

# Estimating Commercial, Industrial, and Institutional Water Use Based on Heated Building Area

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Conserve Florida Water Clearinghouse  
University of Florida  
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# Conserve Florida Water Clearinghouse

- Developing model to serve as water conservation planning tool (EZ Guide 2)
  - Estimates water use within a water budget
  - Evaluates conservation best management practices

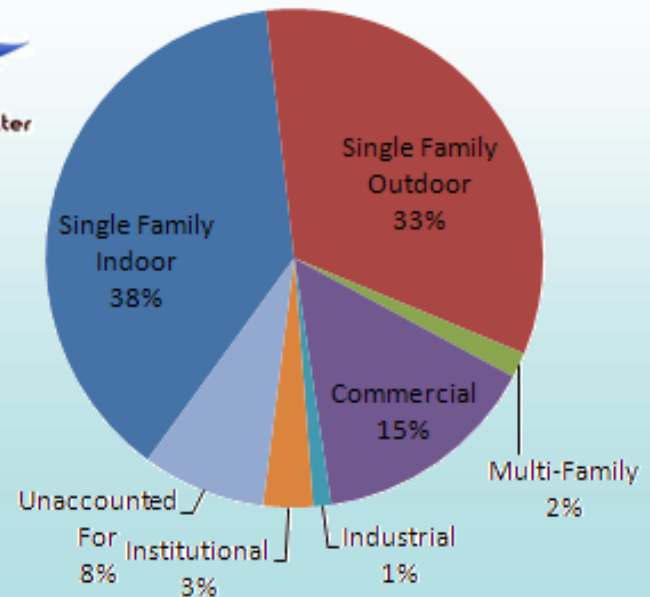
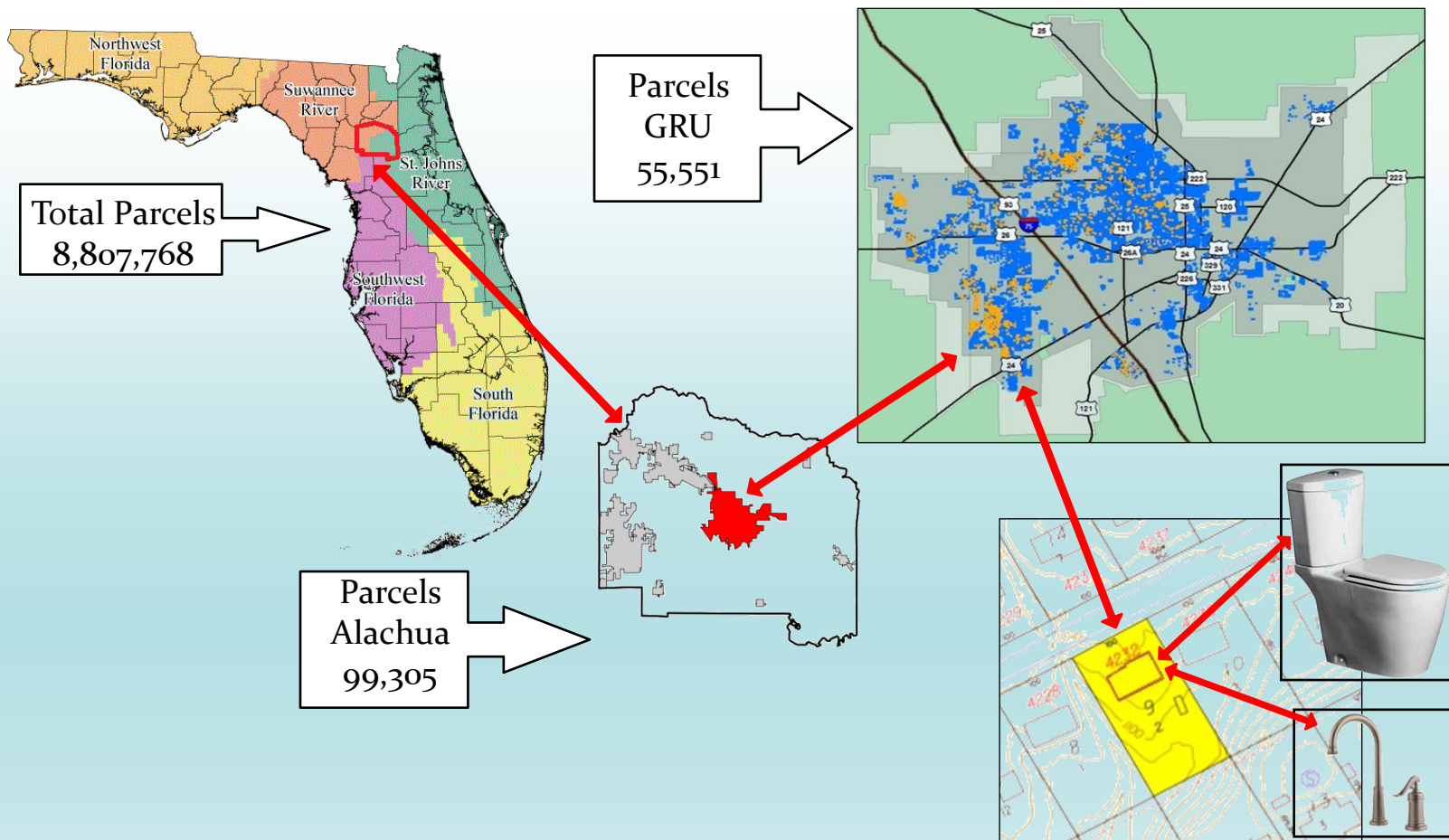


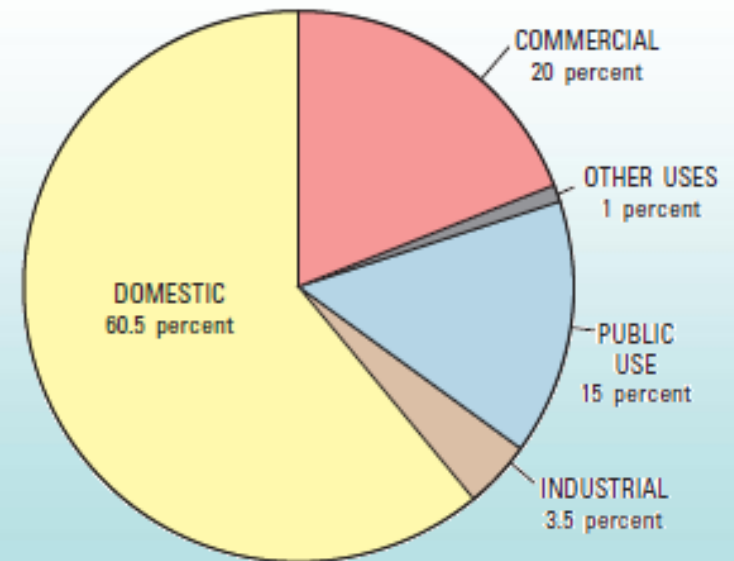
Figure 3.2.1 Calibrated Water Budget by Sector

# Macro to Nano-Scale Evaluation of Urban Water Use is Feasible in Florida



# Significance of CII Water Use

- The USGS estimates that CII water use in Florida is at least 23% of total public supplied
  - 29% nationwide
- Dziegielewski et al. (2000) estimate CII to be 15 to 25% of public water supplied
- **Conclusion: CII water use is significant!**



# Estimating Water Use

- Water use is the product of rate of water use multiplied by a measure of its size

$$Q_{Total} = \sum_{k=1}^n (\alpha_k \times x_k)$$

Where:  $Q_{Total}$  = water use for n sectors

$\alpha_k$  = water use coefficient of sector k

$x_k$  = size of sector k

n = number of sectors

- For projecting water use of future customers, utilities often rely on:
  - similar customers within their service area
  - water use coefficients developed through studies in other locales

# Popular CII Water Use Coefficients

- Number of employees is a popular measure of size given its historical availability:
  - used by IWR-MAIN and Maddaus' DSS Model
  - These coefficients are outdated, and IWR-MAIN is no longer supported
- Other measures of size depend on the type of facility
  - Databases for these measures of size are lacking

CI category	Unit	Gallons/unit/day
Barber shops	Chairs	54.60
Beauty shops	Station	269.00
Bus/rail depots	Square foot	3.33
Car washes	Inside square foot	4.78
Churches	Member	0.14
Golf/swim clubs	Member	22.20
Bowling alleys	Alley	133.00
Residential colleges	Student	106.00
Hospitals	Bed	346.00
Retail space	Sale square foot	0.11
Elementary schools	Student	3.83
High schools	Student	8.02
YMCA/YWCA	Person	33.30
Service stations	Inside square foot	0.25
Theaters	Seat	3.33

Source: Crews, James E. and Mary Ann Miller. 1983. Forecasting Municipal and Industrial Water Use. IWR Research Report 83R-3. U.S. Army Corps of Engineers, Fort Belvoir, Virginia.

# Employment Data

- Available from:
  - U.S. Census
    - Pros: available throughout the United States
    - Cons: Limited by spatial and customer classification aggregation required to ensure anonymity (Traffic Analysis Zone (TAZ), 2-digit NAICS employment size classes)
  - Private Surveys
    - Pros: Produce customer-level data
    - Cons: Expensive to conduct and only provide a “snapshot” in time

# Why Employment Data?

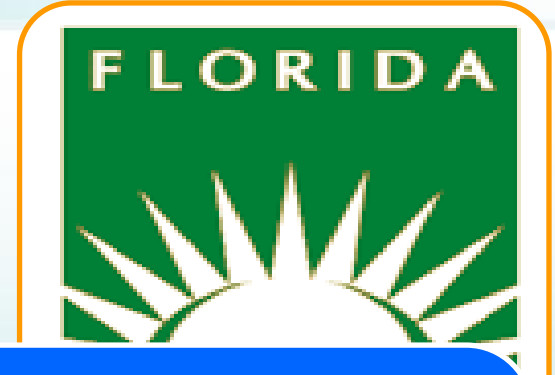
- Other measures of size, such as building area, have been shown to be better predictors of water use across the CII subsectors (Dziegielewski et al. 2000)
- **Reasoning:** Employee data has historically been more available compared to other parameters such as acreage (Mercer and Morgan 1974)

Source	Available	Smallest geographical unit
U.S. Economic Census	Every 5 years	City
County Business Patterns	Annually	Zip code
Longitudinal Employer-Household Dynamics	Quarterly	TAZ
Commercial surveys	Varies	Customer

# Improved Water Use Coefficients

- Measures of size need to be:
  - Good predictor of water use
  - Consistently defined across CII subsectors and available at a finer spatial resolution
- Same measure of size for all CII subsectors allows for:
  - Comparisons of water use across subsectors
  - More readily available databases
- Physical and economic property data available for every parcel in the state of Florida through:
  - Florida Department of Revenue (FDOR) and
  - Florida County Property Appraisers (FCPA)

# FDOR and FCPA Databases



## FCPA

- Parcel and building fields vary between counties
- Obtained individually from county
- Partitions parcels into 100 FDOR land use categories
- Provides building 'heated area'

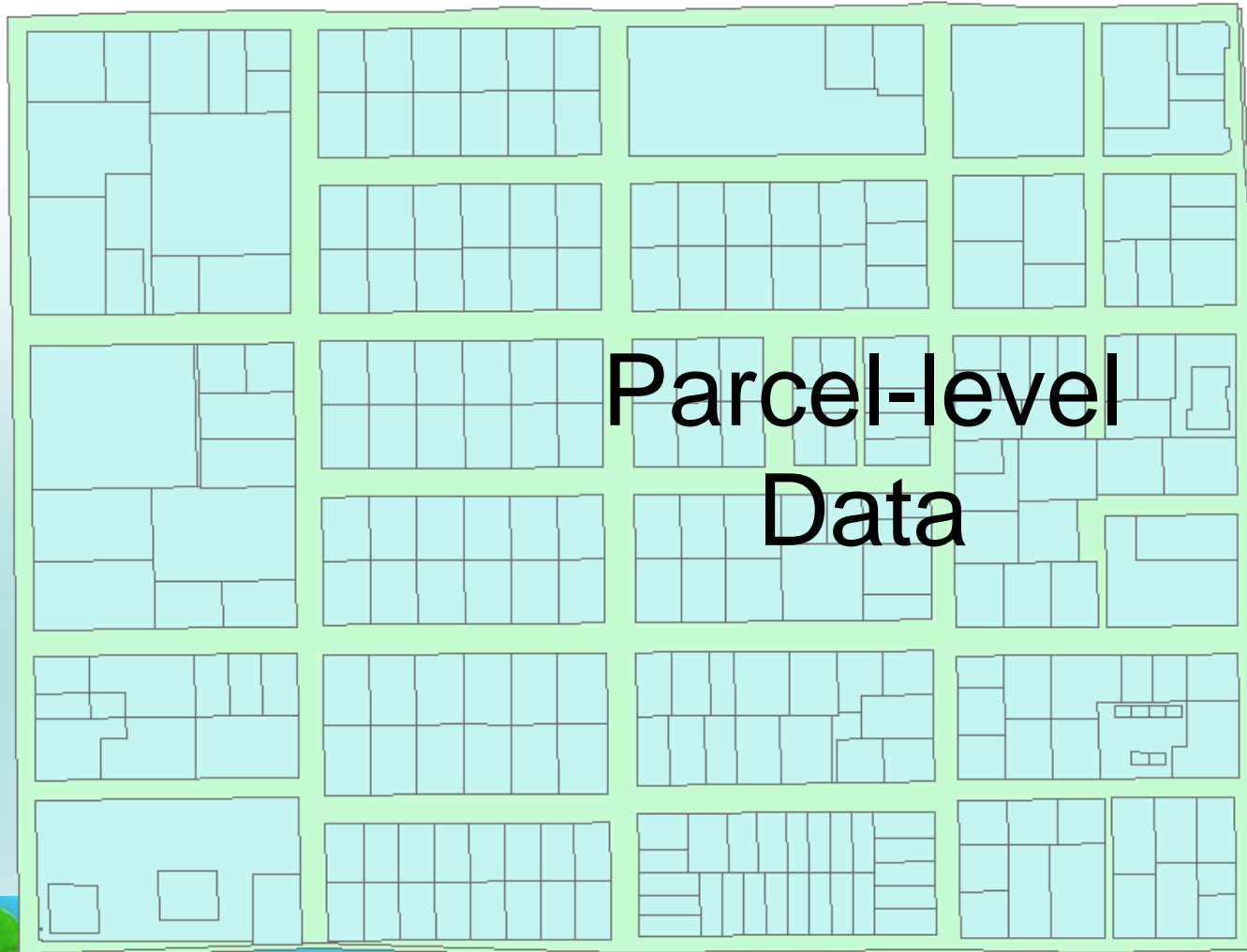
## FDOR

- Standard data fields
- Free and easily accessible
- Partitions parcels into 100 land use categories
- Spatial location and dimensions of every parcel in the state
- Provides building 'effective area'

# Levels of Spatial Aggregation in Florida

Unit	Value	Population/Unit
Population	18,800,000	1
Parcels	8,800,000	2.14
Census Blocks	362,499	51.9
Traffic Analysis Zones (TAZs)	12,747	1,475
Utilities	2,623	7,167
Counties	67	280,597

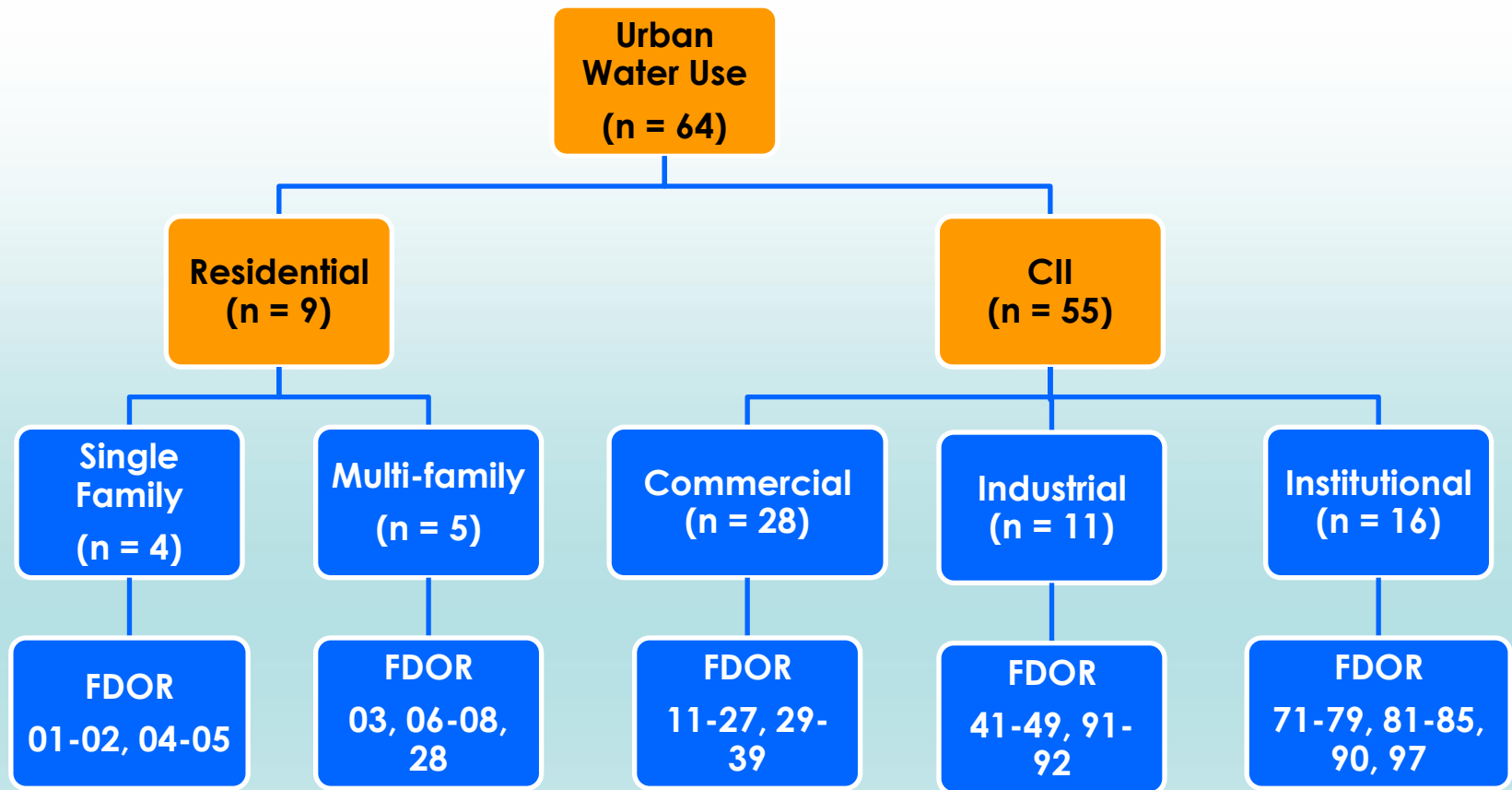
# Parcel-level Data: Finer Spatial Resolution than TAZ or Census Blocks



Parcel-level  
Data



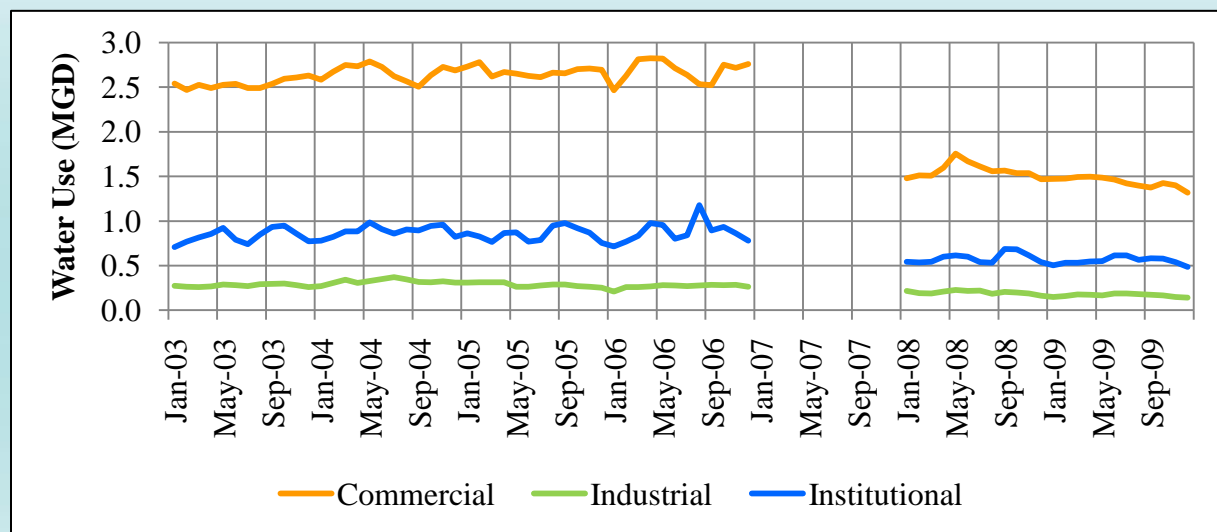
# Standardized State Classification of Customers into 64 Subsectors



# Utility Benchmark CII Water Billing and Property Attribute Data

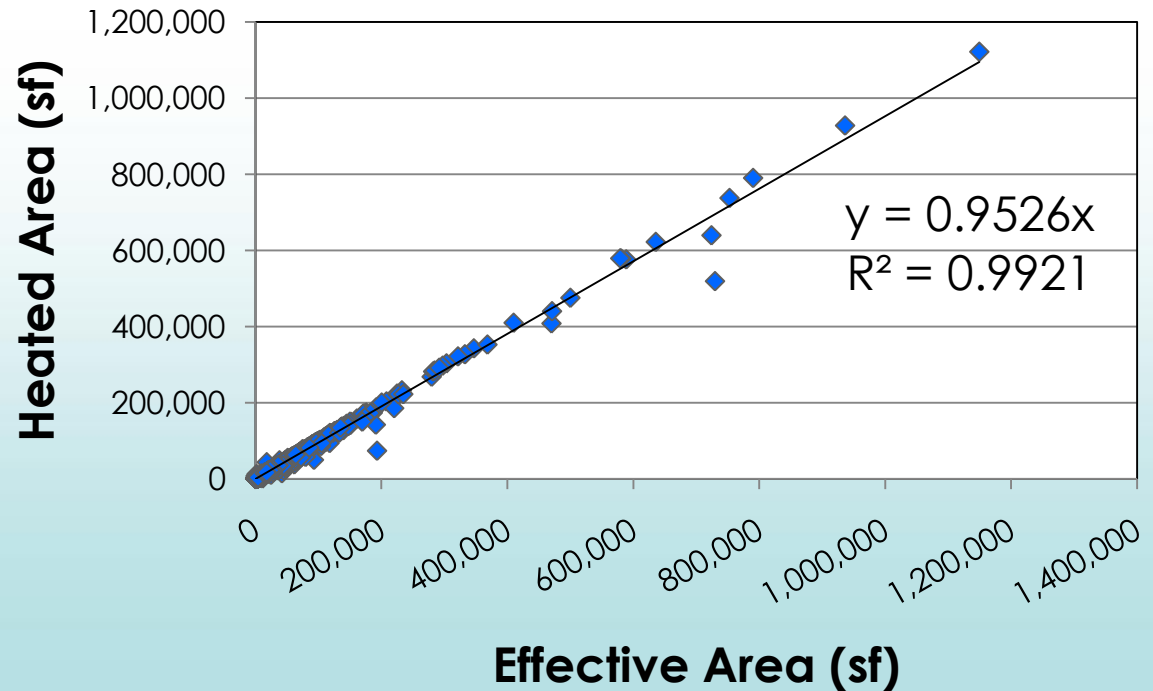
- Utility benchmark water use and heated area data supplied by Hillsborough County Water Resources Services (HCWRS 2003-06), and Gainesville Regional Utilities (GRU 2008-09)
- Corresponding FCPA CII data obtained
- Total benchmark of 3,172 CII parcels out of a total of 432,000 CII parcels in state of Florida

	HCWRS	GRU
Years of billing	2003-07	2008-09
CII parcels	1,770	1,402
Commercial	67%	72%
Industrial	9%	10%
Institutional	24%	18%



# Relationship of Effective Area to Heated Area for 3,172 Benchmark CII Parcels

- FDOR database more readily available than FCPA, but only presents effective area (EA)



- Strong relationship between EA and heated area (HA) for all 3,172 CII parcels allows for reliable conversion between these two measures of size

# Relationship of Heated Area to Water Use

- Strong correlation between heated area and water use for 3,172 CII parcels in HCWRS and GRU:

Correlation Coefficient, r	Heated area (sf)	Effective area (sf)	Parcel area (acres)	Effective year built	Average monthly water use (gal)
Heated area (sf)	1.000				
Effective area (sf)	0.996	1.000			
Parcel area (acres)	0.347	0.356	1.000		
Effective year built	0.028	0.030	0.003	1.000	
Average monthly water use (gal)	0.631	0.639	0.096	0.021	1.000

- Step information of stepwise regression:

	Multiple R	R <sup>2</sup>	Adjusted R <sup>2</sup>	Std. error of estimate
Heated area (sf)	0.6275	0.3938	0.3938	3802
Effective year built	0.6297	0.3966	0.3964	3794
Parcel area (acres)	0.6439	0.4146	0.4142	3738

Indicates little predictive power is gained by addition of other variables

# Developing Water Use Coefficients Based on Heated Area

- The FDOR and FCPA databases linked with customer billing data for 3,172 CII establishments to develop water use coefficients
- Coefficient: water use/heated sq. feet
  - Two coefficients presented: average and May peak
  - May is the peak month use for most water utilities in Florida
- Coefficients based on:
  - Utility monthly water use data
  - Customer classification via FDOR land use code
  - Heated area from FCPA

# Utility Can Compare Their CII Water Use to Statewide Average for FL

		Utility Benchmarks					Statewide Application				
FDOR Code	Description	Sample Size	HA EA	q <sub>j</sub> ( average	q <sub>p</sub> (peak	Peak Avg. Ratio	State Parcel Count	State Total		% CII Heated Area in State	% of CII Water Use in State
				gallons/ heated ft <sup>2</sup> /day)	gallons/ heated ft <sup>2</sup> /day)			Heated Area (acres)	State Total Water Use (MGD)		
11	Stores, One-Story	289	0.926	0.0976	0.1038	1.06	41,049	6,398	27.21	6.23%	5.85%
16	Community Shopping Centers	239	0.952	0.0987	0.1007	1.02	8,164	6,818	29.33	6.64%	6.30%
17	Office, One-Story	384	0.963	0.1290	0.1378	1.07	39,400	4,145	23.29	4.04%	5.01%
18	Office, Multi-Story	73	0.969	0.0692	0.0767	1.11	16,311	7,503	22.63	7.31%	4.86%
19	Medical Office	264	0.971	0.1580	0.1682	1.07	21,976	2,773	19.08	2.70%	4.10%
21	Restaurant	120	0.962	0.7411	0.7574	1.02	8,091	803	25.93	0.78%	5.57%
22	Fast-Food Restaurants	105	0.965	0.6574	0.6803	1.03	4,521	323	9.26	0.31%	1.99%
23	Financial Institutions	98	0.897	0.3732	0.3970	1.06	4,994	781	12.70	0.76%	2.73%
27	Auto Sales / Repair	174	0.866	0.1238	0.1265	1.02	15,807	2,412	13.01	2.35%	2.80%
39	Hotels / Motels	50	0.944	0.2313	0.2451	1.06	22,633	5,803	58.46	5.65%	12.56%
	Other Commercial	418	0.927	0.1012	0.1035	1.02	47,935	10,251	55	9.98%	11.90%
	<b>Total Commercial</b>	<b>2,214</b>	<b>0.941</b>	<b>0.1332</b>	<b>0.1385</b>	<b>1.04</b>	<b>230,881</b>	<b>48,009</b>	<b>296.26</b>	<b>46.75%</b>	<b>63.67%</b>
41	Light Manufacturing	33	0.900	0.0550	0.0567	1.03	19,109	6,227	14.91	6.06%	3.21%
48	Warehousing / Distribution	228	0.947	0.0345	0.0372	1.08	44,419	18,464	27.75	17.98%	5.96%
49	Open Storage	19	0.971	0.1520	0.1693	1.11	12,589	2,852	18.88	2.78%	4.06%
	Other Industrial	27	0.946	0.1196	0.1150	0.96	17,147	3,309	17.24	3.22%	3.71%
	<b>Total Industrial</b>	<b>307</b>	<b>0.942</b>	<b>0.0502</b>	<b>0.0518</b>	<b>1.03</b>	<b>93,264</b>	<b>30,851</b>	<b>78.79</b>	<b>30.04%</b>	<b>16.93%</b>
71	Churches	337	0.946	0.0492	0.0549	1.12	23,275	4,538	9.73	4.42%	2.09%
74	Homes for the Aged	12	0.922	0.1007	0.1082	1.07	4,898	3,251	14.26	3.17%	3.06%
83	Public County Schools	52	0.980	0.0684	0.0743	1.09	5,685	7,962	23.71	7.75%	5.10%
	Other Institutional	283	0.966	0.1054	0.1069	1.01	73,995	8,075	42.54	7.86%	9.14%
	<b>Total Institutional</b>	<b>684</b>	<b>0.963</b>	<b>0.0782</b>	<b>0.0828</b>	<b>1.06</b>	<b>107,853</b>	<b>23,826</b>	<b>90.24</b>	<b>23.20%</b>	<b>19.39%</b>
	<b>Total CII</b>	<b>3,205</b>	<b>0.948</b>	<b>0.1025</b>	<b>0.1070</b>	<b>1.04</b>	<b>431,998</b>	<b>102,686</b>	<b>465.29</b>	<b>100.00%</b>	<b>100.00%</b>

# Weighted Average Coefficient Aggregation of CII Sectors

Sector	HA/EA	Weighted Average Water Use Coef. (gal/hsf /mo)	Number of Parcels	Total Effective Area (sf)	Avg. Heated Area (sf)	Total Heated Area (sf)	% of Total Heated Area in Sector	Avg. Monthly Water Use (gal)	Total Monthly Water Use (MG)	% of Total Water Use in Sector
Commercial	0.95	4.39	884	8,552,417	9,210	8,141,215	43.1%	40,441	35.75	54.7%
Industrial	0.86	0.93	398	7,867,627	16,909	6,729,889	35.7%	15,801	6.29	9.6%
Institutional	0.93	5.83	268	4,288,555	14,940	4,003,940	21.2%	87,048	23.33	35.7%
<b>TOTAL CII</b>	<b>0.91</b>	<b>3.46</b>	<b>1,550</b>	<b>20,708,599</b>	<b>12,177</b>	<b>18,875,044</b>	<b>100.0%</b>	<b>42,173</b>	<b>65.37</b>	<b>100.0%</b>

Commercial Sub-sectors	HA/EA	Weighted Average Water Use Coef. (gal/hsf /mo)	Number of Parcels	Total Effective Area (sf)	Avg. Heated Area (sf)	Total Heated Area (sf)
Stores, One-Story	0.95	2.18	235	1,047,601	4,251	998,933
Mixed Use	0.92	2.78	46	72,378	1,447	66,559
Department Stores	0.97	1.78	14	1,808,360	124,791	1,747,080
Supermarkets / Convenience Stores	0.95	7.92	2	45,650	21,655	43,311
Fast-Food Restaurants	0.96	20.95	23	59,711	2,496	57,405
Financial Institutions	0.87	7.64	18	77,445	3,759	67,664
Auto Sales / Repair	0.88	3.84	95	863,638	8,007	760,670
<b>TOTAL COMMERCIAL</b>	<b>0.95</b>	<b>4.39</b>	<b>884</b>	<b>8,552,417</b>	<b>9,210</b>	<b>8,141,215</b>

- A weighted average of the coefficients is carried out based on the total area of the two-digit FDOR subsectors
- Coefficients are directly dependent on the land use mix within a given service area boundary

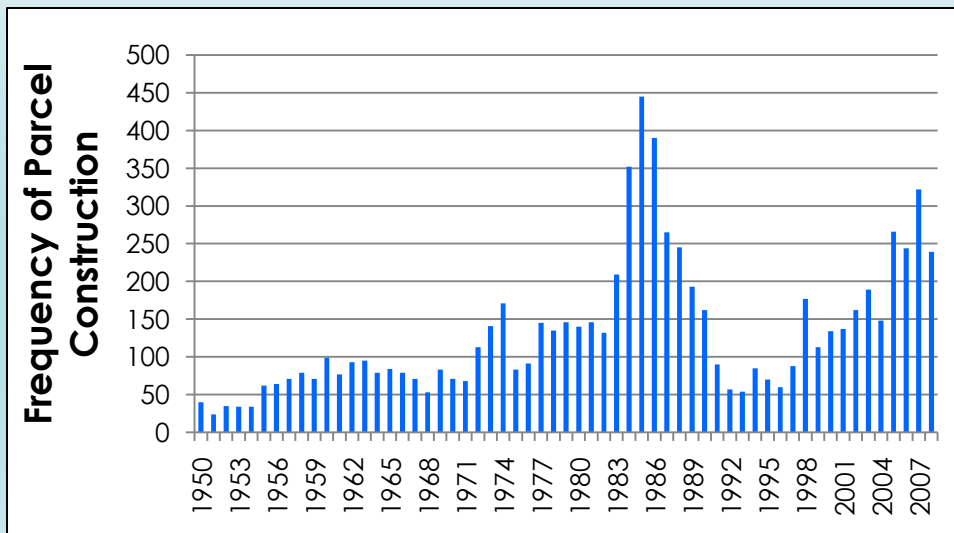
# Projecting Water Use

- FDOR includes year built for each parcel in the state
- Allows for time series projections based on:
  - Number of accounts
  - Measures of size (average building heated area)
  - Water use
- Great improvement over past projecting methods
  - Offers subsector projections
  - Based on all constructed parcels
  - Able to link with population projections

# Projection Example (FDOR 16)

FDOR 016 - Community Shopping Centers				
Age Group	Sample Size	Average Effective Year Built	Average Heated Area (ft <sup>2</sup> )	Weighted Average Water Use Coef. (gal/heated ft <sup>2</sup> /d)
Pre-1983	56	1975	27,289	0.068
1983-1994	115	1988	39,183	0.101
Post-1994	63	1999	47,372	0.108
<b>Total</b>	<b>234</b>	<b>1988</b>	<b>38,541</b>	<b>0.097</b>

- Time series trends for community shopping centers (FDOR 16):
  - Average heated area is increasing
  - Water use per ft<sup>2</sup> of heated area is increasing
  - At the State level, approximately 250 parcels are built each year



# Estimating End Uses

- A true benefit-cost analysis of water conservation best management practices (BMPs) requires:
  - End use inventory of water using devices
    - Based on FL plumbing and building codes
  - Their water use efficiency
    - Based on fixture service life and FL plumbing code
    - Divided into three efficiency age groups (Pre-1983, 1983-1994, and 1995-present )
  - Their frequency of use
    - Based on 'functional population' and the literature

# Estimating Restroom Fixture Water Use

Functional population

Frequency of fixture use

Fixture efficiency

Fixture count

$$\left( \frac{\text{functional population}}{\text{ft}^2} \right) \left( \frac{\text{uses}}{\text{person} * \text{day}} \right) \left( \frac{\text{gallons}}{\text{use}} \right) \left( \frac{\text{ft}^2}{\text{fixtures}} \right) = \frac{\text{gallons}}{\text{fixture} * \text{day}}$$

From FL-specific impact fee studies

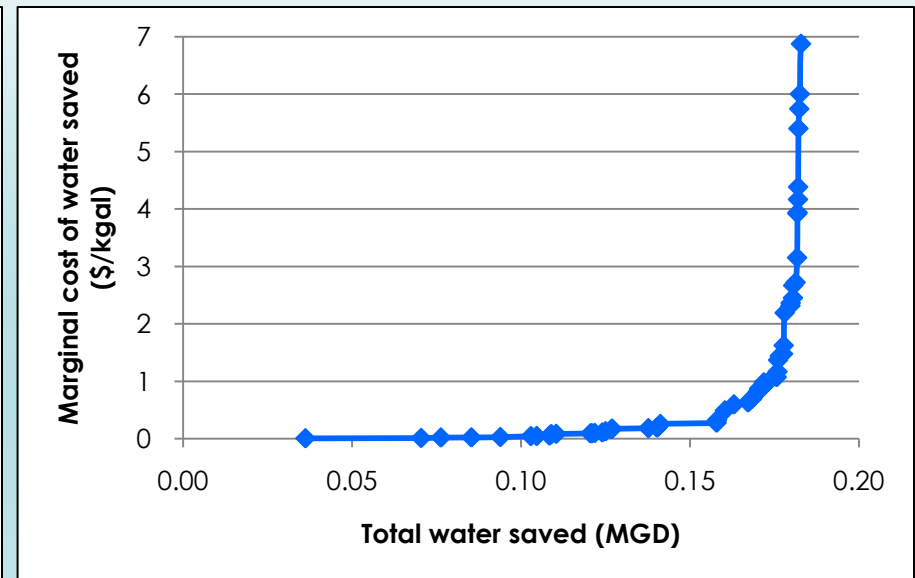
From national studies on residential frequency of use

From FL plumbing and building codes



# Optimization and the Evaluation of CII BMPs

- By knowing cost and water use efficiency of retrofits, BMP performance and marginal cost functions can be produced
- Example: Utility in South Florida doing CII toilet retrofits (0.8 gpf at \$300/retrofit)



# Conclusions

- The availability of the FDOR database and customer water billing data provides a major improvement in our ability to estimate and project CII water use
- The Conserve Florida Water Clearinghouse has developed these water use coefficients and heated area statistics available at [www.conservefloridawater.org](http://www.conservefloridawater.org)
- Methodology allows for:
  - Water budget
  - Projection of water use
  - End-use analysis and BMP optimization
- Heated area as a measure of size allows for application to other property appraiser databases outside the state of Florida

## More Information

- Morales, M., Heaney, J., Friedman, K., Martin, J. 2011. Estimating Commercial, Industrial, and Institutional Water Use Based on Heated Building Area. *Journal of American Water Works Association*, accepted for publication.
- Friedman, K., Heaney, J., Morales, M., Palenchar, J. 2011. Water Demand Management Optimization Methodology. *Journal of American Water Works Association*, accepted for publication.

# Optimization and Evaluation of CII BMPs

- Parcel-level estimates on the number of end use devices, their water use efficiency, and frequency of use:
  - Allows for the calculation of water saved through retrofits
    - Only changing variable is water use efficiency
    - Number of devices and frequency of use remains the same
- Knowing water saved in retrofit, along with cost of retrofit allows for the calculation of the marginal cost of water saved
  - A measure of the cost-effectiveness of water conservation BMPs
  - For any given device, the least efficient fixtures with higher usage rates are the most cost-effective to retrofit
  - BMPs can be ranked in order of cost-effectiveness to optimize targeting of customers for water conservation