Anticipating Mixed Use Water Demand: Chapel Hill & Carrboro, NC

By

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Acronyms

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
AWE	Alliance for Water Efficiency
AWWA	American Water Works Association
BAU	Business as Usual
BGD	Billion Gallons per Day
C&I	Commercial and Institutional
DU	Dwelling Unit
EPA	U.S. Environmental Protection Agency
EPAct	U.S. Energy Policy Act of 1992
FFL	Florida-Friendly Landscaping Program
FTE	Full-Time Equivalent
GBIG	Green Building Information Gateway
GPCD	Gallons per Capital per Day
GPF	Gallons per Flush
GPHSF	Gallons per Heated Square Foot
GPM	Gallons per Minute
GPU	Gallons per Unit
HMXD	High-Density Mixed Use
HSF	Heated Square Foot/Feet
KGPHSF	Thousand Gallons per Heated Square Foot
KGPSF	Thousand Gallons per Square Foot
KGPU	Thousand Gallons per Unit
LEED	Leadership in Energy and Environmental Design
MFR	Multifamily
MGD	Million Gallons per Day
MXD	Mixed Use
MXDR	Mixed-Use Residential
OWASA	Orange Water and Sewer Authority
RES	Residential
SF	Square Foot/Feet
SFR	Single Family Residential
TOD	Transit Oriented Development
TRWSP	Triangle Regional Water Supply Plan
UHI	Urban Heat Island
USGBC	U.S. Green Building Council
USGS	United States Geological Survey

Introduction

This report provides an overview of factors affecting water demand in mixed use developments in order to support the Orange Water and Sewer Authority's (OWASA) ongoing efforts to update their existing Long Range Water Supply Plan. The update will extend demand projections out to 2065, and will inform future decisions regarding water resources and the potential provision of additional incentives for improved water efficiency in the OWASA service area. Given the recent trend of increased mixed use development in Chapel Hill and Carrboro, OWASA officials are interested in both the historical demand patterns of existing developments as well as information about current industry standards for estimating water demand from mixed use properties. The overarching goal is therefore to provide context for the development of more accurate water demand assumptions for modern mixed use properties.

Toward that end, this report includes a summary of major drivers of water demand in mixed use properties, the effects of contextual factors at the site and institutional levels, and demand estimation methodologies that rely on land use as a means of anticipating future demands. In order to provide insight into relevant development trends in OWASA's service area, I conducted a series of interviews with local property managers focused on specific structural, managerial, and operational factors that might explain historical water demand at each site. The primary conclusion of this research is that water use has changed substantially in recent years due to improvements in water efficiency technology and practices across nearly all development types. As a result, ongoing demand estimation projects for mixed use development—and indeed all new development in OWASA's service area—should differentiate between historical water use rates and the lower water use rates exhibited by modern properties.

Factors Affecting Mixed Use Water Demand

Trends in Water Use

According to the United States Geological Survey (USGS), approximately 57 percent—or 23.8 billion gallons per day (bgd)—of water withdrawn for public supply in the United States in 2010 was delivered for domestic use (USGS, 2014a). This figure includes both indoor and outdoor uses such as drinking water, sanitation, and landscaping for residential customers nationwide (USGS, 2014a). OWASA's 50-year projections from 2011 show a total demand for raw water of 10.8-15.0 million gallons per day (mgd) in 2060, representing a substantial decrease from prior long-term estimates of 14.6-16.6 mgd in 2050 (OWASA Staff 2011, 3).

This reduction is largely attributed to an observed increase in water efficiency of 20-25 percent across all sectors (OWASA Staff 2011, 3), and fits with national trends in both total and per capita water use. A 2015 report by the Pacific Institute shows that total water use in the United States "peaked in 1980 at 440 bgd before falling to 400 bgd in 1985" (Donnelly and Cooley, 2015, 1). Total water use stayed somewhat flat between 1985 and 2005, before declining to 350 bgd in 2010 (Donnelly and Cooley, 2015, 1). National per capita water use also peaked in 1980 at 1,900 gallons per capita per day (gpcd), before falling to 1,100 gpcd by 2010 (Donnelly and Cooley, 2015, 1). Notably, nationwide per capita water use decreased by approximately 17 percent between 2005 and 2010, representing the largest decline in any five-year period (Donnelly and Cooley, 2015, 1).

Water use by the municipal and industrial sector—which includes residential use—accounted for only 19 percent of nationwide demand in 2010, but decreased by 4 percent from 2005 levels (Donnelly and Cooley 2015, 6). In fact, "per capita [municipal and industrial] water use has declined in every five-year period over the last three decades, from 360 gpcd in 1980 to 220 gpcd in 2010" (Donnelly and Cooley 2015, 6). Total national water use by the residential sector alone increased steadily between 1950 and 2005, while per capita demand remained somewhat steady at approximately 100 gpcd (Donnelly and Cooley 2015, 7). Between 2005 and 2010, however, "residential per capita water use declined by 7 percent, or 2 bgd, despite continued population growth, reducing per capita water use to 88 gpcd in 2010" (Donnelly and Cooley 2015, 8). These national figures, however, provide a somewhat skewed picture of trends in water use, as significant efficiency gains in most parts of the United States were offset by population increases in relatively hot and dry parts of the country. According to the USGS, per capita domestic water use ranged from a high of 168 gpcd in Idaho to a low of 51 gpcd in Wisconsin (USGS, 2014b). The State of North Carolina fell on the lower end of 2010 per capita domestic water use rates at approximately 70 gpcd, or 18 gpcd below the national average (USGS, 2014b).

As planners and other public officials consider options for ensuring adequate drinking water supplies and resiliency against drought, it is important to understand not only the impacts of increased efficiency at the building level, but also the potential impacts of broad changes in land use mixes and shifting development trends. Improved understanding of these factors will contribute to more accurate long term demand projections and help officials plan capital investments for infrastructure related to raw water supplies, treatment facilities, and distribution networks. While it is important to research key drivers of water demand in all types of development, this report is focused on mixed use properties as an increasingly popular form of urban development. Toward that end, the following subsections review literature from academic journals and publications by practitioners developing water supply plans for utilities and governments across the United States. The review is organized according to scale, beginning with key factors affecting water use at the building level and expanding outward to site characteristics and local institutional context.

Building Level Factors

Water demand at the building level is influenced by multiple factors including fixtures and amenities, landscaping features, and unit types and management practices. One helpful way of considering building level determinants of water consumption is to draw a distinction between efficiency and conservation, where efficiency is largely defined on a physical input versus output basis, while conservation is viewed more as a set of behavioral patterns and choices (Alliance for Water Efficiency, 2016). This subsection provides an overview of recent research on the impacts of both physical and non-physical factors affecting water demand in mixed use properties.

Fixtures & Amenities

In mixed use properties, one relevant factor is the efficiency of fixtures and amenities that draw water for recreation, sanitation, drinking, cooking, cooling, and other common non-industrial uses. In a 2016 review titled *The Status of Legislation, Regulation, Codes & Standards on Indoor Plumbing Water Efficiency*, the Alliance for Water Efficiency (AWE) outlined the progression of efficiency requirements for water-consuming plumbing products and appliances from 1980 to 2015 (Table 1). Included directly from the AWE report, this table uses 'gpf' to indicate 'gallons per flush' and 'gpm' to indicate gallons per minute (Alliance for Water Efficiency, 2016, 2).

Table 1: Water Consumption by Water-Using Plumbing Products and Appliances: 1980 - 2015

Water-using Fixture or Appliance	1980s Water Use	1990 Requirement	EPAct 1992 Requirement	2009 Baseline Plumbing Code	2015 'Green Code' Requirements	% Reduction in Average Water Use since 1980s
Residential Bathroom Lavatory	3.5+ gpm	2.5 gpm	2.2 gpm	2.2 gpm	1.5 gpm	**57%**
Showerhead	3.5+ gpm	3.5 gpm	2.5 gpm	2.5 gpm	2.0 gpm	**43%**
Toilet - Residential	5.0+ gpm	3.5 gpf	1.6 gpf	1.6 gpf	1.28 gpf	**74%**
Toilet - Commercial	5.0+ gpm	3.5 gpf	1.6 gpf	1.6 gpf	1.6 gpf	**68%**
Urinal	1.5 to 3.0+ gpm	1.5 to 3.0 gpf	1.0 gpf	1.0 gpf	0.5 gpf	**67%**
Commercial Lavatory Faucet	3.5+ gpm	2.5 gpm	2.2 gpm	0.5 gpm	0.5 gpm	**86%**
Food Service Pre-Rise Spray Valve	5.0+ gpm	No Requirement	1.6 gpm (EPAct 2005)	No Requirement	1.3 gpm	**74%**
Residential Clothes Washer	51 gallons/load	No Requirement	26 gallons/load (2012 standard)	No Requirement	16 gallons/load	**67%**
Residential Dishwasher	14 gallons/cycle	No Requirement	6.5 gallons/cycle (2012 standard)	No Requirement	5.0 gallons/cycle (ASHRAE S191P)	**64%**

The substantial reductions visible in Table 1 help explain why nationwide water use has declined since the 1980's, as new construction must adhere to at least the minimum federal standards established by the U.S. Energy Policy Act of 1992 (EPAct). An AWE news release from 2014 analyzing national water savings 20 years after the implementation of the EPAct, argues that the 54 percent reduction from 3.5 gpf to 1.6 gpf toilets alone "saved the nation 18.2 trillion gallons of water…enough to supply the cities of Los Angeles, Chicago and New York for 20 years" (Alliance for Water Efficiency, 2014). A more comprehensive study performed by the American Water Works Association (AWWA) in 2001, estimated that the "national plumbing efficiency standards [would] reduce water production by about 8 percent by the year 2020, or 3.5 billion gallons per day" (Maddaus et al., 2001). Again, these savings vary by region such that areas with a higher percentage of indoor versus outdoor water use are expected to realize greater benefits from improved plumbing efficiency. The AWWA report reviews 16 case studies from utilities across the United States, including the nearby Town of Cary, NC, which had the highest anticipated reduction rate of all 16 utilities at 9.1 percent in 2020 (Maddaus et al., 2001, 22). The report's findings for the Town of Cary were higher than the 7.2 to 8.4 percent savings estimated in the AWWA's analysis of the EPA region including North Carolina, potentially suggesting that the state may be among the largest beneficiaries of the EPAct efficiency standards (Maddaus et al., 2001, 25).

While some state and local governments have enacted rules that establish higher efficiency standards, the State of North Carolina only requires compliance with the minimum federal standards (Alliance for Water Efficiency, 2012). There are, however, multiple voluntary programs with significant participation rates that encourage consumers and developers to pursue higher levels of water efficiency for fixtures, appliances, and even entire developments. For example, the U.S. Environmental Protection Agency (EPA) created the WaterSense Program in 2006. This program is designed to enable consumers to conserve water by certifying products and services that are at least 20 percent more efficient than federal standards without sacrificing performance (National Conference of State Legislatures, 2015). For toilets, this means that all dual or single flush toilets that use 1.28 gpf or less may possess the WaterSense label, because they use only 80 percent of the 1.6 gpf federal standard. The EPA estimates that the use of WaterSense fixtures and appliances saved approximately 1.5 trillion gallons of water nationwide from 2006 to 2015 (U.S. Environmental Protection Agency, 2015).

Multiple academic studies have confirmed the effectiveness of water conservation programs designed to increase the uptake of high efficiency fixtures and appliances among consumers. In recent research on the impacts of a retrofit and rebate program for high efficiency appliances by the Miami-Dade Water and Sewer Department, Lee et al. found that "the average water savings for the first year of installation [were] 4.24%, 5.45% and 5.17% for showerhead, toilet and washer programs, respectively" (Lee et al., 2011). Another article on the impact of a similar rebate program in Albuquerque, New Mexico by Price et al. compares the water savings from rebate programs in three separate categories: indoor, outdoor, and xeriscape (Price et al., 2014). The authors' goal was to determine which categories of rebate programs were the most effective in yielding substantial water savings, as well as establishing whether or not these savings persisted over time. In general, the indoor rebate programs were for low-flow appliances, while the outdoor programs were for irrigation system upgrades. Xeriscape rebates provided assistance for converting high water-use landscaping to landscaping that required little or no irrigation.

After controlling for the price of water and local weather conditions, they found that low-flow toilets had “the greatest impact on water use, while low-flow washing machines, dishwashers, showerheads, and xeriscape [had] smaller but significant effects” (Price et al., 2014). Notably, they also found that “air conditioning systems, hot water recirculators, and rain barrels [had] no significant impact on water use” (Price et al., 2014).

Considered along with the other findings presented above, these studies suggest that the efficiency of plumbing fixtures within a structure have a large impact on total water demand, and that even seemingly small efficiency upgrades can yield substantial water savings over time. In mixed use buildings, the initial installation of high-efficiency water-using fixtures may therefore lead to a substantially lower average annual demand rate. Officials seeking to estimate or influence the amount of water use from an individual development should consequently examine the types and numbers of each fixture being installed. That said, there are other physical characteristics of mixed use buildings that could impact average annual demand.

For example, the presence of certain amenities such as pools or cooling towers can increase water demand. The amount of water necessary to fill a swimming pool can be easily determined based on the total volume of the pool itself, and the most significant draws come when the pool is actually being filled. The more complicated factor related to swimming pools is the amount of water that is lost to evaporation, and therefore must be replaced on an ongoing basis. Prior studies have shown that evaporation depends upon multiple factors including pool location (i.e. indoor versus outdoor), pool occupancy, pool size, water and air temperature, and airflow from wind or ventilation systems (Shah, 2014). In a survey conducted by Fannie Mae in 2012, researchers found that the median annual water use per unit for multifamily properties that provided information on pools varied from 42.7 thousand gallons per unit (kgpu) for those with no pool, to 46 kgpu for properties with one pool, and up to 64.6 kgpu for properties with two or more pools (Fannie Mae, 2014).

Another potential source of water demand—especially in multistory mixed use buildings—is the use of water-cooled climate control systems. One popular form employs a combination of chillers, cooling towers, and air handling units to circulate chilled water throughout a building in order to reduce indoor air temperatures without the use of a more traditional air conditioning system. The primary driver behind the increased use of this type of climate control system is the fact that “evaporative water-cooled systems consume approximately half the overall energy of comparably sized air-cooled systems, yielding substantial lifecycle cost savings” (Furlong and Morrison, 2005). Closed-loop systems work by sending water through a condenser and evaporator combination that separates heat producing warm and cold water flows, respectively (Furlong and Morrison, 2005). Chilled water is pumped through the building where it is exposed to ambient air in air handling units producing the desired climate control effect. Water that has absorbed heat from the ambient air is then pumped to the roof of the building where heat is removed in a cooling tower that uses fans, nozzles, and baffles to reject heat into the atmosphere before recycling the water back through the system. It is during this final step that water is lost to evaporation. The total amount of water lost to evaporation, however, may vary according to outdoor temperatures, humidity, system size, and technology employed. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) uses a ‘rule of thumb’ that says water will be consumed at a rate of 2-3 gpm per ton of refrigeration (Schwedler, 2014).

Landscaping

The largest potential source of non-swimming-pool-related outdoor water use in mixed use buildings is irrigation and landscaping. Indeed, the EPA estimates that landscape irrigation represents approximately one-third of all residential water use nationwide, and that outdoor use by households in dry climates like the southwest may account for as much as 60 percent of all household water demand (U.S. Environmental Protection Agency, 2013a). In North Carolina, outdoor water use is estimated to account for an average of 20 to 30 percent of total water used in a given facility, and can peak to as much as 70 percent in the summer growing season (N.C. Division of Pollution Prevention and Environmental Assistance, 2009). For mixed use properties in OWASA's service area, the most important factors to consider are the irrigation methods employed, the amount of vegetated area, and the type of vegetation that is present on the property. It is also worth noting that irrigation water demands may change over time, as not all landscaping and irrigation elements may be installed immediately after the end of construction.

Irrigation Methods

In a 1999 report sponsored by the AWWA Research Foundation titled *Residential End Uses of Water*, Mayer et al. reviewed the impacts of various irrigation methods on outdoor water use by single family residential consumers. While there are certainly some differences between irrigation for single family properties and mixed use properties, the following general relationships included directly from the AWWA report should be rather consistent:

- Homes with in-ground sprinkler systems use 35 percent more water outdoors than those who do not have an in-ground system
- Households that employ an automatic timer to control their irrigation systems used 47 percent more water outdoors than those that do not
- Households with drip irrigation systems use 16 percent more water outdoors than those without drip irrigation systems
- Households who water with a hand-held hose use 33 percent less water outdoors than other households
- Households who maintain a garden use 30 percent more water outdoors than those without a garden
- Households with access to another, non-utility, water source displayed 25 percent lower outdoor use than those who used only utility-supplied water (Mayer et al, 1999)

There are several relationships in these findings that are worth further review. First, all of the irrigation systems that required relatively little human interaction resulted in higher water use for irrigation. This makes sense to the extent that—unlike hand-held watering by hose—these systems are less responsive to rain events or other weather conditions that would reduce the need for watering. Indeed, it is difficult to imagine an individual standing in the rain using a hose or watering can to water grass or flowers, yet many have witnessed automatic sprinklers working in those exact conditions. Second, certain behavioral choices, such as the decision to maintain a garden can drive higher water demand for irrigation. Mayer et al. note that the estimated price elasticity for outdoor use is larger than estimated elasticities for other uses, which "is consistent with the belief that outdoor use is more discretionary and therefore more price elastic than indoor water uses" (Mayer et al, 1999). It seems likely that discretionary water using activities would be less prevalent in mixed use properties than in the single family homes analyzed for this study.

More recent research on local outdoor water demand adds further nuance to past findings on the impacts of different irrigation methods. For example, a 2015 report in the Journal of Irrigation and Drainage Engineering analyzed the impacts of multiple 'smart irrigation' technologies on water consumption for 24 residential sites in Cary, North Carolina during the spring and summer months of 2009. For this study, Nautiyal et al., compared water savings from the following three irrigation system types against a control group: (1) standard irrigation controller with a soil moisture sensor; (2) standard irrigation controller with an evapotranspiration-based adjustment sensor; and, (3) standard irrigation controller using seasonal runtimes based on historical climate data. The control group consisted of systems with a standard irrigation control system with no additional sensors or interventions. The authors found that the soil moisture sensing system was the most efficient and used approximately 42 percent less water than the control group, while the other two system types saved water at a significant, yet lower rate (Nautiyal et al., 2015). These findings unsurprisingly suggest that new irrigation technologies are more efficient than those evaluated by Mayer et al. in 1999. Again, this study was conducted on residential properties, but its implications for irrigation demands by new mixed use developments may be substantial. Indeed, since the cost of installing more advanced irrigation systems could be spread across multiple tenants, uptake rates for soil moisture sensors among mixed use property owners could be higher.

Vegetated Areas

Mayer et al. also found that "the amount of water used for outdoor purposes (primarily irrigation) is positively related to the size of the lot…and the percentage of the lot that is irrigable landscape" (Mayer et al., 1999). These relationships appear rather obvious since more water should be necessary to irrigate larger areas and no water would be intentionally used to irrigate non-vegetated surfaces. The more interesting factor at play is that different types of vegetation have been shown to require—or at least appear to require—more water to maintain aesthetic qualities. For example, a 2013 study published by the AWWA titled *Residential Landscape Water Use in 13 North Carolina Communities*, found that "residents whose lawns consisted of cool-season grass used more water on average during the growing season than residents whose lawns consisted of warm-season grass" (Fair and Safley, 2013). In the OWASA service area, surveyed residents with cool-season grass used an average of 6,100 gallons per month while those with warm-season grass only used an average of 5,400 gallons per month (Fair and Safley, 2013). The authors reasoned that "this could be because homeowners may observe cool-season species showing signs of stress more quickly during a drought than warm-season species and therefore apply larger quantities of water" (Fair and Safley, 2013). Given that OWASA customers were shown to have smaller lawns than any of the other communities included in the study, and that certain mixed-use developments (see site context section below) might have larger vegetated areas than single-family homes, the choice of grass type could be an important factor in determining future demands.

Of course, there are other options and strategies for landscaping that reduce the amount of grass on a given property. These options include selecting native or other plants that use less water, grouping plants according to water needs, and reducing grassy areas by using mulch (U.S. Environmental Protection Agency, 2013b). In a 2015 analysis of available research, the AWE reviewed multiple studies reporting the water use impacts of alternative landscaping and found some estimates of water savings ranging from 33 to 76 percent, and others showing reductions from xeriscaping of around 55.8 gallons per square foot (Mayer et al., 2015). They noted, however, that much of the research on outdoor water savings from alternative urban landscaping uses inconsistent measurements and has been concentrated in only three states: Florida, California, and Nevada (Mayer et al., 2015). That said, in a 2014 article referenced by the AWE, Boyer et al., found that residential participants in the Florida-Friendly Landscaping (FFL) program used 50 percent less water for irrigation on average, and that this figure increased to 76 percent compared to properties with 'high-quality' turf grass when only 'good' examples of FFL participants were considered (Boyer et al., 2014). Viewed in combination with other research on landscaping demands, it appears that there is a significant opportunity to reduce water demand from new mixed use developments by encouraging developers to install irrigation systems with soil moisture sensors, reduce total irrigable areas, and utilize a combination of warm-season turf grass and native vegetation.

Unit Types & Management

Another set of building level factors that affect water demand in mixed use properties includes the types of residential and non-residential units available, as well as management and design practices that may influence building efficiency or tenant behavior. One major factor in this category is a developer's option to pursue non-compulsory efficiency and conservation programs such as certifications administered by various public and private organizations.

Residential Units

Residential portions of mixed use properties may take the form of condominiums or apartments, and vary in count, square footage, number of bedrooms, and total occupancy. While there is a substantial amount of research around residential water use, interpretation of this research for multifamily properties is rather difficult. One factor contributing to this difficulty is the fact that multifamily and single family water use are often lumped together into the same 'residential' category. Also, there appears to be no agreed-upon standard for per unit demand (i.e. per square foot, per dwelling unit, per capita, etc.), and data limitations may prevent researchers from identifying the amount of water drawn by individual users or for different uses. For example, in a 2012 survey of energy and water use in over 1,000 multifamily properties across the United States, Fannie Mae found that over 70 percent of respondents providing 12 months of meter data did not differentiate between indoor and outdoor use (Fannie Mae, 2014).

As a recent national study that is not restricted to affordable housing, it is worth reviewing the Fannie Mae findings in more detail. The results of this study are summarized in Tables 2 and 3 on the next page (Fannie Mae, 2014). For ease of comparison with rates included later in this report, all water use rates from the Fannie Mae study have been converted from daily to annual figures and are given in thousands of gallons. Note that the Fannie Mae rates combine both indoor and outdoor use.

Tables 2 & 3: 2012 Fannie Mae Median Multifamily Annual Water Use Rates

Region	Gallons/Unit (000's)	Gallons/SF (000's)
National	44.2	0.047
Northeast	34.7	0.037
Midwest	35.8	0.044
South	44.5	0.044
West	50.7	0.055

Property Type	Gallons/Unit (000's)	Gallons/SF (000's)
Low-rise	45.6	0.048
Mid-Rise	35.4	0.047
High-Rise	40.2	0.039

As expected, there was substantial variation in annual usage rates between individual properties/respondents. For annual per square foot water use, rates ranged from 0.017 thousand gallons per square foot (kgpsf) for the 5th percentile to 0.113 kgpsf for the 95th percentile. For annual per unit water use, rates ranged from 15.3 thousand gallons per unit (kgpu) for the 5th percentile to 98.2 kgpu for the 95th percentile (Fannie Mae, 2014, 7). As expected, there were notable variations in demand according to location and building type. Annual per square foot and per unit usage rates were highest in the West, and second highest in the South. The median annual rates for the South were 0.044 kgpsf and 44.5 kgpu (Fannie Mae, 2014, 22). Results for usage rates by building type were also interesting. On a per square foot basis, the survey found annual demands of 0.048, 0.047, and 0.039 kgpsf for low-rise, mid-rise, and high-rise properties, respectively. For per unit demand, the survey found annual rates of 45.6, 35.4, and 40.2 kgpu for low-rise, mid-rise, and high-rise properties, respectively (Fannie Mae, 2014, 23).

While these figures display substantial variation in usage rates, the story behind them makes sense given the information already presented above. Indeed, water usage is predictably higher in warmer climates, and low-rise multifamily properties are more likely to have vegetated areas that require water for irrigation. Along similar lines, it makes sense that the survey would find evidence that annual usage rates are higher for properties with more bedrooms and residents per unit (Fannie Mae, 2014, 24). This relationship has been confirmed by other studies that have found that adding more residents to each unit creates diminishing increases in water use, and that children and retirement-age adults are among the highest water users (Klein et al, 2006, 27)

Non-Residential Units

Nonresidential portions of mixed use properties often include a combination of retail stores, restaurants, office spaces, and even hotels. In many cases, units designated for these purposes are located on the first few floors of the property, with residential units located above. Other mixed use developments may consist entirely of nonresidential units with retail stores and restaurants again on the first few floors and then office space or hotels on the remaining floors. The water use patterns of these nonresidential units can vary substantially not only from the water demands of the residential portions of mixed use properties, but also between nonresidential units of different types. As noted in a 2009 EPA report on water efficiency in the commercial and institutional (C&I) sector, one challenge in determining the water demands of these customer types is that "the definition of the sector varies among water utilities and in water use literature" (EPA WaterSense, 2009). Another challenge—illustrated in Table 4 adapted from the EPA report—is that there are substantial differences in the end uses of water for relevant C&I subsectors (EPA WaterSense, 2009). Note that there is some overlap in reported end use categories.

Table 4: End Uses of Water in Relevant C&I Subsectors

End Use	Office Buildings	Restaurants	Hotels
Cooling & Heating	28%	1%	11%
Domestic/Restroom	37%	31%	30%
Kitchen	13%	48%	14%
Landscaping	22%	4%	16%
Laundry	N/A	N/A	16%
Other	N/A	8%	12%
Swimming Pools	N/A	N/A	1%
Washing & Sanitation	N/A	4%	N/A
Total	**100%**	**96%**	**100%**

In a 2010 study using a combination of statewide parcel-level land use characteristics and historic water consumption data from two major utilities, Morales and Heaney calculated average water use rates for a wide range of C&I facilities across the State of Florida. These water use rates are included in Table 5 below (Morales and Heaney, 2010). The rates included in Table 5 have been converted to thousands of gallons per year in order to facilitate comparisons with other rates included in this report. It should also be noted that—unlike the Fannie Mae report on multifamily water use—the rates reported in this study are based on the 'heated square feet' of each property, rather than total square feet or number of units. There was, however, a strong relationship between heated area and total area, as heated square feet represented an average of 93 percent of total square feet across all C&I subsectors included in the analysis (Morales and Heaney, 2010).

Table 5: Average Water Use Rates for Selected C&I Subsectors in Florida

Property Type	Average Effective Year Built or Age Group	Sample Size	Average Annual GPHSF (000's)
Community Shopping Cen	Post-1994	63	0.039
Fast-Food Restaurants	1994	105	0.240
Financial Insitutions	1992	98	0.136
Hotels/Motels	Post-1994	11	0.070
Insurance Offices	1988	11	0.027
Medical Offices	1990	264	0.058
Mixed Use	1976	143	0.034
Nightclubs/Bars	1972	20	0.072
Office, Multi-Story	1987	73	0.025
Office, One-Story	1984	384	0.047
Restaurants, Cafeterias	Post-1994	52	0.301
Stores, One Story	1985	289	0.036
		Average Selected	**0.090**
		Total All C&I	**0.049**

It is notable that the C&I subsectors which are most likely to be included in mixed use properties have a higher average annual use than the sector as a whole. Although there are likely differences between water use patterns in Florida and North Carolina, these differences may be smaller for C&I users given that outdoor water use is lower for this sector than for residential users. Indeed, many C&I properties utilize outdoor areas more for parking than for landscaping. There may, however, be some variation between water use rates caused by higher evaporation rates from cooling towers in Florida, but as the authors note, cooling towers are generally only present in larger commercial establishments (Morales and Heaney, 2010). As expected, Morales and Heaney found that there were meaningful differences in the water use patterns of C&I properties based on the year in which they were built. The average age of the properties included in the Florida study are therefore included in Table 5, and when possible, only the average water use rate for the most recent age group is included.

Management & Design Practices

One important trend affecting water efficiency in both residential and commercial properties is the growing popularity of noncompulsory efficiency targets and certifications such as the LEED program administered by the US Green Building Council (USGBC). Developers and property managers have recognized such certifications as an effective means of signaling their commitment to conservation to both tenants and public officials. According to the Green Building Information Gateway (GBIG), 852 LEED certified activities covering nearly 92 million square feet have been recognized in North Carolina as of March, 2017 (GBIG, 2017a). Notably, 21 of these certified activities are located in Chapel Hill and Carrboro, representing over 1.5 million square feet of property in OWASA's service area (GBIG, 2017b; GBIG, 2017c).

In general, LEED and other certification systems are designed as 'point systems' whereby certification is achieved through an accumulation of points awarded for installing specific features or achieving predetermined benchmarks. For water use, the USGBC awards credits related to indoor water use, outdoor water use, and metering technologies. The general requirements for indoor and outdoor water efficiency credits in the LEED Building Design and Construction program are summarized in Table 6 (USGBC, 2017a). All reduction percentages in Table 6 are calculated from a baseline derived from the requirements of the EPAct. Metering requirements apply only to whole property water use, although a building may receive one point for metering two or more of the following subsystems: (1) Irrigation; (2) Indoor plumbing; (3) Domestic hot water; (4) Boilers; (5) Reclaimed water; and (6) Other process water (USGBC 2017b; USGBC 2017c). Additionally, a building may receive up to two points for limiting use by cooling towers (USGBC, 2017d). To place these points in perspective, the required number of points for each certification level are: Certified (40-49 points), Silver (50-59 points), Gold (60-79 points), and Platinum (80+ points) (USGBC, 2017e). It can therefore be said that while water efficiency is an important component of the LEED program, water efficiency upgrades account for a relatively small portion of the total points necessary for higher certification levels.

Table 6: Selected LEED BD+C Water Efficiency Requirements & Credits

Reduction from Baseline	Indoor Water Use Points	Outdoor Water Use Points
20%	***Prerequisite***	
25%	1	
30%	2	***Prerequisite***
35%	3	
40%	4	
45%	5	
50%	6	1
55%		
100%		2

Another noncompulsory management practice that affects water consumption rates is the way residents and tenants are metered and billed for water use. According to the National Conference of State Legislators, the State of North Carolina requires individual meters for electricity and natural gas service for each dwelling unit, effectively banning the use of master meters for those services (National Conference of State Legislatures, 2016). There is, however, no such statewide requirement for water service. That said, the Town of Boone, North Carolina does have a local ordinance—passed in 2012—that requires individual metering for all new commercial and residential water customers, including those in mixed use developments (National Conference of State Legislatures, 2016; Boone, North Carolina, Code of Ordinances §50.109). Submetering programs are intended to more equitably distribute water expenses among residents and tenants by creating a more direct link between the amount of water used and the amount they are billed for that use. The resulting increase in information available to residents and tenants then enables them to make better decisions about their own consumption patterns. In a 2004 national study on submetering practices that controlled for other factors such as number of bedrooms, the year in which the property was built, and average water prices, researchers found that submetering reduced water use by between 5.55 to 17.5 kgpu each year, or 11 to 26 percent (Mayer et al., 2004, xxiii). The same study also found that submetering was somewhat uncommon, with only 3.9 percent of properties indicating that they submeter water compared to 84.8 percent that indicated including water costs in rent (Mayer et al., 2004, xxi).

Site Context

The preceding sections have primarily focused on the determinants of water use for individual structures without considering the location of those structures, or the potential interactive effects of increasingly dense urban development patterns. Some of these effects are straightforward. For example, since the "convenience of [having] live-work-play options in a single location," and the potential to reduce traffic congestion are two of the most attractive features of mixed use development, there is pressure to select sites in central urban locations rather than Greenfields (Rabianski and Clements, 2007). Such sites are less likely to have large vegetated areas, and can therefore be expected to exhibit lower rates of outdoor water use. What is less clear, however, is the way patterns of individual siting decisions may build up over time, and how resulting alterations to the urban form could impact water use overall.

Density & Urban Heat Islands

Recent research on the impacts of 'Smart Growth' as an alternative to traditional urban sprawl sheds some light on the water-saving potential of higher-density urban environments. Before reviewing the findings of these studies, however, it is worth noting that most of the research in this area is model-based, and therefore should be viewed as informed conjecture rather than empirical truth. In a 2013 article comparing estimates of water use in suburban Boston under different scenarios of urban development, Runfola et al. found that "differences in lawn cover, living unit density, and the number of bathrooms [could] explain 90% of the variation in annual residential water use" (Runfola et al., 2013). Extrapolating out to 2030, the researchers estimated that the Town of Ipswich, MA could achieve a 5 percent reduction in water use through densification alone, without the use of new demand side management strategies (Runfola et al., 2013). In a similar study focused on Phoenix, AZ, Nahlik and Chester compared residential water use projections under two separate scenarios: (1) Business as Usual (BAU); and, (2) Transit Oriented Development (TOD). The most relevant difference in these scenarios is that the TOD scenario assumed a higher ratio of multifamily housing units versus single family housing units, which would result in a lower amount of urban sprawl and residential landscaping (Nahlik and Chester, 2014). Overall, they estimated that switching from BAU to TOD development patterns would result in a decrease in total residential water consumption from 45,400 to 28,700 million gallons per year, a decrease of approximately 37 percent (Nahlik and Chester, 2014, 67). Obviously, there is a significant difference between the savings calculated in these two studies, but given known differences in usage rates by region, I would expect savings from densification in OWASA's service area to be closer to the 5 percent in MA than the 37 percent in AZ.

There may, however, be some downsides to increased densification through the impacts of the 'Urban Heat Island' (UHI) effect. In general, UHI effects are relative increases in ambient temperatures caused by higher heat absorption rates and lower heat release rates in urban versus natural environments. This effect "can occur throughout the year, is affected by local weather conditions, and is typically most intense in the urban core and less severe on the urban periphery" (Guhathakurta and Gober, 2007). Factors related to mixed use development that might increase UHI effects include construction materials, building heights and spacing, and increased impervious surfaces. In a 2007 study again focused on Phoenix, AZ, Guhathakurta and Gober found that:

> A 1° F increase in a tract's low temperature increases average water use in single-family units by 1.7% or 290 gallons for the typical single family unit for the month, holding all else constant. The difference between daily high and low temperatures, the second measure of UHI, resulted in greater changes in water use. If the difference between high and low temperature declines by 1° F, reflecting warmer nighttime temperatures, average water use in single-family units increases by 681 gallons. (Guhathakurta and Gober, 2007, 326).

It is important to note two aspects of these results. First, the reported water use increases are for single-family units, so mixed use developments with less vegetated area would likely exhibit less dramatic increases in water use. Second—and perhaps more importantly—UHI effects from increased urban development densities have the potential to increase water consumption rates in surrounding buildings, even those of a different development type. In Chapel Hill, there are already examples of mixed use developments that directly abut existing single family properties, so it would be interesting to see if water consumption in those properties has increased over time (see Greenbridge property profile).

One way of attenuating the UHI effect is to plant vegetation or install features that increase shade on vegetated and non-vegetated areas. A recent study conducted in Israel compared the cooling efficiency of different combinations of vegetation and shading techniques and calculated impacts on water use. The study concluded that while unshaded grass in courtyards had very little cooling effect and required the highest amount of water, combining grass courtyards with trees or mesh that shaded the grass substantially cooled the area and resulted in a more than 50 percent reduction in total water use (Shashua-Bar et al., 2009). Like most of the other studies in this section, this area-cooling research was conducted in a hot and dry environment, so I would expect the effects of both UHI and any mitigation strategies to be less pronounced in OWASA's service area.

Institutional Context & Conservation

Water consumption rates are also affected by certain factors beyond building efficiency, site characteristics, and aspects of the local built or natural environment. These factors include the price of water, the presence of various conservation incentives, and residents' awareness of water issues. Based on the information already presented, the impacts of pricing factors may be less pronounced in mixed use developments. I expect this to be the case because indoor uses are less discretionary than outdoor uses (Mayer et al, 1999), and households living in mixed use developments are less likely to have yards than households living in single family homes. Also—as previously noted—the billing systems applied in multifamily housing do not always provide a clear price signal to individual users. Nonetheless, it is worth briefly reviewing those factors that appear most relevant to future development in OWASA's service area.

Economic & Financial Factors

In a 2006 paper titled *Factors Influencing Residential Water Demand: A Review of the Literature*, Klein et al. provide a helpful summary of existing research on the role of water prices and pricing structures in determining water demand. As with most other determinants of water demand, the authors note that household responsiveness to changes in water prices varies substantially according to multiple factors including season, geographic location, and socioeconomic characteristics (Klein et al., 2006). Two patterns, however, have emerged that are consistent across most studies: (1) residential customers are responsive to changes in price; and, (2) demand for water is relatively inelastic, meaning that the percentage change in demand is less than the percentage change in price (Klein et al., 2006, 6-7). The second point highlights the fact that there is some level of demand that is necessary rather than discretionary. Simply put, regardless of the price of water, households must use at least a certain volume to cover basic needs such as sanitation, cooking, and drinking, while they may choose to skip watering their lawn if the cost is too high.

Seasonal differences in price elasticity are therefore often attributed to increased outdoor use in the spring and summer months (Klein et al., 2006). Klein et al. report that estimates of price elasticity are often "5-10 times higher during summer months as compared to those obtained for winter" (Klein et al., 2006, 7). Geographic differences in price elasticities are also often attributed to the impacts of outdoor uses, albeit less confidently because of confounding variables that aren't always included in available data (Klein et al., 2006). That said, according to a 1992 study cited by Klein et al., residential water users in southern and western states "were more than twice as responsive to changes in price than residents throughout the rest of the United States" (Klein et al., 2006, 7). In a study in nearby Raleigh, NC, Danielson estimated the price elasticity of water to be approximately -0.27 for total water use, and -1.38 for outdoor sprinkling demand (Danielson, 1979). This means that—as expected—water demand at the household level was relatively inelastic, but irrigation-specific demands were elastic, and therefore more susceptible to changes in price. Notably, Danielson's estimate of -0.27 is close to 50 percent of the average -0.51 price elasticity calculated in a 1997 meta-analysis by Espey et al. (Espey et al., 1997, 1370), which conforms with expectations that the price elasticity of water is lower in the south.

In general, low income households have been shown to be more responsive to changes in price than high income households (Klein et al., 2006). For example, in a 2002 study of water consumption in California, Renwick and Green estimated that "a 10% increase in income will increase average household monthly water demand by 2.5%" (Renwick and Green, 2000, 48). Price structures also matter, as it has been estimated that "households facing a two-tier increasing block rate [are] 5 times more sensitive to changes in price than households facing a uniform rate structure" (Klein et al., 2006). It should be noted, however, that much of the research on residential water price elasticity has been focused on single family homes or residential properties in aggregate, and therefore may have limited applicability for housing in mixed use developments. Research pertinent to the price elasticity of water used by the nonresidential portions of mixed use properties suggests that most commercial and office uses are relatively inelastic (Mitchell and Chesnutt, 2009). The following major points about commercial and industrial uses are helpfully included in a White Paper available through the AWE:

- Industrial demand tends to be less price inelastic than commercial demand, though demand for certain industrial processes requiring very high quality water can be very inelastic.
- Commercial demand tends to be inelastic, though empirical estimates span a wide range. Commercial water demand studies reviewed by Renzetti (2002) reported price elasticities ranging from 0.1 to 0.9. Elasticity varied considerably by commercial sector.
- As with residential customer demand for water, commercial and industrial demands are less inelastic in the long-run than in the short run (Mitchell and Chesnutt, 2009, 4).

Overall, while pricing factors and elasticities are important, they may not be as important as other factors affecting demand by mixed use buildings in OWASA's service area. Indeed, given the area's focus on retail and office spaces, most of the water use for both residential and nonresidential units in new mixed use buildings is likely to be indoor and nondiscretionary.

Local Knowledge & Awareness

Utilities and other organizations have also sought to influence water use through non-price mechanisms such as public education campaigns, and voluntary or mandatory water use restrictions. Perhaps with the exception of mandatory restrictions, this type of conservation program is often seen as more politically feasible than increasing water prices, although there is some evidence to suggest that "using prices to manage water demand is more cost effective than implementing nonprice conservation programs" (Olmstead and Stavins, 2009). Again turning to the review provided by Klein et al., the authors found that studies of mandatory water use restriction programs yielded savings of 13 to 64 percent, while studies of savings from voluntary programs and public information campaigns found a range of impacts from a net increase of 7 percent to 33 percent savings (Klein et al, 2006, 17). One potential explanation for the net increase in water use observed by some studies is that consumers may interpret information campaigns or voluntary restrictions as meaning that more stringent restrictions will be implemented in the future, leading them to increase use in anticipation of decreased access in the future (Klein et al, 2006, 14).

Fair and Safley's 2013 article provides some indication of how well price and non-price conservation programs may work in OWASA's service area. Table 7 on the next page displays a summary of survey results for OWASA customers. Note that, at the time of the survey, OWASA "not only had watering restrictions in place but also charged about twice as much on average for water than suppliers in other parts of the state" (Fair and Safley, 2013, E573).

Table 7: Fair and Safley Survey Responses by OWASA Customers

Response	Aware of Water Restrictions	Changed Outdoor Habits	Changed Indoor Habits
Yes	18%	39%	53%
No	68%	59%	47%
Did Not Know	14%	2%	0%
Total	**100%**	**100%**	**100%**

Here we see that 68 percent of customers were unaware of the restrictions that had been implemented, and 14 percent were unsure if there were any restrictions. Interestingly, more customers indicated that they had changed their indoor habits than their outdoor habits. This is strange given that outdoor use is generally considered more discretionary than indoor use, and that OWASA customers had the smallest lawns of all 13 North Carolina communities included in the study. Perhaps having smaller lawns led customers to believe that their impact on water supplies would be limited. Overall, the effects of price and non-price mechanisms for encouraging water conservation can be described as mixed, and it is not immediately clear that their impacts on water use would be substantially different for mixed use developments than other property types.

Anticipating Mixed Use Water Demand in OWASA's Service Area

The previous section provided an overview of factors that affect water consumption rates according to features within individual structures, the locational context of those structures, and the institutional factors at play in a given locality. One primary takeaway is that water use is complicated, and actual consumption rates can vary substantially from one development to the next. Recognizing this fact, most utilities and public officials rely upon average usage rates to project future water demand instead of trying to calculate precise figures for water use by each existing or potential development in their service area. While a comprehensive review of all common demand estimation methodologies is beyond the scope of this report, it is worth briefly reviewing some common assumptions and methodologies employed by local utilities and selected organizations around the country.

Annual Demand Assumptions

This subsection includes a series of tables summarizing the demand projection assumptions used by several local water suppliers during preparation of the 2012 Triangle Regional Water Supply Plan (Triangle J Council of Governments, 2012). These tables only provide local estimates because—as previously noted—there are wide variations in water consumption rates by location, and national averages are skewed upward by the inclusion of relatively high-water-using areas in the Western part of the country. Since it is rare for organizations to have specific assumptions for mixed use properties, the rates included herein are for each of the individual uses that are commonly included in mixed use developments: Residential, Commercial, and Institutional. Assumptions from OWASA are excluded from this section because they were based on 'meter equivalents' and officials have indicated that they wish to move away from this approach.

Table 8: Local Residential Annual Demand Assumptions

Year	Location	Population	Indoor/Outdoor	Gallons/Unit (000's)	Gallons/Capita (000's)
2012	Apex, NC	RES	Indoor + Outdoor		21.9
2012	Cary, NC	MF	Indoor + Outdoor	42.3	
2012	Morrisville, NC	MF	Indoor + Outdoor	47.5	
2012	Durham, NC	MF	Indoor + Outdoor		21.9
2012	Hillsborough, NC	MF	Indoor + Outdoor	32.9	
2012	Orange County, NC (2060)	RES	Indoor + Outdoor		21.2
2012	Pittsboro, NC	RES	Indoor + Outdoor	36.5	
2012	Raleigh, NC (2060)	ALL	Indoor + Outdoor		27.8
			Average	**39.8**	**23.2**

Table 8 above lists local annual demand assumptions for residential properties. It is interesting to note that organizations within the same region are using not only different types of rates for residential (i.e. both gallons per unit and gallons per capita), but also that these assumptions can vary by many thousands of gallons per year. One potential explanation for this variation is that each municipality likely has different mixes of multifamily or residential property types. For example, Morrisville may have a higher percentage of low-rise multifamily properties than Cary. Another potential source of the variation could be the general location of these properties within the urban environment. It stands to reason that if a municipality has a higher percentage of multifamily properties in the urban core than along the periphery, then the average amount of vegetated land—and therefore average annual outdoor use—per property would be lower and vice versa. Additionally, there could be substantial differences in the average age of the properties in each municipality, which could lead to the presence of more or less efficient fixtures.

Table 9: Local Commercial Annual Demand Assumptions

Year	Location	Indoor/Outdoor	Gallons/SF (000's)	Gallons/Capita (000's)	Gallons/Acre (000's)
2012	Apex, NC	Indoor + Outdoor			219.7
2012	Cary, NC	Indoor + Outdoor	0.037		416.8
2012	Morrisville, NC	Indoor + Outdoor	0.037		281.4
2012	Durham, NC	Indoor + Outdoor		14.97	
2012	Hillsborough, NC	Indoor + Outdoor	0.039		
2012	Orange County, NC	Indoor + Outdoor			365
2012	Pittsboro, NC	Indoor + Outdoor		16.8	
2012	Raleigh, NC (2060)	Indoor + Outdoor		27.8	
		Average	**0.038**	**19.9**	**320.7**

As with the residential demand assumptions, there is substantial variation in the assumptions applied for commercial uses as listed in Table 9. The reasons behind this variation are likely very similar. Indeed, the commercial category includes a variety of uses including retail stores, restaurants, and hotels. The local mix of these different subcategories is likely the primary driver behind variations in assumptions for each municipality. Some differences may also be artifacts of different demand estimation models or customer classification systems, as each municipality employed a different model for determining their assumptions.

Table 10: Local Institutional Annual Demand Assumptions

Year	Location	Indoor/Outdoor	Gallons/SF (000's)	Gallons/Capita (000's)	Gallons/Acre (000's)
2012	Apex, NC	Indoor + Outdoor		0.69	
2012	Cary, NC	Indoor + Outdoor	0.037		78.1
2012	Morrisville, NC	Indoor + Outdoor	0.037		55.8
2012	Durham, NC	Indoor + Outdoor		14.97	
2012	Hillsborough, NC	Indoor + Outdoor	0.033		
2012	Orange County, NC	Indoor + Outdoor			365
2012	Pittsboro, NC	Indoor + Outdoor		16.8	
2012	Raleigh, NC (2060)	Indoor + Outdoor		27.8	
		Average	**0.036**	**15.1**	**166.3**

The institutional demand assumptions, which include office uses, listed in Table 5 also vary widely between local municipalities. It should be noted, however, that even with those municipalities that either did not differentiate between commercial and institutional uses, or did not differentiate between any uses at all (Raleigh), these are the lowest assumptions of all uses that might be present in mixed use buildings. This relationship makes sense to the extent that office water users are less likely to take showers, cook large amounts of food, or maintain an outdoor garden than any of the other uses covered in this subsection. Comparing these assumptions to the average rates included in the previous section is somewhat more difficult. For residential use, the average local assumption of 39.8 kgpu per year is approximately 12 percent below the 44.5 kgpu rate found for properties in the South by the Fannie Mae survey. For C&I, the combined average local assumption is 0.037 kpsf, while the average C&I rate reported across all subsectors by Morales and Heaney was 0.049 kphsf. This means that the average combined annual assumption for C&I properties is 32 percent less than the reported average for Florida.

Mixed Use Demand Estimation Methods

A 2007 water supply analysis guidebook prepared for the Northern California Water Association provides a helpful overview of the two most common demand estimation methodologies: (1) Population-based; and, (2) Land use based. The population based approach involves calculating a per capita demand rate and then multiplying that rate by population projections over time (Northern California Water Association, 2007). The problem with population-based methodologies is twofold. First, they are based on historical rates and therefore do a poor job of accounting for changes in residential development or household sizes. The result is that "if water demands are based on historic per-capita water use and new developments do not have the same balance of residential land uses and persons per household as existing areas, projected water demands are less likely to be accurate" (Northern California Water Association, 2007, 14). Second, they do not differentiate between residential and non-residential demand. For areas with large industrial or agricultural uses, this means that per capita rates could be significantly inflated, which would result in overestimation if the majority of new development is residential. Since land use based demand methods are specifically designed to account for these issues, they are generally considered more useful and accurate.

In fact, the entirety of this report has been predicated on the land use demand estimation method. This method involves calculating a demand factor—like average use per unit, per square foot, or per acre—for each land use category and then multiplying that factor by the total existing and expected amount of each development type included in local planning documents (Northern California Water Association, 2007, 5). These demand factors can then be adjusted for development densities, districts with specific microclimates, and the presence of varying amounts of non-vegetated land across different parts of a utility's service area. During my review of local and nonlocal demand projection documents, it was difficult to find examples of organizations that had calculated specific demand factors for mixed use properties. Most documents either did not mention mixed use properties or simply treated them as multifamily developments. For example, a 2040 demand study by the East Bay Municipal Utility District in Oakland, California recognized mixed use development as one of the most prevalent types of planned uses going forward, and identified multiple subcategories for mixed use, but did not develop a separate land use demand factor for mixed use developments (East Bay Municipal Utility District, 2009, 5-17). Instead, the study used the demand factor for the underlying residential density of the category because water demand in mixed use properties was assumed to be dominated by residential use (East Bay Municipal Utility District, 2009, 5-17).

The nearby Town of Cary used a more sophisticated approach for estimating demands by mixed use developments that recognized the presence of nonresidential uses, albeit in a somewhat inconsistent manner. The Town's 2009 Water System Distribution System Master Plan identified three different types of mixed use development based on existing land use codes and assigned both a development density factor and customer classification assumption (Town of Cary, 2009).

The breakdown of different assumptions for each mixed use category is included in Table 11. Interestingly, assumptions for the distribution of residential and nonresidential uses in the first two categories are the same except for the fact that the second category uses single family residential (SFR) demand factors instead of multifamily residential (MFR) demand factors. Also, the 'Mixed-Use Residential' category follows the same pattern observed in other utility planning documents and simply applies the standard MFR demand factor to the entire property.

Table 11: Town of Cary 2009 Mixed Use Density Factors, and Classifications

Land Use Code	Land Use Designation	Development Density Factor	Customer Classification
HMXD	High-Density Mixed-Use Development	30 DU / Acre & 30,000 SF / Acre	33% MFR / 67% COM
MXD	Mixed Use	5.13 DU / Acre & 8,000 SF / Acre	33% SFR / 67% COM
MXDR	Mixed-Use Residential	15 DU / Acre	100% MFR

Estimated demand for each mixed use category is calculated by multiplying the number of acres planned for that category by the customer classification percentage and development density factor and then applying the appropriate demand factor. Referring to Tables 8 and 9 above, the formula for estimating gallons of annual water use for a 10-acre HMXD development would be:

$$Annual\ Demand = (10 \times 0.33 \times 30 \times 42.3) + (10 \times 0.67 \times 30{,}000 \times 0.037) \approx 11{,}625$$

In general, I think this 'additive' approach makes more sense than simply relying upon the demand factor for the underlying residential land use. It has the advantage of recognizing differences in water use between customer types and could be further refined as necessary to account for emerging patterns of development. Also, the fact that it is based on existing land use codes facilitates coordination between utilities and planning departments for municipalities within their service area. Another alternative approach would be to actually develop demand factors that specifically apply to mixed use developments.

Water Use in Selected Local Developments

Methodology

Given the wide variation in water use rates between different properties and locations, and the relative lack of information about the water use patterns of mixed use properties in particular, it is helpful to examine the actual characteristics and historical demands of mixed use developments in OWASA's service area. Toward that end, this section presents the results of interviews conducted with property managers at several sites in Chapel Hill and Carrboro along with analyses of historical water use data provided at the meter level by OWASA. A copy of the questionnaire that guided these interviews as well as a series of profiles summarizing water use at each property are included as Figures A.1 through A.5 in the Appendix. The overarching goal of this research was to capture information about the presence of various efficiency and conservation measures in order to provide a point of comparison for the average annual demand assumptions presented in the previous sections. The properties included in this process were selected as examples of the types of developments that OWASA officials expect to become more prevalent in their service area going forward. Future studies could expand upon this research by attempting to survey a larger number of properties both inside OWASA's service area, and in other local municipalities. Topics covered in the interviews include:

- Fixture sizes/types
- Metering/billing systems
- Mission statements, marketing collateral, and/or expressed ethos
- Behavioral programs targeting sustainability
- Maintenance staff size
- Known maintenance issues
- Management type
- Property ownership
- Building size and number of units
- Irrigation practices
- Land size and characteristics
- Amenities including pools and cooling towers
- Occupancy patterns
- Any additional water saving features

Since the properties included in this process were constructed at different times, the amount of meter data available for each development varies from nearly 5 years for Greenbridge to just over 2 years for 300 East Main. Additionally, it should be noted that certain data points acquired during the interviews may be rather imprecise. For example, occupancy data was reported only on an annual basis, and should likely be viewed as estimates rather than hard figures based on rent rolls or reviews of actual leases.

Mix of Uses

As noted above, there is an inherent degree of variability between the distributions of individual uses in mixed use developments. In those surveyed as part of this project, it is clear that some place more emphasis on retail and restaurant activity, while others focus on office space and residential units. The Lux at Central Park is the only surveyed property that is not technically mixed use (Table 12). It is included both to illustrate demand patterns for recent multifamily developments and to provide a point of comparison for the other properties. Those fields that are marked with a '?' represent questions that the interview subject could not answer, either because they were unaware of the exact figures, or because tenant turnover created a high degree of uncertainty. Also, metering technologies and approaches continue to change, so future studies could benefit from a higher degree of granularity in historical use patterns. For example, Greenbridge has recently installed a separate meter for the cooling tower in that property, so in the future it should be possible to differentiate cooling tower water from water drawn through the master meter.

Table 12: Survey Property Characteristics

Use	300 East Main	East 54	Greenbridge	Lux at Central Park
Office	✓	✓	✓	✗
Units	12	?	18	0
Square Feet	23,000	113,191	30,000	0
Residential	✗	✓	✓	✓
Units	0	186	98	194
Square Feet	0	179,545	180,000	294,512
Restaurant	✓	✓	✗	✗
Units	?	in retail	0	0
Square Feet	?	in retail	0	0
Retail	✓	✓	✓	✗
Units	20	15	?	0
Square Feet	80,000	55,578	?	0
Hotel	✓	✓	✗	✗
Units	?	?	0	0
Square Feet	100,000	74,990	0	0
Total Units	**32**	**201**	**116**	**194**
Total Square Feet	**203,000**	**423,304**	**210,000**	**294,512**

Fixtures & Amenities

During the interview process, property managers were asked to indicate whether or not their structures contained the water-related features included in Table 13 on the next page. Their responses point to many differences between the structures, but also mask certain facts that might help explain why a specific feature might be present in one property but not another. For example, since they are both infill developments with little to no greenspace, it would not make sense for either Greenbridge or 300 East Main to invest in an automatic irrigation system. Along similar lines, 300 East Main's decision not to install WaterSense appliances is simply a reflection of the lack of residential units in the property, not a lack of effort to save water.

As a LEED Gold building, Greenbridge has taken the most extreme steps to conserve water. In fact, Greenbridge has installed all of the most efficient options for restroom fixtures, appliances, and irrigation included in the questionnaire. The Lux at Central Park, however, has nearly identical in-unit features with the exception of 1.28 gpf and dual flush toilets. East 54 has also received LEED recognition, with the entire development earning recognition through the pilot LEED-Neighborhood Development program, and the office portion receiving LEED-Platinum through the Core and Shell program. The fact that some properties have installed high-efficiency features without seeking LEED certification may suggest an opportunity to supplement market pressures with other incentives in order to push new development toward higher water conservation standards.

Table 13: Survey Property Features

Feature	300 East Main	East 54	Greenbridge	Lux at Central Park
Pool	✓	✓	✗	✓
Chillers/Cooling Towers	✗	✓	✓	✗
Reuse System	✗	✗	✓	✗
Rain Barrels/Cisterns	✗	✓	✓	✗
Submetering	✗	✓	✗	✗
Toilets				
3.5-5 gpf (Older)	✗	✗	✗	✗
1.6 gpf (Conventional)	✓	✓	✗	✓
1.28 gpf (Low Flow)	✗	✓	✓	✗
Dual Flush	✗	✗	✓	✗
Low Flow Showerheads	✗	✗	✓	✓
WaterSense Dishwashers	✗	✗	✓	✓
WaterSense Washing Machines	✗	✗	✓	✓
Irrigation System				
Traditional Automatic Spray	✗	✓	✗	✓
By Hand	✓	✓	✗	✓
Drip	✗	✓	✗	✓
Rotor Sprinklers	✗	✗	✗	✓
Rain or Soil Moisture Sensors/Guages	✗	✗	✗	✓

Building Level Average Annual Demand

Average annual demand was calculated for each year in which both of the following conditions were met: (1) the property was operational for at least 10 months; and, (2) meter data was available for at least 10 months. All demand figures represent a combination of both indoor and outdoor demand, since metering was inconsistent across properties. If a property was operational or data was only available for 10 months in a given year, then an average monthly demand rate was used to produce *implied* annual demand. For example, meter data for the Lux at Central Park was only available for the first 10 months of 2016, so the annual demand calculated for that year is equal to the total actual demand for the first 10 months plus two times the average monthly demand in 2016. The reported average annual demand figure for the Lux at Central Park was then calculated by taking the average of actual and *implied* water demand figures for both 2015 and 2016.

A similar approach was used for average annual demand per dwelling unit (DU) in order to account for occupancy levels. Demand per DU was calculated as the total demand for each month divided by the estimated number of occupied DUs. Again, using the Lux at Central Park as an example, the questionnaire indicated that there was a 75 percent occupancy rate across 194 total units at the end of 2014. The calculated demand per DU for December 2014 is therefore equal to the actual volume of water reported by OWASA divided by 0.75 × 194 = 146 units. Average annual demand per DU was then calculated as the average of these monthly figures for each year of operation. That said, since the Lux at Central Park was only operational for 2 months in 2014, the reported average annual per DU and average annual demand figures exclude averages from that year. East 54 did not provide occupancy data, so a flat rate of 95 percent occupancy was assumed for the entire period. Since we do not know which DUs were occupied at any given point in time, it is not practicable to estimate the number of occupied square feet for each month. Average annual demand per square foot figures have therefore not been adjusted to account for occupancy.

Table 14 below provides a summary of average water use for each of the surveyed properties. There are several patterns within this table worth noting. First, there is substantial variation across the water use rates for both per DU and per SF demands. Annual per DU demand ranges from a low of 31.9 kgpu for Greenbridge to 40.5 kgpu for East 54. This fact may be surprising given that both of these properties have received some level of LEED recognition, but the difference makes more sense considering the distribution of uses (Table 12). Indeed, residential uses account for approximately 86 percent of the total square footage at Greenbridge, but only around 42 percent of the total square footage at East 54. This means that the per DU rate for East 54 is skewed upward by the presence of over 243,000 SF of nonresidential units, thus illustrating one of the drawbacks of using per DU demand factors for mixed use properties. Another pattern worth noting is that both Greenbridge and East 54 display a substantially lower per SF water use rate than the two non-LEED properties. Finally, it is interesting that all four properties had their highest monthly use in 2016, although two properties (300 East Main, and The Lux at Central Park) only had two or three years of available data.

Table 14: Survey Property Average Demand

Historical Water Use (000's gal)	300 East Main	East 54	Greenbridge	Lux at Central Park	Average
Average Annual Demand	**4,709**	**7,169**	**2,489**	**7,517**	**5,471**
Per DU	N/A	40.5	31.9	38.8	37.1
Per Sq Ft	0.023	0.017	0.012	0.025	0.019
Average Monthly Demand	**389**	**595**	**205**	**619**	**452**
Peak Demand	525	796	421	961	676
Peak Month	July, 2016	June, 2016	August, 2016	October, 2016	N/A

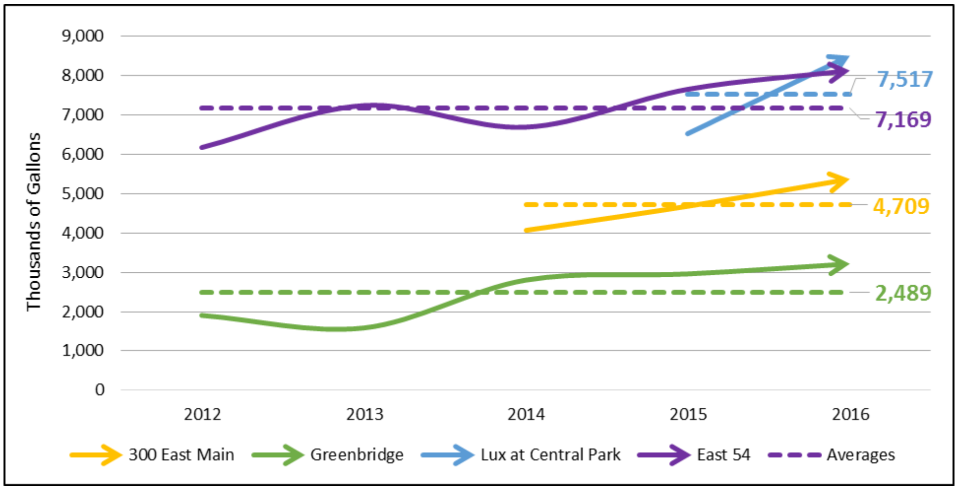
Table 15 provides a comparison between the average annual rates observed for the four survey properties and the average rates referenced earlier in this report. Note that the value of this comparison is very limited since the rates included in this table are not always for the same types of uses (i.e. commercial, institutional, and residential rates are compared against mixed use rates as a whole). That said, it is not surprising that the relatively new properties included in the survey are more water efficient on average than averages based on populations that include older properties. Overall, these findings should be viewed as little more than a directional indication that new mixed use properties are more efficient than older properties in general.

Table 15: Comparison of Survey Property Average Demand to Other Cited Rates

Source	Annual Rate (000's)	Survey Rate Type	Average Annual Surveyed Property Rates (000's)	Percentage Difference
TRWSP Averages				
Residential	39.8	Per DU (all uses)	37.1	-7%
Commercial	0.038	Per SF (all uses)	0.019	-97%
Institutional	0.036	Per SF (all uses)	0.019	-87%
Florida Study (All C&I)	0.049	Per HSF (all uses)	0.019	-155%
Florida Study (Mixed Use Only)	0.034	Per HSF (all uses)	0.019	-79%
Fannie Mae MF Study (South)	0.044	Per SF (all uses)	0.019	-129%

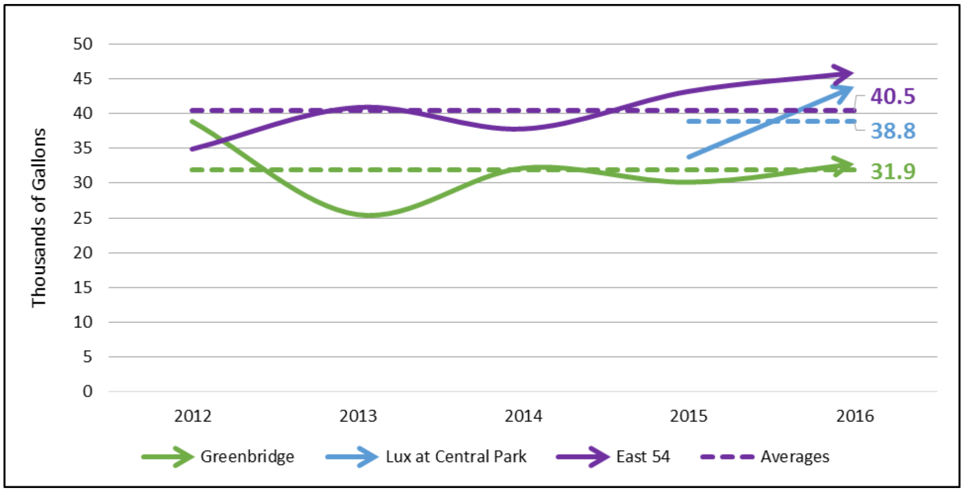
Since average demand figures are exposed to the influence of outliers and other factors that might skew results, and most of the surveyed properties have been in operation for fewer than five years, it is prudent to examine changes over time in order to provide context for reported averages. Average annual demand continues to change over time for each of the surveyed properties (Chart 1). Since these figures have been adjusted for occupancy, increases in demand are likely being driven by other causes. Potential sources of increased demand could be changes in the number of residents per unit, or increased water use due to higher temperatures in recent years. It is interesting to note that even the oldest two properties, Greenbridge and East 54, appear to show increasing annual demand. Regardless of the cause, it is clear that annual demand can continue to shift for individual properties well after their initial opening.

Chart 1: Annual Demand by Survey Property



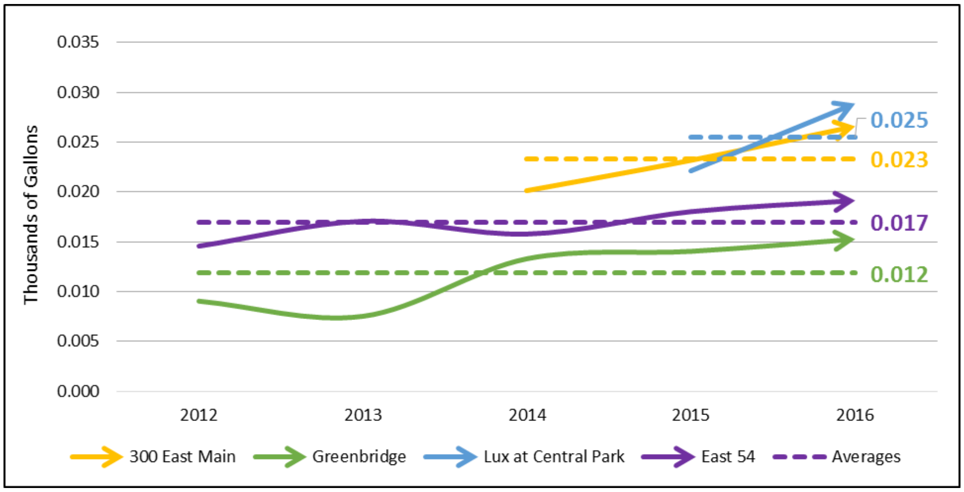
Charts 2 and 3 display average annual demand per DU over time and average annual demand per SF over time for the surveyed properties. We have fewer data points available for analyzing average demand per DU because only three of the currently surveyed properties include residential uses, and East 54 did not provide occupancy data. Also, the distribution of residential versus nonresidential uses is inconsistent across the surveyed properties. It is, however, notable that all surveyed properties displayed a lower average annual demand per DU than the regional average of 44.5 kgpu found in the Fannie Mae study, and that the average per DU demand for the surveyed properties is within 10 percent of the average per DU rate in the TRWSP.

Chart 2: Average Annual Demand per DU by Surveyed Property



There appears to be some convergence in the per square foot demand rates for non-LEED versus LEED buildings, regardless of their usage mixes (Chart 3). This pattern, however, may be misleading. First, it is supported by very few data points, and it is not clear that any of the averages presented will remain constant over time. Second, although these figures have been adjusted for partial years, they do not account for how much square footage was actually occupied at any point in time. The increases may therefore be either fully or partially attributable to changes in occupancy. Along similar lines, we do not know how the occupied square footage was actually used at any particular point in time. Per square foot demand rates could therefore be affected by the timing of residential, restaurant, and office move-ins, which would skew results for properties with less than a 100 percent occupancy rate.

Chart 3: Average Annual Demand per Square Foot by Surveyed Property



Water Demand Estimation for Local Mixed Use Properties

OWASA has several options for estimating future water demand by mixed use properties in their service area. These options include: (1) Using a single per unit rate or range of rates for all new mixed use properties; and, (2) Using an additive method that recognizes different uses. One way to evaluate these approaches is to apply them to the four surveyed properties and then compare results with actual historical usage rates. Given the small number of properties involved in this comparison, these results should be viewed as suggestive rather than conclusive.

Per Unit Assumptions

Both of the estimation methods identified above require selecting per unit assumptions. Toward that end, OWASA could use: (1) Assumptions from other local utilities included in the TRWSP; (2) Assumptions based on nonlocal studies; or, (3) Independently-developed assumptions based on local historical data. Since a broad analysis of historical use records is beyond the scope of this report, and meter data for the surveyed properties does not always differentiate between uses, the evaluation in this section relies on whole property rates for mixed use developments.

Findings for the surveyed properties suggest that annual water usage rates for new local mixed use properties have a range of 0.012 to 0.025 kgpsf, with an average of 0.019 kgpsf. This range, however, includes two LEED properties and may therefore be artificially low. An alternative approach might be to use two separate sets of assumptions that differentiate between 'normal' mixed use developments and 'high-efficiency' mixed use developments. Under this approach, the average annual rate for 'normal' mixed use developments could be 0.024 kgpsf, and the average annual rate for 'high-efficiency' mixed use developments could be 0.015 kgpsf. The fact that these rates are substantially lower than any of the local or nonlocal assumptions previously presented may be attributed to the generally higher efficiency of new developments compared to the older properties that are included in other averages.

Applying Whole-Property per Unit Rates

Since none of the local utilities in the TRWSP used per unit rates specifically for mixed use developments, it is only possible to evaluate the results of using whole-property per unit rates from nonlocal studies and those based on the surveyed properties. Using the 0.034 per heated square foot rate found by Morales and Heaney in Florida did not result in accurate estimates (Table 16). The high error rates using this approach mostly likely have two causes. First, the average building in the sample of 143 properties from which this rate was derived was built in 1976, long before the EPAct. Second, there are likely differences between water use rates between properties in Florida and properties in North Carolina, regardless of property type.

Table 16: Application of Average Florida Mixed Use Water Demand Rates

Property	Square Feet	Actual Average Annual Water Use (000's)	Estimation		Error	
			Per SF Assumption	Gallons per Year (000's)	Gallons Per Year (000's)	%
300 East Main	203,000	4,709	0.034	6,902	2,193	32%
East 54	423,304	7,169	0.034	14,392	7,224	50%
Greenbridge	210,000	2,489	0.034	7,140	4,651	65%
Lux at Central Park	294,512	7,517	0.034	10,013	2,497	25%
Total	**1,130,816**	**21,883**		**38,448**	**16,564**	**43%**

Using the average rate of 0.019 kgpsf derived from historical data for the surveyed properties, and the previously described alternative approach with one set of assumptions for 'normal' properties and another for 'high-efficiency' properties resulted in more accurate estimates (Tables 17 and 18). In both cases, the estimated use is much closer to actual use than the estimates in Table 16. In many ways, this is an unsurprising result. First, the assumptions applied are based on these exact properties, so they—by definition—should closely approximate actual water use. A better evaluation would use this approach to compare expected results for a separate set of mixed use developments against their actual historical demands. Second, all of the surveyed properties were constructed after the implementation of the EPAct, so they should be substantially more efficient than older properties, or the average property in most utilities' service areas. That said, I think it is clear that applying annual demand rates based on older properties to new mixed use developments would lead to significant overestimations of actual water demands.

Table 17: Application of Average Surveyed Property Demand Rates

Property	Square Feet	Actual Average Annual Water Use (000's)	Estimation		Error	
			Per SF Assumption	Gallons per Year (000's)	Gallons Per Year (000's)	%
300 East Main	203,000	4,709	0.019	3,857	-852	-22%
East 54	423,304	7,169	0.019	8,043	874	11%
Greenbridge	210,000	2,489	0.019	3,990	1,501	38%
Lux at Central Park	294,512	7,517	0.019	5,596	-1,921	-34%
Total	**1,130,816**	**21,883**		**21,486**	**-398**	**-2%**

Table 18: Application of 'Normal' & 'High-Efficiency' Surveyed Property Demand Rates

Property	Square Feet	Actual Average Annual Water Use (000's)	Estimation		Error	
			Per SF Assumption	Gallons per Year (000's)	Gallons Per Year (000's)	%
300 East Main	203,000	4,709	0.024	4,872	163	3%
East 54	423,304	7,169	0.015	6,350	-819	-13%
Greenbridge	210,000	2,489	0.015	3,150	661	21%
Lux at Central Park	294,512	7,517	0.024	7,068	-448	-6%
Total	**1,130,816**	**21,883**		**21,440**	**-443**	**-2%**

Applying the Additive Method

As with the whole-property method, there are challenges associated with evaluating the additive method due to a lack of available information. Specifically, I was unable to identify historical water demands for particular nonresidential uses in every surveyed property. Also, there was some ambiguity in the reported distribution of nonresidential uses in the survey responses. For example, East 54 did not differentiate between square footage for restaurants and retail stores. The result is that I was unable to calculate an average historical per unit demand rate for specific nonresidential uses in local mixed use developments. That said, it is possible to evaluate the additive method using local assumptions from the TRWSP and nonlocal assumptions from the State of Florida.

Toward that end, I took the actual distributions of nonresidential uses for each property based on the information included in Table 12 and combined them into broader categories. Restaurant, retail, and hotel uses were combined into a single 'commercial' category, while office uses were placed in the 'institutional' category. Multiplying these combined distributions by their respective average demand factors in the TRWSP did not produce accurate estimates (Table 19). Indeed, the application of these assumptions again leads to a substantial overestimation of annual water demands. The only exception is for the Lux at Central Park, which is not actually a mixed use property. I think the problem, however, is more related to the assumptions than the methodology. To be sure, the average assumptions included in the TRWSP are not tailored for LEED certified properties, and they are based on analyses of all properties in each municipality, not just those constructed after the implementation of the EPAct.

Table 19: Application of Average TRWSP Assumptions

Property	Distribution of Uses		Actual Annual Average Use (000's)	Estimation		Error	
	Use	Units or SF		Average TRWSP Annual Assumption (000's)	Gallons per Year (000's)	Gallons Per Year (000's)	%
300 East Main	Residential Units	0	4,709	39.8	7,668	2,959	39%
	Commercial SF	180,000		0.038			
	Institutional SF	23,000		0.036			
East 54	Residential Units	186	7,169	39.8	16,439	9,271	56%
	Commercial SF	130,568		0.038			
	Institutional SF	113,191		0.036			
Greenbridge	Residential Units	98	2,489	39.8	10,380	7,891	76%
	Commercial SF	0		0.038			
	Institutional SF	180,000		0.036			
Lux at Central Park	Residential Units	194	7,517	39.8	7,721	205	3%
	Commercial SF	0		0.038			
	Institutional SF	0		0.036			
		Total	**21,883**		**42,209**	**20,326**	**48%**

I also tested using the same additive method but with the regional per unit residential assumptions for the South included in the Fannie Mae survey, and selected per unit rates from the Morales and Heaney article on commercial use in Florida (See Table 5). For institutional uses, I applied the 'Office, Multi-Story' rate, and for commercial uses, I applied the average rate across all C&I subcategories most likely to be present in mixed use developments. Again, the error rate is higher when using nonlocal assumptions (Table 20), but neither approach provides an accurate estimate of actual annual use in the surveyed properties.

Table 20: Application of Average Assumptions from Fannie Mae (South) and Morales (Florida) Studies

Property	Distribution of Uses		Actual Annual Average Use (000's)	Estimation		Error	
	Use	Units or SF		Fannie Mae (South) & Florida Annual Assumption (000's)	Gallons per Year (000's)	Gallons Per Year (000's)	%
300 East Main	Residential Units	0	4,709	44.5	16,775	12,066	72%
	Commercial SF	180,000		0.09			
	Institutional SF	23,000		0.025			
East 54	Residential Units	186	7,169	44.5	22,858	15,689	69%
	Commercial SF	130,568		0.09			
	Institutional SF	113,191		0.025			
Greenbridge	Residential Units	98	2,489	44.5	8,861	6,372	72%
	Commercial SF	0		0.09			
	Institutional SF	180,000		0.025			
Lux at Central Park	Residential Units	194	7,517	44.5	8,633	1,117	13%
	Commercial SF	0		0.09			
	Institutional SF	0		0.025			
		Total	**21,883**		**57,127**	**35,244**	**62%**

Takeaways for OWASA Planners & Officials

Based on the research and analysis included in this report, I think OWASA planners and officials involved in the ongoing update of the Long Range Water Supply plan should consider the following main points related to mixed use water demand:

1. **There is little existing water demand research on the average annual demands of mixed use properties.** In general, much of the research on historical water use focuses specifically on residential demand or demand from other sectors. Moreover, the research on these sectors uses neither consistent definitions of the sectors themselves, nor consistent measurements of past use. There are also challenges related to geography, as there is a disproportionate amount of research on western states, and national studies are skewed upward by differences in local and regional climate.

2. **Water efficiency is increasing for new properties due to the effects of improved national standards, the proliferation of noncompulsory efficiency programs and certifications.** As a result, newer properties are displaying substantially lower water use rates than older properties. This means that using average water use rates based on historical data may lead to an over estimation of water use in new developments. The increasing popularity of Smart Growth and Transit-Oriented planning concepts that encourage higher densities may exacerbate this issue by decreasing outdoor demands for residential properties. One mitigating factor may be increased demand from chillers and cooling towers.

3. **Research on the effectiveness of price and non-price conservation programs is mixed.** There are, however, growing market pressures that are pushing developers toward building more efficient structures that should result in lower average annual water demand rates for new properties. This pressure may be higher for mixed use developments, as they are often touted as a more sustainable approach to development than traditional urban sprawl.

4. **Land use based methods of future demand estimation are generally more accurate.** I suggest adopting a modified version of the approach used by the East Bay Municipal Utility District in California. Specifically, OWASA should consider developing separate demand assumptions for future versus existing properties. By differentiating between new and older properties, OWASA would be able to more effectively account for the challenges outlined in Point 2 above.

5. **More research is necessary to develop quality per unit demand assumptions for mixed use properties.** The surveyed properties displayed average annual demand rates of 0.012 to 0.025 kgpsf, with an average of 0.019 kgpsf. In addition to differentiating between new and existing properties, OWASA should consider defining separate assumptions for ‘normal’ versus ‘high-efficiency’ properties. Under this approach, the average annual rate for ‘normal’ mixed use developments could be 0.024 kgpsf, and the average annual rate for ‘high-efficiency’ mixed use developments could be 0.015 kgpsf. These rates, however, are only based on four examples, and should therefore be continually monitored and evaluated over the next few years using additional (new) mixed use properties’ water demands to ensure validity and adjust according to more recent empirical data.

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Appendix

A.1: Survey Instrument

QUESTIONNAIRE: PROPERTY MANAGERS

NOTE: Participation in this study is entirely voluntary. Results will be shared with OWASA and incorporated into a publically available report as part of my Master's Project for the Department of City and Regional Planning at The University of North Carolina at Chapel Hill. The goal of the study is to improve water resource planning by contributing to our understanding of how water is used in local, newer mixed-use developments.

As part of the update to its Long-Range Water Supply Plan, Orange Water and Sewer Authority (OWASA) will estimate water needs through 2065. OWASA would like better information on which to base its water demand projections to ensure our water resources meet the community's needs. The study is intended to collect general information about your property and management practices. It is not intended to criticize any specific property, management company, or set of building management practices, nor is it intended to evaluate the veracity of any specific marketing materials or strategies. If there are questions contained within this questionnaire that you do not feel comfortable answering, please skip them and provide whatever information you can. Thank you for your involvement!

SECTION 1: PROPERTY CHARACTERISTICS

1. What is the total square footage of the property by use?

Use	Square Feet
Residential	
Retail	
Restaurant	
Commercial	
Lawn or Greenspace	
Other: ________________ (Describe)	
Total	

2. How many units does the property have by use?

Use	Unit Count
Residential	
Retail	
Restaurant	
Commercial	
Total	

3. What percent of the units are owned by the tenant (i.e. not rented)?

Use	Unit Count
Residential	
Retail	
Restaurant	
Commercial	

Total

4. Please indicate which of the following water-related features and/or amenities are present in the property:

Feature	Present? (Y/N)
Pool(s)	
Chillers	
Cooling Towers	
Reuse Systems	
Irrigation Systems	
Rain Barrels/Cisterns	
Rain or Soil moisture Sensors/Gauges	
Other: ________________ (Describe)	

5. If your property has an irrigation system, what type is it? Please check all that apply. If an appropriate option is not provided, please describe it in "other".

Irrigation System Type	Checkbox
Drip	
Traditional Automatic Spray	
Rotor Sprinklers	
Irrigate by hand	
Do not irrigate	
Other: ________________ (Describe)	

6. How often does your irrigation system operate? If there are seasonal differences, please describe them.

7. Is the irrigate system controlled by an automatic timer? If so, how frequently do you adjust the timer?

8. If your property does not have an irrigation system, how do you water landscaping features? How often does this occur?

9. How many residential units fall into each of the following categories? (*Note: Please fill in the grid below with the **count** of units. For example, if there are 10 units with 1 bathroom and 1 bedroom, please write 10 in the top left cell.)*

	1 Bathroom	**1.5 Bathrooms**	**2 Bathrooms**	**2.5 Bathrooms**	**3 Bathrooms**	**4+ Bathrooms**
1 Bedroom						
2 Bedrooms						
3 Bedrooms						
4+ Bedrooms						

10. Are any of the following installed in your residential or other units? Please only indicate those fixtures that were installed by the management company, not those installed independently by residents or tenants.

Fixture	**Checkbox**
Older, 3.5-5 gallon per flush (gpf) toilets	
Conventional (1.6 gpf) toilets (*any toilets installed in residences after 1/1/94 or in commercial after 1/1/97 must use 1.6 gpf or less)*	
Low Flow (1.28 gpf) toilets	
Dual flush toilets	
Low Flow shower heads	
Body jets/jetted showers	
WaterSense dishwashers	
WaterSense clothes washers	

SECTION 2: BILLING & METERING PRACTICES

1. Do you sub-meter and re-bill tenants for their water use?

2. If you do not sub-meter and re-bill for water use, how do tenants pay for water and sewer services?

3. Have you noticed any recent changes (within the last two years) in water bills or usage levels for your tenants? If so, do you have an explanation as to why?

4. Do you sub-meter for specific uses like irrigation, chillers, etc.? Please indicate all that apply.

Use	Checkbox
Irrigation	
Cooling towers or Chillers	
Pool Maintenance	
Other: ________________ (Describe)	

SECTION 3: TENNANT CHARACTERISTICS

1. How many full time equivalents (FTEs) do commercial and/or retail tenants maintain on-site? (*Note: If you do not know an exact number, please provide a range estimate.)*

Use	# of FTEs	# of Tables
Retail		
Restaurant		
Office		
Hotel		
Other: ________________ (Describe)		

2. What is your current occupancy rate? Please provide estimates for each of the past 5 years. *(Note: If your property is less than 5 years old, please provide an estimate for each relevant year)*

	2016	2015	2014	2013	2012
Occupancy Rate					

Please describe the type of rate provided (e.g. annual average, rate as of January 1st, etc):

____

3. Do you see significant seasonal variations in occupancy? If so, what is your average monthly occupancy rate?

SECTION 4: OPERATING AND MAINTENANCE PRACTICES

1. Is this property managed by a professional management company? If so, is the company local and how many properties does it currently manage?

2. How many FTEs are involved in the operation and maintenance of the property? *(Note: If an employee performs tasks related to more than one function, please categorize them according to their primary responsibility.)*

Function	FTEs
Operation/Management	
Maintenance	
Landscaping	
Other: ________________ (Describe)	

3. Are there any known or suspected maintenance issues that might affect water use? For example, do you know of any existing leaks or aging systems? If so, please describe.

4. Do you hire an outside firm to handle landscaping? If so, what services do they provide? *(Note: Please check all that apply.)*

Service	Checkbox
Planting	
Watering	
Maintenance	
Other: ________________ (Describe)	

5. What is your company or organization's mission statement?

6. Does water efficiency or sustainability factor into your marketing strategy? If so, how?

7. Do you provide information, workshops or incentives to tenants for water conservation?

8. Have you ever conducted a water audit or landscape audit for the property?

9. Are there any water-saving features or practices that have not been covered by this questionnaire?

10. Are there any questions you have for me?

A.2: Profile of 300 East Main, Carrboro, NC

The 300 East Main property consists of several mixed use buildings located along the Main Street corridor in Carrboro. The buildings include 20 units dedicated to retail and 12 units for office space. The larger structure is also home to a Hampton Inn hotel. There is a total of approximately 80,000 square feet of retail space (including the nearby Art Center), 22,000 square feet of commercial and office space, and 100,000 square feet of hotel space. Other than the Art Center and Hampton Inn, all units are owned by Main Street Partners and leased to tenants under different agreements depending on tenant type. Office tenants are held under a full service lease agreement that includes utilities without separate submetering or rebilling. The newer retail and restaurant tenants, however, operate under a triple net lease and are therefore responsible for their own utility costs. In the older structure that includes the Art Center and Cat's Cradle, tenants are responsible for some utility costs, but water is included in rent.

Construction on the redevelopment project began in 2012, and the shell for the larger structure was completed in August 2013. Although the Hampton Inn opened in early September 2013, tenant upfits for most units continued through the end of that year. The property saw an approximately 80 percent occupancy rate through 2014 while construction continued on the smaller structure until around February 2015. At that time, Fleet Feet moved in on an accelerated timeline and began operation while other tenants performed upfits. Since 2016, management reports that 300 East Main has maintained an approximately 90 percent occupancy rate due to regular turnover and strong demand in the area. It should be noted that significant further development is planned for the site. In March 2016, the Town of Carrboro approved plans for a 42,228 square foot, five-story Hilton Garden Inn and announced that it is considering adding more structured parking. While Main Street Partners does not intend to pursue LEED certification for the new project, they have announced that the construction plan will mostly comply with LEED energy efficiency and sustainability standards.

Water-Related Features

- Hotel Pool
- Conventional (1.6 gpf) Toilets

Landscaping & Irrigation

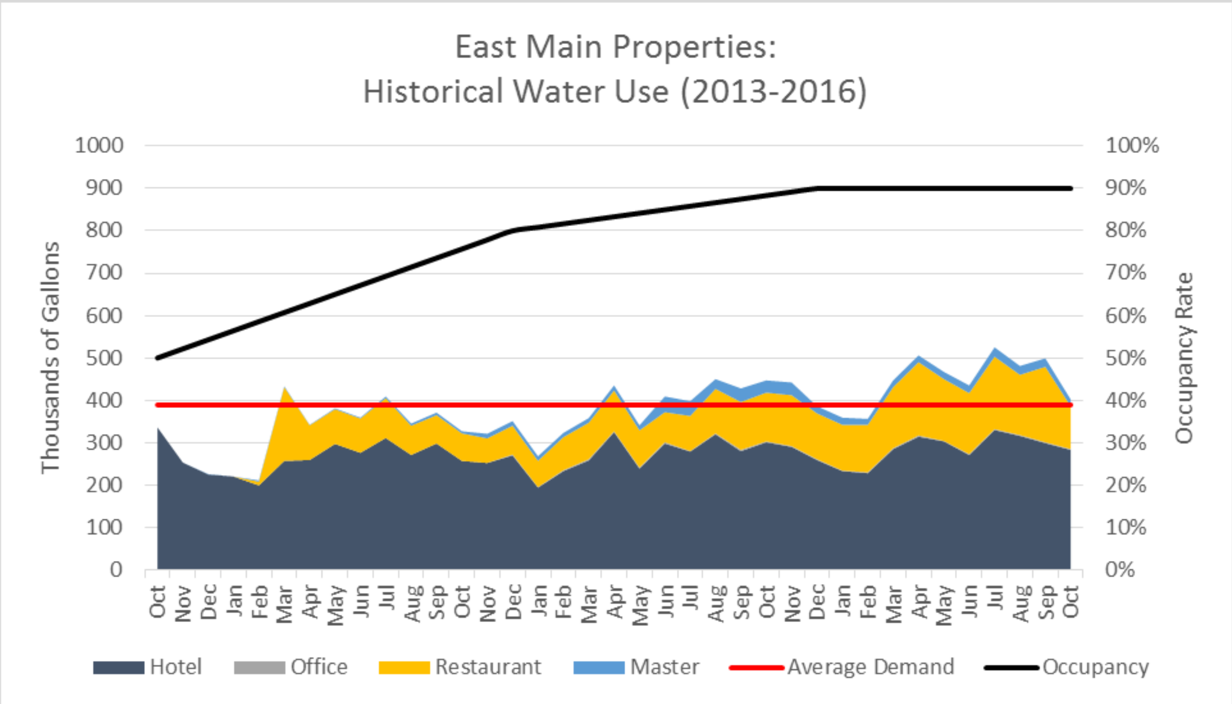
300 East Main is an infill redevelopment project with a large parking area, so there is little open greenspace that requires regular landscaping and irrigation. Rather than installing an automatic irrigation system, Main Street Partners hires an outside firm to handle occasional planting, watering, and maintenance for decorative potted plants and parking islands during the summer. Management reports that they try to rely on rain for irrigation and that they intentionally planted hardy plants to minimize watering and maintenance requirements.

Management

Main Street Partners owns and manages most of the structures at 300 East Main. Rather than maintaining employees to perform basic operations, maintenance, and landscaping functions, they hire companies as partners. While unsure of the exact number of FTEs employed by tenants, Main Street Partners estimates that there are between 200-300 FTEs total on-site. This includes approximately 100 for the Hampton Inn, 60-70 for Fleet Feet, and the remainder spread among restaurant and retail tenants.

Historical Water Use

Chart A.1: East Main Historical Water Use

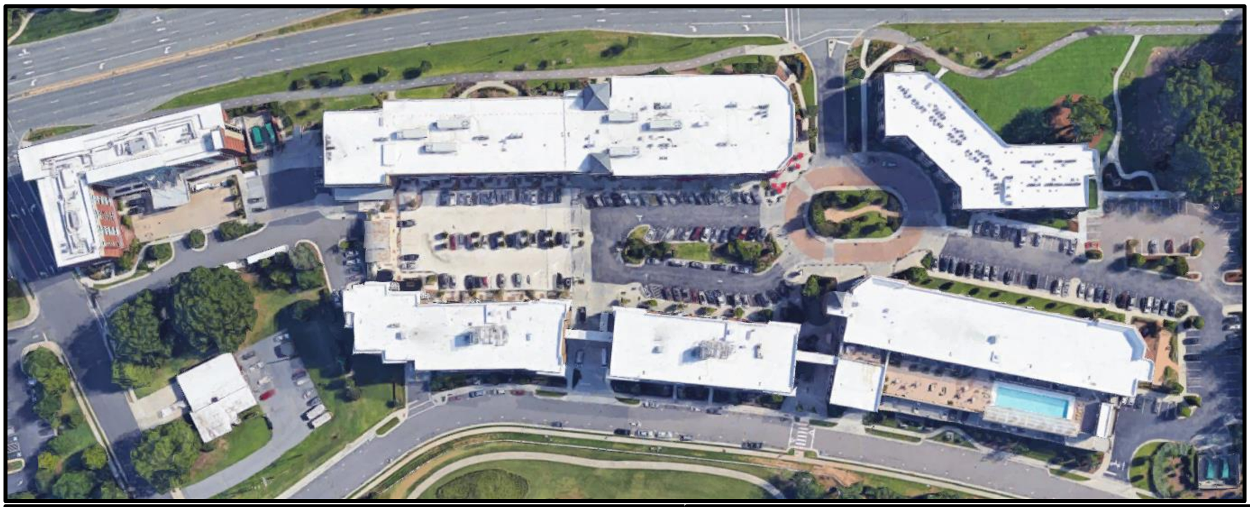


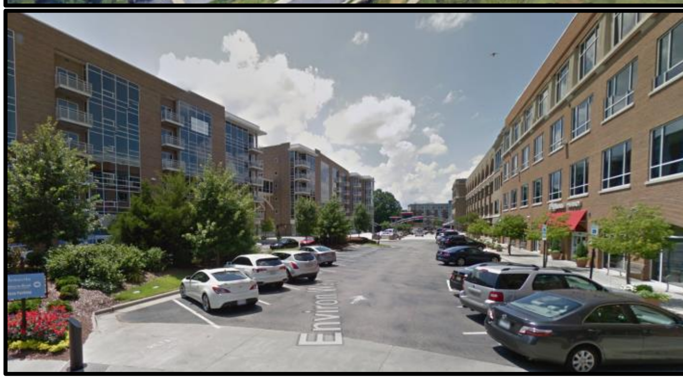
Historical Water Use (000's gal)	
Average Annual Demand	**4,709**
Per DU	N/A
Per Sq Ft	0.023
Average Monthly Demand	**389**
Peak Demand	525
Peak Month	July, 2016

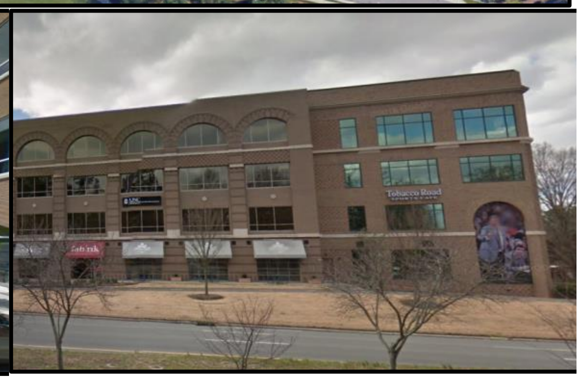
Historical water demand at 300 East Main is dominated by the Hampton Inn. In fact, hotel water use accounts for more than 60 percent of total demand in all but one month since October, 2013. Restaurants account for the second largest source of demand, while contributions from office tenants and the property's master meters are relatively minimal. There are several trends worth noting that both comport with information provided by East Main Partners and suggest the potential for additional demand in the future.

First, restaurant water use rapidly increased from near 0 to over 170 thousand gallons in February, 2014 which aligns with reports from East Main Partners that occupancy jumped after tenant upfits were completed near the end of 2013. Second, master meter draws were highest between June and November of 2013, and never exceeded 37 thousand gallons during the entire period of analysis. Since the average master meter flow for all other months is approximately 15 thousand gallons, this suggests that there is some—albeit relatively low—demand for irrigation use during the warmer months. Of course, there could be other factors driving this temporary increase, but they have not currently been identified. Third, 300 East Main has the flattest demand and weakest seasonal effects of any of the other properties profiled so far. This fact fits with management's report that irrigation use is minimal and may be driven by bot the lack of residential units and the large amounts of impervious surface in the development. Finally, it is worth noting that total water demand appears to be increasing over time. It is not clear whether this trend is caused by increased occupancy or increased demand from existing occupants, but when considered in light of the current 90 percent occupancy rate, it suggests that annual demand may continue to rise in the short to medium term.

A.3: Profile of East 54, Chapel Hill, NC







East 54 is a large mixed use development located on Raleigh Road in Chapel Hill. Comprised of multiple buildings, East 54 includes 186 apartments and condominiums with nearly 180 thousand square feet of space. The property also includes over 113 thousand square feet of office space, the 75 thousand square foot Aloft hotel, and 15 units of retail and restaurant space. The property is managed by East West Partners which has an office on site. According to the East 54 website, the development received Gold Certification in the pilot LEED-ND program, and the office building on site is certified LEED Platinum for Core and Shell. Unfortunately, less information was provided for East 54 than for the other surveyed process during the questionnaire process.

Water-Related Features

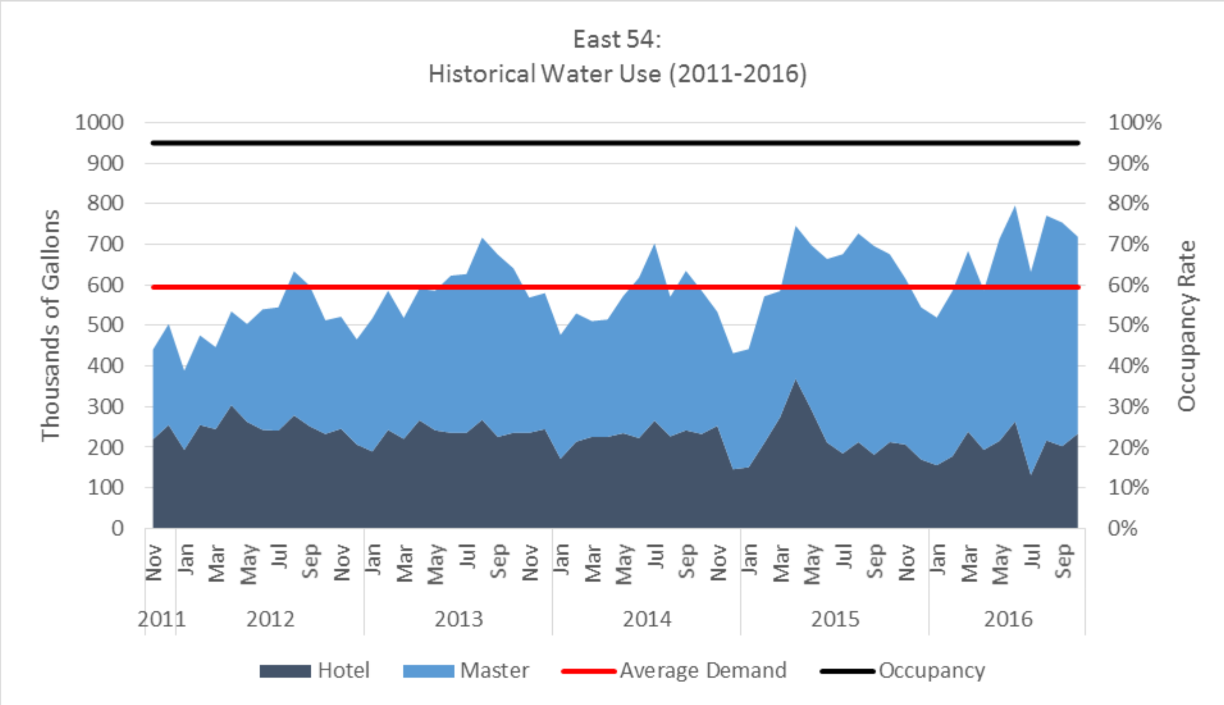
- Pool
- Chillers & Cooling Towers
- Conventional (1.6 gpf) Toilets
- Low Flow (1.28 gpf) Toilets
- Irrigation by Hand
- Drip Irrigation System
- Rain Barrels/Cisterns
- Traditional Automatic Spray Irrigation System

Historical Water Use

Historical water use at East 54 is difficult to parse because the majority runs through a master meter. There is however a substantial amount of use from the Aloft hotel. Notably, water use at

East 54 has increased in recent years. Like other properties included in this study, there are noticeable dips in water use during the winter months, and peaks during the summer.

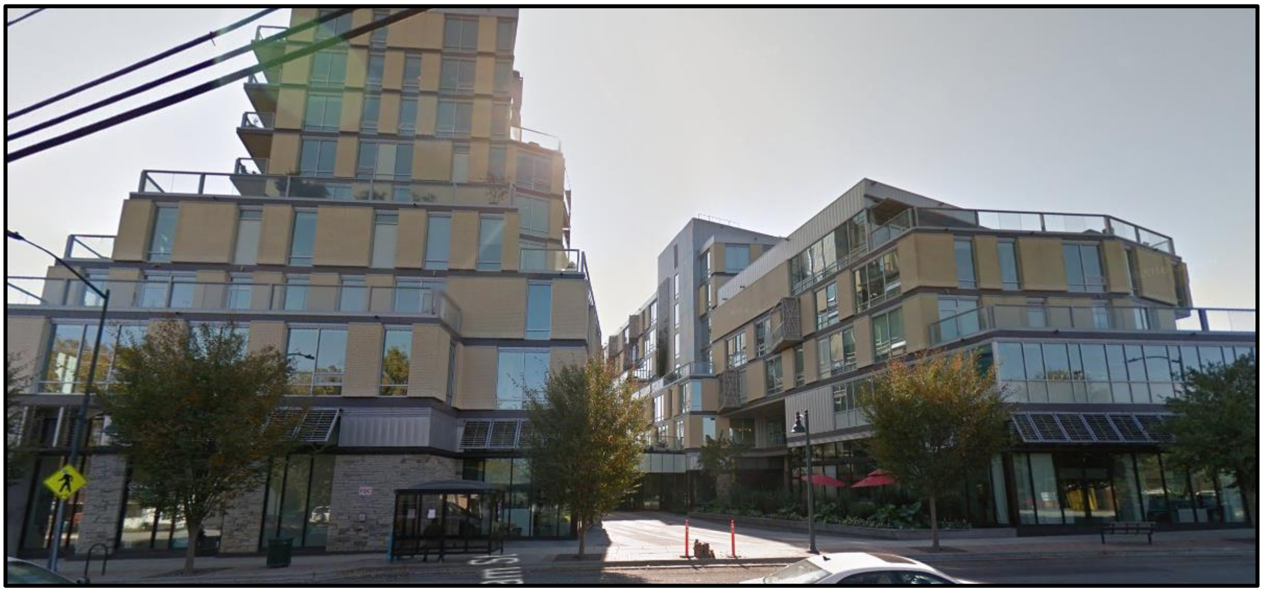
Chart A.2: East 54 Historical Water Use



Since no occupancy rate data was provided, a flat rate of 95 percent has been assumed for the entirety of the study period. As a result, per DU demand rates for East 54 are likely less accurate than the others included in this report. The per square foot use rate, however, is noticeably lower than those associated with the surveyed properties that did not receive LEED certification.

Historical Water Use (000's gal)	
Average Annual Demand	**7,169**
Per DU	40.5
Per Sq Ft	0.017
Average Monthly Demand	**595**
Peak Demand	796
Peak Month	June, 2016

A.4: Profile of Greenbridge Condominiums, Chapel Hill, NC



Residential Units by Type	
1 Bed / 1 Bath	10
2 Beds / 2 Baths	80
3 Beds / 3 Baths	8
4+ Beds / 4+ Baths	0
Total Units	**98**
Total Beds/Baths	**194**

Greenbridge is a mixed use development located near downtown Chapel Hill and the UNC campus at the intersection of West Rosemary Street and Merritt Mill Road. The project broke ground in April 2008, and was the first development in North Carolina to achieve LEED Gold certification. After its completion in mid-2010, financial troubles led to foreclosure and a change in ownership in 2012. The property contains 98 residential units covering approximately 180 thousand square feet and 19 commercial units covering about 30 thousand square feet. All residential and commercial units are owned by the tenants, and Greenbridge has shown a near 100 percent occupancy rate since 2014. As part of its LEED certification, Greenbridge earned credits for taking the following steps to achieve higher water efficiency standards.

(1) Reducing potable water consumption for irrigation by 50 percent from a calculated mid-summer baseline case;
(2) Using only captured rainwater for irrigation;
(3) Reducing potable water use for building sewage conveyance by 50 percent; and,
(4) Employing strategies that in aggregate use 20 percent less water than the water use baseline calculated for the building after meeting the Energy Policy Act of 1992 fixture performance requirements.

Management reports that there are no significant seasonal variations in occupancy, and that many commercial tenants have employees working from home. Greenbridge does not submeter water usage for residents, so water use is included in flat condo fees. There is, however, supposed to be a separate meter for the building's chiller and cooling tower.

Water-Related Features

- Chiller
- Cooling Towers
- Water Reuse System
- Dual Flush Toilets
- Low Flow Shower Heads
- Rain Barrels/Cisterns

- Low Flow (1.28 gpf) Toilets
- No Active Irrigation System
- WaterSense Dishwashers
- WaterSense Clothes Washers

Landscaping & Irrigation

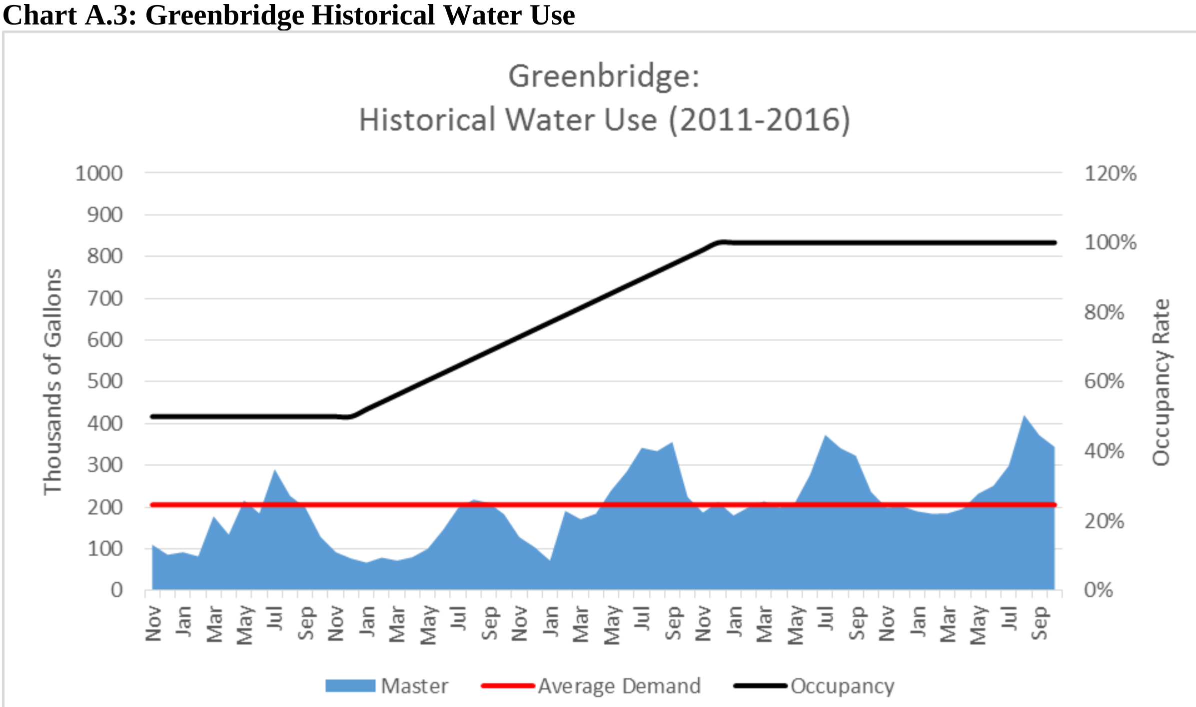
Greenbridge was intentionally designed to use less water for irrigation than most other similarly-sized developments. This goal is achieved through three different approaches. First, Greenbridge landscapes using native species that are better adapted to survival in the local climate without constant irrigation. Second, the building was constructed as infill, so there is no large open greenspace to be watered other than the three green roofs. Third, Greenbridge utilizes a rainwater capture and reuse system instead of more traditional irrigation techniques. That said, some basic landscaping services are provided by an outside landscaping firm that covers planting, maintenance, and some light watering when necessary.

Management

Greenbridge is professionally managed by The Lundy Group which has locations in Raleigh and Chapel Hill. They report that 2 FTEs are involved in the operation and maintenance of the property, and that office tenants have an estimated 100 to 150 FTEs on site. The Lundy Group stated that there are no currently known maintenance issues, and that they check weekly for water leaks throughout the building. Since the building is fully occupied, Greenbridge is not currently engaged in active marketing that highlights its higher efficiency standards. The LEED Gold Certification and other sustainability-oriented features, however, were a prominent point in prior years. For example, the Greenbridge Facebook Page includes several advertisements highlighting green roofs, water efficient fixtures, and solar thermal water heating. The Lundy Group does not provide information, workshops, or incentives to residents for water conservation, but such information is covered in Unit Owners Association (UOA) meetings at least annually.

Historical Water Use

Chart A.3: Greenbridge Historical Water Use

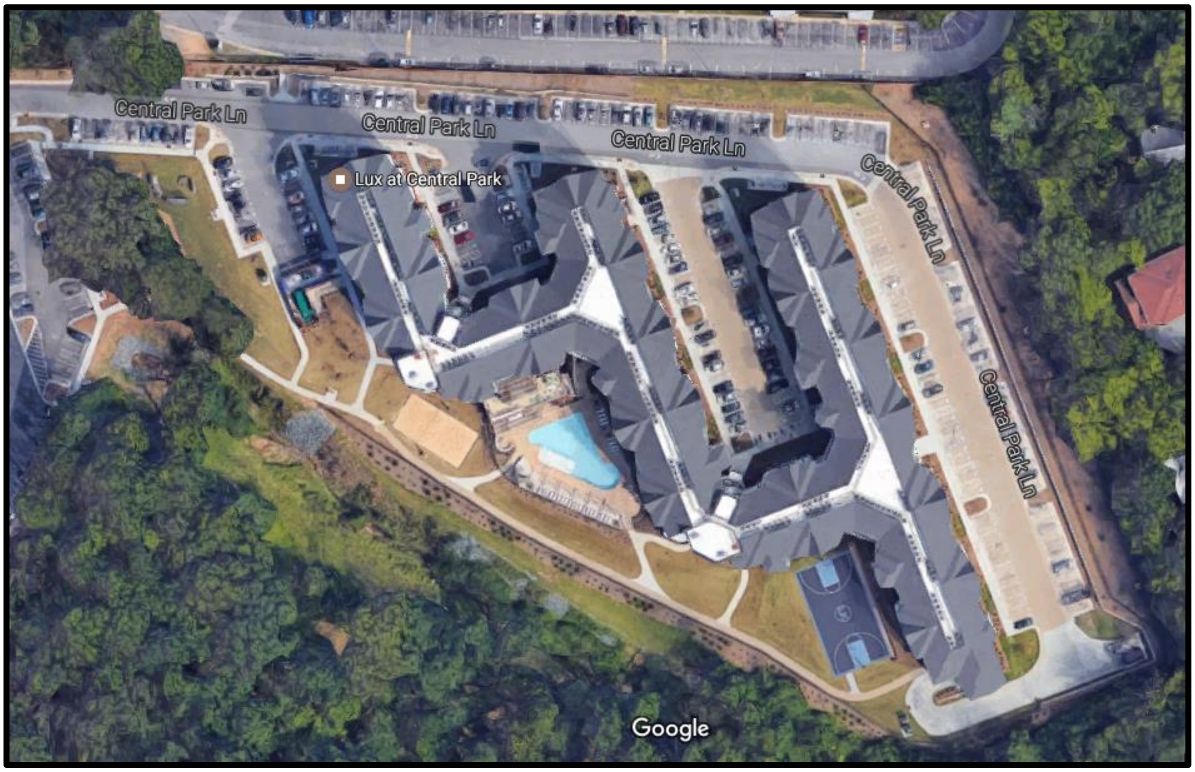


Historical Water Use (000's gal)	
Average Annual Demand	**2,489**
Per DU	31.9
Per Sq Ft	0.012
Average Monthly Demand	**205**
Peak Demand	421
Peak Month	August, 2016

Historical water demand at Greenbridge displays both a substantially lower rate per dwelling unit (DU) than the LUX, and a far lower rate per square foot than both the LUX and 300 East Main. These historical rates, however, are skewed downward by the property's relatively low occupancy rate through the third quarter of 2014. Looking only at 2014-2016, average annual demand increases to 2,986 thousand gallons per year, average annual demand per DU increases to 31.7, and average annual demand per square foot increases to 0.014. This means that Greenbridge uses approximately 32 percent less water per DU and 50 percent less water per square foot than the LUX. Assuming the LUX is representative of most built-to-code multifamily developments, it seems that Greenbridge has exceeded the water use reduction goals laid out in the initial LEED application.

There are several other trends worth noting beyond the increase in demand due to higher occupancy. First, despite its lack of an irrigation system or non-roof greenspace, Greenbridge displays seasonal increases in water demand during warmer months. Although there is no meter data available to support this claim, it seems likely that increased summer usage may be at least partially attributable to the effects of increased evaporation from the building's cooling towers. Second, since the building is fully occupied and has been operational for several years, the current rate of demand does not seem likely to increase further over time. Overall, the data appear to support Greenbridge's water efficiency claims.

A.5: Profile of Lux at Central Park, Chapel Hill, NC



The Lux at Central Park is a multifamily rental housing development located close to downtown Chapel Hill and the UNC campus. The property has 194 residential units totaling approximately 295 thousand square feet and began taking tenants in 2014. Given its central location and the high demand for this type of housing in Chapel Hill, the Lux at Central Park was able to achieve a roughly 75 percent occupancy rate in its first year of operation, and has maintained near full occupancy for the past two years. Management reports that there are no significant seasonal variations in occupancy due to the exclusive use of 12 month leases. The Lux does not submeter water usage, so tenants pay for water as part of their monthly rent, and management does not possess records of individual use.

Residential Units by Type	
1 Bed / 1 Bath	24
2 Beds / 2 Baths	40
3 Beds / 3 Baths	16
4+ Beds / 4+ Baths	114
Total Units	**194**
Total Beds/Baths	**608**

Water-Related Features

- Pool
- Irrigation System
- Conventional (1.6 gpf) Toilets
- Low Flow Shower Heads
- WaterSense Dishwashers
- WaterSense Clothes Washers

Landscaping & Irrigation

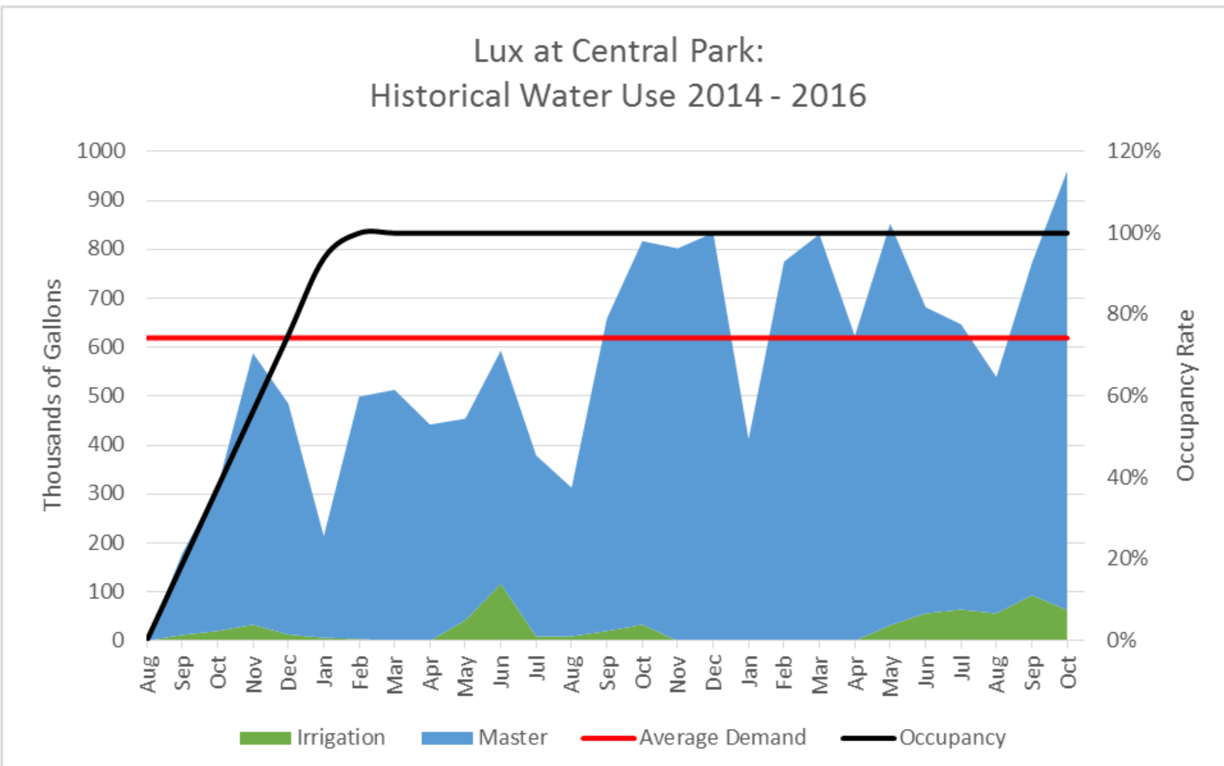
Irrigation practices combine manual and automated systems, including drip systems, traditional automatic spray, rotor sprinklers, and some watering by hand. The property also utilizes rain and soil moisture detection systems to control irrigation. Water used for irrigation is tracked through a separate meter. Landscaping services are provided by a separate company that handles planting, watering, and maintenance for certain parts of the property.

Management

The Lux is locally managed and maintains a staff of 15 FTEs. Three FTEs are dedicated to maintenance while the remainder works on operations and management. Maintenance staff reported no known maintenance issues that might affect water use beyond routine replacements of toilet valves or other fixtures. Water efficiency and sustainability do not appear to be major marketing points for the Lux, and management has not conducted a water audit or provided information, workshops, or incentives to tenants for water conservation. There are, however, some sustainability-oriented features worth noting. Specifically, a significant portion of the parking lot consists of permeable pavers with underground baffles, and the basketball court is designed to capture and store rainwater.

Historical Water Use

Chart 6: Lux at Central Park Historical Water Use



Historical Water Use (000's gal)	
Average Annual Demand	**7,517**
Per DU	38.8
Per Sq Ft	0.025
Average Monthly Demand	**619**
Peak Demand	961
Peak Month	October, 2016

Historical water demand at the Lux illustrates how usage can change over time as new buildings gather tenants. For example, average use per DU in 2015 was only 2.7, but it increased to 3.47 in the first 10 months of 2016. Since there were no major maintenance issues reported during 2016, and irrigation use did not increase substantially from year to year, it seems likely that the Lux may not have been at 100 percent occupancy throughout all of 2015. In this case, it may be reasonable to assume that water demand going forward will be closer to 2016 levels than those observed in 2015.

Another interesting trend is the presence of discernable dips in total demand around July/August in both 2015 and 2016. One potential explanation for this pattern is that the Lux advertises itself as 'Student Apartments' and uses 12-month leases for all units. Many students arrive in Chapel Hill around this time as classes typically begin in the third week of August. The dips might therefore be caused by temporary vacancies during these months as leases expire for students that either graduated or decided to move to a new apartment. A similar explanation might apply to the dips in January of each year, as students may be out of town for the first part of the month while the University is on winter break.