Estimating Non-Surveyed Groundwater Use for Texas Regional and State Water Supply Planning

TWDB Contract Agreement 2500012882

Progress Report 3

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Project Goals

1. Better understand how other states, regulators, and organizations assess or project water demand for water use groups that are not monitored or reported and identify best practices that could be applied within the Texas water planning process.
2. Evaluate improved methods for estimating non-surveyed use (NSU) gallons per capita daily (GPCD) demand metrics that incorporate identified best practices and can be applied using available data and reasonable TWDB resources.
3. Test and demonstrate the improved methods by applying them to a case study area.

PROJECT PROGRESS DISCUSSION

Summary

We have made significant advancements in the following areas since our last progress report:

- Development of a supplemental data collection tool (i.e., survey)
- Data collection from TWDB databases and groundwater availability models (GAMs)
- Implementation of the well capacity assessment

The project has received a no-cost extension in order to support the implementation of the data collection survey. The project now concludes on December 4, 2026. A revised project timeline proposed by BEG is provided under separate cover.

Subtask 1. Literature Review & Data Assessment

Status: Aside from the development and distribution of the survey, we consider Subtask 1 functionally **complete**.

The literature review is complete and was discussed in a prior progress report.

Data assessment and collection is largely complete but may continue strictly as required to support our analysis needs in Subtask 2 and 3. We have collected, assessed, and preprocessed data describing:

- Well infrastructure and usage attributes (TWDB databases)
- Hydrostratigraphy and water levels (GAMs and TWDB databases)
- Environmental and climate conditions (various public sources)
- Population, socioeconomics, and public water systems (TWDB and US Census)
- Property values and improvements (county tax records)

TWDB GAMs within the study area have been processed and relevant data extracted to support the analytical well capacity assessment. Two aquifers within the study area are modeled by GAMs, the Edwards-Trinity Plateau aquifer and the Edwards-Balcones Fault Zone aquifer. Both models characterize the same geological formations in some locations. The latest version of the GAMs for these aquifers were run by BEG using the most recently available (2021 desired future condition) planning data inputs. A digital elevation model was used to convert GAM data elevations to depths from land surface for analytical processing.

Key information extracted from GAM runs includes:

- Hydrostratigraphy (i.e., geologic formation top and bottom elevations)
- Aquifer storage properties (i.e., hydraulic conductivity and storage coefficients)
- Projected 2026 water levels
    - Water levels are projected forward from GAM calibrated levels (e.g., 2006 for the Edwards-Trinity Plateau aquifer) using pumping estimates gathered in planning processes
    - Projected water levels are unavailable for the Edwards-Balcones Fault Zone aquifer GAM

Data Collection Survey

The survey was originally classified by the proposal as a component of Subtask 2, but it is discussed here under "data assessment" for the sake of thematic clarity.

The survey is being conducted to gather additional information needed to supplement the data available from the TWDB Groundwater Database (GWDB) and Submitted Drillers Report Database (SDRD). Additional data characterizing non-community public water systems, commercial, institutional, and transient uses is particularly needed. (*See* Subtask 3.) The survey was initially proposed to be conducted only for the eight-county study area. However, in consultation with TWDB, BEG has decided to maximize this opportunity to collect data and will deploy the survey (in cooperation with stakeholder group partners) statewide.

The survey is designed to provide information of general utility, but it is specifically designed to support this and other well capacity and GPCD estimation methods. The Qualtrics survey platform was selected to accommodate a potentially high volume of survey participants across the state. The objective of the anonymous survey is to gather data about NSU well equipment and operation. The survey does *not* ask respondents to provide the daily volume of groundwater pumped. Respondents may not know this value and BEG concluded, in consultation with TWBD, that many respondents may feel uncomfortable providing this value. Therefore, the survey seeks three key pieces of information:

- The production rate of respondent wells (i.e., gallons per minute (GPM))
- The daily production period of respondent wells (i.e., hours per day of operation)
- The horsepower of the well pump

Combining production rate and production period allows for calculation of daily production volume, and thence GPCD, without the need to explicitly ask respondents for this information. Similarly, well pump horsepower data facilitates analytical approaches to calculating production volumes. (*See* Subtask 2.)

While workshopping the survey in November–December 2025 it became evident that many respondents may not know how to find the information required to answer some survey questions. To address this and potentially expand response rates survey content was added to be informative about where to find

basic well information. For example, visual diagram(s) were added to demonstrate where to find well equipment and pump horsepower.

The current iteration of the survey provides guidance to help well owners look for pertinent well details (horsepower, production rate, etc.) and includes the following (summarized) questions:

- What (Texas) county is your groundwater well located in?
- What "use type" does your groundwater well serve?
- Does your well serve this “use type” continuously, or intermittently (e.g., campground or RV park, vacation home, seasonal industry)?
- What is the best estimate for how often this well is used?
- What is the production rate, in gallons per minute, of your groundwater well?
    - How confident are you in the production rate that you provided?
    - Would you like to learn about how to find your well production rate?
        - You can determine the production rate of your well, in gallons per minute, the following ways:
            1. By conducting a "bucket test" to measure how fast your well can fill a container with a known volume of at least 1 gallon (e.g. a 5-gallon bucket). Requirements: A bucket test requires a direct water line that allows you to access your water directly from your well. This water line for the test should come directly from your well, and not from any type of storage tank.
            2. If you have access to your well report from your drilling operator or by using public records. Requirements: A production rate, often shown with the units "gallon per minute or GPM" is often provided if the well was tested after completion. A well test is only useful here if the report indicates that the well was "pumped" to test it. (“Estimated”, “bailed”, or “jetted” well test results are not accurate enough for purposes of this survey.)
- What is the horsepower (HP) of your well pump?
- Is the well's pumping controlled manually or automatically?
    - How is your well automatically controlled? Is it on a timer or “pump saver?
    - How long is the timer on our well set to run? OR
    - You use a pump saver, how many times per day does it run? How many hours per session is the pump running for?
    - On average, how many hours per day is your well actively pumping?
- How would you describe your use of your groundwater?

Timeline Summary: Survey Development and Testing

In October 2025 Dolores van der Kolk, a BEG communication specialist, was brought onto the project to support survey development and distribution. In November 2025, BEG verified that the Qualtrics survey platform is a proper survey platform for the volume of anticipated respondents. Around the same time, BEG workshopped survey questions and started building an initial version of the survey. In a meeting with TWDB in December 2026 the first version of the survey was previewed by TWDB and early feedback from TWDB was provided.

The survey was significantly revised following the December meeting. In January, BEG continued internal discussions to review the survey. Beginning in late January, and over a 3-week-period, the survey was tested by hydrologists from the Jackson School of Geosciences and TWDB personnel. This review generated 34 survey “responses”. A synthesis of survey testing feedback is provided in **Appendix A**.

BEG is reviewing survey feedback and will discuss those results with TWDB at the forthcoming February progress meeting. At this time, BEG anticipates minor revisions to survey language and incorporating at least one additional guidance figure.

Survey Distribution

BEG plans to finalize the survey in early March 2026. Once finalized, BEG will not directly contact well owners to solicit survey responses. Instead, BEG plans to leverage existing groundwater stakeholder organizations for survey distribution. BEG, in consultation with TWDB, will provide stakeholder organizations with a brief document describing the survey and its purpose. Key stakeholder organizations BEG anticipates facilitating survey distribution include:

- Study area groundwater conservation districts (GCDs) (direct BEG contact):
  - Real-Edwards C and R District
  - Headwaters GCD
  - Bandera County River Authority & Groundwater District
  - Cow Creek GCD
  - Blanco-Pedernales GCD
  - Comal Trinity GCD
  - Hays Trinity GCD
  - Barton Springs/Edwards Aquifer CD
  - Blanco-Pedernales GCD
- Hill Country Alliance
- Texas Alliance of Groundwater Districts

Next Steps:

Throughout the survey response period BEG will map responses by GCD or county and will evaluate the need for contacting stakeholder organizations with reminders and/or re-distribution of survey to enhance response rates in lagging areas. BEG anticipates the following timeline for survey distribution and data collection:

- February/March – Compose a brief document describing the survey and its purpose and consult with TWDB on such
- March – Finalize survey content
- March, April, and May – Survey is live and collecting response data
- June – Survey is closed, supporting stakeholder organizations are thanked, and QA/QC of survey results is conducted
- June and July – Survey results are integrated into well capacity and GPCD assessments

Subtask 2. Methodology Development

Status: Subtask 2 is progressing and **ongoing**.

Development of methods and tools for estimating NSU GPCD demand is ongoing. BEG effort for this subtask during this reporting period primarily focused on development and testing of the well capacity assessment. The well capacity assessment is the primary NSU demand estimation method described by the original project proposal. As previously reported, some version of a well capacity assessment is also the chief methodology appearing in the literature review. Preliminary well capacity assessment results and discussion are provided below (*See* Subtask 3.)

Well Capacity Assessment Methodology

In this approach the production capacity of wells serving NSUs is evaluated to better estimate water demand. As previously reported, it is not possible to conduct a full "energy lift method" analysis because energy consumption or other data that characterize pumping periods are generally not available in Texas. Therefore, we are conducting a well capacity assessment to characterize pumping rates (i.e., GPM). Estimating NSU GPCD demand requires additional conditions and assumptions regarding pumping periods. BEG is developing well capacity assessment approaches that fall into two categories: a database approach and an analytical approach.

All well capacity assessments are guided by the premise that well capacity is a function of several interrelated physical processes and properties:

- The storage conditions and transmissivity of the aquifer
- The construction of the well (i.e., well screen design and pump placement)
- The power of the pump

Database Approach

This is the simpler well capacity assessment of the two approaches developed here. It relies exclusively on data found in the Groundwater Database (GWDB) and the Submitted Drillers Report Database (SDRD), both of which are hosted by TWDB. Preliminary results using this method were documented in the prior progress report and are briefly summarized again below (*See* Subtask 3.)

To implement this approach, BEG has constructed a Python script that parses the pipe (|) delimited GWDB and SDRD text files to extract relevant well data for a study area of interest (i.e., a list of Texas counties). Most critically, the script searches for wells that have records of a well test that includes a reported GPM production rate. Only wells with a reported well test type of "pumped" are recorded. Other well test types, such as "bailed" or "jetted", are only estimates of the aquifer's ability to transmit water to the well; they do not account for capacity limitations associated with pump power and are therefore deemed unsuitable for this study.

GPM well capacity aggregated from the databases is grouped by use type, e.g., "domestic", "livestock", "irrigation", etc. Descriptive statistics of database reported GPM well capacity are generated, including the mean GPM for each use type. For all wells that do *not* present a database reported GPM, the mean GPM for that use type is assigned to the well.

Finally, to arrive at daily production volumes, the reported or assigned GPM for each well is multiplied against an assumed pumping period duration. In testing thus far, BEG has applied a conservative daily pumping period of one hour to calculate production volumes.

BEG has explored two possible extensions of this approach:

> *Casing-Based GPM Assignment* – There is a general relationship between well casing and pump power; larger casings can support larger, more powerful pumps. An extension to this approach could bin GPM capacity not only by well use types but further by well casing sizes. E.g., an 8-inch domestic well casing could be assigned a larger GPM capacity than a 4-inch domestic well casing (if the database data supports such assignment). One key limitation of this approach is in the determination of where in the well casing to assign

the pump depth; while the depth of the pump is only stipulated in the databases for some wells. Additionally, many wells report multiple casing diameters, often decreasing in diameter with increasing depth of bore. This approach is not recommended for assessing well capacity across multiple aquifers as the impact of variable aquifer storage conditions and transmissivities on GPM capacity may introduce significant error.

Pumping Period Optimization – BEG has determined that it is theoretically possible to implement a pumping period optimization similar to the one described below in the Analytical Approach using only TWDB databases. To do so would require integrating database records describing well construction, aquifer lithology, and water level observations. Some aquifer characteristics, such as hydraulic conductivity and storage coefficients, would have to be assumed where no pump test record is given. BEG has explored this technique and has concluded that it is not recommended. The heterogeneity of databased aquifer lithology descriptions poses parsing challenges and the number of database records with sufficient data appears small (i.e., zero study area wells in the GWDB and only 193 wells in the SDRD).

Analytical Approach

This is the more complex well capacity assessment of the two approaches developed here. It relies on (a) well data found in the Groundwater Database (GWDB) and the Submitted Drillers Report Database (SDRD) as well as (b) data extracted from GAMs, all of which is hosted by TWDB. Preliminary results using this method are summarized below (*See* Subtask 3.)

In this approach, the ultimate limitation on GPM well capacity occurs where the water level in the pumping well is drawn down to the depth of the submersible pump or the top of the well screen interval. (In the first case, air entering the pump causes the pump to cavitate which may result in damage to or destruction of the pump or well. In the latter case, “waterfalling” may occur which also introduces cavitation risk and other pumping performance concerns.) Analytical solutions for drawdown under pumping are implemented to calculate this limit in accordance with well properties and aquifer characteristics.

Well properties extracted from the GWDB and SDRD for this approach are:

- Well use type (domestic, livestock, etc.)
- Well screen diameter
- Well screen interval (depth of screen top and bottom)
- Pump depth (assigned to screen top depth if unreported)
- Well test (pumped) yield (GPM)
- Well test (pumped) drawdown
- Water level measurement(s)

Aquifer characteristics extracted from the GAMs for this approach are:

- Land surface elevation (sourced from DEM if not provided by GAM)
- Aquifer top and bottom elevation (specific to each geologic formation modeled)
- Horizontal hydraulic conductivity
- Vertical hydraulic conductivity
- Specific storage
- Specific yield
- Water level elevation (2026 projected elevation from 2021 planning period GAM runs)

The following parameters, discussed further below, are user-defined:

- Wire-to-water well efficiency (assumed thus far at 70%)
- Net positive suction head required (assumed thus far at 10 feet)
- Well screen entrance velocity limit (assumed thus far at 0.1 feet / second)
- Well screen open area (assumed thus far at 10%)
- Pumping period limit (assumed thus far at 2 days)

In the first step of this approach, GPM well capacity is limited by the aquifer's ability to transmit water to the well within given well entrance velocity limits. Well screen intervals are integrated with aquifer formation geometries. Wells with screen intervals falling wholly outside the aquifer geometry are discarded and not tested further. Wells with one interval (top or bottom) falling outside the aquifer geometry are adjusted to align with either the top or bottom of the aquifer to account for uncertainty between the GAM and observed drilling. Improvements to the operator parsing legacy (un-delimited) SDRD data is needed to increase screen interval data. The entrance velocity limit to GPM well capacity is calculated from databased screen interval data and the user-defined well entrance velocity and well screen open area.

Next, the GPM well capacity is further constrained by drawdown under pumping. This analytical approach uses a combination of the transient Theis (1935) drawdown/residual (superposition) drawdown solutions, the Hantush (1962) partially penetrating well drawdown solution, and a dynamic operator to capture changes in storage conditions and drawdown as water levels fluctuate (including confined-to-unconfined transition effects). If at any point during the modeled pumping period drawdown at the well would cause the water level to exceed the allowable limit (i.e., the pump depth less the net positive suction head required), that GPM well capacity is considered infeasible.

At this point in the approach, a wide range of GPM well capacities are feasible. The well could be pumped for a very short period at a very high GPM, or for a very long period with a much lower GPM, before exceeding the water level limit at the depth of the pump. Moreover, at this point in the solution, the horsepower (HP) of the pump is not yet considered. GPM, HP, and water levels are all related. In this study their relationship is described as:

$$GPM = \frac{HP \times Well\ Efficiency \times 3960}{Total\ Dynamic\ Head}$$

where: total dynamic head is the sum of the depth of the water level and drawdown under pumping.

To further constrain GPM well capacity, we introduce a stipulated HP for each well. To accomplish this, we calculate HP for each well (by rearranging the above equation and solving for HP) where sufficient data is available from the GWDB and SDRD. We bin these results by use type and for wells with insufficient data to calculate HP we assign the mean value for that use type calculated from the databases. The assigned HP is given as at least ½ HP. (In subsequent experiments this minimum was increased to 1 HP and 1 ½ HP to observe the effect on results.)

At this point in the approach the GPM well capacity is constrained by hydrologic processes, but a wide range of GPM capacities are still possible pursuant to the pumping period. To address this, BEG developed an optimization solution that maximizes the total production volume that honors the above hydrologic constraints over an infinite time horizon. ***In essence, this optimization solution considers pumping and rest periods to solve for the maximum production rate that can be sustained indefinitely at the given (2026) water level. We consider this an appropriate approach for determining a practical "well***

capacity". Pumping and rest periods tested for optimization are user-defined and in testing thus far we limit pumping to two days and resting to five days as we assume that the average well operator does not have sufficient storage to meet demand for more than one week.

BEG is currently workshopping the following adjustments and enhancements to this methodology:

> Casing-Based Parameterization – Some parameter assignments, such as GPM and HP, could be informed by well casing data in a manner similar to the one described above for the Database Approach.
>
> Optimization Adjustments – The optimization solution currently fails to converge (i.e., provide a solution) for the majority of wells tested (*See* Subtask 3.) BEG is conducting sensitivity analysis and other testing to determine if and how the optimization solution could be adjusted, while continuing to honor hydrologic constraints, to enhance model performance.

Next Steps:

BEG is considering how certain use types, such as livestock wells, could be incorporated into TWDB calculations for county-specific GPCD estimates. Additionally, methodological work expected includes:

- Finalize well capacity Database Approach
- Complete development and testing of well capacity Analytical Approach
  - Improve parsing of legacy SDRD data to expand well screen data
- Circulate well capacity approach scripts to TWDB for review and additional testing

Subtask 3. Case Study Evaluation

Status: Subtask 3 has been initiated and is **ongoing**.

In consultation with TWDB, a study area has been selected for the case study and consists of: Bandera, Blanco, Comal, Edwards, Hays, Kendall, Kerr, and Real Counties. For reference, TWDB has historically assumed rural domestic water use at a range of 95-105 GPCD.

BEG is developing and testing the methodologies described in Subtask 2 using data collected for the study area. Preliminary study area findings (subject to change) are provided for each methodological approach for reference and discussion. Thus far, BEG study area testing has been limited to the Edwards-Trinity Plateau aquifer.

BEG has concerns about the sufficiency of data for analysis of certain use types; such as industrial, commercial, and institutional. Domestic and livestock wells appear to be the dominant use types with sufficient database entries. Available well records for the study area are informative for pending study results:

- 28,392 total well records in the databases (GWDB = 5,155 and SDRD = 23,237)
  - 72% (20,417) domestic wells
    - 737 "pumped" well test data
  - 6% (1,820) livestock wells
    - 121 "pumped" well test data
  - < 1% (122) industrial wells

    - 12 “pumped” well test data
  - < 1% (29) commercial wells
    - 1 “pumped” well test data
  - < 1% (8) rig supply wells
    - 0 “pumped” well test data
  - < 1% (7) institutional wells
    - 0 “pumped” well test data
  - 21% (5,989) other: monitoring, test well, unknown, unused, plugged, soil boring, etc.

Database Approach (previously reported)

The descriptive statistics for the distribution of GPM well capacity for domestic and livestock well “pumped” testing are markedly similar (**Figure 1**). The mean GPM capacity of domestic wells is 11.43 GPM with livestock wells at 15.52 GPM and the median for both well types is 10 GPM. However, the distribution for domestic wells is significantly broader than livestock wells and includes more outliers; with a maximum value reported at 160 GPM.

Using the Database Approach and considering only domestic wells, **we arrive at 200 GPCD** if we assume:

- All wells are pumped for 1 hour per day;
- All wells are pumped at the median rate of 10 GPM; and;
- Each domestic well serves 3 persons (150 GPCD at 4 persons served).

Analytical Approach

7,314 wells (26% of total wells) present sufficient well screen data for analysis. (Improvements to SDRD legacy entry parsing may increase this value.)

Only 180 wells (< 1% of total wells) present sufficient data in both well testing and water level measurements to calculate HP for the well and the use type class; 112 domestic, 41 livestock, 26 public supply, and 1 irrigation. One irrigation well is considered an insufficient sample size for use type class HP assignment so this use type is not considered further at this time. Similarly, there are no wells with sufficient data available to determine use type HP assignments for the following types and they are not considered further at this time: industrial, commercial, rig supply, and institutional. HP assignments by use type class were derived as:

- Domestic = 0.5 HP
- Livestock = 0.5 HP
- Public Supply = 8.5 HP

5,877 wells (21% of total wells) were found to overlie the Edwards-Trinity Plateau aquifer and were joined with GAM data. These wells were analyzed using the full Analytical Approach. The descriptive statistics for the distribution of GPM well capacity for domestic and livestock wells determined using the Analytical Approach are again markedly similar (**Figure 2**).

Key results for domestic and livestock wells are summarized as:

- Domestic Wells
  - 1,602 wells (31% of fully tested domestic wells) achieved optimization convergence
  - 156 GPM = mean maximum infinitely sustainable well capacity
  - 8.39 GPM = median maximum infinitely sustainable well capacity
- Livestock Wells

- 81 wells (16% of fully tested livestock wells) achieved optimization convergence
- 159 GPM = mean maximum infinitely sustainable well capacity
- 12.77 GPM = median maximum infinitely sustainable well capacity

Note that if we apply the median optimized GPM well capacity and apply the same assumptions, we arrive at similar GPCD results as seen in the Database Approach. However, **the Database Approach also calculates the daily gallon production if the well is pumped for the maximum sustainable duration over an infinite time horizon. This is what could be considered the "capacity" of use for the well**. If we apply the median optimized GPM, the Analytical Approach finds that the averaged daily production for domestic wells is 12,014 gallons per day. **This equates to 4,000/3,000 GPCD if the well serves three/four persons**.

Next Steps:

- Continue study area testing with methods developed and finalized in Subtask 2
- Integrate survey results with methods parameterization when available

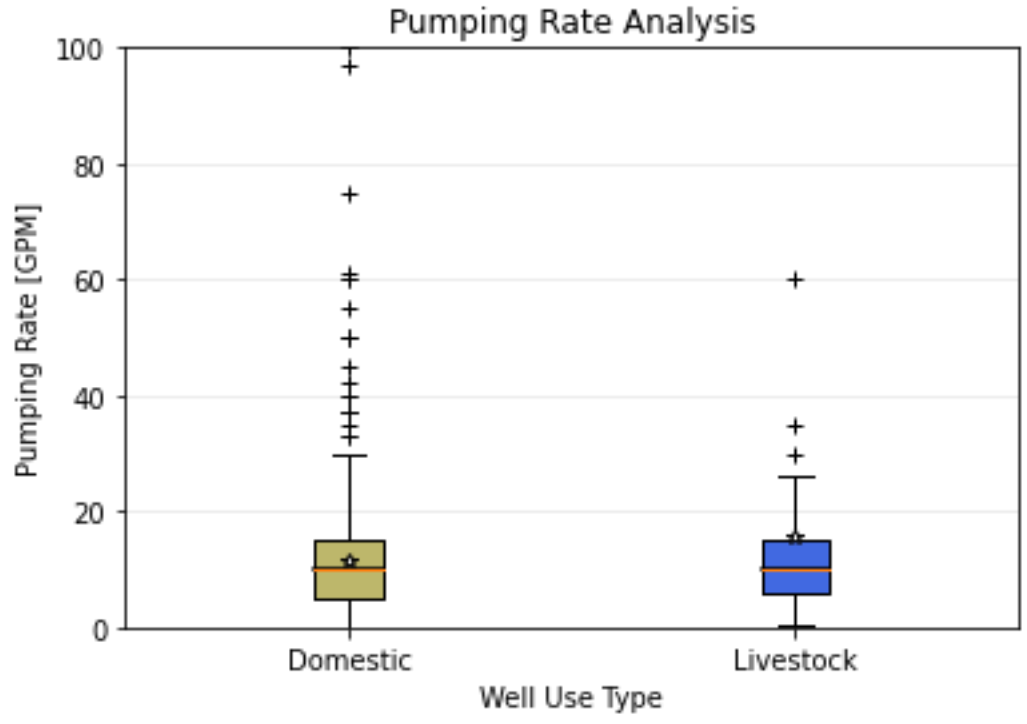

Figure 1: Descriptive statistics in the form of box plots for the GPM well capacity of domestic and livestock wells using the Database Approach

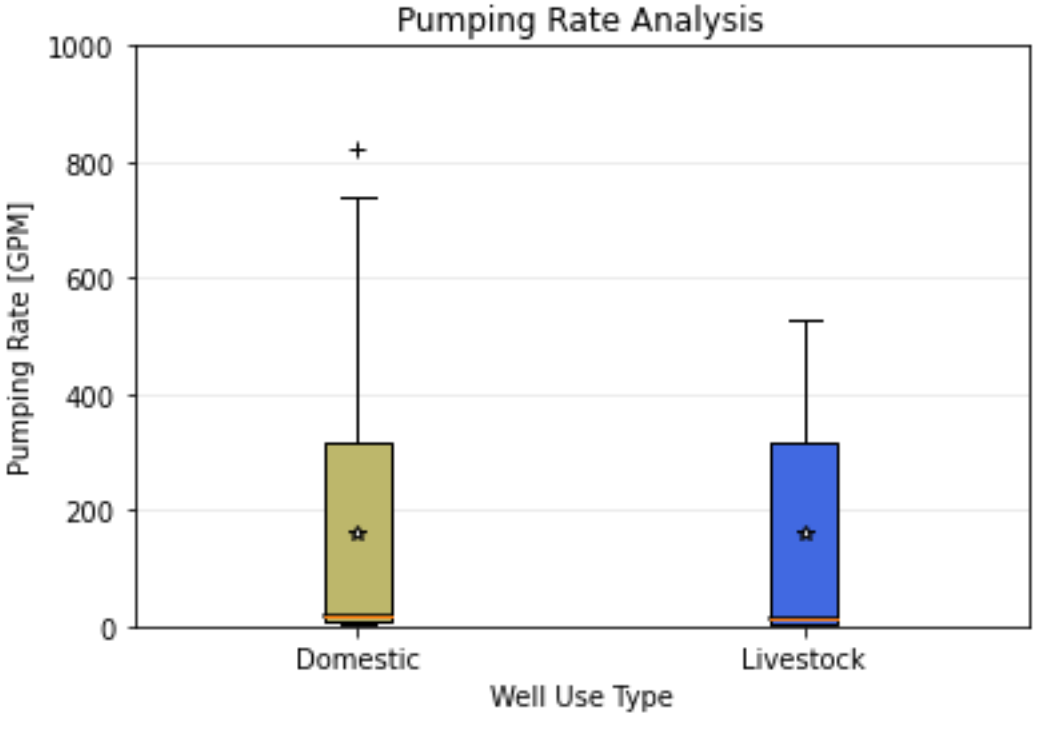

Figure 2: Descriptive statistics in the form of box plots for the GPM well capacity of domestic and livestock wells using the Analytical Approach