwater conservation districts. After the Legislature initiated the joint groundwater planning process in 2005 (the process that leads to the development of DFCs and modeled available groundwater (MAGs)), TWDB began to use the GAMs as a tool in the joint planning process. This involved using the GAMs to predict groundwater elevations and, when appropriate, surface water flows under assumed or alternative pumping scenarios extending out 50 to 60 years. TWDB later used the GAMs to estimate the MAG once the DFCs have been adopted.

**Q. How does the GAM work?**

A. The structure of an aquifer is represented by a 3-dimensional grid of cells, represented by rows, columns, and layers, where the rows and columns represent the area of the aquifers, i.e., as seen on a map, and the layers represent the individual aquifers and intervening low-permeability units. The spacing of the grid cells for the Central Queen City-Sparta GAM (the Old GAM) are a constant one square mile. The spacing of the grid cells of the Central Carrizo-Wilcox GAM (the New GAM) has a variable grid that uses quadtree mesh refinement that reduces the cell size in the area of selected surface water features. The largest cell size in the new GAM is one square mile (640 acres), the smallest cell size is 40 acres (1/16 square mile).

Boundaries of the aquifer and the thicknesses and depths of the layers are represented in the grid based on the best information available to the modelers. Properties of the aquifer -- i.e., numerical values such as horizontal and vertical hydraulic conductivity -- that control how water moves and how water levels change in response to stresses to the aquifer -- e.g., pumping from wells -- are applied to each model cell. Processes that add and subtract water to and from the model, including recharge to the various aquifers, movement in and out of the model from areas outside of the model boundaries, discharge to streams and springs, evaporation and transpiration (i.e., uptake of water from plants), and pumping from wells is also included in a separate set of text files with one text file representing each process, e.g., a .wel file (or "welfile") for the well pumping, a .rch file for the recharge, etc. In model terminology, the processes that add and subtract water from the model domain are called "stresses." The GAMs are "transient" models, in that they simulate changes throughout time, e.g., through an historical period and throughout the multi-decadal planning period. Time in the model is simulated by a set of stress periods. In the case of the Old GAM and New GAM, each stress period represents a single year.

The actual functions of the aquifer -- i.e., the movement of water through the aquifer, changes in water stored within the aquifer layers, and changes in water levels throughout time -- are simulated by a set of equations that basically calculate the hydraulic head, i.e. water level, in each model cell in each stress period. Calculating hydraulic head is specifically what the GAMs do, and the changes in hydraulic head from one cell to the next, and from one stress period to the next, can then be used to determine fluxes of water throughout the model and changes in hydraulic head, i.e., drawdown, throughout time.

**Q. What GAM-related work have you done in this case with respect to the permit amounts and locations requested in the LCRA Applications?**

A. Initially, I obtained the model files and documentation for the Old GAM and the New GAM from the TWDB. I also reviewed Mr. Andy Donnelly's April 6, 2018 memorandum concerning estimated drawdown from the proposed LCRA Permits. Subsequently, I obtained the model files used by INTERA (LCRA's witnesses) that used both the Old GAM and New GAM to simulate the impacts of the proposed LCRA pumping.

I completed a comparison of the calibration in Bastrop County of the old GAM and the new GAM and concluded that the New GAM had better calibration statistics.

I developed groundwater budgets to better understand the impacts of pumping in Bastrop County. Groundwater budgets are an accounting of all inflows, outflows, and storage changes within a specified area.

Next, I compared model results from the INTERA runs of the New GAM with and without the proposed LCRA pumping and extracted specific groundwater elevation results at the location of each well in the District's registered well database. Registered wells include all non-exempt permitted wells.

Finally, I compared model results from the INTERA runs of the New GAM with and without the proposed LCRA pumping and extracted specific groundwater elevation results at the location of each well in the District's monitoring well network.

**Q. What is the reasonableness of considering results of GAM modeling in determining whether the District is managing total groundwater production on a long-term basis to achieve an applicable desired future condition?**

A. Texas Water Code § 36.108(d) requires the groundwater conservation districts of GMA 12 to consider GAM information in developing the DFCs for GMA 12. The DFCs for the District (and GMA 12) are set as regional drawdown levels. The GAM calculates predicted water levels and drawdown levels and is therefore directly related to the DFCs. The GAM can provide a prediction of how production will affect achievement of DFCs.

**Q. Does the GAM have any limitations for reviewing local impacts?**

A. Yes.

**Q. What are those limitations?**

A. In general, GAMs are regional tools and as such should be limited in use to developing regional results and drawing regional conclusions.

Also, Section 3.2 of the Hutchison Report provides that the New GAM showed that historic pumping has been relatively low in the sense that historic pumping has not been a major factor in changes in groundwater levels in Bastrop County. Analysis of the historic model results show that 94 percent of the variation in groundwater levels in Bastrop County can be explained by the variation in recharge. (Recharge to aquifers results primarily from precipitation on the outcrop areas of the aquifer. The outcrop is the surface extent of an aquifer -- *i.e.*, the area in which the aquifer formations are exposed at the land surface.)

**Q. How does the District address these limitations when managing groundwater and issuing permits?**

A. The fact that historic pumping has not had a major impact on groundwater levels in Bastrop County represents a limitation of the use of model results under scenarios with much higher pumping because the model has not been calibrated under high pumping conditions. Given this limitation, the model results should serve only as a guideline for groundwater management until the model can be updated in the future when pumping rates have increased to the point that they have affected groundwater levels to an extent that the model can be reasonably calibrated with updated data.

**Q. What other tool(s) are useful in considering whether the District is managing total groundwater production on a long-term basis to achieve an applicable DFC?**

A. A phased approach to increased pumping and an active program of collecting and evaluating actual monitoring data are useful to managing groundwater in Bastrop County. Information from monitoring wells will provide data on actual aquifer conditions at various times and under various conditions and hence will provide information on whether the District is managing total groundwater production on a long-term basis to achieve an applicable DFC. Data from the District's monitoring wells can also be included in future GAM improvements.

## V. IMPACT ON OVERLYING AND UNDERLYING FORMATIONS

**Q. What impact, if any, would LCRA's proposed withdrawals in the Simsboro have on overlying formations?**

A. The Calvert Bluff Formation and Carrizo Formation overlie the Simsboro Formation in the Carrizo-Wilcox Aquifer. The Hooper formation underlies the Simsboro Formation. Near the outcrop area of the Simsboro, the Simsboro is overlain in some areas by river alluvial formation.

The Simsboro is somewhat hydraulically isolated from the overlying and underlying formations. However, the Simsboro is not completely isolated. As detailed in Section 4.5 of the Hutchison Report, the increase in pumping in the base case (i.e. the projected pumping associated with the DFC) and the increase in pumping associated with the proposed LCRA pumping will result in some drawdown in the overlying and underlying formations.

**Q. Does your opinion change based on how quickly or slowly the overlying aquifers recharge?**

A. Recharge to aquifers is primarily from precipitation on the outcrop areas of the aquifer. This is a different process that occurs when pumping results in induced vertical inflow under high pumping conditions. In this case, high pumping in the Simsboro would result in increased inflow from overlying and underlying formations due to the drawdown in the Simsboro. This induced inflow would result in additional vertical outflow from the overlying and underlying formations into the Simsboro. Thus, recharge is essentially unaffected, but the additional outflow from the overlying and underlying formations would result in some drawdown in the underlying and overlying formations.

In general, the impact, if any, would be greatest in areas closest to the pumping and reduce with distance from the pumping wells. The attached Hutchison Report (at Section 4.5 and the associated Excel files) contains details of simulated impacts on each registered well in the District database.

## VI. SURFACE WATER RESOURCES

**Q. What does the GAM tell us about how the proposed Draft Permit would impact surface water resources?**

A. The New GAM represents an improvement to the simulation of surface water-groundwater interactions. However, the model cannot provide specific quantifiable results as contained in the New GAM documentation. From a regional groundwater perspective, the model does show a reduction in groundwater discharge to surface water under the base case in Bastrop County, and shows that the scenario that adds proposed LCRA pumping would eventually result in a condition where surface water in Bastrop County would recharge the groundwater system.

As discussed in the question on model limitations, it is unknown how accurate these estimates are because historic pumping has been low. Increased pumping may result in groundwater level reductions that alter the surface water-groundwater relationship. However, until better data exist to calibrate the model under conditions of increased pumping, it is not possible to rely on the quantitative estimates. It is only possible to state that there is likely to be an impact.

## VII. SUBSIDENCE

**Q. Please explain whether the proposed LCRA production causes or contributes to subsidence in the District.**

A. Subsidence has been a documented problem in the Gulf Coast Aquifer. Historically, subsidence has not been an identified problem in the aquifers associated with the New GAM (i.e. Sparta, Queen City, and Carrizo-Wilcox). The New GAM does not include the subsidence package, so there is no ability to explicitly evaluate the potential for subsidence under alternative future groundwater elevations.

I am generally familiar with a recently released subsidence report and tool report referenced by Brown Landowner Michael MacLeod in his pre-filed testimony (see page 3:39 to page 4:5). The tool developed as part of the report is highly dependent on the input values "Predevelopment Water Level", "Base Water Level", and "Future Water Level". Under certain combinations of these parameters for the Carrizo-Wilcox Aquifer, it is possible to achieve a result of about 1 to 2 feet of maximum subsidence by 2070 as stated in Mr. MacLeod's testimony. However, if the specified "Future Groundwater Level" is based on model results, it is subject to the limitations of the model that have been discussed earlier. Moreover, the phased approach proposed by the General Manager's Draft Permit and the planned monitoring program will provide better data to complete a more thorough evaluation of subsidence potential, and adjustments should be made to the pumping if the potential for subsidence proves to be an issue. It should be noted that using the tool, the initial two phases of pumping for the first six years of LCRA pumping as proposed would not result in any measurable subsidence.

With respect to the overall subject of subsidence, it is important to note that Mr. Michael Keester, one of the witnesses for Aqua Water Supply Corporation and the City of Elgin, is the primary author of the subsidence report and tool that is referenced by Mr. MacLeod. Mr. Keester references the report and tool in his qualifications but does not make reference to subsidence potential or apply the tool in his pre-filed testimony for either Aqua Water Supply Corporation or the City of Elgin.

## VIII. PROGRESSING THROUGH PHASES

**Q. Have you reviewed LCRA's phased request for production from the Simsboro?**

A. Yes. In the Applications, LCRA requests to produce and transport up to 25,000 acre-feet of groundwater annually from eight (8) wells in the following phases:

- Phase 1 – Initial Production – two (2) wells with the maximum instantaneous rate of production of up to 6,000 gallons per minute (gpm) with an annual production of up to 8,000 acre-feet/year (AFY).
- Phase 2 – Expanded Production – four (4) wells with the maximum instantaneous rate of production of up to 10,000 gpm with an annual production of up to 15,000 AFY.
- Phase 3 – Maximum Production – eight (8) wells with the maximum instantaneous rate of production of up to 18,000 gpm with an annual production of up to 25,000 AFY.

**Q. Based on your understanding of the Draft Permit, how has the General Manager recommended managing this phased withdrawal in the Draft Permit?**

A. The Draft Permit details a process that relies on a series of calculations and comparisons of actual data and model results that would be used to make decisions regarding moving from Phase 1 to Phase 2 of the pumping, and from Phase 2 to Phase 3 of the pumping.

**Q. Is there anything that you would add for the General Manager to consider when determining whether or not to increase LCRA's proposed production to the next phase?**

A. Yes.

**Q. What additional information would you want him to consider?**

A. The Hutchison Report and the associated files contain estimates of the drawdown attributable to LCRA's proposed pumping for each of the 37 monitoring wells in the District network. These data can be used to provide additional guidance in interpreting future monitoring data from individual wells.

**Q. What additional information do you recommend that that General Manager consider regarding LCRA's phased production request?**

A. As explained in Section 5.3 of the Hutchison Report, the model results show that the most responsive well in the network to the proposed LCRA pumping is located near the Simsboro outcrop, and the model simulations predict that the drawdown in that well due to the pumping of the proposed LCRA wells (as simulated in the model) would be 229 ft from 2019 to 2070. However, the data also shows that after the three years of the initial phase of pumping, the drawdown in this well would be about 50 feet in the first year, 52 feet in the second year, and 52 feet in the third year. Thus, if there is no other new pumping in the area of the LCRA wells at the time of their start-up and the precipitation/recharge conditions are near average, the actual monitoring data from this well should show about a 50 foot decline in the first year and remain fairly consistent for the next two years.

The possible deviation from this prediction could be the result of other pumping in the area or an abnormally wet or dry period. If none of these conditions occur and the drawdown is substantially more or less than 50 feet, more investigation is warranted, including updating and recalibrating the model.

If, on the other hand, the actual monitoring data from this well and the other wells are substantially the same as the model predictions, then the model appears to be reasonably accurate and the next phase of pumping should proceed.

## IX. <u>EFFECT ON EXISTING WATER RESOURCES AND PERMIT HOLDERS</u>

**Q. What did you consider in assessing whether the proposed use of water unreasonably affects existing groundwater and surface water resources or existing permit holders?**

A. I extracted the results of the runs of the New GAM that were provided by INTERA (LCRA's witnesses) and completed my own analysis of all registered wells and all monitoring wells in the District.

**Q. What information did you use for your well impacts analysis?**

A. I used the District's database of registered wells and the results of the model simulations.

**Q. What does your analysis show regarding impacts to registered and permitted wells in the District?**

A. As described in the Hutchison Report, the analysis developed estimates of drawdown impact under the base case and under the Base+LCRA scenario for each well that was located on the model grid for which there was a well bottom listed (2,031 wells). The associated files with the results are included with my report.

**Q. Was the General Manager reasonable in concluding that impacts to registered and permitted wells in the District would not be significant?**

A. Yes.

**Q. Please explain why he was reasonable.**

A. Predictions are difficult in Bastrop County because relatively low historic groundwater pumping has not had a large impact on groundwater levels. This results in difficulty in model calibration and assessing the accuracy of the model under scenarios with large pumping increases. However, the initial phase of pumping should yield drawdown in the nearby monitoring wells that should be useful in assessing the reasonableness of the New GAM as a predictive tool. Drawdowns in the initial phase of pumping are minimal, and, subject to verification with actual monitoring data, adjustments can be made to future pumping once actual data are available.

## X. <u>REBUTTAL TO LCRA</u>

**Q. What are you addressing in this section of your testimony?**

A. I address certain issues raised by LCRA witnesses Van Kelley and Steve Young in their Prefiled Direct Testimony.

**Q. Have you reviewed the direct testimony of Van Kelley filed in this proceeding on the behalf of LCRA?**

A. Yes.

**Q. Does Mr. Kelley's testimony propose changes to the General Manager's Draft Permit with respect to the General Manager's Calculation (GM Calculation)?**

A. Yes. Mr. Kelley recommended changes to the GM Calculation by drafting an entirely new calculation -- the LCRA Calculation -- discussed at pages 31 to 38 of his testimony and at LCRA Exhibits 26 and 27.

**Q. Between the GM Calculation and the LCRA Calculation, which calculation is most appropriate to determine whether or not to increase production to the next phase?**

A. Both calculation approaches are dependent on DFCs, which also include the effects of other planned pumping, which may or may not be taking place when LCRA begins pumping. As developed in the Hutchison Report, I recommend that actual monitoring data be compared with estimates of drawdown attributable to LCRA's proposed pumping in order to make decisions regarding the move to Phase 2 or Phase 3 of LCRA's proposed pumping. My recommended approach provides additional flexibility to delete monitoring wells based on other nearby pumping that may affect the interpretation of the data and provides some flexibility if the proposed pumping does not begin on January 1, 2020, as simulated in the model.

**Q. Have you reviewed the direct testimony of Steve Young filed in this proceeding on the behalf of LCRA?**

A. Yes.

**Q. How do you respond to Dr. Young's testimony stating that the Simsboro is a "drought resistant" aquifer?**

A. I agree with the characterization of the Simsboro Aquifer as "drought-resistant" compared with the Edwards Aquifer. This characteristic is an important consideration for LCRA and other similarly situated individuals and organizations seeking to develop groundwater that is not as dependent on precipitation and recharge as the Edwards

Aquifer. But the drought resistant character of the Simsboro as compared to the Edwards is not particularly relevant to managing groundwater in the district because the district does not have any management responsibilities for the Edwards Aquifer.

**Q. Should the District manage the Simsboro any differently based on his conclusion?**

A. No.

**Q. To your knowledge, why did the two well files used for the Donnelly Report end in 2060?**

A. The model run was based on the Old GAM and the DFC that was adopted in 2010, which simulated conditions only through 2060. The original run by Mr. Donnelly used this as a baseline in order to be comparable and consistent with past permit application simulations.

**Q. Is there a problem with Dr. Young's analysis regarding impacts to existing users? If so, please explain.**

A. I agree with his discussion of what constitutes an "unreasonable impact". However, the fact that historic groundwater pumping in Bastrop County is so much lower than the proposed pumping in the Base Case or the Base+LCRA Scenario is a model limitation. This limitation is strong enough that definitive statements regarding impacts in 2070 are not advisable. The phased approach in the Draft Permit provides the appropriate opportunity to assess actual monitoring data to determine if Phase 2 and/or Phase 3 of the pumping would result in "unreasonable impacts" in 2070 (as currently suggested by the model), or if additional model updates and evaluations are required once the monitoring data associated with the first phase of pumping are available and processed.

**Q. How do you respond to Dr. Young's considerations and conclusions related to impacts to surface water resources?**

A. The model was developed by Dr. Young and I used Dr. Young's model files in my report. The results of my analysis are clear that the model predicts impacts to the surface water system as a result of the proposed LCRA pumping. However, because of model limitations, it is not possible to confidently conclude that these impacts can be quantified with any precision. It is reasonable to qualitatively conclude, based on the model results and my experience, that surface water impacts may be possible. It is unreasonable to summarily dismiss the potential for impact.

Future monitoring of groundwater levels once Phase 1 of the pumping has begun will provide some degree of insight as to the potential for surface water impacts. However, given the current state of modeling technology (and this model in particular), it is not reasonable to expect that an accurate and precise assessment of potential impacts will be possible.

**Q. How do you respond to Dr. Young's discussion related to the District's use of the MAG?**

A. I agree with his conclusion, but for slightly different reasons. Because DFCs are developed based on broad regional assumptions and idealized representations of pumping and recharge, they should not be viewed as regulatory limits. MAGs are developed from these DFCs, and the foundation of these calculations (DFCs) should guide their use. By statute, the District is required to consider the MAG as one factor. DFCs and MAGs are updated every five years and should be viewed as planning numbers that are subject to change as conditions and the understanding of the aquifer system warrant.

## XI. REBUTTAL TO PROTESTANTS

**Q. What are you addressing in this section of your testimony?**

A. I address certain issues raised by the Protestants in their pre-filed Direct Testimony. Some issues overlap and were raised by multiple protestants. For the same or similar issue, I respond on behalf of the General Manager to all Protestants.

### A. Aqua Water Supply Corporation

**Q. Have you reviewed the direct testimony of Mike Keester, P.G. filed in this proceeding on behalf of Aqua Water Supply Corporation?**

A. Yes.

**Q. Based on your review of district-wide impacts from LCRA's proposed production, how do you respond to Mr. Keester's conclusions that 11 of Aqua's 15 wells will be adversely impacted by the proposed LCRA production on page 12 of his testimony?**

A. Mr. Keester does not state which model he used (Old GAM or New GAM). He also apparently "supplemented" the analysis with an analytic model, and it is unclear whether this resulted in higher or lower groundwater levels than the GAM simulation.

Mr. Keester does not state when the "undesirable impact" would occur (groundwater level drops below the pump setting).

Finally, Mr. Keester does not distinguish impacts of pumping from the proposed LCRA pumping and other planned increases in pumping that have been incorporated into the predictive simulations using the old GAM and the new GAM.

Because of the limitations of the GAM, it is not possible to state with confidence drawdowns or impacts beyond the first few years of operation. As developed in my report, the model results should be used to interpret monitoring results to decide if subsequent phases of pumping should proceed.

**Q. What is your opinion on Mr. Keester's concerns about the uncertainty of the updated GAM on pages 26 to 27 of his testimony?**

A. The real issue in identifying the better model is how well the model matches actual data. My report provides a basis to conclude that the New GAM is a better tool than the Old GAM. It is important to note that the New GAM has limitations and my report discusses those limitations and provides details of how the results of the model can be used in interpreting actual monitoring data in the phased approach to the LCRA project.

**B. <u>Brown Landowners</u>**

**Q. Have you reviewed the direct testimony of Brown Landowners 1 to 29 filed in this proceeding?**

A. Yes.

**Q. What is your opinion on faults underground that may change the flow of groundwater, and whether those faults impact the review of the Applications?**

A. Faulting can affect how a drawdown cone expands from a pumping well. However, the problem is less one of where the faults are and more one of how the faults affect the hydraulics of the aquifer. As developed in the Hutchison Report, the relatively low historic pumping in Bastrop County has not had a major impact on groundwater level fluctuation. Because there has been limited change in groundwater levels due to pumping, it is difficult to interpret the effect of the numerous faults in the area. The New GAM is an improvement over the Old GAM in this regard. However, a relatively high degree of uncertainty will remain until pumping increases and monitoring data of the groundwater level response can be used to develop a better understanding of the role of the faults.

**Q. What is your response to the concept that the LCRA Applications if issued would result in mining the aquifer if more water is pumped than replaced by recharge?**

A. As shown in the Hutchison Report, the base case simulation is the equivalent of the DFC simulation using the New GAM. Even without the proposed LCRA pumping, groundwater levels will decline with the planned future pumping increases. With LCRA pumping, the groundwater levels will decline further. Because of the relatively low pumping from the aquifers in Bastrop County, there is uncertainty relative to what level of pumping would be considered "mining".

**Q. Have you reviewed the direct testimony of George Rice filed on behalf of the Brown Landowners in this proceeding?**

A. Yes.

**Q. Based on your review of district-wide impacts from LCRA's proposed production, how do you respond to George Rice's conclusion as to the impacts from LCRA's proposed production on the Brown Landowners?**

A. I reviewed the predicted impacts from LCRA's proposed pumping on a district-wide basis. The results of my analysis are presented in my report. My report and the associated files include data and information that summarize impacts to each registered well in Bastrop County.

Based on my review, adverse impacts to registered wells within the District are not expected during the first phase of the proposed LCRA pumping. In my report, I have provided recommendations to guide the interpretation of future monitoring data that would then form the basis of a decision to move to Phases 2 and 3 of the LCRA pumping.

**Q. Have you reviewed the direct testimony of Keith Copeland filed on behalf of the Brown Landowners in this proceeding?**

A. Yes.

**Q. How do you respond to Mr. Copeland's discussion of the papers mentioned on page 6 of his testimony?**

A. The only way to adequately study the variability of the depositional environment is to increase pumping in the area, collect data from monitoring wells, and analyze the data in the context of the present tools (i.e. the New GAM) to assess if it is a reasonable representation of the groundwater flow system. This is essentially the approach that would be taken in Phase 1 of LCRA's proposed pumping.

**Q. How do you respond to Mr. Copeland's recommendation on page 8 of his testimony that 36-hour pump tests and "long term pump and aquifer" tests be conducted to evaluate the aquifer?**

A. The objectives of a "long-term" test are met during Phase 1 of the proposed LCRA pumping, assuming proper monitoring and detailed analysis of the monitoring data. More site-specific drilling, coring and logging is not an adequate substitute to understand the dynamic response of a depositionally complex aquifer that has numerous faults that may or may not have a regional effect on groundwater movement. The New GAM simulations indicate that pumping for about a year should be sufficient time to get a measurable response in a large area. Moreover, the new GAM simulations indicate that the drawdown in Phase 1 of the proposed LCRA pumping should stabilize after about a year for the next two years. This response should be confirmed with monitoring data before Phase 2 is authorized.

**C. <u>City of Elgin</u>**

**Q. Have you reviewed the direct testimony of Mike Keester, P.G. filed in this proceeding on behalf of the City of Elgin?**

A. Yes.

**Q. Based on your review of district-wide impacts from LCRA's proposed production, how do you respond to Mr. Keester's conclusions that some of Elgin's wells will be adversely impacted by the proposed LCRA production?**

A. Mr. Keester does not provide specific drawdown or groundwater elevation estimates in Table 3 of his report (Elgin Exhibit 8). Mr. Keester completed a complex analysis to predict future groundwater elevations under four scenarios. This analysis begins with simulations using the Old GAM. The resulting groundwater elevation is then reduced based on a textbook equation to account for the difference between a static water level and a pumping water level. Finally, a correction was added to adjust for calibration errors. The analysis lacks any description of how the textbook equation correction matches up with actual specific capacity data in the well. If specific capacity data for the wells are available, a better method would be to use New GAM estimates of drawdown and add the actual pumping drawdown from specific capacity data.

Without the details of the calculation, it is impossible to make meaningful comparisons.

**D. <u>Environmental Stewardship</u>**

**Q. Have you reviewed the direct testimony of Joseph Trungale filed in this proceeding?**

A. Yes.

**Q. What is your response to Mr. Trungale's model simulation regarding surface groundwater interaction?**

A. As developed in the Hutchison Report, the results of my analysis are clear that the model predicts some impacts to the surface water system as a result of the proposed LCRA pumping. However, because of model limitations, it is not possible to quantify these impacts with any precision. It is reasonable to qualitatively conclude, based on the model results and my experience, that surface water impacts are possible. But it would not be reasonable to conclude that those impacts will be significant. Future monitoring of groundwater levels once Phase 1 of the pumping will provide some degree of insight as to the potential for surface water impacts.

**E. <u>Hernandez</u>**

**Q. Have you reviewed the direct testimony of Elvis Hernandez filed in this proceeding on behalf of himself and his wife Roxanne Hernandez?**

A. Yes.

**Q. In your opinion, does Exhibit B to Mr. Hernandez' testimony demonstrate that there is significant communication between the Simsboro and Calvert Bluff?**

A. There is some limited communication between the Simsboro Formation and the Calvert Bluff Formation on a regional scale. The significance of that communication cannot be determined based on Exhibit B.

**Q. Please explain the projected impacts shown on Exhibit B.**

A. Mr. Hernandez's Exhibit B appears to be county-wide and district-wide average drawdowns taken from a report. These are not useful to project the impact at a particular well. Mr. Hernandez provided the District well number of his registered well.

**F. <u>Recharge Water, LP</u>**

**Q. Have you reviewed the direct testimony of Michael Thornhill filed in this proceeding on behalf of Recharge Water, LP?**

A. Yes.

**Q. Based on your review of district-wide impacts from LCRA's proposed production, how do you respond to Mr. Thornhill's conclusions regarding the drawdown in Recharge's wells from the proposed LCRA production?**

A. Based on my report, the New GAM is a better tool to simulate estimates of future drawdown. The planned Recharge wells are identified in the District database (IDs 2544 to 2557), but there are no well depths in the database. Therefore, these wells were excluded in the processing of the data as described in my report.

Mr. Thornhill relied on a model simulation using the Old GAM only. The New GAM is a better tool and, based checking other wells; it is likely that the New GAM would give estimated drawdowns less than Mr. Thornhill reported. If requested, I can supplement my analysis if I am provided estimated depths of the proposed Recharge wells.

## XII. <u>CONCLUSION</u>

**Q. Are GM EXHIBITS 11 - 13 accurate representations of what they purport to be?**

A. Yes.

**Q. Does this conclude your prefiled testimony?**

A. Yes, but I reserve the right to amend this testimony as necessary.

**AFFIDAVIT**

STATE OF TEXAS

COUNTY OF GALVESTON

I am the witness identified in the preceding testimony. I have read the testimony and the accompanying attachments and am familiar with their contents. Based upon my personal knowledge, the facts stated in the testimony are true and correct. In addition, in my judgment and based upon my professional experience, the opinions and conclusions stated in the testimony are true, valid and accurate.

William R. Hutchison

SUBSCRIBED TO AND SWORN before me on this 25 day of July 2019.

MARINNA ELIZABETH REVILLA
Notary Public
STATE OF TEXAS
My Comm. Exp. 08-13-22
Notary ID # 13188127-8

Notary Public in and for
The State of Texas

## CERTIFICATE OF SERVICE

I hereby certify by my signature below that on the 26TH day of July, 2019, a true and correct copy of the above and foregoing document was forwarded via SOAH E-Filing, email or First Class Mail to the parties on the attached Service List.

/s/ Natasha J. Martin
Natasha J. Martin

**SOAH DOCKET NO. 952-19-0705**
**SERVICE LIST**
**APPLICATION OF LCRA FOR OPERATING AND TRANSPORT PERMITS FOR EIGHT WELLS IN BASTROP COUNTY, TEXAS**

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# WILLIAM R. HUTCHISON, Ph.D., P.E., P.G.

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## EDUCATION

University of Texas at El Paso: Ph.D., Environmental Science and Engineering, 2004-2006
University of Arizona: M.S., Hydrology, 1980-1981, 1982-1983
University of California, Davis: B.S., Soil and Water Science, 1976-1980

## PROFESSIONAL LICENSES

Professional Engineer (Geological and Civil) No. 96287 (Texas)
Engineering Firm Registration No. 14526 (Texas)
Professional Geoscientist (Geology) No. 286 (Texas)
Registered Professional Geologist No. 0779 (Mississippi)

## PROFESSIONAL HISTORY

| Organization and Location(s) | Position | Dates |
|---|---|---|
| Independent Groundwater Consultant<br>Jamaica Beach, TX | | 2012 – pres. |
| LBG-Guyton Associates<br>Austin, TX | Associate | 2011 – 2012 |
| Texas Water Development Board<br>Austin, TX | Director, Groundwater Resources Division | 2009 – 2011 |
| El Paso Water Utilities<br>El Paso, TX | Water Resources Manager | 2006 – 2009 |
| | Hydrogeology Manager | 2003 – 2006 |
| | Hydrogeologist | 2001 – 2003 |
| TEAM Engineering and Management, Inc.<br>Bishop, CA and Phoenix, AZ | Senior Hydrologist | 1998 – 2001 |
| Woodward-Clyde Consultants<br>Santa Ana, CA and Phoenix, AZ | Associate | 1996 – 1998 |
| | Sr. Project Hydrologist | 1993 – 1996 |
| Luhdorff & Scalmanini Consulting Engineers<br>Woodland, CA | Principal Hydrologist | 1991 – 1993 |
| | Senior Hydrologist | 1988 – 1991 |
| Inyo County Water Department<br>Bishop, CA (now in Independence, CA) | County Hydrologist | 1985 – 1988 |
| Geothermal Surveys, Inc.<br>South Pasadena, CA | Hydrologist | 1983 – 1985 |
| University of Arizona<br>Tucson, AZ | Research Assistant | 1982 – 1983 |
| Mobil Oil Corporation<br>Denver, CO and Glendive, MT | Hydrologist | 1981 |
| Metropolitan Water District of Southern California<br>Yorba Linda, California | Intern | 1979 |

## *REPRESENTATIVE CONSULTING EXPERIENCE SINCE 2011*

**Groundwater Model of Rincon and Mesilla Basins (New Mexico, Texas, Mexico)**
Developed a groundwater model using MODFLOW-USG and associated pre- and post-processors as an expert witness for the State of Texas as part of the Texas v. New Mexico litigation. The model used a 2007 model developed for the New Mexico Office of State Engineer as a foundation. The new model uses a variable grid of Voronoi cells and incorporated new data and information on historic surface water and groundwater use for irrigation. The primary issue of the litigation is the impact of groundwater pumping on Rio Grande streamflow. (2012 to present)

**Update to Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer**
Principal Hydrogeologist for a team of consultants developing an updated flow model for the Southern Carrizo-Wilcox Aquifer (GMA 13 area of Texas) under a contract with the Texas Water Development Board. The updated model will address documented issues with the current model related to outcrop area calibration, surface water-groundwater interactions, and application to long-term predictive simulations. (2019 to present)

**Update to Groundwater Availability Model for the Northern Carrizo-Wilcox Aquifer**
Principal Hydrogeologist for a team of consultants developing an updated flow model for the Northern Carrizo-Wilcox Aquifer (GMA 11 area of Texas) under a contract with the Texas Water Development board. The updated model will address documented issues with the current model related to outcrop area calibration, surface water-groundwater interactions, and application to long-term predictive simulations. (2017 to present)

**Groundwater Management Activities in Kinney County, Texas**
Completed a management plan update, reviewed permit applications, and initiated a data collection effort in Kinney County for the Kinney County Groundwater Conservation District. Currently developing an updated groundwater flow model of Kinney County that will be used for general management initiatives and rules revisions. (2013 to present)

**Joint Planning in Groundwater Management Areas 2, 3, 4, 7, 11 and 13**
Consultant for GMAs 2, 3, 4, 7, 11 and 13 to develop updated desired future conditions. Included in this effort were the review of aquifer conditions and uses, review of water management strategies, review of hydrologic information and data, developing future pumping estimates, running alternative simulations with the Groundwater Availability Models, and preparing an explanatory report. (2012 to 2018)

**Groundwater Flow and Transport Model of Lower Rio Grande Valley**
Principal Hydrogeologist for a team of consultants developing a flow and transport model for the Lower Rio Grande Valley using MODFLOW-USG under a contract for the Texas Water Development Board. The model objectives included the simulation of 23 water management strategies related to proposed fresh groundwater development and brackish groundwater desalination plants. Simulation results included quantitative estimates of groundwater elevation changes, changes in salinity, and impacts to surface water flows. (2015 to 2017).

**Joint Planning Support for Bluebonnet Groundwater Conservation District**
Completed analyses and simulations to support Bluebonnet Groundwater Conservation District's consideration of revising the desired future conditions in GMA 14. Lone Star Groundwater Conservation District requested that the desired future conditions be revised as part of the settlement of litigation over the reasonableness of the desired future conditions adopted in 2016. The requested revision was reviewed and documented, and various alternative revisions were simulated using inverse runs of the Groundwater Availability Model to provide perspective on the requested revision. (2018 to present)

**Groundwater Model Reviews in Pecos County, Texas**
Reviewed two existing groundwater models for Middle Pecos Groundwater Conservation District: one developed by the USGS in 2014 and one developed by a team of consultants in 2011. The models were evaluated in terms of how they could be used for predictive simulations in support of developing desired future conditions and in support of permit applications. (2016 to 2017)

**Groundwater Monitoring Thresholds in Pecos County, Texas**
Reviewed historic groundwater data and model results to develop a groundwater monitoring plan, including regulatory thresholds. The results of the review and associated analyses were used in the settlement of several years of litigation between the Middle Pecos Groundwater Conservation District and a permit applicant. (2017)

**Subsidence Analysis for Bluebonnet Groundwater Conservation District**
As part of a rules revision that simplified the permitting process for small diameter wells and included more detailed requirements to consider subsidence analysis in the permit review process, simulations have been completed to estimate maximum pumping that would avoid subsidence using the Houston Area Groundwater Model, which has recently been adopted by TWDB as the Groundwater Availability Model for the northern portion of the Gulf Coast Aquifer. (2014 to 2015)

**Groundwater Availability Model Development using MODFLOW-USG**
As a consultant to the Hickory Underground Water Conservation District No. 1, Dr. Hutchison worked with staff of the Texas Water Development Board in the development of the Groundwater Availability Model for the Llano Uplift Aquifers. This model was developed with MODFLOW-USG. (2013 to 2016)

**Hydrogeologic Study of Val Verde County, Texas**
Completed a hydrogeologic study of the Edwards-Trinity (Plateau) Aquifer in Val Verde County for the County of Val Verde and City of Del Rio. The study included developing, calibrating, and applying a groundwater flow model of the area to assess impacts of proposed pumping on local spring flow and Rio Grande flows. (2013 to 2014)

**Comparison of Groundwater Monitoring Data with Groundwater Model Results**
As part of the current round of joint groundwater planning, completed assignments for groundwater conservation districts in Groundwater Management Area 9 and Groundwater Management Area 13 to compare groundwater monitoring data with groundwater model results from the desired future conditions process. These efforts examined, in detail, the various assumptions used in developing the initial round of desired future conditions adopted in 2010. (2012 to 2013)

**Groundwater Model Review Panel**
Participated as a member of the Groundwater Review Panel for the Edwards Aquifer Authority related to the new finite element model being developed for the Edwards Aquifer by Southwest Research Institute. (2012 to 2015)

**Groundwater Transport Permit Review**
A private landowner submitted a permit application to transport 22,500 acre-feet per year of groundwater from Austin and Waller Counties to the cities of Richmond and Rosenberg in Fort Bend County. Dr. Hutchison completed the technical review of the application for the Bluebonnet Groundwater Conservation District as part of a contested case hearing. The applicant subsequently withdrew the application. (2012 to 2014)

**Well Classification Study and Hydrogeologic Report Guidelines Update**
Over 2,500 wells in the Bluebonnet Groundwater Conservation District (Austin, Grimes, Waller and Walker Counties) were evaluated to determine the aquifer completion interval by comparing the screened interval with various groundwater models of the region (Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson, and Gulf Coast). The results of this evaluation were used to update and enhance the review process of permit applications submitted to the district. (2012 to 2014)

**Rules Update for Bluebonnet Groundwater Conservation District**

Based on the well classification study and the review of the groundwater transport permit (please see above), the Board of Directors completed a revision to the district rules that simplified the permitting process for small diameter wells and included more detailed requirements to consider subsidence analysis in the permit review process. (2014)

**Mine Dewatering Groundwater Pumping Permit**

Hickory Underground Water Conservation District No. 1 received a permit application from Premier Silica LLC to pump groundwater for dewatering associated with an expansion of an existing aggregate mine in the Brady area. Dr. Hutchison was retained to review the groundwater model that has been developed in support of the permit application, and to review the impact of the proposed pumping on the adopted desired future condition for the Hickory Aquifer. (2012 to 2013).

**Evaluation of a Proposed Groundwater Development Project in East Texas**

Completed an evaluation of potential effects of a proposed groundwater development project located in Anderson, Cherokee, and Houston counties in east Texas for the Neches & Trinity Valleys Groundwater Conservation District. Consultants for the project proponents and the Texas Water Development Board (TWDB) had previously completed simulations of the proposed pumping using the Groundwater Availability Model (GAM) of the Northern Carrizo-Wilcox Aquifer. Neches & Trinity Valleys Groundwater Conservation District asked for the completion of three tasks: 1) review TWDB GAM run reports, including the GAM run model run that was used to establish Desired Future Conditions, and the GAM run that was used to evaluate the regional effects of the proposed project, 2) extend the previous analyses of the project proponent's consultant and the TWDB by evaluating the effects of the proposed pumping on specific wells, and 3) recommend and monitoring network. The analysis was presented to the Neches & Trinity Valleys Groundwater Conservation District and was presented at the GMA 11 petition hearing in February 2012. (2011 to 2012)

**Groundwater Management Plan for Red River Groundwater Conservation District**

Consultant to the Red River Groundwater Conservation District in Fannin and Grayson Counties in the preparation of their initial management plan. This assignment required compiling and organizing the goals, objectives and performance measures from management plans of neighboring districts, preparing a handout for Board members and reviewing the various approaches with the Board in an open workshop session. Based on the discussion, a draft plan was prepared and approved by the Board. The review draft was subsequently approved by the Texas Water Development Board with no changes. The public hearing and final approval were completed by District personnel as a means of reducing costs. (2012)

**Evaluation of Groundwater Availability using Groundwater Budget Analysis**
Completed a groundwater budget analysis to provide data and information pertaining to groundwater availability for a private property owner in California. The analysis involved identifying and quantifying individual components of the inflows to and outflows from the defined area. Based on an analysis of precipitation and groundwater elevation changes, a series of historic groundwater budgets were developed for 20-year periods ranging from 1949-1968 to 1991-2010. The analysis was extended to estimate changes to the groundwater budget, generally, and groundwater elevations, specifically under alternative groundwater pumping scenarios from the subject property. (2011 to 2012)

## *REPRESENTATIVE AGENCY EXPERIENCE (TWDB and EPWU)*

**Joint Groundwater Planning in Texas**
In 2005, the Texas Legislature adopted HB 1763, which required that groundwater conservation districts within each groundwater management area adopt desired future conditions by September 1, 2010. The Texas Water Development Board provided technical assistance to this process. As Director of the Groundwater Resources Division, Dr. Hutchison was responsible for coordinating the effort of division staff and took the lead in 9 of the 15 Groundwater Management Areas. Technical support included developing and running groundwater models to estimate impacts of alternative pumping scenarios and attending meeting to discuss and interpret the results of these analyses. Partly because of the technical support provided by the Groundwater Resources Division staff, all desired future conditions were adopted prior to the statutory deadline. (2009 to 2010)

**Challenges to the Reasonableness of Desired Future Conditions in Texas**
Prepared technical reports related to petitions challenging the reasonableness of desired future conditions for Groundwater Management Area 1 (Ogallala Aquifer) and Groundwater Management Area 9 (Edwards Group of the Edwards-Trinity (Plateau) Aquifer). These petitions were filed with the Texas Water Development Board in accordance with statute and agency rules. The technical analysis was submitted to the Board for consideration in their deliberations as to the reasonableness of the adopted desired future condition. (2009 to 2010)

**Modeled Available Groundwater Development in Texas**
Managed development of modeled available groundwater estimates that were based on the desired future conditions adopted by the groundwater conservation districts. These estimates, required by statute, include estimating the total pumping that will achieve the desired future condition and estimating the exempt use of the area. Prior to the 2011 legislative session, these estimates were termed Managed Available Groundwater, and represented the amount of groundwater available for permitting, and were calculated as the total pumping minus the exempt use. (2010 to 2011)

**Update of the Hueco Bolson Model in Chihuahua, New Mexico and Texas**
Completed an update of the USGS model of the Hueco Bolson (Texas, New Mexico and Chihuahua) by extending the model period to 2002. The model was used to complete simulations of alternative groundwater management strategies. Based on the results of this work, recommendations were developed regarding long-term groundwater management strategies for the Hueco Bolson. (2001 to 2003)

**Groundwater Availability Model Updates in Texas**
Completed updates to groundwater availability models in support of the Joint Groundwater Planning Process in Texas. Updated models included: Dockum Aquifer, Edwards-Trinity (Plateau) Aquifer and Pecos Valley Aquifer, Barton Springs Segment of the Edwards (Balcones Fault Zone) Aquifer, Kinney County portions of the Edwards (Balcones Fault Zone) Aquifer and Edwards-Trinity (Plateau) Aquifer, and Southern Gulf Coast Aquifer (GMA 16 portion). These models were updated because the existing models proved to be inadequate for assisting the groundwater conservation districts in developing desired future conditions. (2009 to 2010)

**Groundwater Model of the Dell City, Texas Area**
Developed a regional groundwater flow model covering a large area in Hudspeth and Culberson Counties, Texas and Otero County, New Mexico. This objective of this groundwater model was to develop a more complete understanding of the hydrogeology of the karstic aquifer in the region, and develop data and information related to acquiring property and water rights for a potential groundwater importation project for the City of El Paso. In 2016, the model was adopted by the Texas Water Development Board as the official Groundwater Availability Model for the Bone Spring-Victorio Peak Aquifer. (2001 to 2008)

**Hueco Bolson Evaluation, Texas**
Completed analyses of groundwater flow and groundwater quality of the Hueco Bolson covering west Texas, southern New Mexico and northern Chihuahua. These analyses included evaluating historic groundwater flow patterns, mapping current groundwater quality in three dimensions, evaluating historic groundwater quality changes caused by pumping, and changes in the groundwater budget including induced inflow from the Rio Grande. Prepared comprehensive report of findings that was peer reviewed by a 5-member panel. Results included the finding that the reduction in groundwater pumping from 1989 to 2002 had fundamentally changed conditions in the Hueco Bolson. Moreover, the assumptions that were the foundation of a conclusion made in a 1979 analysis (depletion of fresh groundwater by 2030) were no longer applicable. (2001 to 2004)

**Mesilla Bolson Groundwater Management, El Paso, Texas**

Completed analyses of groundwater flow and groundwater quality of the Mesilla Bolson in west Texas and southern New Mexico. These analyses included evaluating previous groundwater models developed for a variety of objectives and analyzing the role of the Rio Grande in the recharge of the Mesilla. As a result of the analyses a series of piezometers were constructed to improve data coverage and long-term monitoring of the area. In addition, limitations to previous models were identified, and work is currently underway to better incorporate the known hydrostratigraphy in an updated and improved model of the area. (2001 to 2009)

**Model Documentation of Groundwater Availability Models in Texas**

Completed documentation of the Hueco Bolson and Mesilla Bolson groundwater flow models (Texas, New Mexico and Chihuahua). These models had been previously developed and were designated as official Groundwater Availability Models (GAM) for the Hueco-Mesilla Aquifer by the Texas Water Development Board. Documentation was needed to fully satisfy the requirements of the Texas Water Development Board. (2001 to 2004)

**Brackish Groundwater Well Location, El Paso, Texas**

Completed analyses of the Hueco Bolson related to locations of new wells for use in the Kay Bailey Hutchison Desalination Plant, a joint project between El Paso Water Utilities and Fort Bliss. After initial concerns were raised by Fort Bliss, an investigation was completed in cooperation with the US Army Corps of Engineers to evaluate five alternative well field locations that would produce brackish groundwater to be treated in the planned reverse osmosis plant. Based on this analysis, an alternative was selected and agreed upon. (2003)

**Desalination Concentrate Injection Wells in El Paso, Texas**

Completed preliminary analyses of impacts from injection wells that were proposed for use as part of the Kay Bailey Hutchison Desalination Plant in El Paso, Texas. The analyses included the development of a simple numerical flow model based on a subsurface geologic model developed by researchers at UTEP from gravity data and on the results from slug tests completed during a test hole drilling project funded and managed by the US Army Corps of Engineers. These analyses were incorporated into the Environmental Impact Statement (EIS) for the overall project. Based on the results of the analysis, a full-size injection well was constructed and tested to obtain better data to support authorization from the Texas Commission on Environmental Quality (TCEQ) under the Underground Injection Control (UIC) program. Once authorization was obtained, two additional wells were constructed, and all three wells were equipped and tested. Issues related to the potential for mineral precipitation in the well bores and reservoir were evaluated with a combination of geochemical modeling, experiments with formation samples, formation water and concentrate, and monitoring of initial operation. (2004 to 2009)

**Simulations of Potential Desalination Plant in Mission Valley, El Paso, Texas**

Completed a preliminary analysis of a proposed desalination plant in the Mission Valley area of El Paso. This analysis consisted of simulating three potential configurations of well fields to assess impacts to groundwater elevations and gradients, and to estimate potential impacts to the groundwater budget of the area. Based on this analysis, and a companion engineering analysis completed by a consultant, future pre-design work was recommended. (2003)

**Region E Water Planning, Far West Texas**

Developed the conceptual approach of an Integrated Water Management Strategy for El Paso County that was used in the 2005 Regional Water Plan for Far West Texas. Working with Far West Texas Regional Planning Group and their consultants, the conceptual plan was used to develop six specific alternatives designed to meet expected increased water demands in El Paso County through 2060. Alternatives ranged from reliance on single existing sources to a balanced approach that relied on numerous sources, including importation from Hudspeth, Culberson, Jeff Davis, and Presidio Counties. (2004 to 2005)

**Impacts of Climate Variability and Climate Change in El Paso, Texas**

Analyzed the reliability of El Paso's municipal water supplies under a wide range of climate scenarios, including integration of the Intergovernmental Panel on Climate Change (IPCC) projections for the region. Because El Paso practices conjunctive use management, the analysis included evaluation of impacts to both surface water (Rio Grande) and groundwater impacts. The analysis included developing simulated Rio Grande flows entering Elephant Butte reservoir based on a published 1000-yr tree ring record, developing a simple reservoir operations model to estimate Elephant Butte outflows and El Paso municipal diversions, estimating groundwater pumping, and simulating groundwater storage changes using a groundwater model. A total of 60 climatic scenarios were developed. Each scenario was simulated under 958 50-year simulations for a total of 57,480 simulations. The results demonstrated the effectiveness of the investments in water infrastructure and the efficacy of the management approach that has been developed over the last several decades in meeting municipal water demands over a wide range of climatic conditions. (2007 to 2008)

**Well Construction**

Managed a well construction and equipping program while employed by El Paso Water Utilities that resulted in:

- Drilling of 50 test holes
- Construction of 14 monitoring wells
- Construction of 3 multi-zone piezometers
- Construction and equipping of 16 fresh groundwater production wells
- Construction and equipping of 32 brackish groundwater production wells

Well designs and construction management are completed in-house. Equipping design and construction management are supervised through a consulting engineer. (2001 to 2009)

## *REPRESENTATIVE CONSULTING EXPERIENCE (1983 to 2001)*

**Owens Valley, California**

Hydrology consultant to the Inyo County (California) Board of Supervisors, Water Department, Water Commission and Environmental Health Department from 1985 to 1999 on issues related to water resources management and protection in the Owens Valley and Death Valley regions, including a key role in the development and negotiation of an historic water management agreement between Inyo County and the City of Los Angeles for the Owens Valley and the preparation of the associated environmental documentation. Assignments also included review and analysis of the Anheuser-Busch groundwater export project in the Cartago area, review and analysis of the groundwater pumping proposed by OLSAC in the Cottonwood Creek area, review and analysis of the groundwater export project proposed by Western Water in the Olancha area, and many others. Many of these assignments included the development and application of groundwater models and the development of monitoring networks and environmental triggers and thresholds to manage the pumping operations. (1985 to 1999)

**Owens Valley Indian Reservation Groundwater Modeling**

Completed local scale groundwater models of three Indian Reservations in the Owens Valley, California. The regional model developed by the USGS was used as a starting point for these models. The initial phase consisted of using Telescopic Mesh Refinement to define the boundary conditions of the three local scale models. Subsequent phases included enhancing and updating the local scale models. The preliminary model of the Big Pine area was used to evaluate potential increases in pumping that are associated with the Big Pine Ditch System project. (2000 to 2006)

**Los Angeles Aqueduct Simulation Model**

Consultant to the California State Water Resources Control Board related to the Mono Basin Water rights decision, a court ordered review of water rights licenses held by the City of Los Angeles. Working in partnership with State Board staff and Board members, hydrologic analyses were completed, and a simulation model (LAAMP) of the Mono Basin and Los Angeles Aqueduct system was developed and applied to evaluate the impacts of alternative water rights decisions. The simulation model was accepted by all parties involved in the process and was ultimately used in the final water rights decision that resulted in decreased diversions in order to maintain fish flows and restore lake elevation. (1992 to 1994)

**Tri-Valley Groundwater Evaluation, Mono County, California**

Completed a preliminary groundwater model for the Tri-Valley Groundwater Management District in Mono County, California. This model was based on existing data and was used to preliminarily evaluate the potential impacts of a proposed groundwater export project. Based on the model results, additional data requirements were identified and recommended for Phase 2 of the project. (2000 to 2001)

**Evaluation of Impacts of Increased Capacity of Salinas Dam, California**

Completed analyses related to the evaluation of potential downstream impacts of increased storage capacity of the Salinas Dam in central California. These analyses included estimates of reduced spills associated with the increased storage, evaluating the relationship of river flows and groundwater levels in the Atascadero area, and estimating potential groundwater level impacts that may result from the reduced spills. The analyses were summarized in an Environmental Impact Report, and in several technical appendices to the EIR. Because the work involved modification of a water right held by the City of San Luis Obispo, expert witness testimony was given at the California State Water Resources Control Board. (1997 to 1999)

**Aggregate Mine Expansion, Ventura County, California**

Consultant to Ventura County (California) Resource Management Agency on the analysis of potential hydrologic impacts of the expansion of an aggregate mine. Concerns had been raised about the potential impact of the mine expansion on seawater intrusion and nitrate contamination. The assignment began with the review of a groundwater model prepared by the project proponent's consultant. As a result of the review, the existing analyses was expanded with the development of a site-specific groundwater model to enhance the simulation of the potential impacts on nearby spreading facilities, the development of a solute transport model, the completion of a risk assessment of potential groundwater pollution, and the preparation of the water resources and water quality sections of an Environmental Impact Report. (1995 to 1996)

**Simulation of Impacts of Tunnel Construction, California**

Developed a finite element model for the Metropolitan Water District of Southern California using FRAC3DVS to simulate groundwater inflow during the construction of the Inland Feeder East Tunnel near San Bernardino, California. The model was calibrated under steady-state conditions using groundwater level data from geotechnical boreholes constructed during the design-phase geotechnical investigation. The model was calibrated under transient conditions using tunnel inflow data and groundwater level changes caused by groundwater inflow into the tunnel. Based on the model results, recommendations were made regarding grouting operations for later phases of construction. (1996 to 2002)

**Los Osos Groundwater Model**

Updated and enhanced a groundwater model and developed a groundwater management plan for the three water purveyors in Los Osos, California (Southern California Water Co, S&T Mutual Water Company, and Los Osos Community Services District). The original model had been developed in 1987 by the USGS, and the updated version was used to address specific management questions related to construction and operation of a sewer project, seawater intrusion, conjunctive use strategies, and the need to import surface water. (1997 to 2000)

**San Benito County Groundwater Evaluation, California**

Conducted a countywide evaluation of the groundwater resources of San Benito County, California. This effort included the evaluation of surface water and groundwater quantity and quality, development and calibration of a basin wide numerical model of the groundwater system, and the evaluation of recharge patterns altered by the delivery of supplemental surface water, some of which is used for direct groundwater recharge. At the completion of the model and report, expert witness testimony was given in a groundwater rights lawsuit between a developer and the local water district. Four years after the model was completed, the County requested that the model be updated and enhanced. (1991 to 1992, 1996)

**San Luis Obispo Groundwater Evaluation**

Completed analyses related to a proposed increase in groundwater pumping in the San Luis Obispo area of central California. The initial analysis consisted of integrating potential local groundwater pumping increases into the reservoir operations planning model used by the City of San Luis Obispo to identify conjunctive use opportunities and limitations. The second phase of the analysis consisted of developing and calibrating a groundwater model of the entire groundwater basin. This model was then used to identify potential impacts of increased pumping on groundwater levels in nearby wells, potential reductions in streamflow, and potential subsidence effects. (2000 to 2001)

**Cadiz Valley Groundwater Exploration and Development**

Completed a comprehensive groundwater exploration and development project in the Cadiz Valley near the Fenner Gap in the Mojave Desert region of southeastern California. Exploration work included review of available information and data on groundwater conditions and geology. An extensive geophysical study using shallow ground temperatures was completed and results were used to select drilling sites. Three test holes were drilled, and two production wells were constructed and tested. Based on the results of the investigations, a report was prepared, and a groundwater budget of the area was estimated. Sixteen years later, assisted the Metropolitan Water District of Southern California in the review of a proposed groundwater storage and recovery project in the Cadiz Valley. As part of this assignment, the groundwater model that had been developed to evaluate the feasibility and potential impacts of the project was modified and enhanced. (1983 to 1984, 2000 to 2001)

**Groundwater Management Spreadsheet Models**

Developed management tools in the form of empirical models that can be run in a spreadsheet format for the Soquel Creek Water District in central California, and the Vista Irrigation District in southern California. The models were designed to provide a tool for Soquel Creek Water District to manage their groundwater pumping with the objective of preventing seawater intrusion, and by Vista Irrigation District to conjunctively use local surface water, local groundwater, and imported water (1988 to 1991).

**Groundwater Storage Project Evaluation in Southeastern California**

Developed groundwater models for four basins in southeastern California to evaluate the feasibility of storing Colorado River water for the Metropolitan Water District of Southern California. These models were used to simulate the storage of water in wet years, “holding” the water for 5 to 10 years, then extracting after the “hold” period. Models were developed for the Hayfield, Palen, Chuckwalla, and Rice Valleys. Based on the initial modeling work, a focused field investigation was completed in the Hayfield Valley are, the site chosen as the most desirable. (1996 to 2001)

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**GM EXHIBIT 13**

# Expert Report for the General Manager of the Lost Pines Groundwater Conservation District:

*Application of Lower Colorado River Authority for Operating and Transport Permits for Eight Wells in Bastrop County, Texas*;
Before the State Office of Administrative Hearings;
SOAH Docket No. 952-19-0705


***Prepared for:***
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**July 25, 2019**

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# Expert Report for the General Manager of the Lost Pines Groundwater Conservation District:

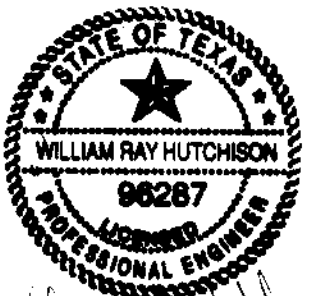
*Application of Lower Colorado River Authority for Operating and Transport Permits for Eight Wells in Bastrop County, Texas;*
Before the State Office of Administrative Hearings;
SOAH Docket No. 952-19-0705

***Professional Engineer and Professional Geoscientist Seals***

This report documents the work of a licensed Texas Professional Geoscientist and licensed Texas Professional Engineer:

***William R. Hutchison, Ph.D., P.E. (96287), P.G. (286)***

Dr. Hutchison completed the model simulations and analyses described in this report and was the author of the report.




7/25/2019


7/25/2019

# 1.0 Introduction and Summary of Conclusions

This report documents analyses related to the *Application of Lower Colorado River Authority for Operating and Transport Permits for Eight Wells in Bastrop County, Texas*; that is before the State Office of Administrative Hearings; SOAH Docket No. 952-19-0705.

The Lower Colorado River Authority (LCRA) has submitted permit applications to pump groundwater from eight wells located on the Griffith League Ranch property owned by the Capitol Area Council, Inc. Boy Scouts of America in Bastrop County.

LCRA's request is for a total combined maximum production of up to 25,000 acre-feet per year (AF/yr) and requested a phased approach to the pumping. LCRA's consultants (INTERA) provided model simulation files (model directory *dfc.braa.wel.2011.2070* and model directory *dfc.braa.wel.lcra.2011.2070*). These files represent two simulations: one that simulates a base condition (i.e. without the proposed LCRA pumping), and one that simulates the base case plus the proposed LCRA pumping. The FORTRAN program *comparewelnew.exe* was written to extract the output pumping from the cell-by-cell file of the two simulations. The results for all model layers were saved in an Excel file named *BastropPumpCompare.xlsx.* Results of that comparison yields the following phased pumping plan in the Simsboro Aquifer:

- Pumping from 2020 to 2022 (3 years): 7,995 AF/yr
- Pumping from 2023 to 2025 (3 years): 14,990 AF/yr
- Pumping from 2026 to 2070 (45 years): 24,894 AF/yr to 24,983 AF/yr

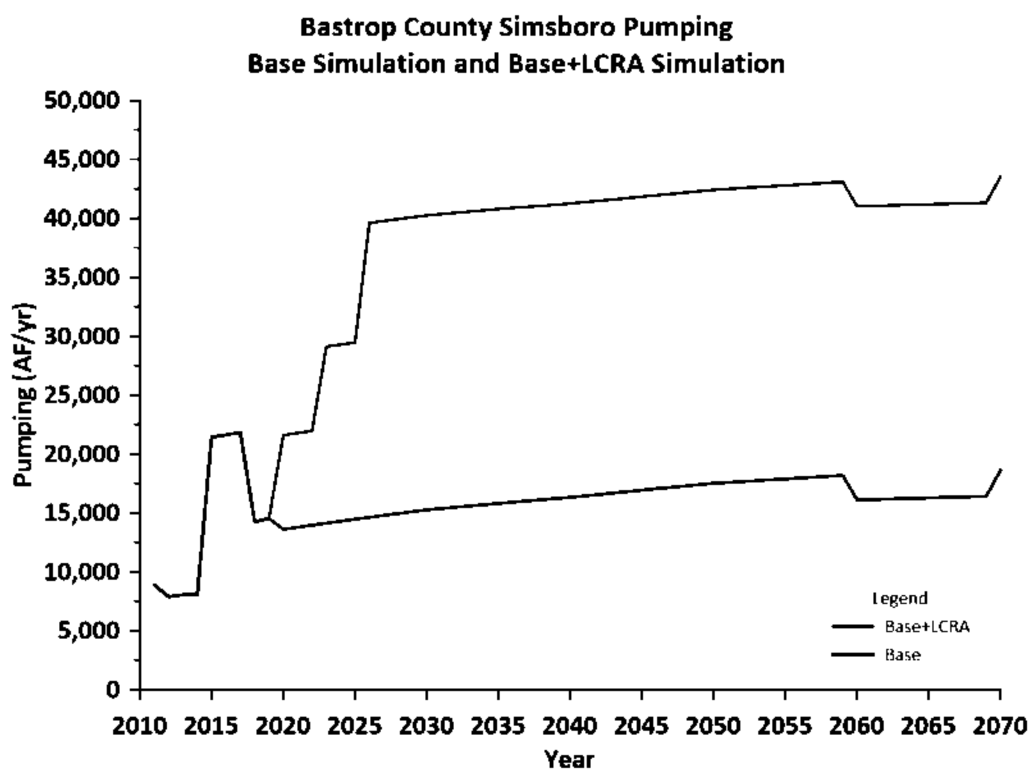



**Figure 1. Bastrop County Simsboro Pumping**

## 1.1 Objective 1: Model Comparison

The current desired future conditions for the area were adopted in 2016 and relied, in part, on model simulations using the Groundwater Availability Model that was documented in Kelley and others (2004). More recently, an updated Groundwater Availability Model of the area was completed as documented in Young and others (2018).

The initial objective was to compare these models and evaluate which one should be used to develop findings and recommendations relative to LCRA's application.

As developed in this report, the Young and others (2018) Groundwater Availability Model (also referred to as the new GAM) is based on a more updated model code, has a more refined spatial discretization approach, was calibrated over a longer time period, and achieved a better calibration fit. These were the primary reasons that the new GAM was used in all analyses contained in this report.

## 1.2 Objective 2: Evaluation of Groundwater Budgets

Groundwater budgets are an accounting of all inflows, outflows, and storage changes within a specified area. For this evaluation, three groundwater budgets for Bastrop County were developed:

1. The historic groundwater budget from 1930 to 2010 (the calibration period of the new GAM) for Bastrop County was developed using the calibrated model (new GAM) from files obtained from the Texas Water Development Board.
2. A groundwater budget from 2011 to 2070 was developed using the predictive model (new GAM) of the "base case" using model files obtained from INTERA as part of the disclosure from LCRA (model directory *dfc.braa.wel.2011.2070*).
3. A groundwater budget from 2011 to 2070 was developed using the predictive model (new GAM) of the "LCRA case" (i.e. base case plus LCRA pumping) using files obtained from INTERA as part of the disclosure from LCRA (model directory *dfc.braa.wel.lcra.2011.2070*).

As developed in this report, these water budgets demonstrate that about 94 percent of the variation in groundwater storage change from 1930 to 2010 is attributable to variation in recharge. The most significant finding from the comparison of the two predictive scenarios (i.e. future water budgets from 2011 to 2070) is the sources of the proposed LCRA pumping:

- About 46 percent from decreased groundwater discharge to surface water (i.e. decreased river base flow).
- About 35 percent from decreased groundwater storage (i.e. decreased groundwater levels)
- About 16 percent from decreased outflow to Lee County
- The remaining 3 percent of the groundwater pumping is sourced from decreased spring and seep flow, decreased evapotranspiration from groundwater, decreased upward flow to younger formations not explicitly simulated in the model, and decreased outflow to Caldwell and Fayette counties.

## 1.3 Objective 3: Groundwater Elevation Predictions in Registered Wells

Lost Pines Groundwater Conservation District provided an Excel file with 2,617 registered wells. Registered wells include permitted wells and non-exempt permitted wells (*LPGCD Well export.xlsx*). As developed in this report, the data in this file were used with the model output from the two predictive scenarios from the new GAM to develop findings and conclusions relative to the predicted drawdowns.

The results of this analysis show:

- The drawdown impacts of the LCRA impact drawdowns are highest in the Simsboro Formation (Layer 9)
- Drawdown in overlying and underlying formations is present, but the restriction in vertical movement results in smaller drawdowns than in the Simsboro Formation.
- Drawdown in the "shallow flow zone" of the model (Layer 2) and in the alluvial formations (Layer 1) are small in comparison to the drawdowns in the underlying layers, but result in gradient changes that result in reduced groundwater discharge to surface water which eventually result in a gradient reversal in the Base+LCRA scenario that result in the surface water providing recharge to groundwater.

## 1.4 Objective 4: Groundwater Elevation Predictions in Monitoring Wells

Lost Pines Groundwater Conservation District provided an Excel file with 37 monitoring wells (*Lost Pines GCD Water Level Monitoring Wells – 20190305.xlsx*). As developed in this report, the data in this file were used with the model output from the two predictive scenarios from the new GAM to develop findings and conclusions relative to the predicted groundwater elevations in these wells.

The analysis resulted in estimates of annual drawdown attributable to the proposed LCRA pumping in each of the 37 monitoring wells. These estimates can be used to assist in the interpretation of future monitoring data relative to decisions on moving into the next phase of pumping.

For example, the most responsive well in the network to the proposed LCRA pumping is Well 58-55-407. The model simulations predict that the drawdown due to the pumping of the LCRA wells (as simulated in the model) would be 229 ft from 2019 to 2070. However, the data also show that after the three years of the initial phase of pumping, the drawdown in this well would be about 50 feet in the first year, 52 feet in the second year, and 52 feet in the third year. Thus, if there is no other new pumping in the area of the LCRA wells at the time of their start-up and the precipitation/recharge conditions are near average during the first three years of operation of the LCRA wells, the actual monitoring data from this monitoring well should show about a 50 ft decline in the first year and remain fairly consistent for the next two years.

The possible deviation from this prediction could be the result of other pumping in the area, and/or an abnormally wet or dry period. If none of these conditions are true and the drawdown is substantially more or less than 50 feet, it should be concluded that the model is not a good predictor of drawdown and more investigation is warranted, including updating and recalibrating the model.

If, on the other hand, the actual monitoring data from this monitoring well and the other monitoring wells are substantially the same as the model predictions, then it could be concluded that the model appears to be reasonably accurate and the next phase of pumping should proceed.

# 2.0 Model Comparison

## 2.1 Overview of Models

The old GAM (Kelley and others, 2004) and the new GAM (Young and others, 2018) cover approximately the same area.

The old GAM was developed using MODFLOW-96, an earlier code in the MODFLOW series of finite difference modeling codes developed by the USGS (Harbaugh and McDonald, 1996). The old GAM has a uniform model grid consisting of one-square mile (640 acres) grid cells.

The new GAM was developed using MODFLOW-USG (Panday and others, 2013). The new GAM has a variable grid using quadtree mesh refinement that reduces the cell size in the area of selected surface water features. The largest cell size is one square mile (640 acres), the smallest cell size is 40 acres (1/16 of a square mile).

The layering of the old GAM and the new GAM are somewhat different. The old GAM has 8 layers, the new GAM has 10 layers. The new GAM included an explicit layer (Layer 1) to simulate the Brazos River Alluvium and the Colorado River Alluvium. Layer 2 of the new GAM is the "shallow flow zone", which cuts across all layers in the outcrop area. Except for the "shallow flow zone", layers 3 to 10 of the new GAM represent the same formations as Layers 1 to 8 of the old GAM.

Figure 2 (taken from Figure 3.5a on page Vol. 1-125 of Young and others, 2018) is a conceptual illustration of the layering approach of the new GAM. Please note that the illustration includes the term "overlying formations" which are not explicitly included in the model. These formations include Yegua Formation (part of the Yegua-Jackson Aquifer), and the Cook Mountain Formation.

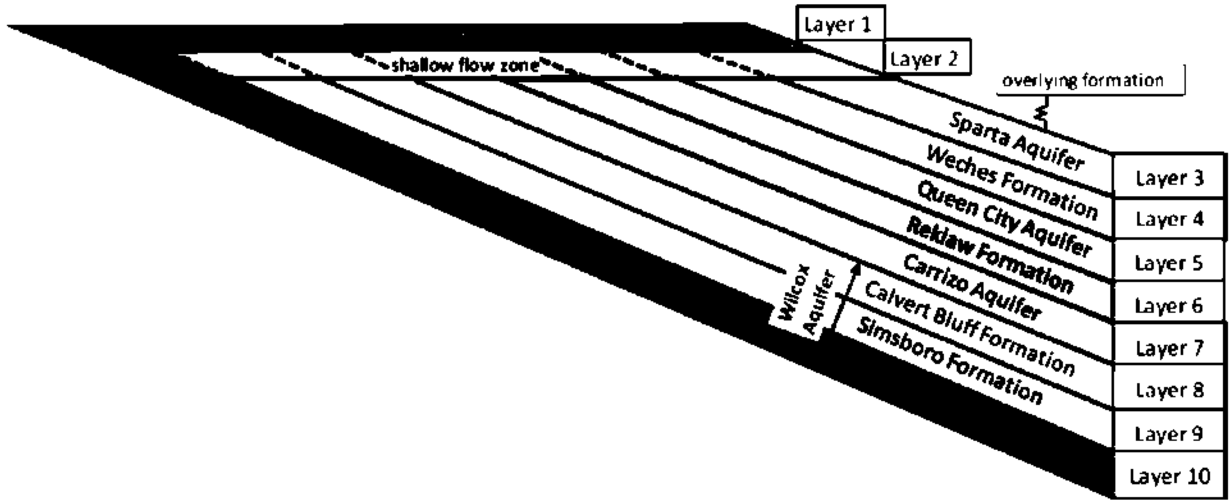



**Figure 2. Conceptual Illustration of New GAM Layering (from Young and others, 2018)**

## 2.2 TWDB Groundwater Data

The Old GAM (Kelley and others, 2004) and the new GAM (Young and others, 2018) were evaluated primarily on how well the model estimated groundwater elevations in Bastrop County matched actual groundwater elevation data obtained from the Texas Water Development Board. Actual data were obtained at the website:

http://www2.twdb.texas.gov/ReportServerExt/Pages/ReportViewer.aspx?%2fGWDB%2fWaterLevelsByCounty&rs:Command=Render

Data were obtained by entering the county (Bastrop), the aquifer (all), the observation type (all), and the coordinate format (decimal degrees). The resulting 3,445 records were saved in the file *BastropWL070919.csv*. The latitude and longitude of the well location were converted into GAM coordinates using Surfer, a commercial gridding program and the specifications of the GAM coordinate system.

The records were sorted and records with no recorded groundwater level or well depth were deleted. The remaining 3,424 records were saved in the file *BastropWL070919.xlsx*. The same file was also saved as *BastropCoWL.csv* for further use in FORTRAN programs as described below.

### 2.2.1 Well List and All Water Levels

The FORTRAN program *getallwl.exe* was written to obtain a listing of the 553 wells in the TWDB data, the number of data points for each well, the earliest and latest year of data for each well, the depth of the well, the surface elevation of the well, the bottom elevation of the well, and the x-and y-coordinate for each well. Output from the program is saved in the file *allwelsum.dat*.

### 2.2.2 End-of-Year Water Levels

The FORTRAN program *geteoywl.exe* was written to limit the data to end-of-year groundwater elevations because the groundwater models are run on annual stress periods. Thus, comparison of actual data and model estimated groundwater elevations is best made using end-of-year data. The program used the following preference in filtering the data:

- December of current year
- January of subsequent year
- November of current year
- February of subsequent year
- October of current year

All other data were discarded. Results were saved in the file *BastropEOYwl.dat*. A list of the wells for the end-of-year data along with the number of records for the well, and the earliest and latest data points are saved in the file *eoylist.dat*. The filtering resulted in 385 wells and 1,109 data points.

## 2.3 Locate Wells on GAM Grids

The old GAM grid file provided by the Texas Water Development Board (*qcsp_c_poly082615.csv*) was used in FORTRAN programs (*getoldgamtopbot*.exe and *getrcoldgam.exe*) to obtain the layer, row, and column for each record. These results were saved in the file *BastropELoldgrid.dat*. Please note that only 1,010 records were located on the model grid. The rest were well locations that fell outside the grid or were not completed in aquifers simulated in the model. Please recall that the model does not explicitly include the formations associated with the Yegua-Jackson Aquifer or the Cook Mountain Formation.

The new GAM grid file provided by the Texas Water Development Board (*getnodenewgam.exe*) was used in a FORTRAN program (*getnodenewgam.exe*) to find and save the closest cell or node center for each record. These results were saved in the file *BastropWLnewgrid.dat*. Please note that only 1,060 records were located on the model grid. The rest were well locations that fell outside the grid or were not completed in aquifers simulated in the model. Please recall that the model does not explicitly include the formations associated with the Yegua-Jackson Aquifer or the Cook Mountain Formation.

## 2.4 Model Estimated Groundwater Elevations

Calibrated model groundwater elevations were extracted from model output files (*qcsp_c_ps12.hds* for the old GAM, and *gma12.hds* for the new GAM).

Please note that the old GAM model files were obtained from TWDB for the most recent desired future condition/modeled available groundwater simulation. The first 25 stress periods of this model run covers the calibration period (1975 to 1999) and are the same as the 25 stress periods of the calibrated model.

The saved head files from the GAMs were read by FORTRAN programs (*gethednewgam.exe* for the old GAM and *gethednewgam.exe* for the new GAM). The old GAM saved file is *oldgridactsim.dat* and contains 391 comparisons of actual groundwater elevations and model estimated groundwater elevations. Please note that records that were either before or after the calibration period were not used.

The new GAM saved file is *newgridactsim.dat* and contains 968 comparisons of actual groundwater elevations and model estimated groundwater elevations. Please note that records that were either before or after the calibration period were not used.

Both comparisons were saved in a single Excel file named *actsimoldnew.xlsx*. Summary statistics of the calibrations in Bastrop County are presented in Table 1. Please note that the new GAM has more data points and a better fit as evidenced by the residual mean, the absolute residual mean, the residual standard deviation, and the root mean square error. Of note is the scaled residual standard deviation, where the value for the New GAM in Bastrop County is less than 0.1, which is considered an acceptable error.

**Table 1. Comparison of Calibration Statistics for Old GAM and New GAM – Bastrop County**

| Statistic | Old GAM | New GAM |
|---|---|---|
| Residual Mean | -9.56 | -8.38 |
| Absolute Residual Mean | 28.91 | 21.70 |
| Residual Standard Deviation | 37.37 | 28.11 |
| Sum of Squared Residuals | 580,290.91 | 832,288.53 |
| Root Mean Square Error | 38.52 | 29.32 |
| Minimum Residual | -121.74 | -143.77 |
| Maximum Residual | 124.72 | 116.16 |
| Number of Observations | 391 | 968 |
| Range in Observations | 317.00 | 354.00 |
| Scaled Residual Standard Deviation | 0.1179 | 0.0794 |
| Scaled Absolute Residual Mean | 0.0912 | 0.0613 |
| Scaled Root Mean Square Error | 0.1215 | 0.0828 |
| Scaled Residual Mean | -0.0302 | -0.0237 |

Summary graphs comparing the actual and simulated groundwater elevations in Bastrop County are presented in Figure 3 (old GAM) and Figure 4 (new GAM). The summary graphs confirm that the new GAM has a better fit to the 1:1 line than the old GAM.

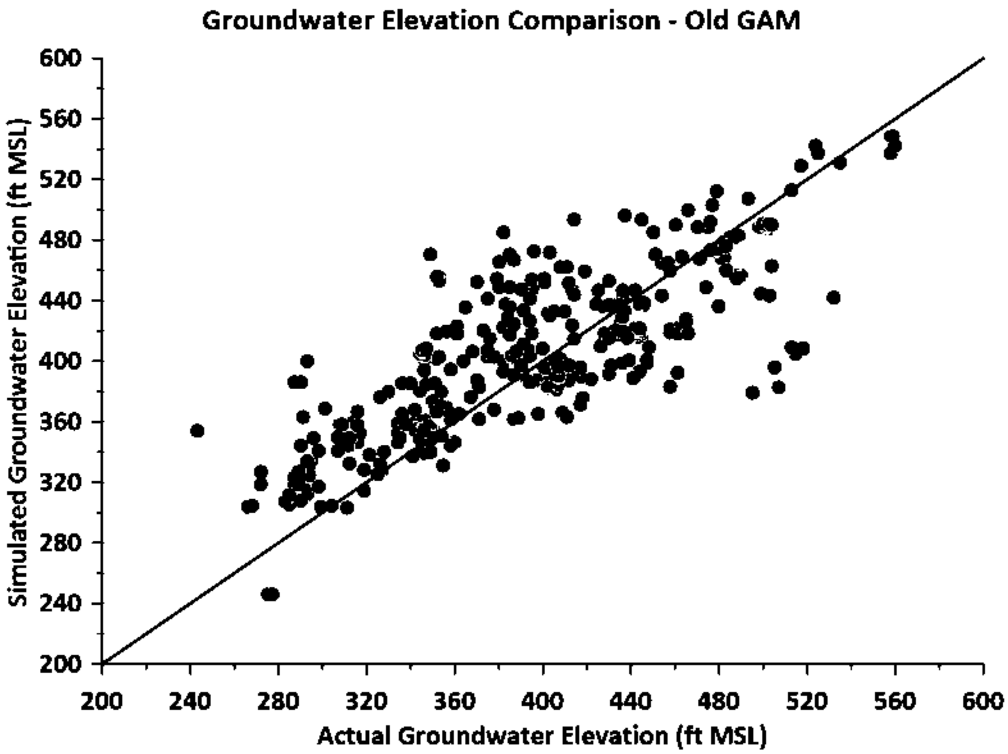



**Figure 3. Groundwater Elevation Comparison - Old GAM**

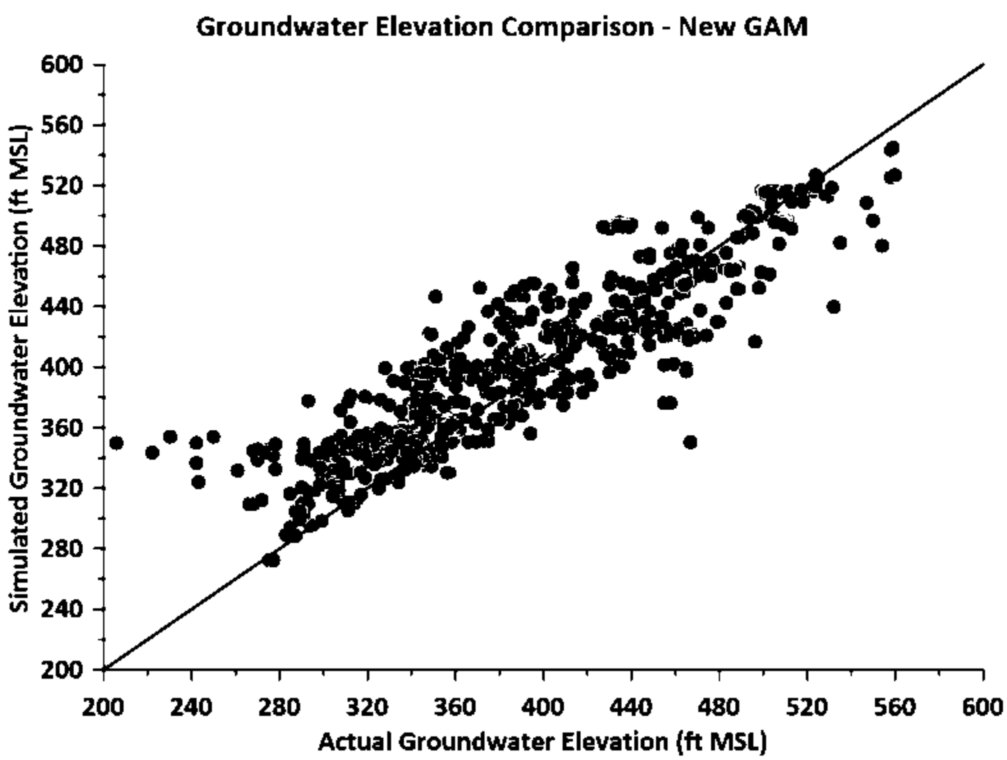



**Figure 4. Groundwater Elevation Comparison - New GAM**

# 3.0 Groundwater Budgets

## 3.1 Zone Budget Input and Output

Groundwater budgets for Bastrop County were extracted from model output files using the USGS program *zonbudusg.exe*. Three groundwater budgets were developed using the cell-by-cell output files from three runs of the model:

- The calibrated model cell-by-cell file was obtained from the Texas Water Development Board. The file has a date of June 8, 2018 and was renamed *gam12cal.cbb* for use in this analysis.
- The base case model run was provided by INTERA in the directory *dfc.braa.wel.2011.2070* was renamed *gma12base.cbb* for use in this analysis.
- The simulation where proposed LCRA pumping is added to the base case was provided by INTERA in the directory *dfc.braa.wel.lcra.2011.2070* was renamed *gma12lcra.cbb* for use in this analysis.

Other input files common to all three runs of *zonbudusg.exe* are the discretization file (*gma12.dis*) obtained from the Texas Water Development Board and the zone file *(sevenzone.dat*). The zone file was developed by the FORTRAN program *makezone.exe* that uses the new GAM grid file as input (*czwx_c_v3.01_grid_point092118.csv*), which was obtained from the Texas Water Development Board. Six zones were designated to distinguish all counties that border Bastrop County, the seventh zone includes all counties that do not border Bastrop County:

1. Bastrop County (code 11 in the grid file)
2. Caldwell County (code 28 in the grid file)
3. Fayette County (code 75 in the grid file)
4. Gonzales County (code 89 in the grid file)
5. Lee County (code 144 in the grid file)
6. Williamson County (code 246 in the grid file)
7. All other counties (all other codes in the grid file)

Output was saved as follows:

- Output for the calibrated model: *cal.2.csv*
- Output for the base case: *base.2.csv*
- Output for the base+LCRA case: *lcra.2.csv*

The output files contained data for all zones. The output for Bastrop County for each instance was saved as follows:

- Calibrated model: *zbcal.xlsx*
- Base case: *zbbase.xlsx*
- Base+LCRA case: *lcra.xlsx*

For each of the Excel files with the Bastrop County results, there are five sheets:

- Full output from the *zonbudusg.exe* program (named *cal.2* for the calibrated model, named *base.2* for the base case, and named *lcra.2* for the base+LCRA case)
- *Bastrop-cfd* contains all data for Bastrop County in cubic feet per day
- *Bastrop-AFY* contains all data for Bastrop County in acre-feet per year
- *Bastrop-NetAFY* contains the net components for Bastrop County in acre-feet per year
- *WB* contains a summary water budget

## 3.2 Calibrated Model Groundwater Budget for Bastrop County

Table 2 presents a groundwater budget for Bastrop County from the results of the calibrated model. Two time periods are presented: 1930 to 1995 and 1996 to 2010.

**Table 2. Calibrated Model Groundwater Budget for Bastrop County**
**All Values in AF/yr**

| **Inflow** | **1930 to 1995** | **1996 to 2010** |
|---|---|---|
| Recharge | 61,383 | 54,307 |
| Caldwell | 2,401 | 2,445 |
| Williamson | 21 | 21 |
| Total | 63,805 | 56,773 |

| **Outflow** | | |
|---|---|---|
| Pumping | 3,594 | 13,268 |
| Springs | 4,791 | 3,936 |
| River Baseflow | 52,311 | 41,489 |
| Evapotranspiration | 261 | 210 |
| GHB (overlying) | 259 | 1,173 |
| Fayette | 2,345 | 4,498 |
| Lee | 2,061 | 5,279 |
| Total | 65,622 | 69,853 |

| | | |
|---|---|---|
| **Inflow-Outflow** | -1,817 | -13,079 |
| **Storage Change** | -1,817 | -13,079 |
| **Model Error** | 0 | 0 |

Please note that the pumping in the later period is about 10,000 AF/yr higher than in the earlier time period (about 14,000 AF/yr vs. about 4,000 AF/yr). Also, please note that the storage decline increases in the later period as compared to the earlier period by about 11,000 AF/yr (about 2,000 AF/yr vs. about 13,000 AF/yr. The recharge in the later period is about 7,000 AF/yr less than the earlier period. Finally, the discharge to river baseflow is about 11,000 AF/yr less in the later period than the earlier period (about 41,000 AF/yr vs. about 52,000 AF/yr).

As discussed by Bredehoeft and others (1982) and Bredehoeft (2002), when pumping increases, three impacts are expected to happen: 1) declining storage (manifested by declining groundwater levels), 2) induced inflow from connected surface water and/or subsurface flow from surrounding areas, and 3) decreased natural outflow to surface water, and/or decreased subsurface outflow to surrounding areas. The groundwater budgets in Table 2 above show an increase in pumping, an increase in the rate of storage decline, and a decrease in discharge to rivers. However, the lower recharge between the two time periods complicates the interpretation on the impact of pumping.

Figure 5 plots the annual recharge and the annual groundwater storage change from 1930 to 2010 in Bastrop County. Please note that the regression line is also plotted along with the regression equation and $r^2$ value of the regression that is a quantitative expression of how well the line fits the data (perfect fit = 1.0). The $r^2$ value of 0.94 can be interpreted as 94 percent of the variation in groundwater storage change can be explained by the variation in recharge. This suggests that, historically, groundwater pumping has had a relatively minor impact on changes in regional groundwater storage (i.e. groundwater levels).

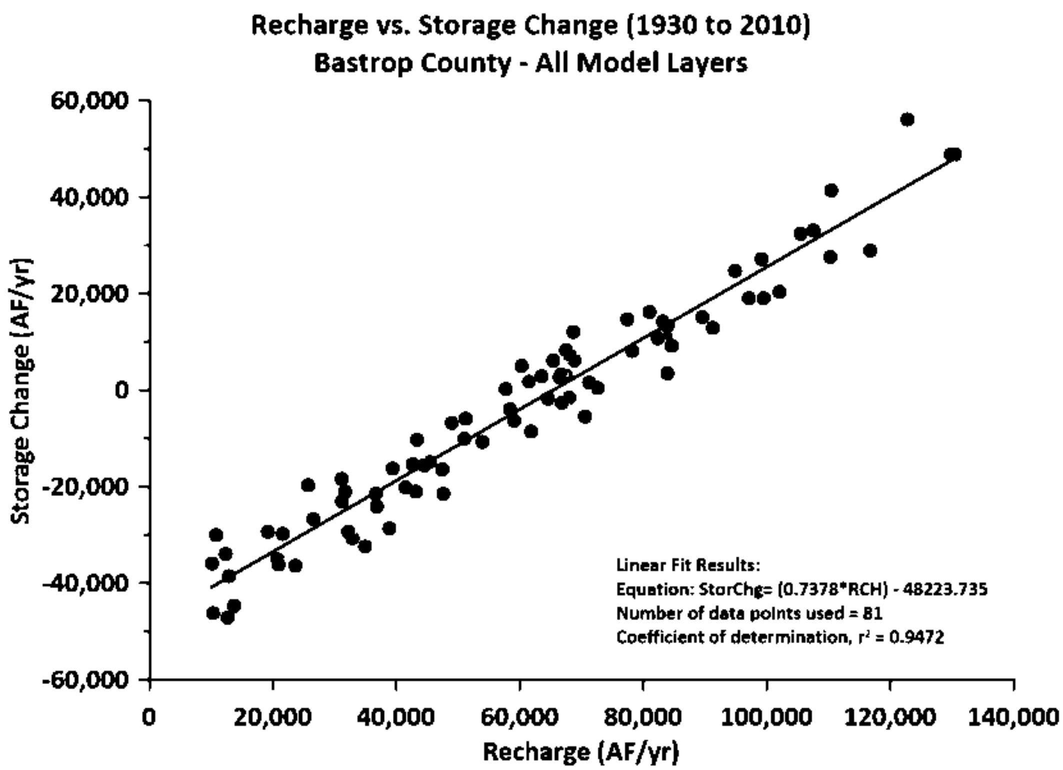



**Figure 5. Recharge vs. Storage Change - Bastrop County**

## 3.3 Groundwater Budgets of Predictive Scenarios

Table 3 presents the groundwater budgets for the two predictive scenarios (Base and Base+LCRA) from 2011 to 2070.

**Table 3. Bastrop County Groundwater Budget for Two Predictive Scenarios - 2011 to 2070**

| **Inflow** | **Base** | **Base+LCRA** |
|---|---|---|
| Recharge | 62,666 | 62,666 |
| Williamson | 21 | 21 |
| Total | 62,686 | 62,686 |

| **Outflow** | | |
|---|---|---|
| Pumping | 29,546 | 49,375 |
| Springs | 2,707 | 2,498 |
| River Baseflow | 18,053 | 8,898 |
| Evapotranspiration | 172 | 171 |
| GHB (overlying) | 985 | 979 |
| Caldwell | 6,176 | 6,052 |
| Fayette | 13,974 | 13,722 |
| Lee | 9,982 | 6,907 |
| Total | 81,594 | 88,603 |

| | | |
|---|---|---|
| **Inflow-Outflow** | -18,908 | -25,917 |
| **Storage Change** | -18,908 | -25,917 |
| **Model Error** | 0 | 0 |

Please note that the proposed LCRA pumping increases total pumping about 20,000 AF/yr (average increase from 2011 to 2070). Because the LCRA pumping is the only change to model input, the changes in output are all attributable to the LCRA pumping. River baseflow is decreased about 9,000 AF/yr (about 18,000 AF/yr to about 9,000 AF/yr). Storage declines increase by about 7,000 AF/yr (about 19,000 AF/yr to about 26,000 AF/yr). The remaining large change is the subsurface outflow to Lee County (reduced about 3,000 AF/yr from about 10,000 AF/yr to about 7,000 AF/yr). These components of the water budget represent the source of about 97 percent of the pumping.

The groundwater budget comparison suggests that about 46 percent of the pumping will be sourced from reduced baseflow to the surface water system in Bastrop County. About 35 percent of the pumping will be sourced from reduced groundwater storage, and about 16 percent will be sourced from decreased subsurface outflow to Lee County.

The results highlight the fact that groundwater pumping results in three impacts: 1) reduced storage (manifested by reduced groundwater levels), 2) induced inflow from surrounding areas and from surface water, and 3) reduced natural outflow to surface water and/or subsurface outflow to surrounding area.

Figure 6 presents the annual surface water-groundwater interaction graph and includes the calibrated model results and the two predictive scenario results. Please note that negative values represent a flow from groundwater to surface water (groundwater discharge to rivers that forms baseflow), and positive values represent a flow from surface water to groundwater (surface water providing recharge water to groundwater).

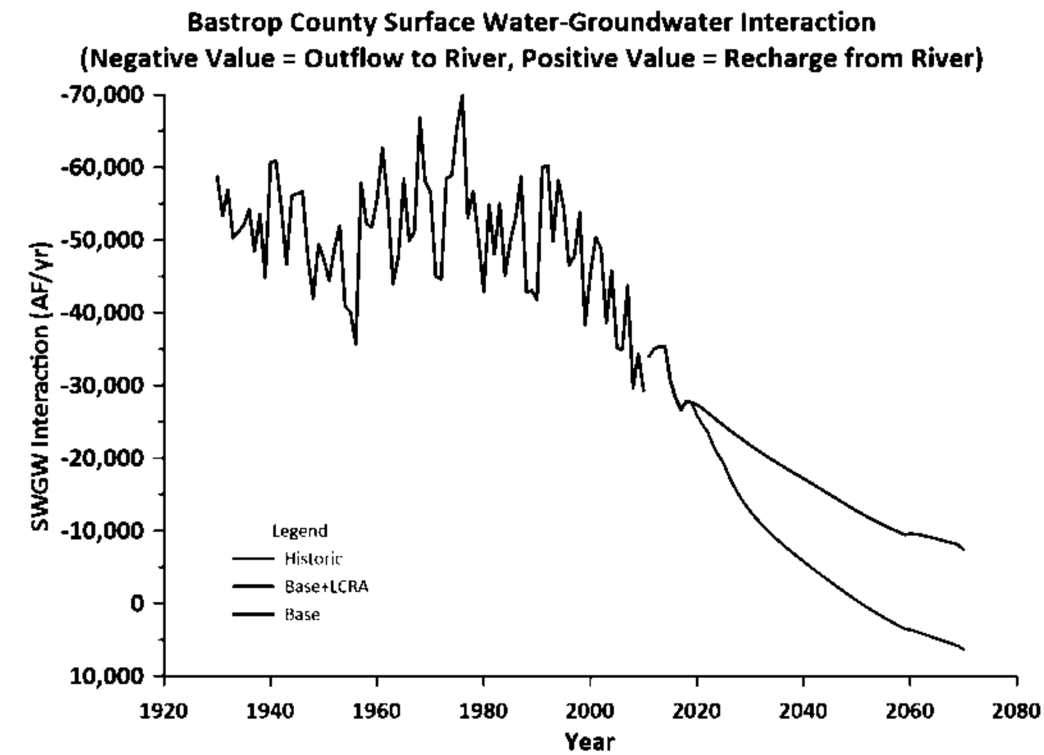



**Figure 6. Bastrop County Surface Water-Groundwater Interaction**

Please note that prior to about 1990, groundwater discharge to surface water varied without a discernible trend. Beginning in about 1990 a trend begins to be observed where the rate of discharge to surface water declines (from about 60,000 AF/yr to about 30,000 AF/yr in 2010).

The base case simulation shows a continued decline in the rate of discharge, but the Base+LCRA scenario shows that, in about 2040, the discharge is eliminated, and the surface water system begins to act as a recharge source to groundwater.

Based on the groundwater budget for Bastrop County, the two largest sources of the proposed pumped groundwater are reduction in baseflow to surface water and storage decline. The annual contribution to the pumping for each of these components to presented in Figure 7.

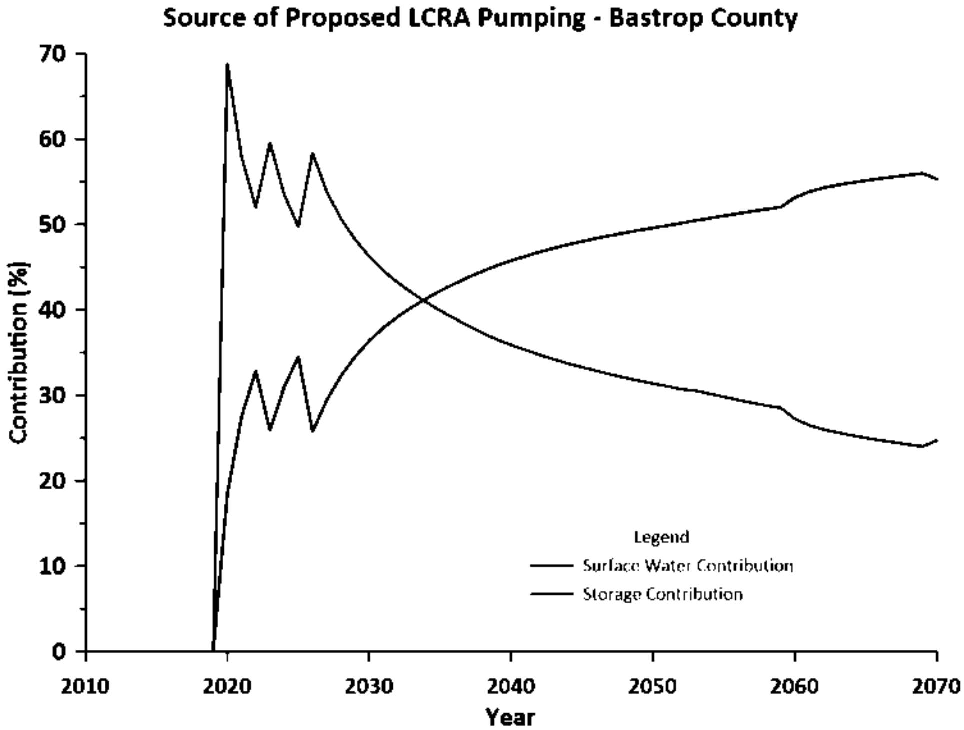



**Figure 7. Source of Proposed LCRA Pumping**

Please note that when the proposed LCRA pumping begins in 2020, about 70 percent of the pumped water comes from groundwater storage, and the relative contribution from reduced storage declines with time. Conversely, the relative contribution from reduced discharge to surface water/induced recharge from surface water increases with time. The steps in pumping can also be seen in Figure 6. Please note that when the simulated pumping is increased in 2023 and 2026, the initial response is to increase the relative contribution from groundwater storage increases and the relative contribution from surface water decreases. These results suggest that by 2050, over half of the proposed LCRA pumping would be sourced from surface water.

# 4.0 Groundwater Drawdown Predictions in Registered Wells

## 4.1 Initial Processing of Registered Well Data

Lost Pines Groundwater Conservation District provided an Excel file with 2,617 registered wells. Registered wells include permitted wells and non-exempt permitted wells (*LPGCD Well export.xlsx*). This file contained data on the latitude, longitude, surface elevation, and depth for each well. For purposes of this analysis, 242 wells without a recorded depth were not used. Also, 344 wells were not used that had the same latitude and longitude (30.5 and -97 respectively), which appeared to be "place-holders". These wells were not used in further analysis.

Of the remaining 2,031 wells, 510 did not have surface elevation listed. Of the wells that had a surface elevation listed, 22 wells were listed at 300 ft MSL or lower. The elevation of the Colorado River at the Bastrop-Fayette County line is about 300 ft MSL based on an online topographic map:

https://en-us.topographic-map.com/maps/sqvz/Bastrop-County/

Therefore, these surface elevations were considered erroneous and were reset to zero for further processing.

Of the wells that had a surface elevation listed, 14 wells were listed at 670 ft MSL or higher. The apparent high elevation in Bastrop County is about 731 ft MSL and is about 678 ft MSL in Lee County. These high points are close to each other near the Bastrop-Lee County line. Thus, all elevations above 670 were set equal to zero for further processing.

The final dataset, therefore, contains 2,031 wells: all of which include a well depth, 1,485 with a surface elevation, and 546 without a surface elevation.

The latitude and longitude were converted into GAM x- and y-coordinates using Surfer, a commercial gridding program.

The resulting file was saved as *RegWellLatLongSurfDepthGAMxy.csv* for further use.

## 4.2 Locating Registered Wells on Model Grid

The FORTRAN program *getregwellnode.exe* was written to find the cell or node center closest to each well. The program also compared the well bottom elevation to cell top and bottom elevations to place the well in the correct layer. Well bottom elevation was set based on the database value of surface elevation, where available, or the surface elevation of the surface cell in the model if the database had no surface elevation data available. Output from the program is a file named *regwel3dnode.dat*.

The results were sorted by the LPGCD ID number and saved in the Excel file *RegWellNodeLayer.xlsx*. Please note that a total of 1,833 were located on the model grid. The rest of the wells were either located outside the model grid or completed in aquifers not simulated in the model.

## 4.3 Model Simulated Groundwater Elevations in Registered Wells

The FORTRAN program *getrwhed.exe* was written to extract simulated groundwater elevations from three model runs of the new GAM: 1) the calibrated model, 2) the predictive simulation of the base case, and 3) the predictive simulation of the base+LCRA scenario. The output of the program is a file named *rgwelhed.dat*.

The results were saved in the Excel file *RegWellImpacts.xlsx*. The Excel file has three sheets:

- "GWE" includes the output from the program
- "DD" includes various calculated drawdowns
- "Averages" includes average drawdowns for each model layer

The GWE sheet includes the following data:

- LPGCD ID number (Column A)
- New GAM Node Number (Column B)
- Layer (Column C)
- Surface Elevation (Column D)
- Well Depth (Column E)
- Well Bottom Elevation (Column F)
- Simulated Groundwater Elevation in 2010 (Column G)
- Simulated Groundwater Elevation in 2019 (Column H)

For the Base Case:

- Simulated Groundwater Elevation in 2022 (Column I)
- Simulated Groundwater Elevation in 2025 (Column J)
- Simulated Groundwater Elevation in 2070 (Column K)

For the Base+LCRA Scenario:

- Simulated Groundwater Elevation in 2022 (Column L)
- Simulated Groundwater Elevation in 2025 (Column M)
- Simulated Groundwater Elevation in 2070 (Column N)

The DD sheet includes the same identifying data as the GWE sheet (Columns A to F). Columns G to M contain various drawdown calculations, and columns N to P contain estimates of the simulated drawdown attributable to the proposed LCRA pumping at three points in the project for each registered well located in the model grid. Each calculation is the difference between the simulated groundwater elevation from the base case and the simulated groundwater elevation from the Base+LCRA scenario. These columns represent the drawdown in each registered well located in the model grid attributable to the proposed LCRA pumping in each well.

- Column N includes the simulated drawdown attributable to the proposed LCRA pumping at the end of three years of pumping (i.e. end of the initial phase of pumping 7,995 AF/yr, or 2022).
- Column O includes the simulated drawdown attributable to the proposed LCRA pumping at the end of six years of pumping (i.e. three years of pumping 7,995 AF/yr followed by three years of pumping 14,990 AF/yr, or 2025).
- Column P includes the simulated drawdown attributable to the proposed LCRA pumping at the end of the simulation period, or 2070, and after three years of pumping 7,995 AF/yr

followed by three years of pumping 14,990 AF/yr, followed by 45 years of pumping between 24,894 AF/yr and 24,983 AF/yr.

## 4.5 Discussion of Simulated Drawdown in Registered Wells

The last sheet of the Excel file with the simulated groundwater elevation results and calculated drawdowns discussed in the previous section (*RegWellImpacts.xlsx*) is reproduced below as Table 4.

**Table 4. Layer-Averaged Simulated Drawdowns and LCRA Impacts in LPGCD Registered Wells**

| Layer | Formation | Number of Wells | Drawdown (ft) | | | | | | | LCRA Impact (Drawdown in ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2010-2019 | 2019-2022 Base | 2019-2025 Base | 2019-2070 Base | 2019-2022 LCRA | 2019-2025 LCRA | 2019-2070 LCRA | 2022 | 2025 | 2070 |
| 1 | BRAA and CRA | 22 | 0.00 | 0.07 | 0.14 | 1.06 | 0.14 | 0.40 | 2.73 | 0.07 | 0.25 | 1.67 |
| 2 | "Shallow Flow Zone" | 127 | 0.22 | 0.25 | 0.52 | 4.49 | 0.38 | 0.84 | 6.65 | 0.13 | 0.32 | 2.16 |
| 3 | Sparta Aquifer | 104 | 11.44 | 1.84 | 3.28 | 14.68 | 1.88 | 3.38 | 15.33 | 0.04 | 0.10 | 0.65 |
| 4 | Weches Formation | 14 | 7.84 | 1.54 | 2.76 | 13.44 | 1.61 | 2.93 | 14.32 | 0.08 | 0.17 | 0.88 |
| 5 | Queen City Aquifer | 257 | 10.27 | 1.75 | 3.14 | 17.22 | 1.86 | 3.39 | 18.36 | 0.11 | 0.25 | 1.14 |
| 6 | Reklaw Formation | 94 | 15.84 | 3.65 | 6.39 | 32.30 | 4.27 | 7.69 | 37.14 | 0.62 | 1.30 | 4.84 |
| 7 | Carrizo Aquifer | 134 | 28.35 | 6.11 | 10.47 | 54.98 | 6.85 | 12.03 | 61.48 | 0.74 | 1.55 | 6.50 |
| 8 | Calvert Bluff Formation | 505 | 9.17 | 2.79 | 5.06 | 27.07 | 4.81 | 8.99 | 41.79 | 2.03 | 3.93 | 14.72 |
| 9 | Simsboro Formation | 173 | 14.48 | 4.19 | 6.62 | 25.78 | 11.73 | 20.58 | 55.29 | 7.54 | 13.96 | 29.52 |
| 10 | Hooper Formation | 301 | -4.36 | 1.58 | 3.00 | 14.43 | 3.12 | 6.21 | 23.31 | 1.55 | 3.21 | 8.88 |

Please note that the new GAM layers are listed, and the names associated with those layers are also listed. The number of registered wells in each layer are included. The drawdowns for each layer and time period represent the average of all registered wells in that layer. The LCRA impact is the average drawdown in each layer attributable to the proposed LCRA pumping.

Please note that the drawdown from 2010 to 2019 is not attributable to the proposed LCRA pumping because the simulated LCRA pumping begins in 2020. Thus, the drawdown is associated with increases in pumping that were contemplated in the simulation that was used in the development of the desired future condition by GMA 12 and subsequently adopted by the Lost Pines GCD.

As noted earlier, historic pumping in Bastrop County has been relatively low. The simulation represents a large increase in pumping starting in 2015 (about 32,000 AF/yr) compared with about 20,000 AF/yr in 2010. The effect of this increase in pumping is manifested in significant drawdown from 2010 to 2019.

Drawdowns from 2019 to 2022 corresponds to the first three-year period of the proposed LCRA pumping. The Base Case 2019 to 2022 drawdown represents the case without LCRA pumping and the LCRA column for 2019 to 2022 represents the drawdown with the LCRA pumping. The LCRA impact column for 2022 represents the drawdown that is attributable to the proposed LCRA pumping and is the difference between the base case column and the LCRA column.

The columns labeled 2019 to 2025 represent the drawdowns at the end of the second phase of proposed pumping, and the columns labeled 2019 to 2070 represent the drawdown associated with the full simulation period.

Please note that the LCRA impact drawdowns are highest in the Simsboro Formation (Layer 9). However, the simulations show that the vertical connection between the layers results in drawdowns above and below the Simsboro Formation.

For example, the drawdown attributable to LCRA pumping from 2019 to 2070 in the Simsboro is about 30 feet. Immediately below the Simsboro Formation, the drawdown attributable to the LCRA pumping in the Hooper Formation is about 9 feet. Immediately above the Simsboro Formation, the drawdown attributable to the LCRA pumping in the Calvert Bluff Formation is about 15 feet.

Two layers above the Simsboro Formation is the Carrizo Aquifer. The 2019 to 2070 drawdown in the Carrizo Aquifer attributable to the proposed LCRA pumping is about 7 feet. Please note that the drawdowns decrease in layers 6, 5, 4, and 3 in each column. However, the drawdown in layer 2 (the "shallow flow zone") is higher than in layer 3. This is because there are places in the model where layer 2 directly overlies layer 8.

The drawdowns in layer 2 and layer 1 are small in comparison to the drawdowns in the underlying layers, but result in gradient changes that result in reduced groundwater discharge to surface water which eventually result in a gradient reversal in the Base+LCRA scenario that result in the surface water providing recharge to groundwater.

# 5.0 Groundwater Drawdown Predictions in Monitoring Wells

## 5.1 Initial Processing of Monitoring Well Data

Lost Pines Groundwater Conservation District provided two Excel files with 45 monitoring wells used in the District The first file (*Lost Pines Water Level Monitoring Wells- 20180305.xlsx)* included data on the latitude, longitude, and depth for each well. The second file (*2018 Water Level Measurements – 20190130-jt.xlsx*) included data on the surface elevation of the well.

The data from these two files were combined using the well number as a guide to create a single file that includes latitude, longitude, surface elevation, and well depth. When combined, the first file had two wells that were not included in the second file (58-62-208 and 58-46-510), and the second file had two wells that were not in the first file (59-33-408 and 58-46-501). In addition, there was a Queen City well that is listed as removed from the network (58-63-103). Finally, there were three wells that have no surface elevation listed (59-57-201, 59-50-401, and 5951-102) and were deleted.

This combined file with the remaining 39 wells was saved as *MonWells.xlsx*, and included the spatial coordinates converted to the GAM coordinate system using Surfer, a commercial gridding program. An abbreviated version of the file was saved as *MonWells.csv* for further processing.

### 5.2 Locating Monitoring Wells on Model Grid

The FORTRAN program *getrmonwellnode.exe* was written to find the cell or node center closest to each well. The program also compared the well bottom elevation to cell top and bottom elevations to place the well in the correct layer. Output from the program is a file named *monwel3dnode.dat.* Please note that all 38 wells were located on the model grid.

### 5.3 Model Simulated Groundwater Elevations in Monitoring Wells

The FORTRAN program *getmwhed.exe* was written to extract simulated groundwater elevations from three model runs of the new GAM: 1) the calibrated model, 2) the predictive simulation of the base case, and 3) the predictive simulation of the base+LCRA scenario.

A summary output from the program is a file named *monwelhed.dat.* This output file was combined with the identifying information from the original monitoring well file that was provided by Lost Pines GCD and saved as an Excel file named *MonWellSumHed.xlsx.* Columns A to I and Column R contain various identifying or well construction details. Of note is Column E, which is the LPGCD's designation of the aquifer and Column F which is the model layer picked by the location and well bottom elevation. Please note that there are four wells in the "shallow flow zone" (Layer 2). These are indeed shallow wells (basically 100 feet or less in depth). In several cases, the LPGCD designation of the aquifer is not consistent with the model layer.

Column J represents the simulated groundwater elevation at the end of the calibration period (2010). Please note that two of the shallow wells (58-46-301 and 58-46-503) have simulated groundwater elevations below the calculated bottom elevation of the well. As discussed further below, this highlights a limitation of the model that is useful in guiding the use of model results in the future.

Column K is the simulated groundwater elevation at the end of 2019 and is the same for both scenarios because the proposed LCRA simulated pumping does not begin until 2020. Thus, it is only presented once in this table. There is predicted drawdown in all monitoring wells between 2010 and 2019 due to the simulated pumping in the base case. Please recall that the model calibration period ended in 2010, and the proposed pumping of the LCRA wells would not begin until 2020. This complicates the future use of the model results in interpreting actual future monitoring data.

In addition, the simulations assume constant recharge each year approximately equal to the average recharge of the calibration period (1930 to 2010). The calibrated model demonstrated that variations in recharge has historically been the most important factor in explaining variations in groundwater elevations. Thus, the simulations provide an idealized case where drawdown is caused by increases in pumping.

Columns L, M. and N are the estimated groundwater elevations for the base case for 2022, 2025, and 2080, respectively. Columns O, P, and Q are the estimated groundwater elevations for the Base+LCRA scenario for 2022, 2025, and 2080, respectively. These data provide a broad overview of all the wells with the identifying and construction data.

Please note that some of the drawdowns based on 2010 groundwater elevations are negative, which means that there is a predicted groundwater level are rising from the 2010 condition. This usually means that some of the pumping that was included in the last few years of the calibrated model was not included in the predictive model. The issue is most prominent in Well 58-46-516, a Layer 10 well shown in Column AL.

The program also writes two files with more detailed estimates of groundwater elevation. The file that contains the simulated groundwater elevations for the base case is named *allhedbasemw.dat* and the file that contains the groundwater elevations for the Base+LCRA scenario is named *allhedlcramw.dat.*

These files were combined with the well number and model layer into two Excel files: *BaseGWEDDAllMonWells.xlsx* (for the base case) and *LCRAandBaseGWEDDAllMonWells.xlsx* for the Base+LCRA scenario).

Each of these Excel files have three sheets. The first is the identifying information in Rows 1 to 4 and the year in Column A, and the simulated groundwater elevations for the 37 wells in Columns B to AL. The second sheet calculates the annual drawdown in each well using 2010 as the starting point. The third sheet calculates the annual drawdown in each well using 2019 as the starting point. The 2010 calculation is consistent with the end of the calibrated model, and the 2019 calculation is consistent with the beginning of the proposed LCRA pumping.

The groundwater elevation estimates from for the two scenarios (base case and Base+LCRA) from the program were also saved in the first two sheets of an Excel file named *LCRAImpactAllMonWells.xlsx.* The third sheet of this file contain the estimated annual drawdown impact of the proposed LCRA pumping in each monitoring well. These results are the most useful to assist in the interpretation of future monitoring data, especially in the context of providing some guidance or basis related to the decision to move to the next phase of the LCRA pumping (i.e. increase pumping after three years).

For example, the most responsive well in the network to the proposed LCRA pumping is Well 58-55-407 (Column T in *LCRAImpactAllMonWells.xlsx*). The model simulations predict that the drawdown due to the pumping of the LCRA wells (as simulated in the model) will be 229 ft from 2019 to 2070. However, the data also show that after the three years of the initial phase of pumping, the drawdown in this well will be about 50 feet in the first year, 52 feet in the second year, and 52 feet in the third year. Thus, if there is no other new pumping in the area of the LCRA wells at the time of their start-up and the precipitation/recharge conditions are near average, the actual monitoring data from this well should show about a 50 ft decline in the first year and remains fairly constant for the next two years.

The possible deviation from this prediction could be the result of other pumping in the area, and/or an abnormally wet or dry period. If none of these conditions are true and the drawdown is substantially more or less than 50 feet, it should be concluded that the model is not a good predictor of drawdown and more investigation is warranted, including updating and recalibrating the model.

If, on the other hand, the actual monitoring data from this well and the other wells are substantially the same as the model predictions, then it could be concluded that the model appears to be reasonably accurate and the next phase of pumping should proceed.

# 6.0 References

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