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Sensitivity Analysis of Using Municipal Boundaries as a Proxy for Service Area Boundaries When Calculating Water Affordability Metrics

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CONTENTS

SUMMARY

Water is essential for life, and yet one of the nation's most pressing water challenges has become ensuring that water services are affordable for households and communities. While there has been growing attention and concern around affordable water services, the actual scale of the problem remains poorly understood, in part because of the lack of data availability. The Nicholas Institute's Water Affordability Dashboard was developed to provide several affordability metrics pulling together publicly available data from different sources: census data, rates data, and digital service area boundaries. As of January 2022, the dashboard provided affordability metrics for over 3,000 utilities located within 10 states, showing that between a tenth to a third of households struggle with affording water services. The ability to understand affordability challenges in other states is limited in states without digital service area boundaries.

Digital service area boundaries are used to identify which communities are served by drinking water and wastewater utilities. A recent inventory by McDonald et al. (2022) shows that over half of the states do not have digital water service area boundaries. This study sought to determine if municipal boundaries could be used as a proxy for service area boundaries when calculating water affordability metrics. We explored several proxy (substitute) geographical boundaries by using different methods to (1) identify municipalities served by water service providers, (2) obtain the digital proxy boundaries (i.e., state provided municipal boundaries or nationally available census places), and (3) account for "outside" service areas for utilities for utilities that charge different rates to customers located outside municipal boundaries (Table ES1).

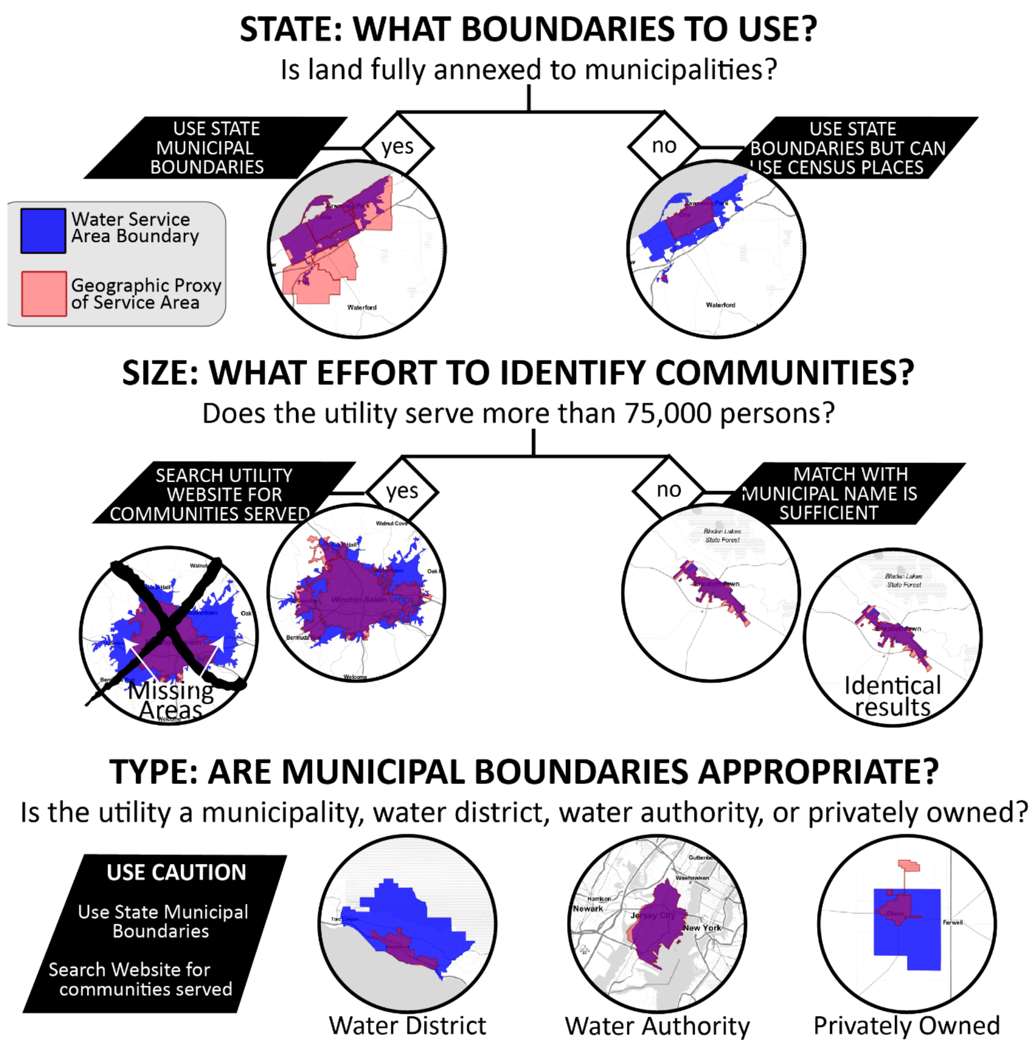
Four affordability metrics were estimated using five different proxies for service area boundaries across 154 utilities representing a sample of states (California, New Jersey, New Mexico, North Carolina, Pennsylvania, Texas, and Washington), system size (small, medium, medium-large, large, and very large), and ownership type (public and private). There was good correlation (Spearman > 0.95) between affordability metrics using service area boundaries and all proxy geographical boundaries. The overall results indicate that municipal boundaries may serve as a proxy for digital service areas for calculating affordability metrics for public municipal water systems, with a median difference for all affordability metrics within ±0.30% of metrics when calculated using service area boundaries.

Table ES1. Name and description of geographical boundaries used when estimating affordability metrics.

Name	Data Source	Identify Communities	Buffer for Outside Area	Description
Observed	State	NA	NA	Original water service area boundaries
State Name	State	Name match only	No	State obtained municipal boundary that matches service area name
State Website	State	Search utility website	No	**State Name** + additional municipalities listed in utility website
National Website	Census Places	Search utility website	No	Identical to **State Website** but use census place boundaries instead of state obtained municipal boundaries
National Buffer	Census Places	Search utility website	Yes	**National Website** + buffer around municipalities based on systems size
State Buffer	State	Search utility website	Yes	**State Website** + buffer around municipalities based on system size

The following recommendations should improve the use of municipal boundaries as a proxy for water service area boundaries (Figure ES1). Municipal boundaries obtained from states outperformed census place boundaries, particularly for Pennsylvania and New Jersey, where the entire state has been apportioned to a municipality. Obtaining municipal boundaries from states is more important for those states with minor civil divisions (28 states), particularly those with legal authority (primarily 12 states located in the Northeast and in the Great Lakes Region) (https://www.census.gov/programs-surveys/popest/about/glossary/geo-terms.html). Matching the name of the water service provider with the municipality was sufficient for small, medium, and most medium-large systems. The additional effort of searching utility websites for a list of communities served improved accuracy for medium-large to very large systems. Affordability metrics in municipal utilities that charge inside-outside rates, particularly if outside rates are significantly different from inside rates (i.e., more than 1.5 times the inside rates), should be viewed with caution because the effect of significantly more expensive water will depend on whether the municipality is surrounded by high-income or low-income areas. The addition of a buffer to represent outside rates added bias that improved performance (i.e., affordability metrics better matched metrics when using actual service area boundaries) for some utilities but worsened performance for others. Lastly, caution should be used when substituting municipal boundaries as a proxy for privately owned systems, public water districts, or public water authorities since it is less likely for municipal boundaries to coincide with the service area of these types of systems.

Figure ES1. Decision tree to create geographic proxies for municipal water service areas.



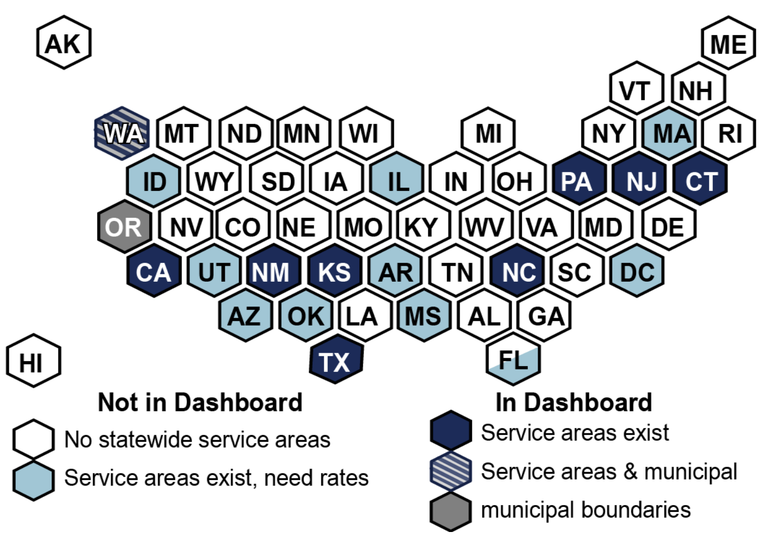
Note. Maps created using Leaflet | Map Sites by Stamen Design, CC BY 3.0 – Map data © OpenStreetMaps contributor.

INTRODUCTION

Patterson and Doyle (2021) developed a standardized approach for quantifying a range of water affordability metrics for water service providers across the United States that is the basis for the Nicholas Institute for Environmental Policy Solution's Water Affordability Dashboard. The usefulness of the approach and dashboard is that it only requires three pieces of data: census data, utility rates, and utility service area boundaries. This simplicity allows the approach to be transferred and applied to any utility with these data.

Service area boundaries and rates data are the primary data constraints limiting our capacity to estimate water affordability across all utilities in the U.S. Currently, rates data are manually located and entered into a database. Given the wide variability in how utilities charge for water, wastewater, and stormwater services, the manual standardization of rates entered into a database remains important. A service area boundary is the geographic area where a utility provides services and is a limiting factor in many states. As of 2022, digital drinking water service area boundaries are publicly available for 17 states and the District of Columbia (Figure 1). Another seven states have created digital service area boundaries but do not make those boundaries publicly available (McDonald et al. 2022). This means that over half of the states do not have a full representation of water service area boundaries available to quantify water affordability or to explore other pertinent questions such as multi-utility scoping projects (California State Water Resource Control Board 2020) and determining nonpublic water supply areas (Pennsylvania Department of Environmental Protection 2009). There is a need for digital service area boundaries nationwide to allow for the estimation of relevant geography-dependent characteristics of a water service provider.

Figure 1. States with digital service area boundary data available. Municipal boundaries have already been used as a proxy for service area boundaries in some states.



Here, we assessed whether municipal boundaries could provide a proxy for water service area boundaries when exploring questions around the affordability of water services, particularly for municipal owned water service providers. There is some precedence for using municipal boundaries to approximate water service areas as McDonald et al. (2022) reported nine states relied on municipal boundaries when creating some of the digital boundaries representing water service areas. Municipal boundaries typically include incorporated cities, boroughs, towns, or villages when using census places; however, in the Northeast and Midwest towns and townships are excluded, and it becomes more important to locate state provided municipal boundaries or minor civil division boundaries.[1]

METHODS

The methods for calculating affordability metrics using service area boundary, rates, and census data are thoroughly described in Patterson and Doyle (2021) and can be referenced from that paper or its companion website. Here, we describe the methods used to assess the sensitivity of affordability metrics using municipal boundaries in place of service area boundaries for utilities in six states: California, New Jersey, New Mexico, North Carolina, Pennsylvania, Texas, and Washington.

DATA

Service area boundaries for were obtained for California, New Jersey, New Mexico, North Carolina, Pennsylvania, Texas, and Washington (Table 1). These service area boundaries were used to estimate affordability metrics based on rates data (provided by Patterson and Doyle (2021) via the Water Affordability GitHub repository) and census data taken from the 2019 five-year American Community Survey (Table 2). The affordability metrics calculated using service area boundaries were also obtained from the GitHub Repository in the utility_afford_scores.csv and the IDWS folder. These metrics provided the baseline against which the adequacy of municipal boundaries as a proxy for service area boundaries was assessed.

1. To learn more about census places—visit the Census Bureau's explanation of places (Understanding Place).

Table 1. Data sources for state-level municipal and service area boundaries to assess the sensitivity of affordability metrics using municipal boundaries as a proxy for service area boundaries.

State	Municipal boundaries	Service area boundaries
California (CA)	https://opendata.arcgis.com/datasets/d8e6e822e6b44d80b4d3b5fe7538576d_0	https://gispublic.waterboards.ca.gov/portal/home/
New Jersey (NJ)	https://opendata.arcgis.com/datasets/3d5d1db8a1b34b418c331f4ce1fd0fef_2	https://gisdata-njdep.opendata.arcgis.com/datasets/purveyor-service-areas-of-new-jersey
New Mexico (NM)	https://opendata.arcgis.com/datasets/d8e6e822e6b44d80b4d3b5fe7538576d_0	https://catalog.newmexicowaterdata.org/dataset/public-water-supply-areas
North Carolina (NC)	https://opendata.arcgis.com/datasets/ee098aeaf28d44138d63446fbdaac1ee_0	http://purl.org/iow/pws/nc
Pennsylvania (PA)	https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=41	https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=1090
Texas (TX)	https://opendata.arcgis.com/datasets/09cd5b6811c54857bd3856b5549e34f0_0	https://www3.twdb.texas.gov/apps/WaterServiceBoundaries
Washington (WA)	https://opendata.arcgis.com/datasets/d8e6e822e6b44d80b4d3b5fe7538576d_0	https://www.doh.wa.gov/DataandStatisticalReports/DataSystems/GeographicInformationSystem/DownloadableDataSets

Census places were also acquired from the Census Bureau—specifically, their "populated places" shapefile (Table 2). Many states also provide their own municipal boundaries (sometimes identical or older versions of census places) (Table 1). In New Jersey and Pennsylvania, municipal boundaries are quite different since these states allocate administrative authority throughout the state to a township, town, or city (also referred to as minor civil divisions). The sensitivity analysis was applied to both nationwide census places and state municipal boundaries where available.

Table 2. Data sources applied to all states.

Location	Data	Purpose	Source
National	Municipal boundaries	Provide a proxy to service area boundaries	https://opendata.arcgis.com/datasets/d8e6e822e6b44d80b4d3b5fe7538576d_0
	Household incomes by block group	Estimate incomes within municipal and service area boundaries	https://www.census.gov/programs-surveys/acs (data accessed from API – B19001 group)
	Poverty by tract	Estimates percent of households in poverty	https://www.census.gov/programs-surveys/acs (data accessed from API – S0101_C01 and S1701_C01 tables)
Select States	Rates data collected from individual utilities	Estimate the monthly water service bills	https://github.com/NIEPS-Water-Program/water-affordability/tree/main/data/rates_data

Analytical Approach

The same metrics and analytical approach for estimating affordability metrics in Patterson and Doyle (2021) were used in this analysis for utilities with service area boundaries to assess how well different geographical proxies could be used for assessing affordability for states and utilities where no digital service area boundaries currently exist. This approach was applied to service area boundaries and municipal boundaries for 154 utilities across six states (Figure 2). This analysis used data from nonrandomly selected utilities: five utilities of each system size from small (serving 500 to 3,300 persons), medium (serving 3,301 to 10,000 persons), medium-large (serving 10,001 to 75,000 persons), large (serving 75,001 to 500,000 persons) and very large (serving more than 500,000 persons) in each state (Table 3). The system sizes here are different from those provided by the Environmental Protection Agency (EPA) categorization where large systems are 10,001 to 100,000 persons and very large systems serve more than 100,000 systems. The majority of large systems are fairly small (fewer than 75,000 persons). As such, we added an additional category to create greater distinction between larger systems. In our database, there are 895 medium-large size systems, 236 large size systems, and 25 very large systems. Not all states had five large or very large systems, and four utilities were excluded from the analysis as neither the utility name or website provided insight into the municipalities they served.

Very small utilities serving less than 500 persons were not included in this analysis, as these utilities often serve unincorporated areas and therefore rarely have a municipal boundary. Many utilities classified as small also did not have a municipal boundary, requiring the analyst to continue searching for small systems that served a location with municipal boundaries. This indicates small systems will likely be underrepresented in states without service area boundaries. The primary focus was to assess the sensitivity for municipal boundaries; however, we also included a privately owned utility for each system size and state where possible (n=26 or 16% of utilities) since more than 10% of the U.S. population is reliant on privately owned utilities (GAO 2021). It was anticipated that privately owned systems, and perhaps publicly owned authorities and districts, would have poorer results as those boundaries are less likely to correspond with municipal boundaries.

Figure 2. Location of the 154 utilities in this analysis.

Table 3. Utilities used in sensitivity analysis by state, size, and ownership type. Not all states had privately owned systems represented, nor did all states have five large or very large systems.

State	Small (500–3,300)	Medium (3,301–10,000)	Medium-Large (10k–75k)	Large (75k–500k)	Very Large (>500k)	Privately Owned
California	5	5	5	5	5	5
New Jersey	5	5	5	5	2	6
New Mexico	5	4	5	3	1	2
North Carolina	4	5	4	5	2	1
Pennsylvania	5	5	5	5	4	6
Texas	5	5	5	5	5	0
Washington	4	5	5	5	1	2

We identified the communities served by the drinking water utility by finding the name of the municipality that matched the system name and by visiting the utility's website (if it existed) to search for information on where services were provided, especially for large and very large systems that often served several communities. A high findability score was given to the municipality whose name matched the utility system name (score = 1) and a lower score (score = 2) for any additional communities listed as being served on the website. It is worth noting that some utilities required significant time to search for information regarding their service area and communities served. This nuance allows for understanding the level of effort needed to identify the municipalities served by a water system when estimating affordability metrics (i.e., is the primary municipality served adequate or do results greatly improve with the additional effort of visiting websites and identifying additional communities served). Note that not all websites provide a list of communities served

Several utilities, particularly in North Carolina, charge inside and outside rates (EFC 2019), meaning households located within the municipality pay one rate while households located outside the municipal boundary pay a different, often higher, rate. A buffer based on system size was created around municipal boundaries as a proxy for outside service areas. Multiple buffer distances were explored with initial efforts producing poor results when comparing affordability metrics with the observed metrics using service area boundaries (data not shown here). After several iterations, buffers were created around municipal boundaries of 0.10 miles (small systems), 0.25 miles (medium systems), 0.5 miles (medium-large systems), 1 mile (large systems), and 2 miles (very large systems). The exploration of the "best" buffer distance was not exhaustive, but was designed to provide insights as to how a buffer might improve affordability estimates for utilities with outside rates. Outside service areas are never symmetrically distant around the entire municipality and such buffers should be applied with caution.

In summary, the sensitivity analysis explores the degree of effort required to produce affordability metrics similar to those obtained using service area boundaries. We explored how much effort must be exerted to (1) identify municipalities served by the utility, (2) obtain state municipal data compared with national census places, and (3) add a buffer for utilities with outside rates (Figure 3). Once the municipalities were identified, the drinking water unique identifier (PWSID) was matched to the municipality unique identifier (state provided and census place GEOID). The state abbreviation was appended to the municipal unique ids when provided by the state (Table 4).

The method for calculating affordability metrics was identical to that of Patterson and Doyle (2021) with the caveat that only inside rates and metrics applied to most of the sensitivity analyses (with the exception of the outside buffer analysis). The following metrics were calculated from 2,000 gallons per month (gal/mo.) to 16,000 gal/mo. at 2,000-gallon increments: poverty prevalence, household burden, overall burden score, and income dedicated to water services. Labor hours were not calculated since they are independent of the incomes of those served by the utility and will be identical regardless of the boundaries used.

Figure 3. Examples of different geographic proxies overlaying service area boundaries.

(A) Difference between State Name and State Website for a very large system. (B) State municipal boundaries provided better coverage than census places in some states. (C) Buffers to capture outside service area improved results for some utilities North Carolina but produced less accurate results elsewhere.

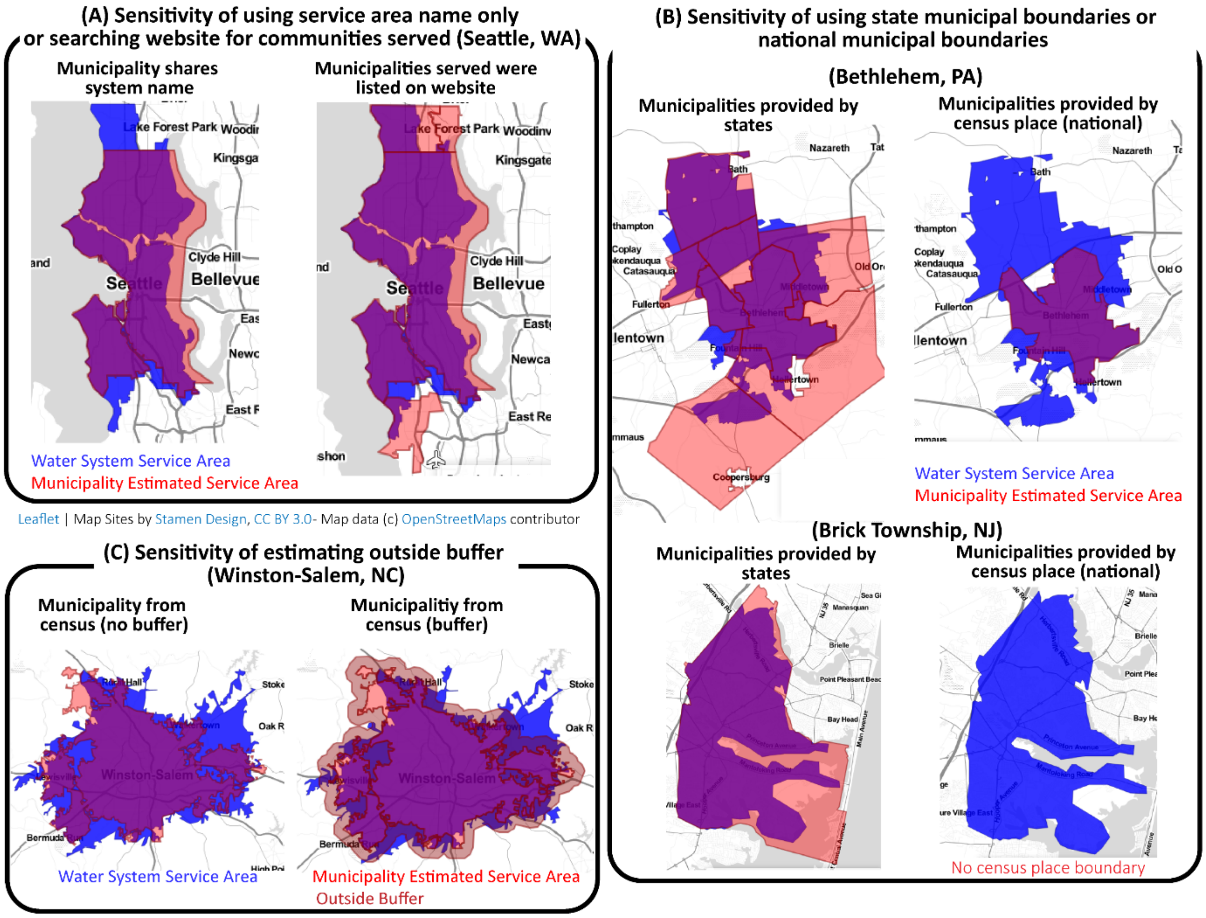


Table 4. Name and description of geographical boundaries for estimating affordability metrics.

Name	Data Source	Findability	Buffer	Description
Observed	State	NA	NA	Original water service area boundaries
State Name	State	High (1)	No	State obtained municipal boundary that matches service area name
State Website	State	Medium (2)	No	**State Name** + additional municipalities listed in utility website
National Website	Census	Medium (2)	No	Identical to **State Website** but use census place boundaries instead of state municipal boundaries
National Buffer	Census	Medium (2)	Yes	**National Website** + buffer around municipalities based on systems size
State Buffer	State	Medium (2)	Yes	**State Website** + buffer around municipalities based on system size

RESULTS

The agreement between variations of municipal boundaries as proxies and water service area boundaries was quantified for four affordability metrics (Poverty Prevalence, Household Burden, Burden Level, and Income Dedicated to Water Services). For each metric, the value obtained using service area boundaries is considered to be the "observed" value and is compared with the proxy values calculated using alternative geographic extents (Table 4). The agreement between these estimates and the observed (i.e., service-area derived) metric were then compared.

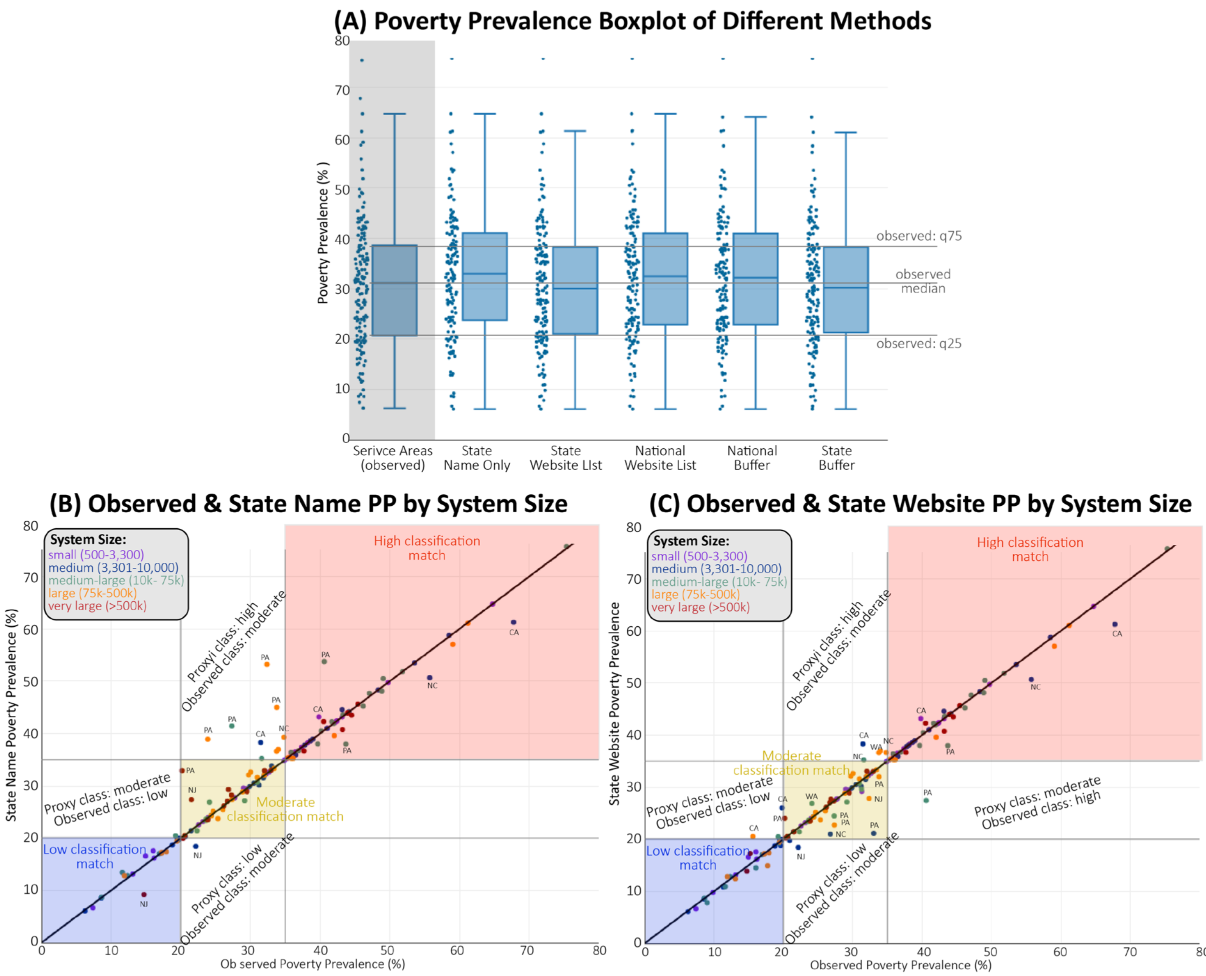
Poverty Prevalence

There was high correlation (Spearman > 0.95) between the observed poverty prevalence (PP) and the PP from different estimation methods (Figure 4A). The State Website method had the highest correlation (0.978) followed by the State Buffer (0.971). The State Website method greatly improved results for medium-large and large systems relative to the State Name approach (Figure 4B and C). This suggests that it is worth the effort to consult utility websites to identify municipalities served for utilities serving more than 75,000 persons. The State Name approach is the simplest to implement and was sufficient for small- and medium-sized utilities.

The median difference in observed PP from the different proxy boundaries was near zero; however, some utilities had large differences. There were 11 systems with more than a 4% difference in PP between the Observed and State Website method, of which two systems were publicly owned. The remaining nine systems represented examples where we might expect to see large differences between results derived from service area and municipal boundaries: three privately owned systems, two districts, and four authorities.

Figure 4. Agreement between geographic proxies and water service areas for Poverty Prevalence (PP).

(A) Boxplot of PP for each method. The box indicates the range for the 25th to 75th percentile PP, the line in the box indicates the median PP, and the whiskers indicate the range for the 10th to 90th percentile PP. Horizontal lines were drawn from the observed PP at the 25th, 50th, and 75th percentile for comparison with proxies. The small dots represent individual PP values. (B) Comparison of the Observed PP with the State Name and (C) State Website. The 45-degree angle indicates an exact match in PP. The recommended 20th and 35th percentile thresholds (Raucher et al. 2019)—indicating low, moderate, and high PP. PPs located within colored boxes match classification. PPs outside of colored boxes have different classifications. The state for PP's scores with large differences are identified. Large systems in PA and NJ performed better when including communities served (State Website) than relying only on the municipality name (State Name).



Household Burden

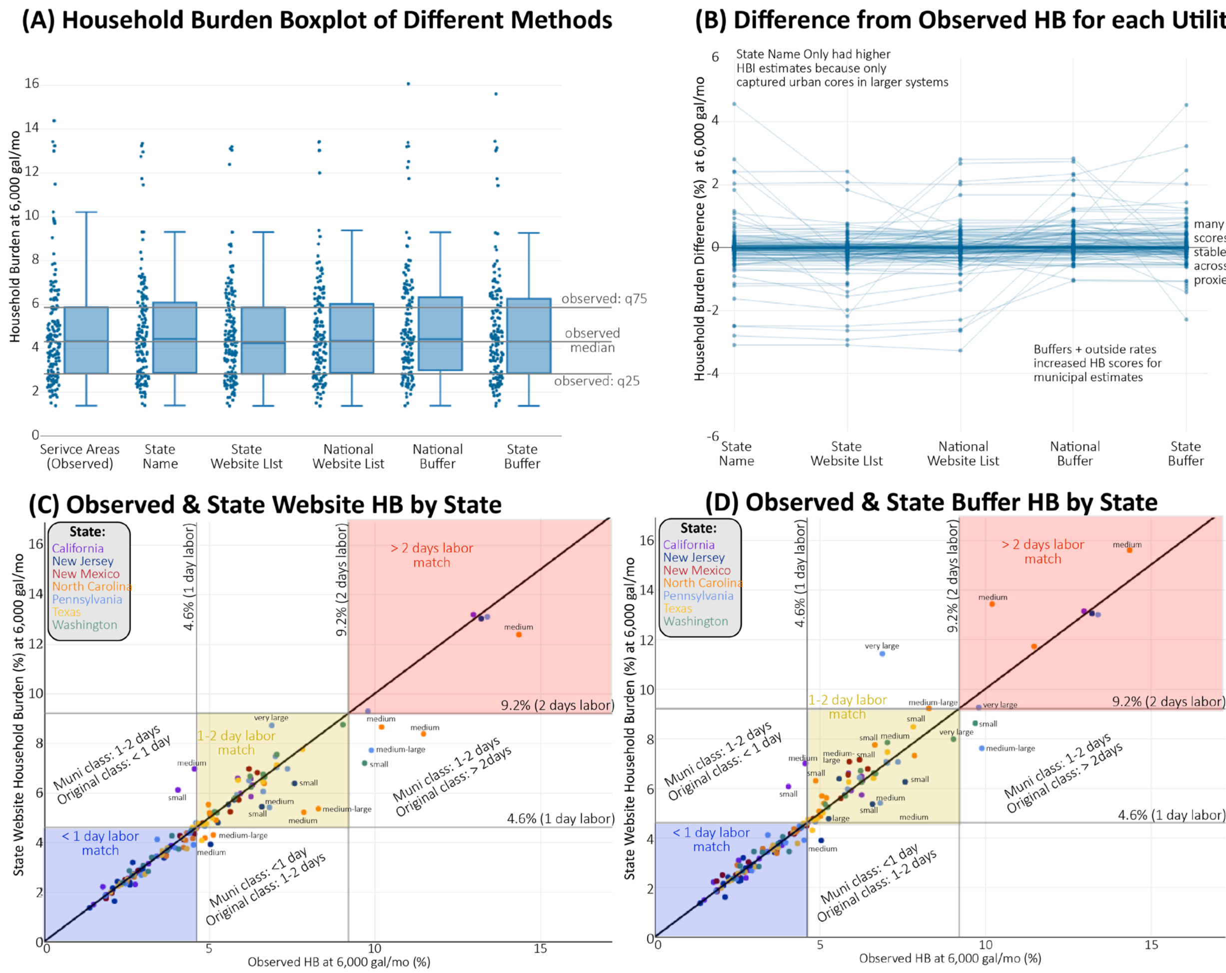
The Household Burden (HB) metric, unlike poverty prevalence, is sensitive to the volume of water used. Even at multiple volumes of water usage, HB from the proxies was highly correlated with that from the original service areas (Spearman correlation for all proxies ranged from 0.96 to 0.98). However, HB metric when using municipal boundaries was consistently underestimated compared to when using original service areas (although the median difference from the observed HB and different proxies was small, typically -0.01 or -0.02%, Figure 5A and B). The inclusion of buffers improved correlations for some utilities, particularly in North Carolina where many utilities have inside-outside rates and the difference between inside-outside rates is large. In North Carolina, the median difference between the HB using Observed and State Buffer proxy was 0.26% (i.e., this proxy overestimated HB) while the proxy based on State Website had a median difference of -0.29% (i.e., underestimated HB, Figure 5C and D). The use of state municipal boundaries greatly improved results for Pennsylvania compared to the use of census places. There was little difference in performance by methods or municipal boundary based on system size.

There were 13 systems with more than a 1.15% difference (two hours of labor) in HB between the Observed and State Website proxy. This included two private systems, two districts, two authorities, and six systems that had inside-outside rates (five public systems in North Carolina and one public system in Washington). There was a single small public system where the cause of a larger difference in HB was unknown. Five systems had an HB that exceeded 2.3% (four hours of labor) and included one private system and four systems with inside-outside rates. The largest difference was an HB of 2.4% for the State Website at 6,000 gal./mo. and that difference increased with volume so that by 16,000 gal./mo. the maximum difference was 4.2%, still less than a day of labor.

The State Buffer proxy resulted in 12 systems with more than a 1.15% difference (two hours of labor) from the Observed HB; including three private systems, two districts, two authorities, four systems with inside-outside rates (three systems in NC and one system in NM), and the small public system that was present for the State Website. Two private systems and one district had a difference exceeding 2.3% (four hours of labor). The largest HB difference for the State Buffer proxy was 4.5% at 6,000 gal./mo., increasing to a difference of 10.5% by 16,000 gal./mo.

Figure 5. Agreement between geographic proxies and water service areas for household burden (HB).

(A) Boxplot of the HB for each method. The box indicates the range for the 25th to 75th percentile HB, the line in the box indicates the median HB, and the whiskers indicate the range for the 10th to 90th percentile HB. Horizontal lines were drawn from the Observed HB at the 25th, 50th, and 75th percentile for comparison with other proxies. Small dots indicate actual HB values. (B) The difference in HB for each proxy compared with the Observed. (C) Comparison of the Observed HB with the State Website and (D) State Buffer HB. The 45-degree angle indicates an exact match. Lines were drawn for each day of labor (4.6% of income)—indicating low, moderate, and high burdens. HBs located within colored boxes match classification. HBs outside of colored boxes have different classifications with large differences identified by the size of the system.



Burden Category

The Burden Category combines Poverty Prevalence and Household Burden together (Raucher et al. 2019; Patterson and Doyle 2021) using thresholds (Table 5) to classify an affordability burden from low to very high.

Table 5. Affordability framework combining Household Burden (HB) and Poverty Prevalence (PP) to reflect that water services become increasingly burdensome and unaffordable as HB and PP increase.

Household Burden by Days of Labor	Poverty Prevalence		
	< 20%	20 to 35%	> 35%
> 2 days (> 9.2%)	Moderate-High	High	Very-High
1–2 days (4.7 to 9.2%)	Low-Moderate	Moderate-High	High
< 1 day (4.6%)	Low	Low-Moderate	Moderate-High

Across all proxies, the classification of burden levels matched those generated using service area boundaries for 79.9% (National Website at 8,000 and 10,000 gal./mo.) to 90.9% (State Website at 16,000 gal./mo.) of systems (Table 6); the use of state municipal boundaries as a proxy for service area boundaries provided consistently better results than using census places. The additional effort of searching for all communities served by a utility resulted in marginal improvements, primarily for large and very large systems. This affordability metric converts multiple numeric values into a classification system which reduced the likelihood of proxies matching Observed results because small differences in PP or HB can result in a different classification. For example, if the PP was 25% and the Observed HB was 4.52%, the resulting classification would be low-moderate burden; however, if the proxy approach resulted in a HB of 4.61%, the resulting classification would be moderate-high burden. Proxies provided similar results to Observed; however, utilities with scores near thresholds, particularly for HB in the range of 6,000 to 10,000 gal./mo., may be classified differently.

Table 6. Percent of burden scores that matched with service area burden scores at different volumes of water usage.

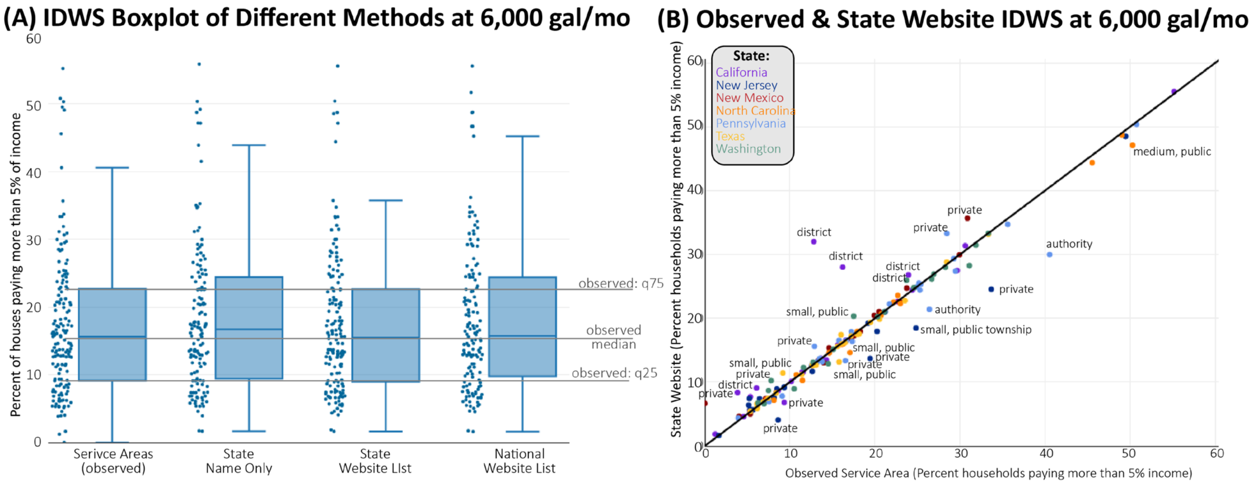
Data Source:	State	State	National	National	State
Findability:	Name only	Website listed	Website listed	Website listed	Website listed
Buffer:	No	No	No	Yes	Yes
Volume (gal./mo.)					
2,000	86.2	89.0	84.0	85.4	87.5
4,000	87.7	88.3	84.7	84.0	86.2
6,000	86.2	86.4	80.6	84.0	87.5
8,000	86.2	87.0	81.9	79.9	83.7
10,000	84.1	83.1	80.0	79.9	82.2
12,000	85.4	85.7	83.3	84.0	86.8
14,000	85.4	86.4	82.6	84.0	86.8
16,000	89.1	90.9	86.1	85.4	88.2
Median Score	86.2	86.70	83.0	84.0	86.80
Missing Data (% utilities)	7.6	3.8	6.3	6.3	3.8

Income Dedicated to Water Services

The income dedicated to water services (IDWS) metric provides information on both the depth (percentage of income spent on water services) and breadth (percentage of households burdened) of affordability. The IDWS metric for proxies at 6,000 gal./mo. At a burden of 5% of income spent on water services (slightly more than a day of labor) for inside rates was similar to the Observed IDWS. The State Website proxy had a median difference of -0.3% from the Observed IDWS with differences ranging from -11% to 19%. Most large differences attributed to systems that were districts, authorities, or privately owned (Figure 6). There were a few public systems with large differences, all of which were small systems where IDWS results are known to be sensitive because of the small number of households (Patterson and Doyle 2021).

Figure 6. Agreement between geographic proxies and water service areas for Income Dedicated to Water Services (IDWS).

(A) Boxplot of the percent of households spending more than 5% of their income on water services when using 6,000 gal./mo. for each method. The box indicates the range for the 25th to 75th percentile of households, the line in the box indicates the median percent of houses, and the whiskers indicate the range for the 10th to 90th percentile. Horizontal lines were drawn from the Observed results at the 25th, 50th, and 75th percentile for comparison with other methods. Small dots indicate IDWS results for each utility. (B) Comparison of the Observed with the State Website percent of households paying more than 5% of their income at 6,000 gal./mo. The 45-degree angle indicates an exact match. The type of system is identified for those systems with large differences; the majority of which were districts, private, authorities, or small public systems.



SUMMARY AND DISCUSSION

Fewer than half of all states have publicly available service area boundaries for water services (McDonald et al. 2022) which limits our ability to quantitatively assess water affordability across the nation (Patterson and Doyle 2021). We sought to understand if geographic proxies for water service area boundaries (Table 4) can provide acceptable estimates of water affordability metrics for utilities where no digital service area boundaries are currently available. Geographic proxies explored included changing which municipalities are included (using name only or website list), data source for municipal boundaries (state provided or census places), and the inclusion of a buffer to capture outside service areas. Individual affordability metrics (PP, HB, and IDWS) were consistent with results from the original service area boundaries for municipal service providers (Tables 4 and 6 and Figures 4–6). The Spearman correlation was greater than 0.95 for PP and HB with a median difference near 0% for all methods and indicators. In short, when quantifying water service affordability metrics, municipal boundaries generally provide similar results as water service area boundaries for public, municipal systems. Accuracy decreased for privately owned systems, water districts, and water authorities since these systems are less likely to conform to municipal boundaries. However, if the utility provided a list of communities served (Website List), the accuracy of geographic proxies improved. We also note that while the metrics of PP and HB were similar between service areas and geographic proxies, the match in burden categorization was lower (around 90%; Table 6). Utilities with a PP or HB near categorization thresholds (i.e., 20% and 35% for PP; 4.6% and 9.2% for HB) could have small differences that resulted in a different categorization.

Based on this analysis, when calculating water affordability metrics, municipal boundaries provide an adequate geographic proxy for the service area for most public municipal water service providers. The use of the State Name Only as a geographic proxy was sufficient for small to medium-large systems; however, results improved markedly when supplemented by searching the website for a list of communities served for large and very large systems. We also found that results using geographic proxies were generally better when using state provided municipal boundaries rather than census places, particularly for states such as Pennsylvania and New Jersey where the entire state has been designated as a township, municipality, or city.[2] The use of buffers did improve results of geographic proxies for some utilities with large differences between inside and outside rates; however, the results worsened for other utilities and it is unclear what buffer size is appropriate since no utility grows outwardly with perfect geometric symmetry. It might be better in these circumstances to simply represent affordability for residents located within municipal boundaries using inside rates.

Findings and Recommendations

(1) Geographic proxies based on municipal boundaries can be used to approximate the geographic service area of water utilities when quantifying water service affordability metrics. For states in the Northeast and Midwest, minor civil divisions or state-provided municipal boundaries yield better results compared to census places.

(2) If proxies based on municipal boundaries are used instead of actual service areas, the most appropriate geographic proxy depends on the size of the utility, specifically:

  (a) State Name Only is generally sufficient for small, medium, and medium-large systems

  (b) State Website—searching the utility's website for a list of communities served to include in the proxy—is ideal for large and very large systems.

(3) Caution should be used when assessing utilities with large differences in inside-outside rates (e.g., outside rates are 1.5 times greater than inside rates); however, we do not recommend adding a buffer as outside service areas do not expand uniformly from the utility and the improvement in metric scores was mixed.

(4) Using a geographic proxy for service area when quantifying affordability metrics is not appropriate for county-level systems, private systems, water districts, or authorities where a list of the communities served are not provided. This accounts for a potentially large number of systems since at least 10% of the U.S. population is served by private systems and there is no database for discerning different types of public systems (i.e., municipal, districts, or authorities) (Beecher et al. 2020).

2. Twenty states have minor civil divisions (MCDs) that are legally defined and function as governing entities. General purpose local government functions exist in 12 states: Connecticut, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Wisconsin. MCDs play a smaller governing role in the remaining 8 states: Illinois, Indiana, Kansas, Missouri, Nebraska, North Dakota, Ohio, and South Dakota. Source: Census Bureau, https://www.census.gov/programs-surveys/popest/about/glossary/geo-terms.html.

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Review

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