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Water Use and Demand Management Options for the Multi-family Residential Sector



Topics to Cover

- Introduction to water demand analysis by sector
- Defining the multi-family sector
 - Current Florida definitions
 - Relative importance
 - Typical characteristics
- Estimation of multi-family water usage
 - Aggregate approach
 - Parcel level (end use) approach
- Demand management options

Water Demand Analysis by Sector

Typical aggregate approach:

$$Total \text{ usage}(gal / month) = 30.4 \cdot gpcd * population$$

- Key assumption: homogeneity among customers
- Improvement: determine usage separately for homogeneous groups of customers (sectors)
- What are the sectors?
 - How many sectors?
 - Which customers belong to each sector?
- How can water usage be determined for each sector?

Water Demand Analysis by Sector

$$q = 30.4 \cdot \sum_{i=1}^m (a_i \cdot x_i \cdot r_i \cdot n_i)$$

q = total water usage (gallons/month)

a = water usage rate coefficient (daily gallons per unit of size)

x = size of the activity, e.g., persons per residence

r = occupancy rate

n = number of customers in the group

i = sector i ($i=1\dots m$)

30.4 = conversion factor from gallons/day to gallons/month

Possible Sector Classifications

- Residential / Non-Residential
- Residential/ Commercial/ Industrial/ Institutional
- Single family/Multi-family/ C/I/I
- Single family/Multi-family/ C/I/I/ Distribution system losses
- Further breakdowns?
 - Single family Indoor/ Single family outdoor/ MF/C/I/I?
 - Single family homes built before 1983 having 1 bathroom?
 - Multi-Family personal home usage/ Multi-family common area usage?

Sectors vs. subgroups (subsectors)

- Sector: A homogeneous set of customers for which water usage can be determined in a unique manner
 - e.g., single family indoor: $\text{usage} = \text{gpcd} * \text{pph} * \text{number of homes} * \text{occupancy}$
 - Commercial: $\text{usage} = \text{gal/sq ft} * \text{sqft/parcel} * \text{number of parcels}$
- Subgroup: A homogeneous set of customers within a sector in which usage may vary, but can be determined in the same manner as the rest of the sector
 - e.g., pre 1983 SFR homes may have higher gpcd than post 1994 SFR homes.
 - Restaurants vs. Gas stations

How is the multi-family sector defined?

Florida Department of Revenue: 66 two digit land use codes (subgroups) are divided into strata (sectors)

U.S. Census, American Housing Survey: Different grouping schemes

Potential MFR FDOR subgroups for water demand analysis

DORUC	FDOR stratum	FDOR description
1	Single family res.	Single Family Residential
2	Single family res.	Mobile Homes
3	Multi-family res.	Multi-family – 10 units or more
4	Single family res.	Condominiums
5	Single family res.	Cooperatives
6	Multi-family res.	Retirement Homes
7	Multi-family res.	Miscellaneous Residential
8	Multi-family res.	Multi-family – less than 10 units
28	Commercial	Mobile Home Parks



Statewide attributes of selected DORUC

- Single family homes predominant group, MFR is important
- Coops, retirement homes, misc residential, mobile home parks are not important
- Condos (and coops) DORUC stratum acceptable: can be grouped with SFR for indoor usage (outdoor?)
- DORUC 3,4,8 predominant MFR groups
- DORUC 28: classify with MFR sector

DORUC	FDOR stratum	FDOR description	Total parcels (thousands)	Percent of total parcels	Total heated area (million sf.)	Percent of total heated area	Heated area (sf)/parcel	Total res. units (thousands)	Units/ parcel	Heated area (sf)/unit
1	Single family res.	Single Family Residential	4,861	68%	8,885	70%	1,828	4,449	0.92	1,997
2	Single family res.	Mobile Homes	446	6%	509	4%	1,142	440	0.99	1,156
3	Multi-family res.	Multi-family – 10 units or more	14	0%	838	7%	59,587	746	53.04	1,123
4	Single family res.	Condominiums	1,569	22%	1,920	15%	1,224	1,547	0.99	1,241
5	Single family res.	Cooperatives	41	1%	39	0%	969	35	0.87	1,118
6	Multi-family res.	Retirement Homes	1	0%	45	0%	78,944	23	40.45	1,952
7	Multi-family res.	Miscellaneous residential	27	0%	9	0%	330	5	0.20	1,636
8	Multi-family res.	Multi-family – less than 10 units	162	2%	375	3%	2,321	304	1.88	1,234
28	Commercial	Mobile home parks	15	0%	151	1%	9,757	72	4.66	2,095
		Total	7,135	100%	12,773	100%	1,790	7,622	1.07	1,676

Aggregate estimation of multi-family water usage

$$q_{mf} = 30.4 \cdot \sum_{i=1}^m (a_i \cdot x_i \cdot r_i \cdot n_i)$$

Where:

- q_{mf} = total multi-family water usage (gallons/month)
- a_i = gallons/person/day for subgroup i
- x_i = persons per residential unit for subgroup i
- r_i = occupancy rate for subgroup i
- n_i = number of residential units for subgroup i
- m = total number of multi-family subgroups
- 30.4 = conversion factor from gallons/day to gallons/month

Three main subgroups to analyze:

1. Apartments ≤ 10 units
2. Apartments > 10 units
3. Condos

Number of residential units

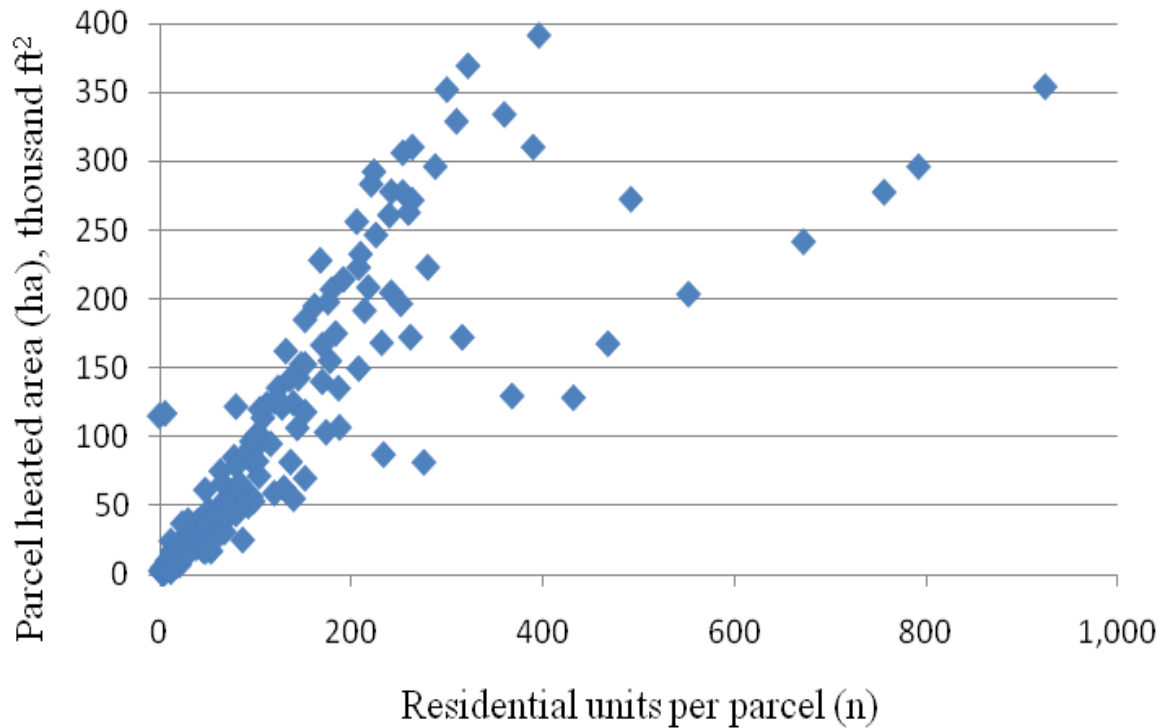
- FDOR reports number of residential units for every parcel in Florida
- Some counties report 1 residential unit for all MFR parcels, which is incorrect
- For these counties, relationship between HA/number of residential units from GRU case study can be used to estimate number of residential units
- Heated area is determined from effective area, assumed to be correct for all parcels

Apartment complexes: 1 parcel per complex

Condos: 1 parcel per condo unit

- Spatially overlapping condo parcels exist

Residential Units vs. Heated area in GRU



10 data points at extreme right of chart indicate individual subleased apartments.

Each bedroom is reported as a residential unit.

These were removed from the analysis.

$$\text{Avg. HA/unit} = (17,231,699 \text{ ft}^2) / (19,669 \text{ residential units}) = 876 \text{ ft}^2/\text{unit}$$

Occupancy Rate

- Total residential occupancy for Gainesville: 90% (Corradino Group, Inc. 2005)
- From FDOR data, 2/3 residential units are SFR. 1/3 are MFR.
- Assuming 95% occupancy in SFR, MFR occupancy must be 80%

$$(0.9=0.95*2/3 + 0.80*1/3)$$

- These estimates can be overridden with local data if available

People per Residence

- U.S. Census reports average residential persons per residence (ppr) at the block level.
- Typical census block has 50-100 residential units
- Each Census Block either:
 1. Contains SFR and no MFR
 2. Contains MFR and no SFR
 3. Contains both SFR and MFR
- For cases 1 and 2, the average ppr is known for each residential sector in the block.
- For case 3, the average ppr is not known for each residential sector in the block.

People per Residence for Hybrid Census Blocks

1. Take the weighted average persons per unit for all case 1 (SFR only) blocks ($X_{b,SFR}$), and case 2 (MFR only) blocks ($X_{b,MFR}$)
2. Determine the ratio $\frac{X_{b,SFR}}{X_{b,MFR}}$
3. Assume this ratio holds for hybrid blocks

- Apply the following formula:

$$X_b = \lambda_b X_{b,SFR} + (1 - \lambda_b) X_{b,MFR}, \quad \frac{X_{b,SFR}}{X_{b,MFR}} = \text{constant}$$

Where:

- X_b = Reported average persons per residential unit for hybrid census block b
- $X_{b,SFR}$ = Average persons per residential unit for single family residences in census block b
- $X_{b,MFR}$ = Average persons per residential unit for multi-family residences in census block b
- λ_b = The percentage of single family residential units in census block b ($0 \leq \lambda_b \leq 1$)

GRU ppr by Census block

Item	Category	Census Blocks in GRU as of			Average Persons per Residential Unit as of	Res. Units per Census Block as of
		2009	Parcels as of 2000	Residential Units as of 2000	2000	2000
Census Blocks With Either SFR or MFR	Single Family Residential	1,172	23,089	23,203	2.55	19.8
	Multi-Family Residential	175	2,711	13,497	1.94	77.1
	Total Residential	1,347	25,800	36,700	2.32	27.2
Census Blocks With Both SFR or MFR Present	Single Family Residential		17,439	17,698	2.44	
	Multi-Family Residential		6,994	29,272	2.15	
	Total Residential	472	24,433	46,970	2.26	99.5
All Census Blocks	Single Family Residential		40,528	42,769	2.39	
	Multi-Family Residential		9,705	40,901	2.18	
	Total Residential	1,819	50,233	83,670	2.29	46.0

$$\frac{X_{b,SFR}}{X_{b,MFR}} = 1.31$$

(Note: In the table, 2.55 is circled and 1.94 is also circled. Arrows point from these values to the numerator and denominator of the equation above, respectively.)

Multi-family water usage

Summary statistics of water usage for FDOR 3,4, and 8 in GRU

DORUC	3	4	8
Avg. usage (monthly gal./res. unit)	2,750	3,593	2,899
Min. month usage (monthly gal./res. unit)	2,498	3,096	2,589
Average persons per residence	1.94	2.55	1.94
Occupancy rate	0.8	0.8	0.8
Avg. usage (daily gal./person)	58.29	57.94	61.44
Min. month usage (daily gal./person)	52.95	49.92	54.87

- National average MFR indoor water usage: 60-70 gpcd.
- Based on GRU data, a value of 60 gpcd for MFR indoor is reasonable.
- Outdoor usage is minimal.

Parcel Level End Use Analysis

$$\alpha_{ij} = (b_{ij} \cdot f_{ij} \cdot x_{ij}) / d_{ij}$$

$$q = 30.4 \cdot \sum_{j=1}^4 \sum_{i=1}^m (\alpha_{ij} \cdot y_{ij})$$

Subgroups are now based on fixture efficiencies and bathrooms per unit in addition to DOR code

Usage is per fixture instead of per person

Where:

- q = single family residential indoor usage (gal/mo)
- b_{ij} = fixture efficiency type (e.g., gal./flush) in subgroup i for fixture j
- f_{ij} = frequency of use (e.g., flush/person/day) in subgroup i for fixture j
- x_{ij} = persons/residential unit in subgroup i for fixture j
- d_{ij} = number of fixtures/residential unit in subgroup i for fixture j
- α_{ij} = daily indoor usage rate (gal./fixture/day) in subgroup i for fixture j
- y_{ij} = total number of fixtures in subgroup i for a fixture j
- m = total number of subgroups for fixture j
- 30.4 = conversion factor from gal/day to gal/month

Parcel Level End Use Analysis

Fixture inventory for DORUC 3, 4, and 8 in GRU based on end use analysis

Fixture efficiency group	Toilets	Showerheads	Clothes washers	Faucets	Total
Pre 1983	11,220	11,113	0	0	22,333
1983-1994	17,785	17,637	0	0	35,422
1995-2008	48,970	48,141	19,747	108,217	225,075
Total	77,975	76,891	19,747	108,217	282,830

- In this end use example, customers were separated by DORUC (not shown) ,current fixture efficiency, and fixtures per res. unit (not shown)

Parcel Level End Use Analysis

Average water usage (monthly gal./unit) for DORUC 3, 4, and 8 in GRU based on end use analysis

DORUC	Toilets	Shower heads	Clothes washers	Faucets	Total	Billing data
3	868	644	481	717	2,709	2,750
4	885	838	1,030	942	3,695	3,593
8	1,221	654	650	717	3,242	2,899
Total	897	657	528	731	2,812	2,814

- Total water usage from indoor end use analysis very close to matching billing data
- Outdoor usage is minimal for MFR

Demand Management Options

- Two main options:
 - Fixture retrofits
 - Individual customer metering
- Outdoor options not considered due to minimal usage
- Advantage of end use analysis:
 - Allows for direct modeling and optimization of fixture retrofit options
 - Inputs are retrofit costs, type(s) of devices to consider, and utilities “benefits” of saved water
 - This procedure is in EZG 2.0

Sub-metering as a BMP

- Only about 5-10% of MFR homes are currently sub-metered
- Water usage is usually recorded for a single meter and divided among customers
- An estimated savings of 15.3% was found in a national study (Mayer et al. 2005)
 - Savings possible due to increased awareness of usage
 - Possibly results in fixing leaks, taking shorter showers, etc.
- Sub-meter savings should be prorated to an end use device to avoid double counting the impact of a retrofit program in combination with sub-metering.

Conclusions

- MFR is a predominant sector for urban water supply.
- The current FDOR definitions are adequate,
 - except classify mobile home parks as MFR
- Parcel level data can be used to accurately estimate MFR water usage at both an aggregate and end use level.
- MFR usage is fairly stable at 60 gpcd, which is mostly indoor usage.
- A parcel level analysis allows for direct analysis of retrofit options.
- Sub metering should also be considered as a demand management strategy.