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

TWDB Contract Agreement 2500012882

Progress Report 2

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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:

- Collection and assessment of key source data
- Supplemental data collection considerations
- Evaluation of a GAM-based methodology (rejected)
- Development and implementation of a well capacity assessment
- Evaluation and development of a property tax record-based demand adjustment
- Adoption of an eight-county study area and commencement of the case study

Subtask 1. Literature Review & Data Assessment

Status: We consider Subtask 1 essentially **complete**.

The literature review is complete and was discussed in our prior progress report. Additional literature has been added addressing methods for tax record-based demand adjustments (*see* Appendix A).

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 (counties)

With the literature review and data assessment essentially complete and methodology development ongoing, we have begun refining our ideas on what data might be collected to best support NSU demand estimations. We believe that a survey or similar data collection instrument could be designed with questions that are perceived as not being overly invasive to respondents while also providing useful insights. For example: How many hours per day do you run your groundwater well? Additional discussion with TWDB is needed on potential survey development and deployment.

Next Steps:
- Collect and assess additional data (as needed)
- Discuss, develop, and deploy survey or similar data collection instrument (as coordinated)

Subtask 2. Methodology Development

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

Development of methods and tools for estimating NSU GPCD demand is ongoing. Three approaches have been developed the furthest and are briefly outlined below. Thus far we have focused on domestic and livestock wells to develop and test our approaches with only limited resources applied for consideration of commercial, industrial, and transient NSUs.

Groundwater Availability Model (GAM) Assistance

In this approach the GAMs would essentially be "reverse engineered" to provide insights on macro-scale changes in water use. In the typical usage, an input file is provided to the GAMs that describes expected pumping and the GAMs output data describing how water levels change over time under the given pumping. Here, one version of this GAM assistance method would be to adjust the pumping file inputs such that GAM projected changes in water levels match observed water levels in monitoring wells. The difference between permitted and surveyed groundwater use (assumed correct and comprehensive) and the volume produced under the pumping inputs that generate water levels which match observations would be considered the NSU demand.

We developed this method far enough to understand its potential for estimating NSU demand and how plausible it would be for use in this way. We collected preliminary data and ran initial testing. Ultimately, this method was rejected for further development after consultation with TWDB on the grounds that it would require too many resources for ongoing, statewide use.

Well Capacity Assessment

This is the primary NSU demand estimation method as the project was originally proposed. It is also, for the most part, the chief methodology appearing in the literature review. In this approach, the production capacity of wells serving NSUs is evaluated to better estimate water demand. Ideally, well capacity (expressed in gallons per minute (GPM) of production capacity) would be combined with energy consumption and other data to conduct a full "energy lift method" analysis (as described in our prior report and literature review). However, energy consumption data is generally not available in Texas. Therefore, we cannot conduct a full energy lift method analysis. Instead, we are conducting a well capacity assessment. The well capacity assessment follows the same methodology as the energy lift method but omits the final step of integrating energy consumption data. The primary limitation of the well capacity assessment when compared to the energy lift method is that it cannot provide a volume of use, only a production rate (i.e., GPM). Therefore, application of the well capacity method to estimate NSU GPCD demand requires prescribing daily pumping time. In our current approach, a range of NSU GPCD demand is generated in accordance with a prescribed range of potential pumping times.

We are currently developing a well capacity assessment tool in a Python environment. Our goal is to develop this tool in such a way that it ingests a limited array of user-specified inputs and readily available datasets to generate desired results. Significant expertise in Python is not required, simply the ability to run the tool.

Additionally, to provide multiple perspectives on NSU GPCD demand, we are developing the well capacity assessment tool in a step-wise fashion with escalating complexity and data requirements. At each step the tool provides NSU GPCD estimates (intermediary data products) using differing assumptions, data inputs, and calculations. In this way, each use of the tool can be customized to the given TWDB needs and interests of the moment. The step-wise analysis in its current development structure includes the following elements, listed in order of increasing complexity:

(1) Database Capacity

In this step the tool parses the TWDB Groundwater Database (GWDB) and Submitted Drillers Report Database (SDRD) to locate well information within the given study area. Importantly, this tool is coded in such a way that it is able to retrieve data stored in the SDRD in the legacy format and therefore maximizes the number of wells considered. Well test data, where available, is assigned to relevant wells. Only well tests that report the testing type as “pumped” are considered. Other test types, such as “jetted” and “bailer”, do not adequately describe the well capacity when the well is ultimately completed but rather describe the response of the aquifer testing (which combines with well infrastructure characteristics like pump size to determine the actual pumping capacity of the well). GPCD demand estimates for each well are generated from the database capacity data and user-specified inputs. Only data from the GWDB and SDRD and the user-specified inputs are required for this step.

(2) Database Filling

In this step the tool generates descriptive statistics (mean, median, etc.) for the pumped well test data assembled in the prior step and organizes it by use type (e.g., domestic, livestock, etc.) These statistics are then used to assign well capacity values (GPM) for wells of the same use type which do not present well test data in the databases. GPCD demand estimates are generated for each well at the stipulated/calculated well capacity and the user-specified pumping period. Essentially, this step answers questions such as: What would demand be if all known domestic wells in the study area produced at the mean capacity? This approach provides GPCD insights where county-based estimates of NSU populations are employed. No additional datasets are required for this step.

(3) Limited Capacity Calculation

In this step the tool maximizes the utility of the GWDB and SDRD to calculate plausible and likely well capacity values for wells that do not present well test data using *only* data present in the databases. This is the final step of complexity before additional datasets are required. In this approach, additional database data (e.g., water level measures, well casing characteristics, pump depth, etc.) are applied to calculate guidance parameters (water-horsepower, pump depth, simplified drawdown under pumping, etc.) that are then used to make the most informed well capacity (in GPM) calculations possible with the given data availability. The outputs of this step are intended to maximize the balance between the most comprehensive analysis possible with the least input data required.

(4) Full Capacity Calculation

This step represents the most comprehensive well capacity assessment considered by the current tool development. This step requires joining well data compiled from the GWDB and SDRD with data extracted from the GAMs. Required GAM data is relatively limited and constrained to the characterizing hydrogeology: depths of water-bearing formation tops/bottoms, water levels, and storage coefficients (i.e., specific yield and storativity). Requisite GAM data can usually be found in either the associated GAM geodatabase or “model grid”. Water level data is required but can be sourced from either the GAMs or the databases. Well infrastructure, aquifer characteristics, water level data, and guidance parameters generated in the prior step are integrated and applied to unsteady state, condition-dependent drawdown under pumping solutions to determine the most likely well capacity (in GPM). Calculated and known (database reported) well capacity values are then used to generate NSU GPCD demand estimates.

The well capacity assessment tool is currently under development and is not yet completed. However, much of the analytical architecture of the well capacity assessment has been established and tested. The development progress of key components of the well capacity assessment tool is briefly described below.

Database Extraction – This component of the tool is designed to parse data from a full download of the pipe delimited text files for both the GWDB and the SDRD. Importantly, it is designed to support parsing data from the legacy SDRD format. Additionally, it takes highly variable data (such as pump test results) and renders it into a format that can be used in calculations. This component is effectively complete but small modifications continue as needed to further refine the quality of data results.

Database Statistics and Assignments – This component assesses well capacity data present in the databases, calculates statistics, and makes simple capacity assignments in order to accomplish the Database Filling process described above. This component is complete and is ready for joining with other components.

Limited Capacity Calculation – This component is still under development and incomplete. Our focus right now is the logical processing of the available data which determines the best approach for calculating well capacity exclusively from data available in the databases. We may seek consultation with TWDB to ensure that our implementation logic is in alignment with TWDB needs and expectations.

Full Capacity Calculation – This component is mostly complete but requires additional modifications for operability. The core framework is established; analytical methods for adaptive drawdown under pumping solutions, residual drawdown, pump power scaling, water horsepower, etc. have been successfully developed and tested. Additional development is required to ensure that the core framework will function correctly at any given study area. For example, the number of water-bearing formations varies from place to place.

Property Tax Record Adjusted Demand

Upon consultation with TWDB, we have elected to explore methods that leverage publicly available property tax records to help estimate NSU demand. Our literature review revealed five principal methods for using property tax data to estimate water use. All five methods and key literature are described in Appendix A.

Our preliminary analysis of study area property tax data indicates some data that may be available in other jurisdictions are not available in Texas. For example, Texas records do not appear to contain data describing so called “consumptive elements” (e.g., number of bedrooms and bathrooms) present at the property. Lacking these and other data precludes us from utilizing some property tax-based methods. Still other methods require the use of additional datasets (e.g., satellite imagery) that are not plausible within the scope and objectives of this project.

The approach we are currently developing utilizes property valuation, lot/living area extent, and pool and greenhouse data from the property tax records and other data to estimate both indoor and outdoor water demand. The exact methodology is still under development but generally consists of the following considerations:

- Estimating occupants from living space area tax record data and census data
- Determining outdoor irrigation area from lot space and living space
- Generating indoor water use from occupancy and baselines (e.g., 55 gal / person)
- Estimating landscape irrigation demand from baseline data (e.g., precipitation, evapotranspiration, etc.) and an irrigation intensity multiplier generated from lot size and valuation
- Calculating swimming pool and greenhouse water demand from baselines

Next Steps:

- Complete testing and development of well capacity assessment method/tool
- Complete testing and development of property tax record demand methods
- Integrate well capacity and property tax record methods
- Conduct commercial, industrial, and transient use analyses and methods development

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.

To support methodology development described in Subtask 2 we are conducting our testing using data collected for the study area. In this sense, the earliest components of the case study have begun and are ongoing. Some preliminary study area findings (subject to change) are provided for reference and discussion.

> There are a total of 28,392 wells in the study area according to the currently implemented iteration of the GWDB (5,155) and SDRD (23,237) records.
>
> 72% (20,417) of study area wells are domestic wells. Other use types of interest to this study present far fewer wells: livestock 6% (1,820), industrial < 1% (122), commercial < 1% (29), rig supply < 1% (8), and institution < 1% (7).

On average, over 800 new domestic wells are completed in the study area annually during the period 2003-2024. The number of new domestic wells completed in the study area peaked in the 2004-2007 period (at a maximum of 1,398 in 2006) with particularly large numbers of wells completed in Comal, Hays, and Kendall counties during the same period (**Figure 1**).

80% (16,372) of domestic wells present some form of GPM well test data in the databases. However, only 4.5% (737) of domestic wells present a "pumped" well test type. Similarly, 46% (833) of livestock wells present GPM well test data but only 14.5% (121) present "pumped" test data.

The descriptive statistics for the distribution of GPM well capacity for domestic and livestock well "pumped" testing are markedly similar (**Figure 2**). 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.

TWDB has historically assumed rural domestic water use at approximately 100 GPCD (at a range of 95-105 GPM).

According to the databased "pumped" domestic well test data, we arrive at 200 GPCD if we assume: (a) all wells are pumped for 1 hour per day, (b) all wells are pumped at the median rate of 10 GPM, and (c) each domestic well serves 3 persons. Similarly, we arrive at 229 GPCD if we assume all wells pump at the mean rate of 11.43 GPM.

Alternatively, we also arrive at 229 GPCD if we assume: (a) all wells are pumped for 1 hour per day, (b) each well pumps at the recorded rate, and (c) each well serves 3 persons where the sum of all gallons produced is divided by the sum of all persons served. The descriptive statistics GPCD demand calculated for each well (**Figure 3**) closely resemble those of the GPM well capacity, as GPM is the only true variable considered.

Next Steps:

- Continue study area testing with methods developed in Subtask 2

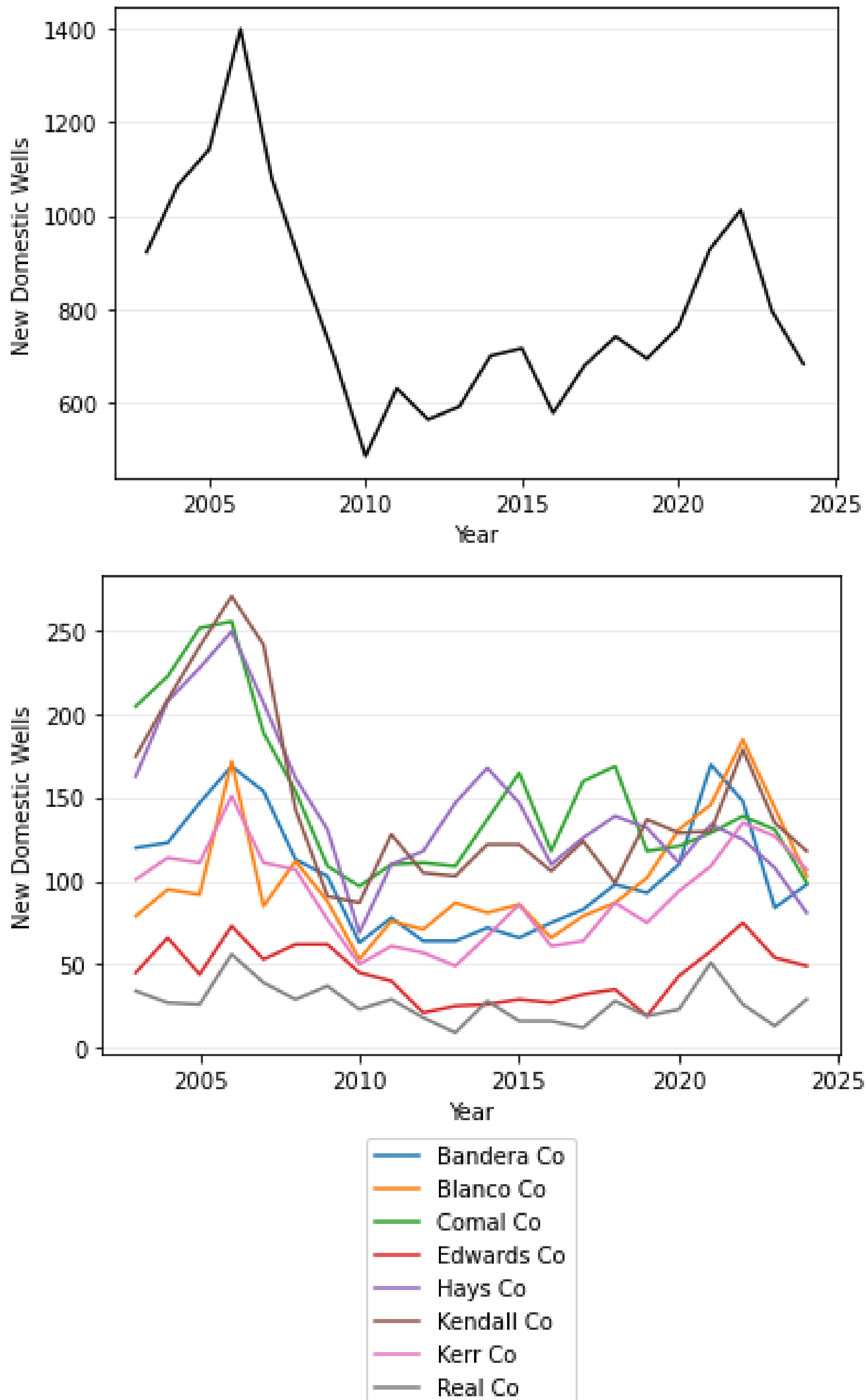

Figure 1: New domestic groundwater wells in the study area

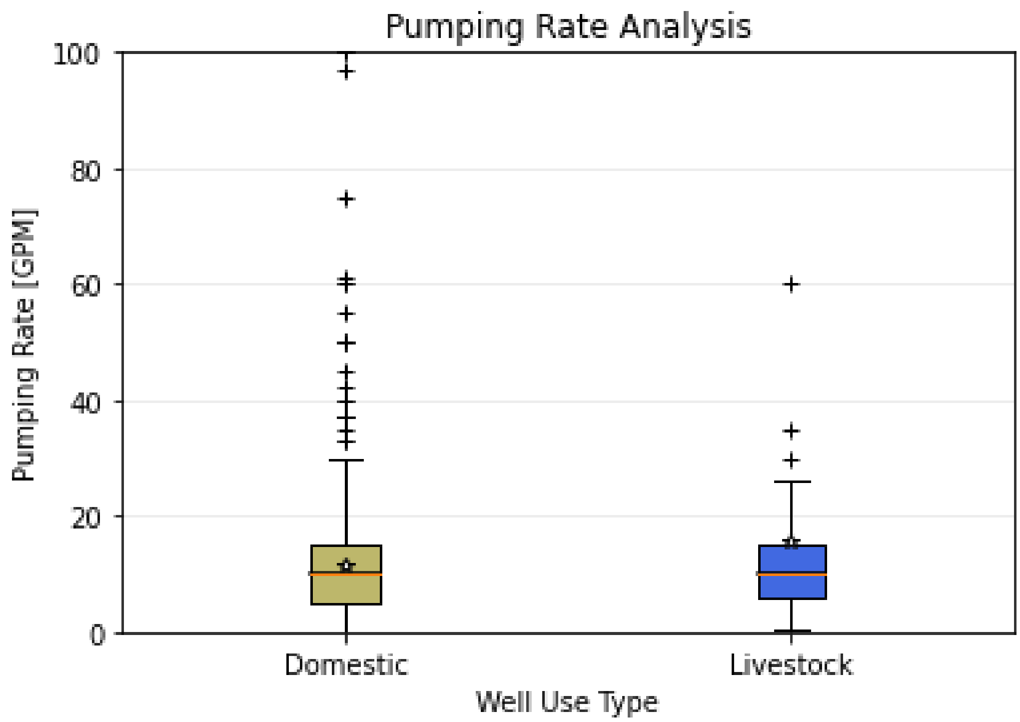

Figure 2: Descriptive statistics in the form of box plots for the GPM well capacity of domestic and livestock wells with "pumped" well test data

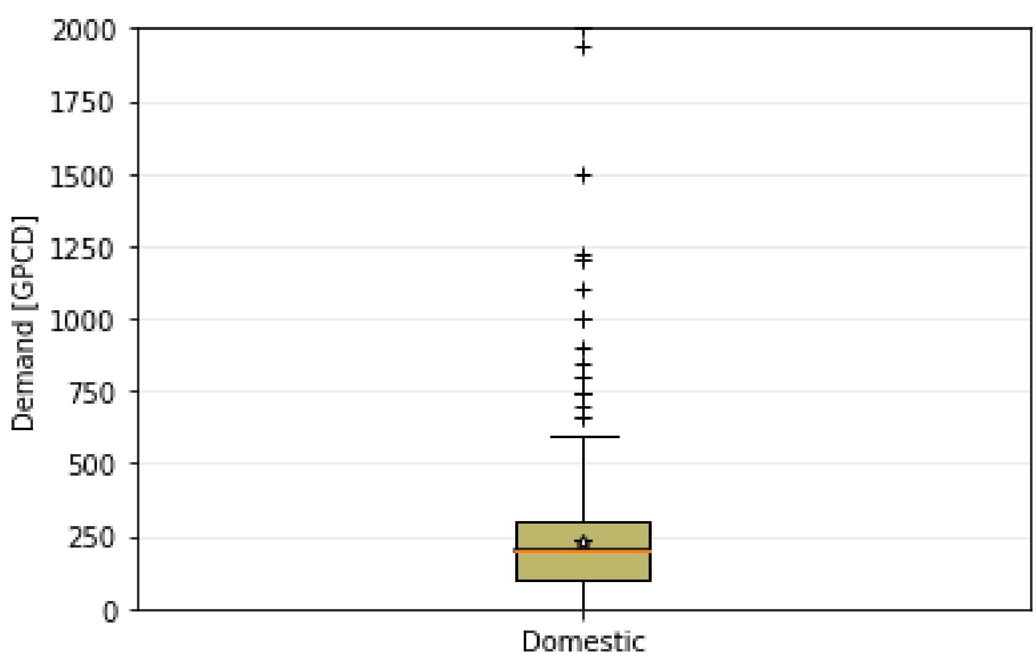

Figure 3: Descriptive statistics in the form of a box plot of GPCD demand derived from domestic wells with "pumped" well test data

APPENDIX A

Method 1: Consumption Elements (CE) + Water Use Index (WUI) Methodology

Overview

The CE + WUI methodology estimates groundwater consumption for Non-Surveyed Users (NSUs) by building consumption from observable property components rather than borrowing inappropriate baselines. The method integrates well capacity constraints and uses property tax data for tailored adjustments.

Step 1: Inventory Consumption Elements (CE)

Goal: Arrive at an estimated Gallons Per Day rate by summing component water uses.

- **Indoor Elements**:
  - Toilets, showers, faucets: Inferred from bathroom/bedroom count
  - Appliances: Based on building size and property value
  - Baseline rates: 10.1 GPD per person for faucets (3 GPD bathroom + 7 GPD kitchen) - example rate, prioritize local/regional data when available
  - Occupancy: Estimate from average household size data or property characteristics (bedrooms, building size) for per-person calculations.
- **Outdoor/Amenity Elements**: From County Appraisal District (CAD) Records:
  - Irrigated areas: Lot size × evapotranspiration rates × crop coefficients
  - Swimming pools: Daily evaporation + maintenance based on surface area
  - Calculation method: Climate-based ET approach for landscape water requirements
- **Commercial/Agricultural Elements** (when applicable):
  - Industry-specific coefficients per USGS methods (gallons per employee, per livestock)

Step 2: Calculate Water Use Index (WUI)

Goal: Adjusts consumption sum based on overall property characteristics.

WUI Formula: WUI = (w_1 × Std Value) + (w_2 × Std LotSize) + (w_3× Std BuildingSize) + (w_4 × Std Amenities)

Standardization Process (Z-Score Method):

- Std Value = (Property Value - Mean Property Value) / StdDev Property Value
- Std LotSize = (Lot Size - Mean Lot Size) / StdDev Lot Size
- Std BuildingSize = (Building Size - Mean Building Size) / StdDev Building Size
- Std Amenities = (Amenities Score - Mean Amenities) / StdDev Amenities

Example: Property worth $15K/acre vs. population mean $8K/acre, StdDev $4K/acre: Std Value = (15,000 - 8,000) / 4,000 = 1.75 (1.75 standard deviations above average)

Final Normalization**:** Adjust WUI so average across all NSU properties = 1.0

Weight Assignment Methods:

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Equal Weights (recommended starting point): $w_1 = w_2 = w_3 = w_4 = 0.25$

- Prevents initial bias when lacking direct evidence for specific weight values
- Provides transparent baseline for comparison

Literature-Informed Relative Importance: Literature shows property value, lot size, and amenities are important water use determinants, but does not provide direct numerical weights for composite indices.

- Approach: Use literature to justify relative ranking rather than exact values:
  - Property value: Consistently strong predictor across studies
  - Lot size: Critical for outdoor/irrigation use (especially rural contexts)
  - Building size: Moderate predictor for indoor use
  - Amenities: Important but may overlap with property value

Context-Adjusted Weights: For NSU rural properties, lot size may warrant higher emphasis due to irrigation demands.

- Example justified adjustment:
  - $w_2 = 0.35$ (lot size - higher weight for rural irrigation context)
  - $w_1 = 0.30$ (property value - reduced because market value incorporates many non-water-use factors, while physical land features have more direct impact on consumption)
  - $w_3 = 0.25$ (building size - standard importance)
  - $w_4 = 0.10$ (amenities - lower to avoid double-counting with value)

Note: No literature provides exact weight values for NSU contexts. Weights can be justified by relative importance reasoning and tested through sensitivity analysis.

Step 3: Final Calculation

1. **Sum CEs:** Preliminary Daily Use = Σ(Indoor + Outdoor + Amenity Elements)
2. **Apply WUI:** Adjusted Daily Use = Preliminary Use × WUI
3. **Capacity Check:** Final Use = MIN(Adjusted Use, Well Capacity × Daily Hours)

Example:

- CE Sum: 150 GPD, WUI: 1.4, Well: 20 GPM
- Adjusted: 150 × 1.4 = 210 GPD
- Capacity: 20 GPM × 20 hours (assumed pumping time) = 24,000 GPD (not constrained)
- **Final:** 210 GPD

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Method 2: Amenities-Based Adjustment (Using External Baselines with Value-Informed Irrigation Caps)

Overview
This method identifies specific water-intensive amenities (e.g., swimming pools, large irrigated areas from tax records) and applies fixed adjustments (e.g., add X GPD for a pool) to a baseline.

Scenario: Vacation rental with a pool and large lawn

- Type: Residential (Vacation Rental)
- Key Features: Swimming Pool present; Large lot (1.5 acres, implying potential for significant irrigation).

Step 1: Define baseline consumption rate

Goal: Establish a baseline GPD/GPCD for typical non-amenity use.

Method: Borrow a standard rate from external data, acknowledging its limitations for NSUs.

Derivation:

- External Baseline GPCD: Assume 85 GPCD based on nearby metered residential areas (e.g., from TWDB data if available, though applicability to NSUs is a known limitation)
- Estimated Occupancy: Assume 4 people based on property size (e.g., 4 bedrooms) or rental patterns

Step 2: Identify amenities and quantify adjustment values

Goal: Determine the additional GPD contributed by specific amenities on the property.

Method: Identify amenities from available data and estimate their water use based on literature, engineering estimates, or local data (Potter, Tremaine, and Banner, 2022; PNNL, 2010).

- **Swimming Pool:** Based on assumed average evaporation (e.g., 0.5 inches/day) and maintenance needs (e.g., backwashing frequency). For an average-sized pool, this might be calculated as: ~343 GPD (total for evaporation + backwash).
- **Irrigated Landscape:**
  - Climate-based ET approach, potentially using a simple water budget based on effective precipitation and reference ET, adjusted by a crop coefficient
    - Let's assume 50% of the 1.5-acre lot (0.75 acres or 32,670 sq ft) is irrigated lawn, needing a net average of 0.1 inches of irrigation per day (after accounting for effective rain) in this climate, according to the Pacific Northwest National Laboratory
      - 32670 sq ft × (0.1 inches/day ÷12 inches) × 7.48 gal/cubic ft = 2030 GPD
- **Other Amenities (e.g., extra bathrooms):** Let's say property has 3 bathrooms (above standard 2).

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- Quantification: Assign an estimated additional GPD per extra bathroom, based on fixture use rates (e.g., +50 GPD per extra bathroom). Total: 50 GPD.

Step 3: Identify amenities and quantify adjustment values

- Sum the baseline and amenity adjustments and add baseline GPD to the sum of amenity adjustment GPDs.
- Estimated Daily GPD = Baseline GPD + Pool GPD + Irrigation GPD + Extra Bath GPD Total Estimated GPD = 340 GPD + 343 GPD + 2030 GPD + 50 GPD = 2763 GPD

Step 4: Compare with well capacity (as constraint)

- Ensure the estimated demand is physically plausible based on well capabilities.
- Well Capacity: Assume 20 GPM Assumed pumping duration = 20 hrs Max Daily Production: 20 GPM × 60 min/hr × 20 hr/day = 24000 GPD
- Compare with well capacity: 2,763 GPD (Estimated) < 24,000 GPD (Max Capacity) – Demand is below capacity
- Estimated GPCD = 2763/4 occupants = 691 GPCD

Limitations

- **Baseline Problem:** Typically starts with an assumed baseline GPCD or GPD before adding adjustments for amenities. The issue of lacking a defensible NSU baseline remains
- **Determining Adjustment Values:** Quantifying the exact GPD associated with each amenity (evaporation from pools, irrigation needs) still requires estimation and potentially context-specific data
- **Incomplete Picture:** Focusing solely on amenities might overlook other important drivers of consumption (like the overall property value or lot size beyond the pool area)

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Method 3: Regression-Based Methods (e.g., Multiple Linear Regression - MLR)

Potential:

- MLR could establish direct relationships between predictors (like property value, lot size, occupancy, well capacity) and a dependent variable representing water use
- Coefficients quantify the impact of each factor, providing insights into the drivers of consumption
- If a reliable proxy for daily water use could be derived (e.g., from landscape demand models plus indoor estimates), MLR could potentially offer a data-driven prediction model.

Limitations

- Requires a Dependent Variable: The fundamental limitation is the absence of a direct, quantifiable dependent variable (actual water use) for NSUs. Cannot perform regression without something to regress against
- Proxy Challenges: While proxies for water use (like estimated landscape demand or assumed pumping hours) can be constructed, they introduce assumptions and potential inaccuracies that regression alone cannot fully resolve
- Model Fit Issues: Without robust observed data, evaluating model fit and assessing the reliability of coefficients becomes highly speculative

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Method 4: Hierarchical Linear Modeling (HLM) / Multilevel Modeling (MLM)

Potential:

- HLM is designed for nested data structures, such as individual properties nested within geographic areas (e.g., counties, watersheds). It allows for the simultaneous study of relationships within and across these levels
- It can model how relationships between individual factors (e.g., property value) and water use might vary across different geographic groups
- HLM addresses issues of non-independence of observations within groups, which can bias standard regression results

Limitations:

- Requires a Dependent Variable: Like standard regression, HLM fundamentally requires a reliable dependent variable representing water use at the lowest level (individual properties/wells). This data is unavailable for NSUs
- Data Structure Assumptions**:** Requires a clearly defined hierarchical structure and sufficient data points at each level (individual well, county/region, aquifer) to achieve reliable estimates

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Method 5: Tiered Adjustment Methods (Using External Baselines)

Potential:

- This method categorizes properties into tiers (e.g., low, medium, high-water users based on basic property characteristics) and assigns a baseline consumption rate (like a GPCD) to each tier
- They are simpler to implement than regression or HLM

Limitations:

- No Defensible NSU Baseline: The primary limitation is the difficulty in establishing a truly defensible, externally validated baseline GPCD or GPD value for NSUs. NSUs are unmetered, meaning actual consumption rates are unknown. Borrowing GPCD values from metered municipal users is problematic due to differences in behaviors, property types, and lack of conservation incentives
- Context Transferability: A GPCD from one region or population group may not apply to NSUs in a different area or with different property characteristics. Most literature focus on urban residential regions
- Lack of Granularity: Simple tiers may not capture the nuances of water use within each tier

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Key Literature Support

Almeida, A., & Pinho, E. (2021). Methodology for estimating energy and water consumption patterns in university buildings: case study, Federal University of Roraima (UFRR).

- **Contribution:** Provides the foundational Consumption Elements (CE) approach for estimating water use in the absence of measured data by summing consumption from identified fixtures, areas, and processes. Introduces the concept of correction factors based on building characteristics. This aligns with building NSU estimates from their component parts.

Grespan, A., Garcia, J., Brikalski, M. P., Henning, E., & Kalbusch, A. (2022). Assessment of water consumption in households using statistical analysis and regression trees.

- **Contribution:** Empirically confirms that building characteristics (like age, type, number of bathrooms, presence of a swimming pool) and socioeconomic factors are significant drivers of household water consumption. This reinforces the justification for including these variables in the Water Use Index (WUI).

Chang, J., Lade, C., & Jago, M. (2017). Determinants of single family residential water use across scales in four western US cities.

- **Contribution:** Identified tax assessed value and building age as main determinants of residential water use, supporting the inclusion of property value as a key component of the WUI. Confirms the correlation between property characteristics and water consumption.

Potter, L. B., Tremaine, D. M., & Banner, J. L. (2022). Predictors of Variations in Residential Water Consumption in Central Texas. Water, 14(11), 1804.

- **Contribution:** Confirmed residential property value and presence of swimming pools as strong predictors of variations in water consumption. This provides direct support for including these key attributes within the WUI.

PNNL (2010). Guidelines for Estimating Unmetered Landscaping Water Use.

- **Contribution:** Provides methodological guidance for calculating outdoor landscape water requirements based on the evapotranspiration (ET) approach, directly supporting the methodology for Outdoor Consumption Elements.

USGS (1982-2022). Water Use in the United States, various publications (e.g., Chapters 11A, 11B).

- **Contribution:** Outlines established methods for estimating water use categories like Commercial/Institutional (e.g., gallons per employee, per square foot) and Agricultural (e.g., gallons per head of livestock, per acre irrigated) using coefficient-based approaches, supporting the Commercial/Agricultural Consumption Elements.