THIRSTY COLONIAS:
DETERMINANTS OF WATER SERVICE COVERAGE IN SOUTH TEXAS

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EXECUTIVE SUMMARY

This paper examines the reasons why some poor communities in the Texas-Mexico border region have obtained central drinking water services, and some have not. Identifying some specific determinants of water service coverage in Texas communities, the paper's conclusions speak to the common global phenomenon of lack of access to drinking water and sanitation services in poor communities.

This study analyzes Texas *colonias*, unincorporated rural and urban subdivisions near the U.S.-Mexico border lacking basic infrastructure, including paved roads, drainage and, in many cases, utility service. In the mid-1990s, Texas *colonias* emitted nearly 2 million gallons per day of untreated wastewater into the Rio Grande, the border river. The region comprises the largest concentration of households without basic sanitation in the United States, and it suffers numerous public health consequences related to this problem.

The most common explanation for the absence of public utility service in these communities is that they are both poor and expensive to connect, making them risky revenue prospects for public or private utility infrastructure. I test this assertion. While the analysis bears out that both of these factors – high potential cost of service and low revenue potential – do play some role in determining which communities obtain service and which do not, they are by far not the only important factors.

This study is the first to examine the influence of institutional factors, specifically the characteristics of state-identified "most likely" water service providers, on service coverage among Texas *colonias*, and I find that these factors are at least equally as important as the cost and revenue factors. For example, *colonias* within the service territories of non-profit water supply corporations were 42 percent more likely to have obtained water service by 1996 than *colonias* within the service territory of municipal water systems, and 31 percent more likely to have obtained service than those within regional water districts or county water service territories. The magnitude of the influence of potential water service provider on service coverage is far greater than the magnitude of the influence of income, location in an urban vs. a rural area, population, and other factors.

This finding is consistent with qualitative analyses of water and sanitation service provision in the developing world, where it is difficult to find examples of efficient, large-scale public monopolies serving the poor. I conclude that this apparent difference among service providers has important policy implications for the State of Texas.

In addition, policies designed to address the problem of inadequate water and sanitation services for Texas *colonias* do not differentiate between urban and rural communities. This analysis indicates that urban and rural water supply are really two separate problems. For example, large rural *colonias* are more likely to obtain service than small rural *colonias*, but the reverse is true for urban *colonias*, which may suffer for their size. Incorporating large populations of low-income ratepayers into existing urban water supply systems may be more of a political problem than an engineering problem. Even when they have similar socioeconomic

characteristics, urban and rural *colonias* appear to face very different challenges to obtaining water service, requiring different policy responses.

While this study examines poor communities in four Texas border counties, its results have implications for extending public services to poor urban, peri-urban and rural communities in other states and countries, as well. Of the 3.9 billion people living in the 25 largest developing countries in 1999, only 84 percent of urban residents and 51 percent of rural residents had access to clean drinking water. Given that many poor households do obtain safe drinking water services, this analysis is a first step at understanding why so many do not. The results indicate that characteristics of potential water service providers are at least as important as characteristics of poor households themselves in determining who obtains service.

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1.0 INTRODUCTION

Fifteen to twenty percent of Texas border residents live in communities called *colonias*, a word meaning "residential area" or "settlement" in Spanish, but commonly used to refer to unincorporated rural and urban subdivisions in Texas and the Southwest lacking basic infrastructure including paved roads, drainage, and public utility service. In 1995, about 20 percent of Texas' 357,000 colonia residents were unconnected to central drinking water systems, and about 99 percent were unconnected to central wastewater treatment systems (Texas Water Development Board 1996). Texas border colonias comprise the largest concentration of people living without basic sanitation in the United States.

Analysts attribute the persistent absence of service coverage among colonias to high infrastructure cost, low utility revenue potential, and weak political influence (Holcomb 1999; Limaye 1999; Lyndon B. Johnson School of Public Affairs 1997; Ward 1999; Wilson and Menzies 1997). In other words, these communities are poor, they tend to be remote, built in floodplains, or otherwise expensive to connect from an engineering perspective, and they have little influence on the political process that might be used to change their condition.

These financial and political factors surely play some role, but this study shows that institutional factors are at least equally as important. Current research has focused on the potential comparative advantage of less traditional service providers in serving poor populations in developing countries (Collignon 1999; Snell 1998; Solo 1998; Solo 1999). While examining a similar problem in south Texas is an imperfect test of this potential comparative advantage, it is illuminating. In the absence of mandatory public services for the poor, this study suggests that in Texas, some types of water service providers are more likely than others to connect low-income, high-cost populations.

This study has two related objectives. First, it tests the assertion that lack of service coverage results in part from a mismatch between high cost of service and low potential revenue associated with providing water to colonias. Although this is a common assertion, this study is the first to test it empirically. Second, it examines for the first time the influence of a colonia's most likely service provider on probability of service coverage, in order to determine which types of providers are more likely than others to serve colonias within their state-permitted service territory.

1.1 Study Sample: Four Border Counties

The sample in this analysis includes colonias in four border counties (Cameron, El Paso, Hidalgo and Webb), which together contain 73 percent of colonias and 75 percent of the colonia population in Texas. Cameron and Hidalgo counties are in the semi-tropical Lower Rio Grande Valley (the Valley), while Webb county is at the arid midpoint of Texas' border with Mexico, and El Paso is at the far western edge. Table 1 lists colonia population as a percent of total population in these four counties.

Table 1. Colonia Populations as Percent of Sample County Populations

County	County Population (Projected 2000)[a]	Colonia Residents as Percent of Projected 2000 Population[b]
Cameron	323,669	12.9%
El Paso	731,781	10.2%
Hidalgo	503,871	26.9%
Webb	186,626	8.1%

(a) County population figures (2000) are projected from 1990 U.S. Census and most likely migration rates, estimated by Texas Natural Resource Conservation Commission, Texas Water Development Board, and Texas Parks and Wildlife Department.
(b) Colonia population from Texas Water Development Board Colonias Database, January 1999.

1.2 Problem Description

The absence of basic water and sanitation services among colonias is widespread. Waste that is not pumped directly into the Rio Grande (the river that marks the 1,254-mile border between Texas and Mexico) is disposed of in outhouses, pit privies and inadequate septic systems. In the mid-1990s, Texas colonias discharged nearly 2 million gallons of untreated wastewater into these sub-surface disposal mechanisms per day (Betts and Slottje 1994). In the Valley this wastewater flow seeps into the high water table, contaminating ground water and threatening public health during regular heavy rainfall events. Yet, many colonia residents are not connected to safe drinking water systems. As a result, the border region experiences high levels of hepatitis, shigellosis and other illnesses associated with inadequate water and sanitation service (U.S. Federal Reserve Bank of Dallas 1996; U.S. General Accounting Office 2000; Warner 1991).[1] Table 2 describes water and wastewater service coverage as of 1996 in the four counties in this study.

Table 2. Status of Water and Wastewater Service Coverage among Colonia Populations in Sample Counties, 1996

County	Colonia Population	Percent without Water Service	Percent without Wastewater Service
Cameron	41,832	20.3%	94.1%
El Paso	74,642	36.1	99.8
Hidalgo	135,770	11.9	99.9
Webb	15,140	86.0	99.1
Total	**267,384**	**18.9**	**99.1**

Source: Texas Water Development Board Colonias Database, 1996.

[1] For example, the rate of Hepatitis A in Texas' 32 border counties is 35 per 100,000, compared with a rate of 15 per 100,000 in Texas as a whole (U.S. Federal Reserve Bank of Dallas 1996).

1.3 Summary of Results

The models in this analysis use maximum likelihood probit estimation to examine the relationship between a colonia's probability of obtaining water service by 1996 (the dependent variable), and six independent variables: (1) colonia population; (2) customer density, or average number of residents per dwelling; (3) per capita income; (4) whether the colonia is in an urban or rural area; (5) type of current or most likely colonia water service provider; and (6) the county in which a colonia is located. Results confirm the common assertion that lack of service coverage results in part from a mismatch between high cost of service and low potential revenue associated with providing water to colonias. Higher potential infrastructure cost diminishes the likelihood that a colonia had received water by 1996. For example, urban colonias, which are closer to existing drinking water systems, more densely populated and therefore less costly to connect, are more likely to have been served by 1996 than rural colonias. Colonias with higher per capita income are served in larger proportion than those with lower per capita income.

The most important result of this analysis concerns the second research objective. There is substantial variation in water service providers' propensity to serve these high-cost, low-revenue communities. Non-profit water supply corporations had served a significantly greater proportion of colonias within their service areas by 1996 than public municipal systems, counties, and general law water districts. This indicates that these institutions may be better suited to cope with the high cost and low revenue potential associated with serving colonias. Water supply corporations' higher propensity to serve colonias may be attributed, in part, to rate-setting flexibility and access to an extra source of low-cost funding for colonia infrastructure.

A colonia's county of residence has a strong effect on probability of service coverage as of 1996. Counties are the primary level of government responsible for implementing and enforcing state regulations on colonia development, thus the county variable was included in the analysis to control for some political factors. Its strong influence on probability of service indicates that political factors may be important determinants of the presence or absence of water service in a colonia and that water service coverage models might be improved by the inclusion of more refined political variables.

1.4 Three Caveats

This analysis has three main limitations. First, the models in this analysis include a colonia's county of residence as an independent variable, controlling for some political factors, but other political characteristics are excluded from the set of independent variables in this study. Second, Texas colonias are more likely to have water than wastewater service, like their counterparts in developing countries. Sanitation is the more pressing regional environmental and public health problem, but too few colonias have wastewater service to detect patterns in service evolution through econometric analysis. As a result, the factors that determine the presence or absence of *water* service in individual colonias are the locus of this study.

Finally, in water supply research, the problem to be addressed is the quality of water service, not whether households receive service at all (World Bank 1995). Unfortunately, no data are available on the quality of service among colonias that are connected to central water systems, and service coverage may represent an upper bound on access to safe drinking water, rather than a true estimate. Results should be interpreted in light of this fact.

2.0 DESCRIPTION OF COLONIAS AND TEXAS WATER SERVICE PROVISION

2.1 Origins and Description of Colonias

Poorly regulated development, weak enforcement of regulations, and limitations on county regulatory authority are frequently cited reasons for the development of colonias (International City/County Management Association 1995; Lyndon B. Johnson School of Public Affairs 1997). Others emphasize low-income housing shortages in border cities, and the inability of the poor to obtain credit from commercial banks (Ward 1999; Wilson and Menzies 1997). Both of these factors push very low-income residents out of areas with utility service and into unincorporated areas, where they have been able to purchase cheap parcels of land with no water and sanitation infrastructure.

Modern colonias are poorer, more rural, and Hispanic in slightly greater proportion than the border counties in general and than the State of Texas as a whole. Colonia per capita income in the four counties hovers around 40 percent of the state average and between 35 and 40 percent of the national average. Tables 3 and 4 compare colonia per capita incomes and Hispanic populations with county, state and national levels. Table 5 compares urban and rural populations of colonias in the four counties.[2] Colonia residents own their homes, in large part, differentiating these communities from squatter settlements. The size of colonias in the sample for this analysis ranges from four to 5,200 residents, with a mean population of 264.

Table 3. Comparison of Colonia, County, State, and National Per Capita Incomes

County	Per Capita Income			
	Colonia	County	Texas	U.S.
Cameron	$5,413	$7,125	$12,904	$14,420
Colonia per capita income as percent	100.0%	76.0%	41.9%	37.5%
El Paso	5,399	9,150		
Colonia per capita income as percent	100.0%	59.0%	41.8%	37.4%
Hidalgo	5,156	6,630		
Colonia per capita income as percent	100.0%	77.8%	40.0%	35.8%
Webb	5,665	6,771		
Colonia per capita income as percent	100.0%	83.7%	43.9%	39.3%

Source: Colonia data from Office of the Attorney General of Texas Border Database. County, State, and U.S. Figures from 1990 U.S. Census Database C90STF3A, available at http://venus.census.gov/cdrom/lookup.

[2] The Census defines urban housing units as those in urbanized areas and in places of 2,500 or more persons outside urbanized areas. Most urban colonias are in unincorporated areas in or near border Metropolitan Statistical Areas like El Paso, Brownsville-Harlingen-San Benito, Laredo and McAllen-Edinburg-Mission.

Table 4. Hispanic Population as Fraction of Total: Colonias, Counties and State

County	Hispanic Population as Fraction of Total Population		
	Colonia	County	Texas
Cameron	0.93	0.82	0.25
El Paso	0.89	0.70	
Hidalgo	0.88	0.85	
Webb	0.94	0.94	

Source: Colonia data from Office of the Attorney General of Texas Border Database. County and State figures from 1990 U.S. Census Database C90STF3A, available at http://venus.census.gov/cdrom/lookup.

Table 5. Urban vs. Rural Population: Colonias and Counties

County	Colonia Population		Total County Population	
	Percent Urban	Percent Rural	Percent Urban	Percent Rural
Cameron	13%	87%	79%	21%
El Paso	80	20	97	3
Hidalgo	31	69	76	24
Webb	0	100	93	7

Source: Colonia data from Office of the Attorney General of Texas Border Database. County data from 1990 U.S. Census Database C90STF3A, available at http://venus.census.gov/cdrom/lookup.

2.2 Part of a Global Problem

Lack of access to water and sanitation services has caused some analysts to compare border colonias and developing nations, where absence of utility service in poor neighborhoods is common (Holz and Davies 1993; Ward 1999). In many developing countries, service areas are delegated by the state to monopolies, as in developed countries, but it is hard to find examples of efficient, large-scale monopolies serving the poor (Solo 1999). National water companies in African nations, for example, rarely supply water to small urban, peri-urban and rural communities, because they are not considered sufficiently profitable and require cross-subsidies (Collignon 1999; Idelovitch and Ringskog 1995; Swaroop 1994). Frequently, small-scale providers in the informal sector fill the service gap (often illegally) where state or local public enterprises do not reach low-income populations. In most cities in developing countries, more than one-half the population obtains basic water service from suppliers other than the official utility; the percentage is even higher in rural areas (Solo 1998). Prices in the informal sector typically, but do not always, exceed those of public services (Collignon 1999; Solo 1999).

Similar forces are at work in south Texas, where the costs of providing infrastructure to colonias historically have "greatly outweighed the tax revenues a city could garner from taxes paid by colonia residents," making annexation economically undesirable and politically

impossible (Wilson and Menzies 1997).[3] In addition, until federal and state funds were made available in substantial quantities for the provision of publicly subsidized services to colonias in 1989, most of these communities were forced to find water services through private sources (Ward 1999). They typically purchased drinking water, for example, from tanker trucks and stored it in plastic or metal tanks. A representative charge for such services to Texas colonias in 1988 was $22 per 1,000 gallons.[4] As a point of comparison, residents connected to the City of El Paso's public water supply in 2000 pay approximately $1.07 per 1,000 gallons of city water, for amounts up to 150 percent of average winter consumption (El Paso Water Utilities Public Service Board 2000).[5] Colonia households that are not connected to public drinking water systems continue to acquire water in this relatively expensive fashion.

The issue of alternative water and sanitation providers for very low-income communities is related to the phenomenon of so-called self-help or popular housing. The popular housing literature has focused on irregular peri-urban settlements as partial solutions to low-income housing shortages in developing countries, noting their flexibility and responsiveness to families' individual financial capacity and housing priorities (Abrams 1964; Turner 1970; Turner 1976; United Nations Seminar of Experts on Land for Housing the Poor 1983). World Bank funding began in the 1970s to focus on upgrading of sites and services for irregular housing (Payne 1984). More recently, others have argued that policies supporting irregular settlements may perpetuate their growth and worsen inequality of access to the regulated housing market (Burgess 1992; Connolly 1982; Pezzoli 1987). The wide-ranging debate on popular housing has not been part of the policy discussion about Texas colonias, which are viewed within the state as a "temporary problem of dysfunctional urbanization," rather than an acceptable option for very low-income families (Ward 1999).

2.2 Persistence of Inadequate Public Services

Weak regulation has encouraged the development of colonias and the persistence of inadequate utility service in the Texas border region.[6] Since the early 20th century, Texas municipalities have had the power to regulate development within their boundaries and extraterritorial jurisdiction, but explicitly have been denied the power to regulate development in unincorporated areas. Until 1989, Texas counties could require filing of subdivision plats in unincorporated areas, but could enforce few requirements for plat approval and no penalty for failing to file.[7] Counties could not withhold plat approval for failure to provide rights-of-way sufficient for paved roads, for example. They had no authority to require standard utility connections, meters or minimum lot size (Lyndon B. Johnson School of Public Affairs 1997).

[3] The city of Brownsville, for example, has consistently drawn its city limits so as to avoid incorporating the large Cameron Park colonia (Ward 1999).

[4] Adjusting for inflation using the consumer price index, the equivalent charge in 2000 would be about $32 per 1,000 gallons.

[5] Because public water prices are subsidized (for example, through state revolving loan funds for treatment infrastructure), some additional price is paid through other taxes. Still, the per unit difference is quite large. Total water service expenses for households that haul water may be lower than the per-unit price indicates, however, since those without piped water use it in much smaller quantities, and those connected to central systems also pay monthly fixed charges.

[6] Arizona and California largely have avoided colonia development through zoning and land use restrictions in unincorporated areas (Warner 1991).

[7] A plat is a map that indicates all planned and existing landmarks and structures on a tract of land.

The combination of population growth, demand for very inexpensive housing, a plentiful supply of idle agricultural land, lax land development regulations, and a financing practice called contract-for-deed led to tremendous colonia growth from the 1960s through the early 1990s (Ward 1999).[8] Between 1975 and 1998, the estimated total colonia population in the Valley grew from about 10 percent to 27 percent of total population. Populations in two El Paso colonias (Socorro and San Elizario) grew from approximately 3,360 residents in 1970 to 27,380 in 1990, an 800 percent increase (Wilson and Menzies 1997).

State legislation passed between 1989 and 1995 generally has stemmed new colonia development by requiring minimum standards for subdivision development and increasing county regulatory authority. State general obligation bond proceeds of $250 million between 1989 and 1991, supplemented by $200 million in federal funds from the U.S. Environmental Protection Agency (EPA) and other, smaller sources of federal and state funds, have increased substantially the grants and low-interest loans available for colonia infrastructure projects.[9] Local governments have been slow to take advantage of these grants and loans, however. By 1996, only a handful of colonias had been connected to central wastewater systems, and 20 percent lacked access to adequate drinking water, despite seven years of state and federal financial commitment.

2.3 Water Service Institutions in Texas

Texas water service provision is phenomenally decentralized. Drinking water suppliers to colonias and other communities alike are monopolies within their service areas. A supplier's service area is defined when it obtains a Certificate of Convenience and Necessity (CCN) from the Texas Natural Resource Conservation Commission (TNRCC), the state environmental regulatory agency. Universal service coverage is not required by law, even within a defined CCN, and not all state residents live within areas covered by a CCN.

This system fosters a limited degree of competition among water service providers. Water providers can buy and sell CCNs, with sufficient public notice and TNRCC approval. Providers can expand their territory by challenging other providers' CCNs on a number of grounds, including adequacy of service currently provided, need for additional service, and the probable improvement of service or lowering of cost to consumers in that area.[10]

Suppliers in Texas include public and investor-owned municipal systems, county systems, non-profit water supply corporations, for-profit private suppliers, more than a dozen types of public general law water districts, and special law water districts. TWDB has identified 45 current and potential water service providers to sample colonias in this analysis. Suppliers differ in terms of rate-setting authority, access to low-cost state and federal funds for colonia infrastructure, and ability to issue debt. Table 6 summarizes relevant water provider characteristics.

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[8] A contract-for-deed requires residents to make monthly payments on their land, financed by the developer, but they establish no equity until the final payment. The practice was restricted by the Texas Legislature in 1995.

[9] Combined funding available from state, federal and binational programs for Texas colonia infrastructure was almost $580 million by 1999 (Haurwitz 1999).

[10] Texas Water Code Chapter 13, "Water Rates and Services," Sec. 13.246, available at http://www.capitol.state.tx.us/statutes/coses/WA000008.html.

Table 6. Texas Water Service Provider Characteristics

Type of Water Service Provider	Percent of Colonias Served[a]	Rates Regulated[b]	Issues Debt[c]	Able to Tax	Borrows from RD[d]	Borrows from EDAP[e]
Public Providers						
Municipal system	7.8%	Internal	GO, R	Yes	No	Yes
County system	0.3	TNRCC	R	Yes	If rural	Yes
General law district	11.9					
Water district		TNRCC	R	Yes	If rural	Yes
Water control and improvement district		TNRCC	R	Yes	If rural	Yes
Municipal utility district		TNRCC	R	Yes	If rural	Yes
Private Providers						
Non-profit water supply corporation	74.7	None[g]	No	No	If rural	Yes[f]
Small, for-profit water provider	2.4	None	No	No	No	No
No Current or Potential Provider						
Community or individual wells	0.4	N/A	N/A	N/A	N/A	N/A
Haul water	2.5	N/A	N/A	N/A	N/A	N/A

(a) Percent of colonias is percent of sample colonias, not all Texas colonias.
(b) Entities regulated by TNRCC are regulated by municipalities, and entities otherwise unregulated are regulated by municipalities, if they operate within a municipality's corporate limits.
(c) Abbreviations: GO – General obligation bonds; R – Revenue bonds. Revenue bonds issued by these entities, except for municipalities, require voter approval.
(d) Abbreviation: RD – Rural Economic and Community Development Agency, U.S. Department of Agriculture
(e) Abbreviation: EDAP – Economically Distressed Areas Program, Texas Water Development Board
(f) EDAP interest rates for private non-profit water supply corporations are higher than for public entities.
(g) Rates not regulated, although potential ratepayers can appeal rates, extension costs, capital recovery fees, and other costs to TNRCC if deemed unreasonable by 10,000 or 10 percent of ratepayers.

Sources: Texas Natural Resource Conservation Commission, "District Powers and Duties," available at http://www.tnrcc.state.tx.us/water/wu/district/distpubs.html#info; Texas Water Code, Chapter 67, "Nonprofit Water Supply or Sewer Service Corporations," available at http://www.capitol.state.tx.us/statutes/codes/WA000050.html; Carol Limaye and Doug Holcomb, Water Utilities Division, Texas Natural Resource Conservation Commission, telephone interviews (9 April 1999); Texas Water Code, Chapter 13, "Water Rates and Services," Sec. 13.042 – 13.187, http://www.capitol.state.tx.us/statutes/codes/WA000008.html.

2.4 Water Supply Corporations

The majority of sample colonias in the four counties (75 percent) are either currently or most likely to be served by non-profit water supply corporations, which merit special description. Water supply corporations have existed in Texas since the 1950s. Texas law allows the formation of a non-profit water supply corporation (WSC) by agreement among three or more potential ratepayers. WSCs must distribute any profits earned among their members; their non-profit status does not denote a charitable mission.

WSC boards are elected exclusively by ratepayers. They have none of the competing priorities of other Texas political subdivisions, as they are legally able only to provide water service (Limaye 1999). They have no taxing or bonding authority, but like cities, counties and water districts, they can obtain grants and low-cost loans from state pools of general obligation bond proceeds and federal grants and loans for colonia infrastructure. Their rates are set internally and are not regulated by TNRCC, unless disputed by 10,000 or 10 percent of ratepayers, whichever is smaller. A WSC is legally bound to respond to requests for new service connections (within the service area defined by its CCN) by calculating an estimate of tap fees, membership fees, capital recovery costs, and any other allowable charges to a new member. If the potential ratepayer cannot afford these fees, the WSC has met its legal obligation by providing the cost estimate, and is not obligated to provide service. Potential customers can appeal fee estimates to TNRCC, but no service obligation can be enforced if fees are deemed reasonable.

Of the remaining 25 percent of colonias not served by WSCs, almost 8 percent are currently or likely to be served by public municipal systems, and 12 percent are currently or likely to be served by general law water districts. Two percent of colonias are currently or likely to be served by small, for-profit water providers, most of these in El Paso county where scarce surface water has given rise to a trade in private groundwater pumping. Less than one-half of one percent are currently or likely to be served by counties. For the remaining colonias, TWDB had identified no likely water service provider as of 1996.

3.0 FACTORS INFLUENCING WATER UTILITY SERVICE COVERAGE

Factors influencing service acquisition among colonias can be broadly classified as: (1) economic and financial; (2) institutional; and (3) political. The econometric analysis in Section 5.0 uses proxies for these factors as independent variables, gauging their influence on the likelihood that a colonia had received water service as of 1996. While political factors are included only indirectly in the models, they are discussed below to highlight an area for further research.

3.1 Economic and Financial Factors Influencing Water Service Coverage

One would expect cost to be negatively correlated with a colonia's likelihood of water service coverage. The persistence of inadequate service coverage may be due to the fact that colonias are distant from existing facilities, built in floodplains, or otherwise difficult to serve from an engineering perspective. Ideally, this analysis would incorporate precise measures of engineering cost. For example, road-feet from the nearest existing water treatment facility would be one of a group of engineering cost variables. The ideal analysis would also include data on colonia plumbing facilities. Unfortunately, reliable engineering cost and household connection cost data currently are unavailable. In this analysis, three independent variables are tied to the cost of serving colonias: urban or rural status, population and density.

Urban or rural status is a measure of proximity to an existing system; urban location should be positively correlated with probability of water service. Inclusion of total population as an explanatory variable accounts for economies of scale in serving colonias; in this regard, we

would expect population to be positively correlated with likelihood of service coverage. For urban areas, the population effect may work in reverse, as larger populations of low-income ratepayers are more expensive to absorb into existing systems if they require cross-subsidies. The density of a colonia should relate inversely to the cost of service provision, as higher density means that water lines will serve larger numbers of ratepayers (Ward 1999). The ideal measure of density in a colonia would be number of homes per acre, or average number of empty lots between developed lots. This information is not available; thus, I have used number of persons per household to reflect population density.

One also would expect provision of service to colonias to be influenced by the possibility of obtaining revenue sufficient to cover infrastructure investment, operations and maintenance costs. Low incomes among colonia residents inhibit user fee-based financing of colonia water and wastewater systems, even when they may be easily connected to an existing system. Colonia median per capita income is used in this analysis as a measure of ability to pay, or a potential service provider's perception of ability to pay for utility services, which should be positively correlated with probability of service coverage. Ideally, the models would include independent variables to account for other aspects of revenue risk, such as the presence of other utility services within a colonia, the status of plumbing facilities, or the age of housing stock.[11]

3.2 Institutional Factors Influencing Water Service Coverage

A colonia's type of current or most likely service provider is included as an independent variable in the econometric models in Section 5.0.[12] Public policy regarding colonias has focused on the characteristics of these settlements that make them less likely to obtain service. Service provider characteristics have been almost completely overlooked. Two factors that may be important determinants of service to colonias are providers': (1) access to federal and state grants and low-cost loans for colonia infrastructure; and (2) ability to charge different prices to high-cost and low-cost customers.

All service providers can access state general obligation bond proceeds for colonia infrastructure funding, available from the TWDB's Economically Distressed Areas Program (EDAP). This program provides financing packages that can be up to 90 percent grant funds, depending on a colonia's particular economic and demographic characteristics. Loans are for a period of 20 years at below-market rates. The Rural Economic and Community Development Agency (Rural Development) offers 100 percent grant funding for household plumbing improvements, and grant/loan combinations for other colonia infrastructure investments.[13] Loans are for a period of 40 years, and rates are below EDAP rates. Water supply corporations, counties, and general law water districts can access both of these programs to connect colonia

[11] Many colonias are unable to finance indoor plumbing improvements and curb-to-household connections. According to the 1990 U.S. Census, 18 percent of colonia homes in Hidalgo county lack complete plumbing facilities, compared to 5 percent of non-colonia homes. If ratepayers cannot afford to connect, the project revenue stream is jeopardized.

[12] Among sample colonias, 81 percent had obtained water service as of 1996 from a provider on record at the Texas Water Development Board (TWDB). TWDB has identified a "most likely" service provider, based on geographic proximity and other factors, for most of the 19 percent of sample colonias without water service.

[13] Rural Development is part of the U.S. Department of Agriculture and was once called the Farmers' Home Administration.

ratepayers; most municipalities have access only to EDAP, and not to Rural Development, due to the cap of 10,000 ratepayers.

Freedom to establish rates and to set different rates for high and low-cost customers also varies among service providers. Non-profit water supply corporations and private, for-profit suppliers have the greatest freedom in this regard. The rates of private, for-profit suppliers are unregulated.[14] Non-profit water supply corporations are responsible only to their ratepayers regarding price, unless 10,000 or 10 percent of ratepayers appeal a WSC's rates to the TNRCC. Municipalities regulate rates within their corporate limits. Ratepayers outside corporate limits, but connected to municipal systems, can appeal unreasonable rates to TNRCC. In contrast, TNRCC sets the water utility rates of general law water districts and counties.

One would expect that a relatively "better" position on each of these fronts would increase the probability that a given provider would extend service to colonias. For example, non-profit water supply corporations have access to both EDAP and Rural Development funding for colonia projects. They also have the freedom, within their CCN, to charge ratepayers differential prices based on costs of connection. In practice, their capital recovery fees and other initial charges to new ratepayers do vary on the basis of cost (Holcomb 1999). It is unclear whether this price difference extends to monthly utility bills.

In contrast, municipalities, who cannot access Rural Development funds, but only the relatively more expensive, shorter-term EDAP funds, may be less willing to connect colonias. Municipalities can set utility rates within their corporate limits, but they are politically responsible to all registered voters, not just ratepayers. In this regard, they may have less freedom to charge different prices to different customers, and to exclude high-cost customers from service networks, once these customers are within a municipality's CCN.

3.3 Political Factors Influencing Water Service Coverage

In addition to economic factors described above, political factors may play an important role in determining which colonias obtain service. Providing utility service to areas that lag behind an urban core in infrastructure development can be a political problem, especially when services must be financed by taxing those who already have services (Gardner 1984). The nature of a colonia's similarity or dissimilarity to its neighboring communities (in terms of race, income, employment, etc.) may play an important role in obtaining service from central utilities. Colonia voting power may also be important. Activist groups like Valley Interfaith and the El Paso Interreligious Sponsoring Organization (EPISO) have helped obtain utility services for individual colonias through successful community organizing, media strategies, and state and local political lobbying. Political factors are addressed only indirectly by the independent variables in this analysis, which may lead to omitted variables bias.

[14] These suppliers generally serve colonias in El Paso county, where some colonias have contracted with private groundwater pumping suppliers, rather than connecting to existing systems or continuing to haul water from distant sources.

4.0 DATA DESCRIPTION

4.1 Texas Water Development Board Colonias Database

The most important sources of data for this analysis are a series of surveys made by the Texas Water Development Board (TWDB) Facility Needs Section. In 1992, the TWDB surveyed all 32 Texas border counties, an area the size of Louisiana, to determine colonia locations, populations, and the magnitude of their water and wastewater infrastructure needs. The survey was widely believed to have undercounted colonias. The agency updated this survey in 1995, adding several hundred colonias missed in 1992. TWDB used updated 1995 survey results to compile the Colonias Database, containing the infrastructure-related data used in this analysis. Table 7 defines variables drawn from the TWDB Colonias Database for this analysis.

Table 7. Variables Drawn From TWDB Colonias Database

Variable	Description
water96	Identifies colonias as (1) served; or (0) unserved by a water system.
county	Identifies colonia's county as (1) Cameron; (2) Hidalgo; (3) El Paso; or (4) Webb.
popn	Colonia population, 1996.
density	Average number of persons per household.
providr	Type of current or potential water provider. Categories: (1) non-profit water supply corporation; (2) municipal; (3) county or general law water district; (4) wells, unknown, or haul water; and (5) private, for-profit supplier.

4.2 Office of the Attorney General of Texas Border Database

The colonia demographic data used in this analysis is drawn from the Texas Border Database, compiled by the Litigation Technical Support Division of the Office of the Attorney General of Texas (OAG). Colonia demographic data are available only for the four counties that comprise the sample in this study. I use the OAG data, rather than pulling observations directly from the U.S. Census, because colonias are not incorporated areas (with one exception) or census-designated places and as such are not listed in Census data as individual entities. The two variables in this analysis drawn from the Texas Border Database are *income*, which represents median colonia per capita income in 1989; and *urban*, which indicates whether a colonia is (1) urban; or (0) rural.

5.0 ECONOMETRIC ANALYSIS OF WATER SERVICE COVERAGE

This section examines the relationship between a colonia's receipt of water service by 1996 (the dependent variable) and six independent variables: (1) colonia population; (2) customer density, or average number of residents per dwelling; (3) per capita income; (4)

whether the colonia is in an urban or rural area; (5) type of current or most likely colonia water service provider; and (6) the county in which a colonia is located. Some important results are listed below.

- For rural colonias, population gains increase probability of water service coverage, ceteris paribus. For urban colonias, the relationship between population and water service is more complex. For small urban colonias, population gains increase slightly the probability of water service coverage. But the reverse is true for larger urban colonias, ceteris paribus.

- Urban location increases probability of water service coverage, holding all other variables constant. Urban colonias are between 5 and 16 percent more likely to have received water service by 1996 than rural colonias, simulated at mean values of all other independent variables. This may be due to the smaller distance between these colonias and existing systems, which results in lower connection costs. Urban colonia housing may also be more dense, lowering the cost of internal distribution infrastructure relative to rural colonias.

- Higher per capita income increases the likelihood that a colonia had received water service by 1996. For every $1,000 in per capita income, a colonia is two to three percent more likely to have received water service by 1996, ceteris paribus. Income appears to be more strongly correlated with water service coverage for rural than for urban colonias.

- Water service provider type strongly influences the likelihood that a colonia had received water service by 1996. If a colonia's most likely or current service provider in 1996 was a non-profit water supply corporation, the colonia was much more likely to have received service than if its most likely service provider was a municipality (42 percent more likely), county system or general law water district (31 percent more likely), ceteris paribus.

- The county in which a colonia resides influences probability of water service. Colonias in Webb county were least likely to have received service by 1996, ceteris paribus, than colonias in El Paso, Cameron, or Hidalgo. Colonias in Hidalgo and Cameron counties colonias were most likely to have obtained service by 1996. El Paso county colonias fared better than those in Webb county did, but not as well as colonias in Cameron and Hidalgo.

5.1 Probit Models of Water Service Coverage

This analysis uses maximum likelihood probit analysis because the dependent variable, water service coverage as of 1996, is binary. If a colonia had obtained water service by 1996, the value of the dependent variable is one; if not, the value is zero. I estimate two models (A and B). Model A assumes that probability of water service in rural and urban colonias will be affected identically by the explanatory variables. Model B tests whether the effect of some explanatory variables on probability of water service differs, depending on whether a colonia is urban or rural. The basic probit model equation for Model A is listed below, where $\Phi(.)$ is the standard normal cumulative distribution function. The results of Model A are listed in Table 8.

Probit Equation: Model A

Prob (water service by 1996) = $\Phi[\beta'x]$

$= \Phi[\ \beta_0 + \beta_1(popn) + \beta_2(lnpopn) + \beta_3(density) + \beta_4(income) + \beta_5(urban) + \beta_6(county1) + \beta_7(county2) + \beta_8(county3) + \beta_9(providr1) + \beta_{10}(providr2) + \beta_{11}(providr3) + \beta_{12}(providr4)]$

Table 8. Results of Probit Model A

Observations	781			
Likelihood Ratio Index[a]	0.3701			
Correct Predictions (% of total)	0.9117			
Variable	**Coeff**	**SE**	**p>|z|**	**dF/dx**
popn (000)	0.13162	0.22581	0.560	0.01919
ln(popn)	0.29276	0.10013	0.003	0.04268
density	-0.09721	0.09697	0.316	-0.01417
income ($000)	0.15415	0.04795	0.001	0.02247
urban	0.40848	0.19521	0.036	0.05463
county1 (Cameron)	1.81622	0.54164	0.001	0.09819
county2 (Hidalgo)	1.84470	0.47394	0.000	0.45368
county3 (El Paso)	0.76892	0.75979	0.312	0.07596
county4 (Webb)[b]				
providr1 (non-profit WSC)	-0.25188	0.74266	0.734	-0.03363
providr2 (municipal)	-1.81976	0.75838	0.016	-0.54281
providr3 (district/county)	-1.11664	0.54395	0.040	-0.27030
providr4 (wells/unknown)	-2.23857	0.94880	0.018	-0.70712
providr5 (private for-profit)[c]				
constant	0.39240	1.03600	0.705	N/A

(a) Likelihood Ratio Index = $(1 - (\ln L/\ln L_0))$. The index is an analog to R^2; it is bounded by zero and one and increases with the fit of the model.
(b) County 4 (Webb) dropped to avoid multicollinearity.
(c) Provider 5 (private, for-profit) dropped to avoid multicollinearity.

Urban colonias are 5.5 percent more likely to have obtained service by 1996 than rural colonias, at mean values of all other variables.[15] The likelihood that a colonia had received water service by 1996 is also increasing in per capita income. For every $1,000 increase in per capita income, a colonia's probability of water service by 1996 increases by 2.2 percent. Larger colonias also are more likely to have obtained service by 1996, although the relationship between population and probability of water service exhibits diminishing returns. For colonias with

[15] The model coefficients (β) cannot be interpreted as the marginal influence of the independent variables on water service, as they would be in a linear regression model. The column labeled dF/dx converts probit coefficients into the more familiar marginal influence parameters, taken at the mean values of continuous regressors, and for a discrete change from zero to one for the binary regressors.

population less than 1,000, the natural log of the population variable (*lnpopn*) is negative (population is expressed in thousands). The population effect for colonias with fewer than 1,000 residents (the combined effect of *popn* and *lnpopn*) may still be positive, but small. All Model A coefficients are significant at a 95 percent confidence level, except the coefficients on *popn*, *density*, *county3* (El Paso), and *providr1* (non-profit water supply corporations). Model A correctly predicts water service coverage in more than 91 percent of sample colonias.

Model B tests for differences between urban and rural colonias, with respect to the influence of the explanatory variables on water service coverage probability. This was accomplished by interacting the variable *urban* with some of the other independent variables.[16] Model B incorporates two interactions, one between urban location and population, and the other between urban location and income. Results are listed in Table 9.

Table 9. Results of Probit Model B

Observations	781			
Likelihood Ratio Index[a]	0.3836			
Correct Predictions (% of total)	0.9104			
Variable	**Coeff**	**SE**	**p>|z|**	**dF/dx**
popn (000)	0.75112	0.48315	0.120	0.10432
ln(popn)	0.29081	0.10781	0.007	0.04039
density	-0.12032	0.09934	0.226	-0.01671
income ($000)	0.21815	0.06113	0.000	0.03030
urban	1.47053	0.54547	0.007	0.16288
county1 (Cameron)	2.33739	0.63027	0.000	0.09976
county2 (Hidalgo)	2.36829	0.57076	0.000	0.60367
county3 (El Paso)	1.71916	0.88529	0.052	0.11052
county4 (Webb)[b]				
providr1 (non-profit WSC)	0.06383	0.75222	0.932	0.00907
providr2 (municipal)	-1.51651	0.77046	0.049	-0.42015
providr3 (district/county)	-1.26923	0.56086	0.024	-0.31329
providr4 (wells/unknown)	-1.72482	1.00814	0.087	-0.52295
providr5 (private for-profit)[c]				
*urban*popn*	-0.92583	0.45783	0.043	-0.12859
*urban*income*	-0.16502	0.09431	0.080	-0.02292
constant	-0.73314	1.17596	0.533	N/A

(a) Likelihood Ratio Index = $(1 - (\ln L/\ln L_0))$. The index is an analog to R^2; it is bounded by zero and one and increases with the fit of the model.
(b) County 4 (Webb) dropped to avoid multicollinearity.
(c) Provider 5 (private for-profit supplier) dropped to avoid multicollinearity.

[16] Inclusion of interactive variables was complicated by covariate data patterns which predict service or lack of service perfectly. For example, all sample colonias in urban areas with a private, for-profit water supplier had obtained water service as of 1996. No sample colonias in rural areas with unidentified water service providers had obtained water service as of 1996. It was not possible, therefore, to test for differences in provider types' influence on probability of service among urban and rural colonias.

The coefficient on *urban*popn* is significant and negative, indicating that the slope of the relationship between population and water service is different for urban colonias than it is for rural colonias. While larger colonias are more likely to obtain water service in general, the linear population effect is relatively stronger for rural colonias than it is for urban colonias. This is actually quite logical, given that urban colonias are more likely to be connected to existing municipal systems. In an urban setting, as a colonia increases in size, an existing system must absorb a greater number of low-income ratepayers. The combined effects of *popn*, *lnpopn*, and *urban*popn* may actually work against large urban colonias. For example, a colonia of 3,000 residents in an urban area would be two to three percent less likely to have obtained water service by 1996 due to the size of its population, ceteris paribus.

The coefficient on (*urban*income*) is significant at a 90 percent confidence level. This indicates that the slope of the relationship between income and water service is different for urban colonias than it is for rural colonias (although the combined income effect for both urban and rural colonias is still positive). For every $1,000 in per capita income, a rural colonia is three percent more likely (and an urban colonia is less than one percent more likely) to have obtained water service by 1996, ceteris paribus.

Other Model B results differ slightly from those of Model A. Once we control for interactions between urban location, population, and income, the "pure" urban effect becomes much stronger. Model B estimates that an urban colonia is 16 percent more likely to have obtained water service by 1996 than a rural colonia, ceteris paribus. Model A, in contrast, estimated that urban location increased probability of water service by only 5 percent. The county effects for Hidalgo and El Paso are also significantly different in this model, as are the provider effects for types two, three, and four. Model B also correctly predicts water service coverage or lack of coverage for more than 91 percent of sample colonias.

5.2 Interpretation of Probit Model Results

Results concur with the hypothesis that non-universal water service among colonias results, in part, from the high cost and low revenues associated with serving these communities. More importantly, they concur strongly with the hypothesis that some types of water suppliers are more likely than others to serve colonias within their state-permitted territories. The following paragraphs summarize results of the econometric analysis, using Model B as the definitive model.

- ***Proximity to existing facilities, which suggests lower water infrastructure cost, increases a colonia's probability of water service.***

The significance of the urban effect, a proxy for water infrastructure project cost, indicates that lower cost is correlated with higher probability of water service. Colonias located in urban areas are as much as 16 percent more likely to have obtained water service by 1996 as colonias located in rural areas, due at least in part to the higher cost of extending service to communities distant from existing drinking water facilities.

- ***Average number of persons per household, a proxy for internal water distribution project costs, does not appear to affect probability of water service.***

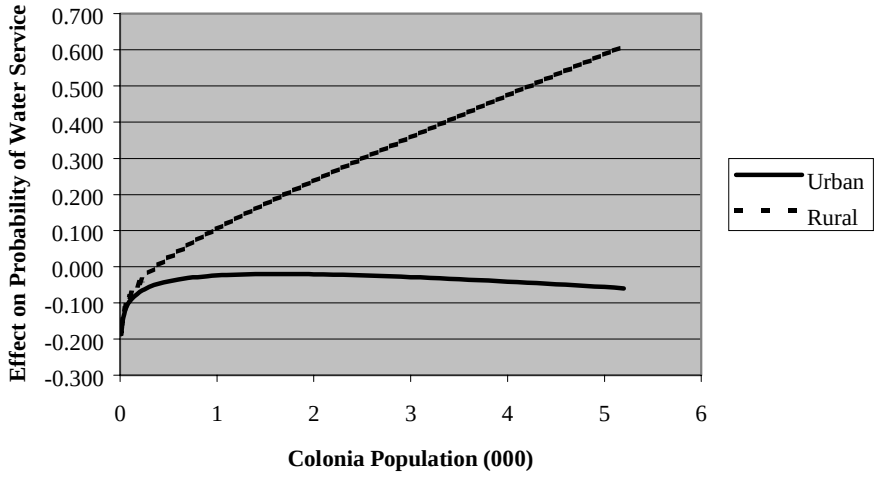
Density variable coefficients were not statistically significant in either model. Identifying a better measure of settlement density, to account for the cost implications of serving more or fewer households with each water line, is an area for further research.

- ***The impact of population on probability of water service depends on whether a colonia is located in a rural or an urban area.***

Colonias within urban areas are more likely to obtain water service if they are small. Colonias outside of urban areas are more likely to be served if they are large. The relationship between colonia population and probability of service is described by three variables in Model B (*popn*, *lnpopn*, and *urban*popn*). When calculated at mean values of all other variables, the total population effect is increasing and concave for rural colonias, and slightly parabolic for urban colonias. Figure 1 demonstrates the effect of increases in population on probability of water service, holding all other independent variables constant at their means.

The probability of water service for rural colonias is increasing across all values of population and slightly concave. The population effect for urban colonias is negative and concave across all values of population, increasing for colonias with fewer than 2,000 residents, and decreasing thereafter. For colonias with more than 2,000 residents, gains in population decrease probability of water service. Urban colonias are more likely to be absorbed by existing systems than their rural counterparts, which may explain the shape of the urban population effect. To a point (2,000 residents), colonias may be absorbed by existing systems without significant financial impact. Large colonias may be too expensive for existing systems to absorb, or they may be more attractive to other potential service providers, in which case they may be involved in the protracted negotiations resulting from a contested CCN.

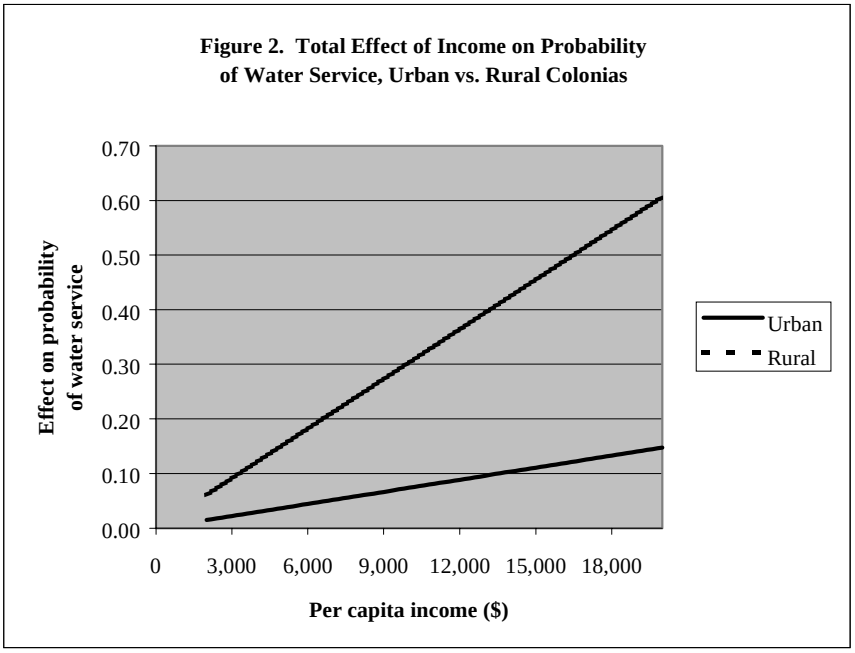
Figure 1. Total Population Effect on Probability of Water Service, Urban vs. Rural Colonias



- ***Higher ability to pay increases a colonia's probability of water service coverage.***

Colonia per capita income is positively correlated with service coverage, but income has relatively more influence on service provision for rural colonias than for urban colonias. One possible explanation is that rural colonias may require larger initial infrastructure investment, relative to their size. The total effect of income on probability of service is described by two variables in Model B (*income* and *urban***income*). Figure 2 illustrates the total effect of per capita income on water service, ceteris paribus.

Figure 2. Total Effect of Income on Probability of Water Service, Urban vs. Rural Colonias



- ***Colonias in or near the service areas of non-profit water supply corporations and for-profit water suppliers are relatively more likely to have received service by 1996 than those served by municipalities, water districts, and counties.***

For-profit suppliers are used as the base case for models A and B, because these suppliers have almost 100 percent service levels among their current and projected colonia customers. They do not obtain monopoly service areas from the state, but are hired by communities for whom it is cheaper to purchase heavily treated groundwater pumped by private companies than to connect to surface-water-dependent systems. (For-profit suppliers are sought out by colonia customers. In contrast, the other types of providers simply end up with colonias within their state-permitted territory and decide to serve or not to serve them.)

There is no statistically significant difference in the effect on probability of service between colonias served by these for-profit suppliers and those served by non-profit water supply corporations. Colonia customers of non-profit and for-profit suppliers are statistically equally likely to be served, ceteris paribus. This is a surprising result, indicating that WSCs are prodigious connectors of colonia customers, when compared with other types. General law water districts and counties are the "next best" connectors of colonia ratepayers, followed by

municipalities. Colonias in or near the state-permitted service territories of WSCs are 42 percent more likely to have obtained water service as of 1996 than those relying on municipalities, and 31 percent more likely to have obtained water service than those relying on counties or water districts.

Although one could question the direction of causation, WSCs do not appear to be "cream-skimming," or selecting only the most financially attractive colonias to connect. If WSCs have served nearby colonias in greater proportion than municipalities, counties and general law water districts in this analysis, they have done so despite the relatively less "attractive" nature of the colonias that they serve. Table 10 compares four characteristics of colonias, summarized by water service provider type.

Table 10. Colonia Characteristics by Water Provider Type

	Characteristics of Colonias Served or Likely to be Served by Provider in 1996			
Water Provider Type	Mean Population (000)	Mean Income	Proportion Urban	Proportion Served, 1996
Non-profit WSC	0.195	5,093	0.270	0.951
Municipality	0.322	6,287	0.279	0.590
County or District	0.650	4,844	0.833	0.646
Wells/Unknown Provider	0.057	5,517	0.000	0.043
Private, For-profit Provider	0.512	7,354	0.579	0.947

Colonias currently or likely to be served by WSCs are on average smaller, poorer, and less urban than colonias currently or likely to be served by municipalities. WSC current and potential colonia ratepayers have the lowest among all median per capita incomes, but the highest of all proportions served.[17] Only 27 percent of WSC current and potential colonia customers are urban. Excluding those colonias for whom no likely central water provider has been identified, this is the lowest proportion of urban customers of all provider types.[18] On average, WSCs serve colonias with fewer than 200 residents, the smallest average colonia customer base among service providers.[19]

[17] Per capita income among colonias served or projected to be served by WSCs is, on average, 19 percent lower than per capita income among those served or projected to be served by municipalities, and 30 percent lower than among those served or projected to be served by private, for-profit providers. Both of these differences are statistically significant at a 95 percent confidence level, by a t-test of difference in means. Perhaps due to the small number of observations in the other two categories (wells/unknown and county or district), the apparent differences in per capita incomes between these categories and the WSC colonias are not statistically significant.

[18] Differences in proportion of urban colonias among those currently or likely to be served by WSCs and all other types are significant at a 95 percent confidence level, according to a z-test for difference in proportions, except for the difference between urban proportion of WSC and municipal colonia customers.

[19] This excludes those colonias with unidentified central providers, which are smallest, on average. Differences of average population among colonias served by WSCs and all other types of providers are significant at a 95 percent confidence level, using a t-test for difference in means.

WSCs' successful service record may be explained, in part, by the differences noted in Sections 2.3-2.4 (see Table 6). Recall that, unlike most provider types, WSC rates are not regulated by TNRCC. Water supply corporations operating in rural areas also have access to grant and low-cost loan funds from Rural Development, which offers 40-year loans at lower "poverty" interest rates than the 20-year loans offered by the largest state-level source of colonia infrastructure funds, EDAP (Limaye 1999). Municipalities cannot access these funds, as Rural Development borrowers must have fewer than 10,000 ratepayers. The combination of these two factors (greater rate flexibility and access to funding on better terms) may be enough to explain WSCs' better record of colonia coverage. Determining whether WSCs cross-subsidize colonias, or whether colonia ratepayers have generated sufficient revenue for their connections to be self-supporting, is an important area for further research.

- ***Residence in the Lower Rio Grande Valley increases a colonia's probability of water service coverage, relative to colonias in the middle and upper border regions.***

The county effects in models A and B are noticeably large. The magnitudes of these coefficients are second only to the provider type coefficients. The effect of county on a colonia's probability of water service coverage is almost identical for Cameron and Hidalgo counties, and colonias in both of these counties are significantly more likely to have obtained service than those in El Paso and Webb counties, controlling for all other independent variables.

Counties are an important level of local government for colonia service provision. Development within unincorporated areas generally falls under county jurisdiction in Texas, and the extent to which counties have focused resources on stemming colonia development and upgrading conditions in existing colonias varies widely. Although the presence of a county effect was predicted by this analysis, the magnitude of that effect is surprising. Further research will be necessary to separate the county effect into its political and other components.

6.0 CONCLUSIONS

Inadequate drinking water service coverage among Texas border colonias is a multi-dimensional problem. This study offers the first empirical evidence that potential for high infrastructure cost and low revenue reduce a colonia's likelihood of obtaining water service. It also demonstrates for the first time the strong influence on water service coverage of a colonia's current or most likely water service provider. Non-profit water supply corporations appear to have been more pro-active in providing water service to colonias within reach of their service areas than have municipalities, counties, and general law water districts. This study also offers evidence that political factors may strongly influence service coverage, identifying an area for further research.

6.1 Policy Implications of Differences among Water Service Providers

Econometric results regarding water service provider types indicate that policymakers should pay more attention to this issue than is currently the case. For example, WSCs' notable propensity to connect colonia ratepayers may be attributed to their pricing flexibility. Assuming cost-minimization, rates paid by colonia residents are less than or equal to their next best solution

for water service, which may entail hauling water from distant sources or consuming water from unregulated sources with its associated health risks. If WSC colonia customers are paying unsubsidized rates, and those rates are acceptable, given the low incomes typical of these communities, then pricing flexibility may be a key component of service expansion to colonias.

If WSCs' high performance as colonia connectors is due to their access to Rural Development grant and loan programs from the U.S. Department of Agriculture, then EDAP and other programs should consider copying some of the more flexible pieces of Rural Development programs. Political and institutional capacity may also explain some of the variation in colonia service among water provider types. For example, the competing priorities of municipalities, and their accountability to taxpayers at large, may make them less efficient providers of colonia services than WSCs.

The impressive record of non-profit water supply corporations in colonia service provision is not an unqualified endorsement of expanding their role in service provision. As mentioned earlier, the problem to be addressed is the quality of water service, not whether colonias receive service at all. Without data on quality of service, it is difficult to tell whether connection to a WSC (or any other central provider) indicates access to safe drinking water.[20]

6.2 Need for Different Policies regarding Urban and Rural Communities

Econometric analysis in Section 5.0 illustrates that the problem of providing water service to colonias is quite different for urban and rural communities. These problems of rural and urban water supply require different policy responses. While proximity to existing systems works in favor of urban colonias, size works against them, and income gains do not increase probability of service as quickly as they do for rural colonias. Distance from existing systems works against rural colonias, but size works in their favor, and income gains can increase substantially their probability of service coverage.

Urban areas with colonias effectively are segregated into neighborhoods with public water provision, and those without. Colonias are a source of extremely low cost housing in border counties, in part because of low or zero utility costs. The fact that many colonias lack utility services is incorporated in residents' housing decisions. If expanding service to these residents is socially desirable, then the state faces a choice between stricter development regulation in urban and peri-urban areas, increased state or local subsidies to support service expansion, and greater pricing flexibility on the part of municipal and other water systems. These three options differ both in terms of economic efficiency and equity. For example, greater pricing flexibility for colonia water suppliers would allow prices to rise toward cost of service—this is the most efficient option. But among the three options, greater pricing flexibility will also likely result in the highest rates for colonia water customers. [21]

[20] In addition, agricultural cooperatives with some similarities to WSCs in developing countries have been shown to have disproportionate control rights wielded by wealthier members (Banerjee et al. 2001). In addition to water service quality, the financial and equity implications of WSC service may be important.

[21] Without regulations requiring universal water service coverage, using this option may price many colonia residents and future residents out of the market for water service, limiting expected coverage increases.

The large initial infrastructure investment required to connect rural communities to centralized systems calls into question the wisdom of universal service coverage, from an economic efficiency perspective. (This is similar to the questions raised by the Rural Electrification program in the U.S.) In addition, the potential for negative public health externalities resulting from inadequate water service is smaller for rural colonias. The issue of water coverage for rural colonias is therefore quite different from the question of urban colonia service provision. One Texas legislator notes that some rural colonia households are "so remote that it would cost more to extend utility lines than the houses are worth." He is not the first to suggest that relocating these colonia residents might be the wiser policy option.[22]

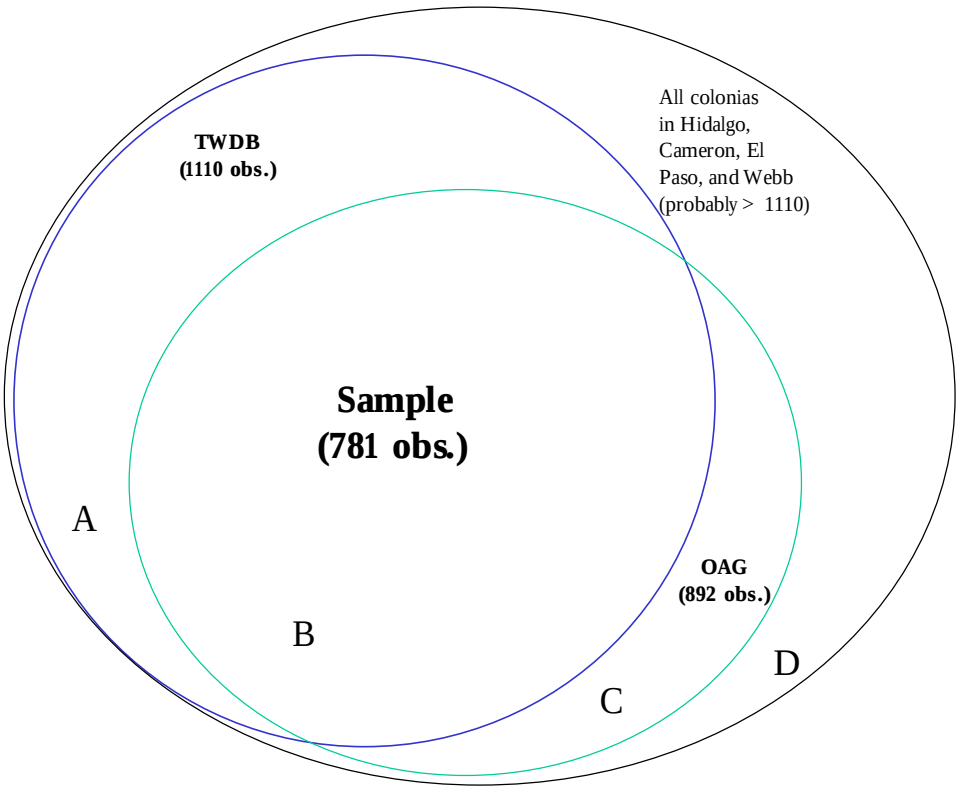
Thus two very different problems face state policymakers concerned with extension of drinking water service to colonias. First, how can they encourage the expansion of service to colonias adjacent to urban neighborhoods already receiving service? Second, how can policymakers define an appropriate decision rule for water service provision to rural colonias, based upon some combination of efficiency and distributional criteria, and how will they encourage extension of service to those that qualify under this rule? The concept of "adequate service coverage," in terms of efficiency and equity, remains to be defined in Texas.

[22] Eliot Shapleigh, D-El Paso, quoted in Haurwitz (1999).

Appendix: Data and Sources of Bias

The sample resulting from the merger of OAG and TWDB data in this analysis is a subset of all available data. Some colonias included in the TWDB database were not included in the OAG database; the opposite is also true. Figure A1 describes the sample colonias in this manner. The sample used for this analysis comprises the 781 colonias in area B, for which data was available in both the TWDB and OAG databases. Area A in the figure includes 329 colonias included in the TWDB database, but excluded from the OAG database. Area C in contains 111 colonias included in the OAG database, but excluded from the TWDB database. Area D in the figure below represents the only unknown quantity of colonias in the four sample counties—those excluded from available data because they are not part of the public record. It is possible that the total number of colonias in Cameron, Hidalgo, El Paso, and Webb counties exceeds the number recorded by TWDB.

Figure A1. Sample as Intersection of TWDB and OAG Databases



This appendix examines potential sample selection bias due to exclusion of those 329 observations in group A in Figure A1. Results indicate that the county and provider coefficients may be biased by the exclusion of these colonias from the sample. For the 111 colonias omitted from the sample and represented in group C above, we have only demographic information (per capita income and urban vs. rural status). These two colonia characteristics do not vary

significantly between the sample and group C.[23] Due to lack of infrastructure data on group C, there is no way to determine whether they differ along these lines. This is a potential source of bias in the model coefficients in Section 5.0 that cannot be eliminated with available data. The same can be said of colonias in group D. We have no information on these communities. Due to the fact that they were not discovered either during the 1992 TWDB colonias survey, or during the subsequent research that comprised the 1995 survey update, they may be quite distant from existing facilities, and therefore more difficult to serve. This analysis does not address the potential bias from group D, those colonias not yet on public record.

A final data limitation applies to the demographic data from OAG. Agency staff note that Census block groups identified as colonia block groups may include some areas outside the true boundaries of the colonia, and some areas that actually belong with a colonia may be excluded from a colonia's collected block groups (Falks 1999). The OAG cautions users of the database that a colonia's collected census units "can be expected to be somewhat 'better off' than the colonias themselves," in terms of income (Office of the Attorney General of Texas 1993). This may be partially counterbalanced by the systematic underreporting of household income data, especially for income sources not derived from direct earnings, noted by the U.S. Bureau of the Census.[24] Median per capita income data are the best available at the level of individual colonias.

If the income data are inaccurate, according to OAG, they probably err on the high side. This possible measurement error in per capita income data could introduce attenuation bias into the parameter estimates in Section 5.0, pulling the estimated coefficient on income toward zero and underestimating the relationship between income and water service coverage. Moreover, if income and the other independent variables are correlated, measurement error in the income data may also bias the other coefficients, but it is impossible to determine the direction of potential bias in coefficients other than the income coefficient. This analysis includes income as an independent variable, despite potential attenuation bias, because income may be an important indicator of ability to pay for utility services, and therefore an important determinant of a community's receipt of service. The omitted variables bias certain to enter if income is excluded is likely to be worse than attenuation bias.

5.3 Examination of Potential Bias Due to Sample Selection

The largest group of excluded observations are those 323 colonias for which we have TWDB infrastructure-related data, but no demographic data from OAG. If sample colonias and "missing" colonias are heterogeneous, sample selection may bias parameter estimates in Models A and B.

Table 11 compares variable mean values for sample observations with mean values from this excluded group. The two groups do appear to be heterogeneous. Those in the sample have larger populations. They are also served to a greater extent by non-profit water supply

[23] Among sample colonias, 34 percent are urban, while 43 percent of colonias in group C are urban. This difference is not significant at a 95 percent confidence level, but it is significant at a 90 percent confidence level. Per capita income differs among the two groups by $54, a statistically insignificant difference.

[24] U.S. Bureau of the Census, 1990 Census Summary Tape File 3 Technical Documents, *Appendix B: Definitions of Subject Characteristics*, p. 29, available at http://www.census.gov/td/stf3/append_a.html.

corporations, and to a lesser extent by municipalities. The county distribution of the two groups is also different. A much greater proportion of sample colonias had obtained water service as of 1996, relative to those missing from the sample due to lack of demographic data.

Table 11. Differences in Means,
Sample vs. Observations Missing Demographic Data

Variable	Sample Mean	Missing Data Mean	Difference	Significance (p-value)
Colonia population*	265	183	83	0.004
Proportion served by provider types				
Non-profit water supply corporation	0.75	0.63	0.12	0.000
Municipal supplier	0.08	0.20	-0.12	0.000
General law water district	0.12	0.09	-0.03	0.132
Wells/haul water	0.03	0.05	-0.02	0.015
Private, for-profit supplier	0.02	0.02	0.00	0.764
Proportion in each county				
County 1 (Cameron)	0.07	0.19	-0.12	0.000
County 2 (Hidalgo)	0.75	0.65	0.10	0.001
County 3 (El Paso)	0.14	0.13	0.01	0.723
County 4 (Webb)	0.04	0.03	0.01	0.345
Proportion with water service	0.86	0.69	0.17	0.000

*Note: Colonia population tested using t-test for difference in means. All other variables tested using z-test for difference in proportions, with a 95 percent confidence interval.

Two variables are missing from the excluded observations—income and urban or rural location (those drawn from the OAG database), so it is not possible to perform a Heckman sample selection correction. A probit model using the "missing" status of these 323 observations as the dependent variable can test whether sample selection is systematically correlated with the independent variables in this analysis, minus the missing income and urban variables.[25] The results of this probit model indicate that there may be sample selection bias in Models A and B. While the population coefficient in this probit model is not significantly different from zero, all of the county and provider type coefficients are statistically significant at a 95 percent confidence level.

It is difficult to predict how inclusion of these missing observations might affect the models, but it is likely that they would alter provider type and county coefficients. "Missing"

[25] The dependent variable in this model is called "missing," and takes on the value of one for the 329 observations missing from Models A and B, and zero for the 781 observations included in Models A and B.

colonias currently or most likely to be served by municipalities have obtained water service in greater proportion than their counterparts in the sample. In addition, "missing" colonias currently or most likely to be served by WSCs have obtained water service in lesser proportion than their counterparts in the sample. Inclusion of the missing observations might be expected to shrink the differences in propensity to serve colonias between municipalities, which might fare relatively better, and WSCs, which might fare relatively worse than indicated by their coefficients in the models. In addition, water districts might fare relatively worse than indicated by the models.

Water service among missing colonias in Cameron and Hidalgo county is substantially lower than service among their counterparts in the sample. Inclusion of these 329 colonias might therefore be expected to diminish the county effects observed in the models. More substantial conclusions about the possible effects of sample selection on model coefficients cannot be drawn without including all of the independent variables (including income and urban location) in the sample selection probit model. But results, especially those for county and provider type effects, should be interpreted with potential bias in mind.

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