

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

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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

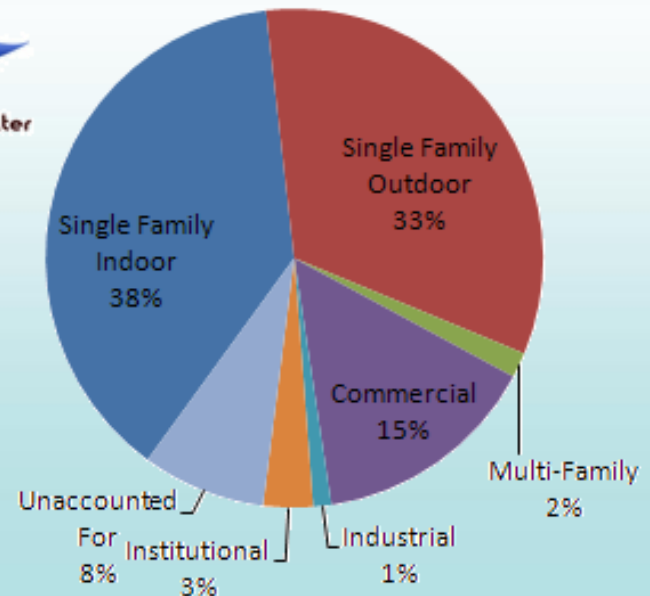
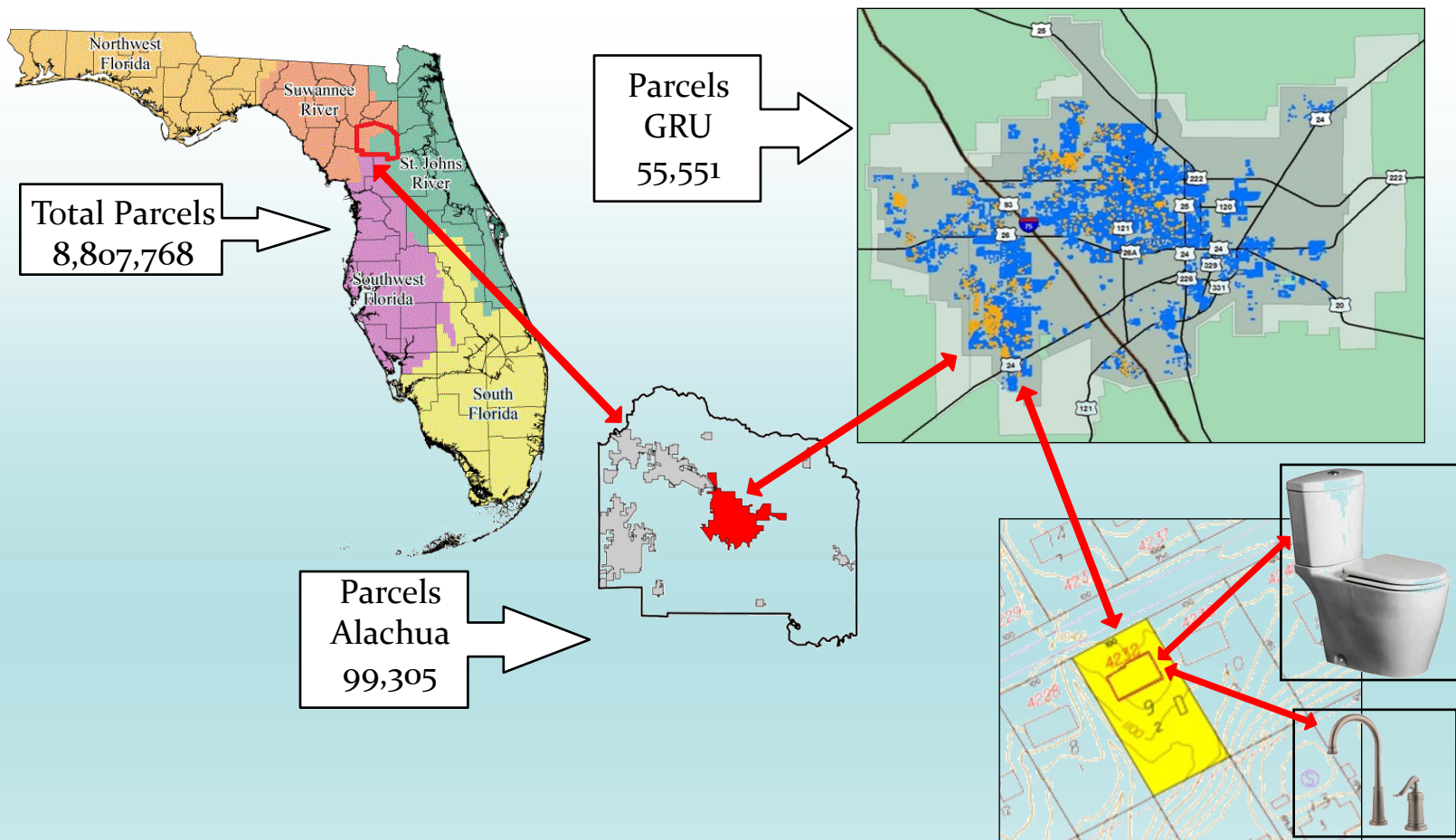


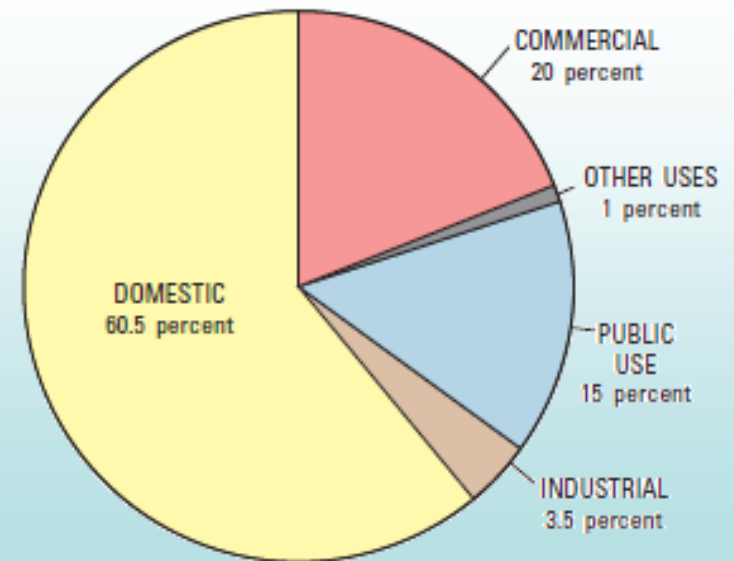
Figure 3.2.1 Calibrated Water Budget by Sector

# 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  - These coefficients are outdated, and IWR-MAIN is no longer supported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)

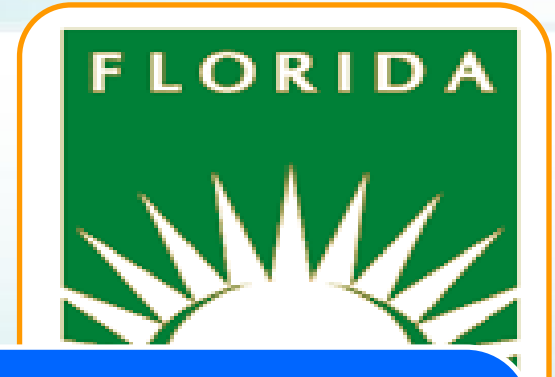
| Source                                   | Available     | Smallest geographical unit |
|--|---------------|----------------------------|
| U.S. Economic Census                     | Every 5 years | City                       |
| County Business Patterns                 | Annually      | Zip code                   |
| 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'

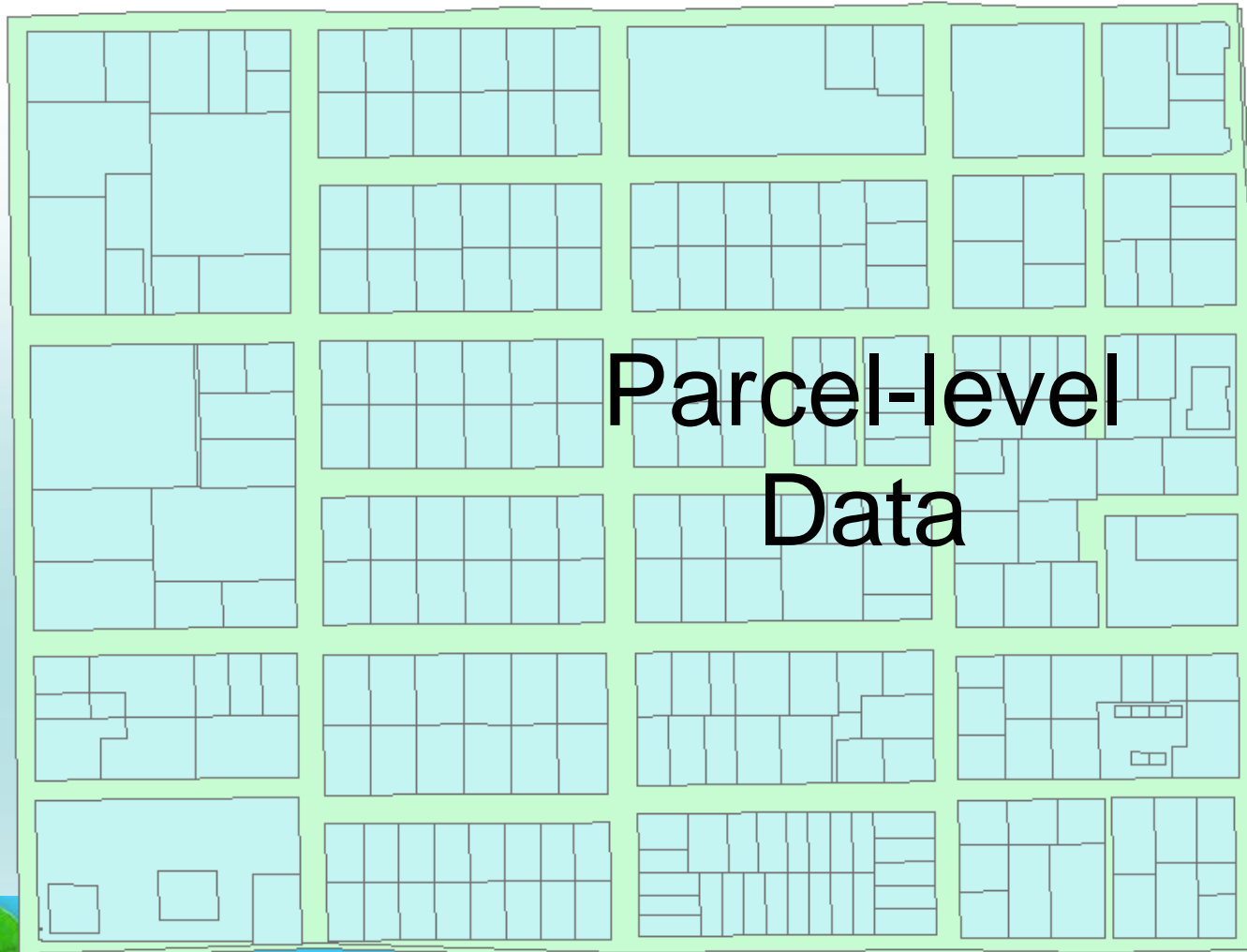
## FDOR

- 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         |

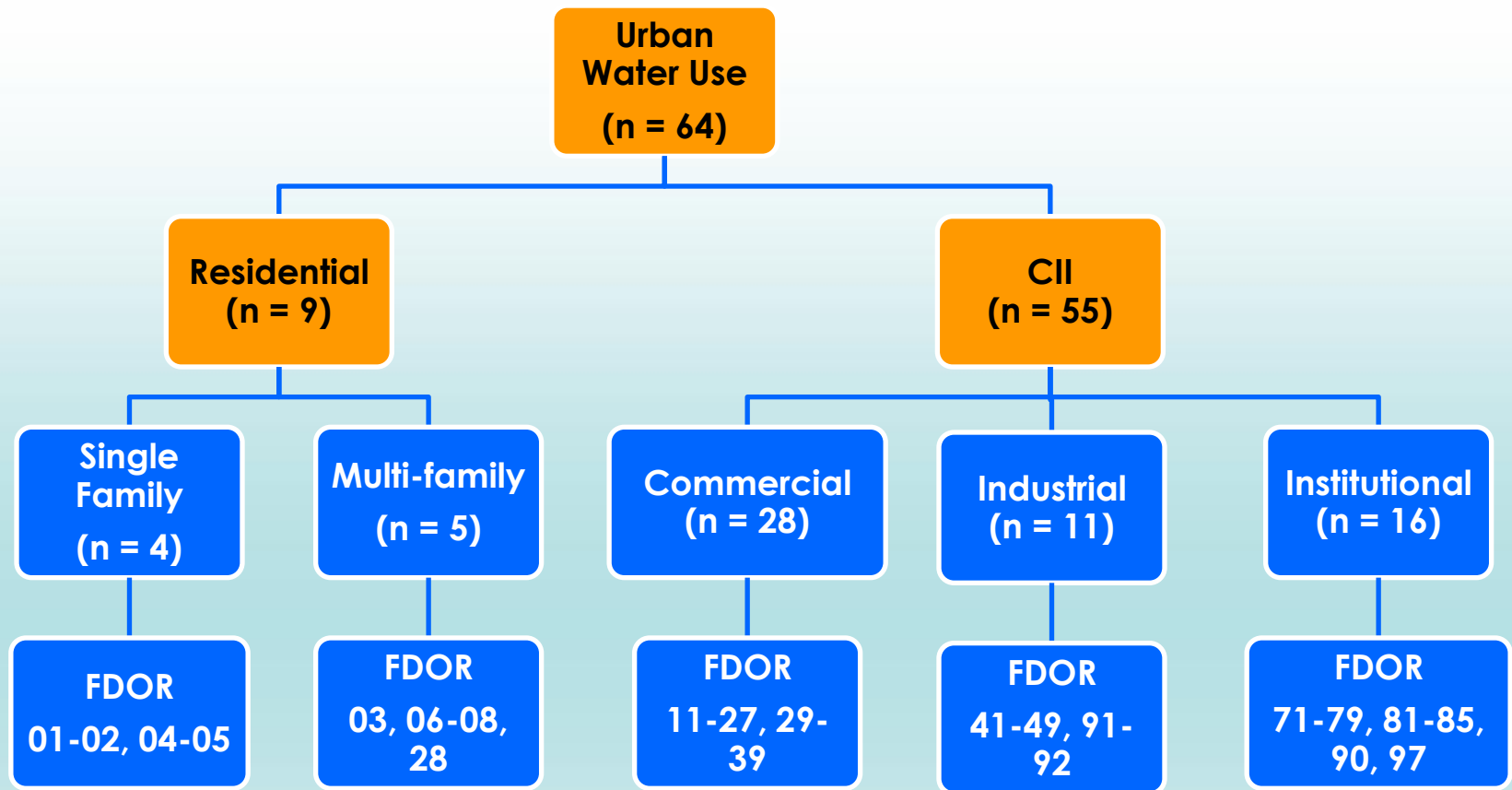
# Parcel-level Data: Finer Spatial Resolution than TAZ or Census Blocks



Parcel-level  
Data



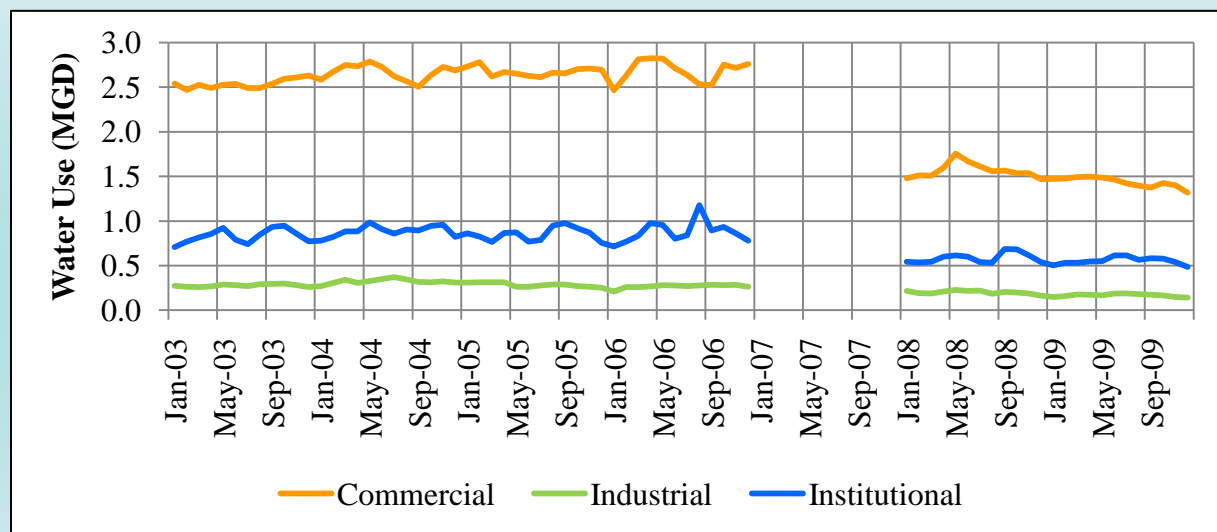
# Standardized State Classification of Customers into 64 Subsectors



# 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

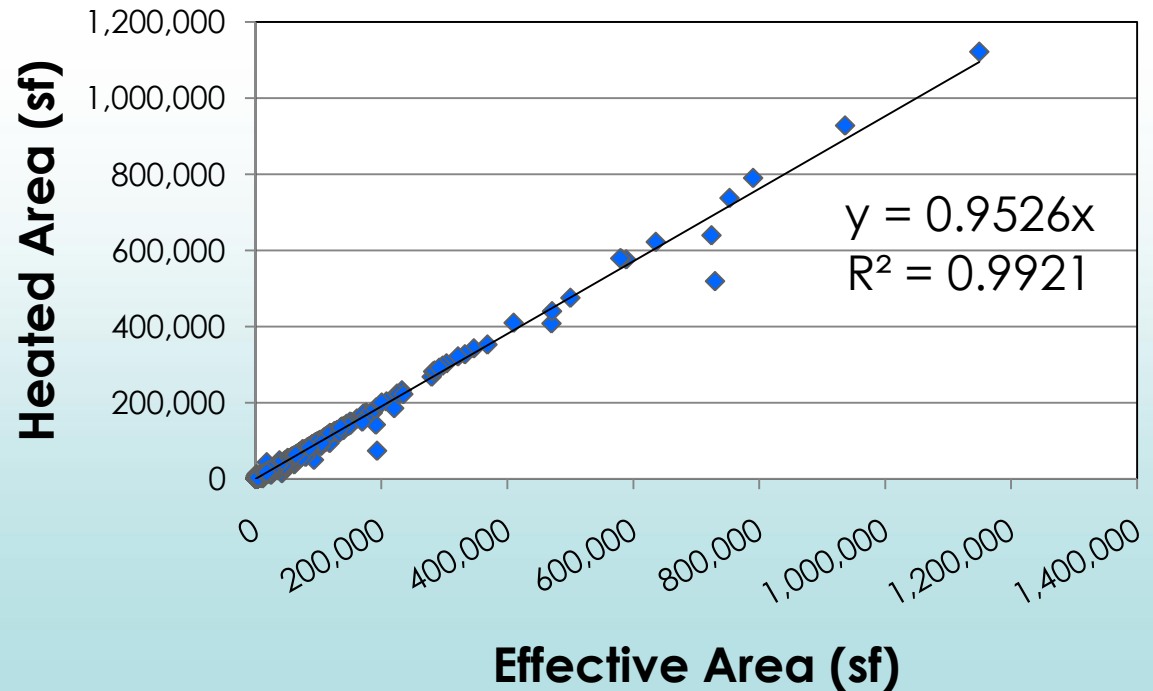
|                  | HCWRS   | GRU     |
|------------------|---------|---------|
| Years of billing | 2003-07 | 2008-09 |
| CII parcels      | 1,770   | 1,402   |
| Commercial       | 67%     | 72%     |
| Industrial       | 9%      | 10%     |
| Institutional    | 24%     | 18%     |





# 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<br>Code | Description                   | Sample<br>Size     | HA<br>EA     | q <sub>j</sub> ( average                    | q <sub>p</sub> (peak                        | Peak<br>Avg.<br>Ratio | State<br>Parcel<br>Count | State Total               |                                   | % CII<br>Heated<br>Area in<br>State | % of CII<br>Water<br>Use in<br>State |
|              |                               |                    |              | gallons/<br>heated<br>ft <sup>2</sup> /day) | gallons/<br>heated<br>ft <sup>2</sup> /day) |                       |                          | Heated<br>Area<br>(acres) | State Total<br>Water Use<br>(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<br>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 /<br>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<br>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

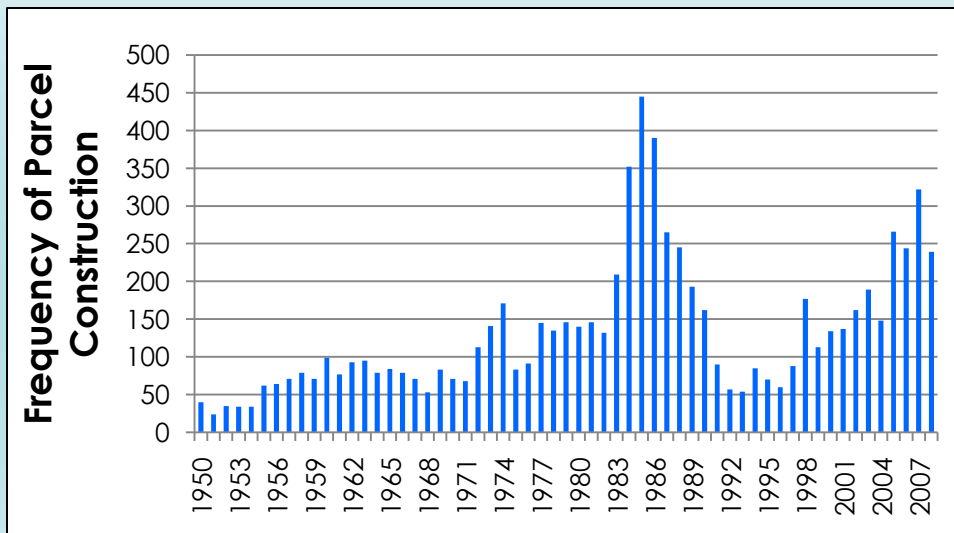
- FDOR includes year built for each parcel in the state
- Allows for time series projections based on:
  - Number of accounts
  - Measures of size (average building heated area)
  - Water use
- Great improvement over past projecting methods
  - Offers subsector projections
  - Based on all constructed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

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

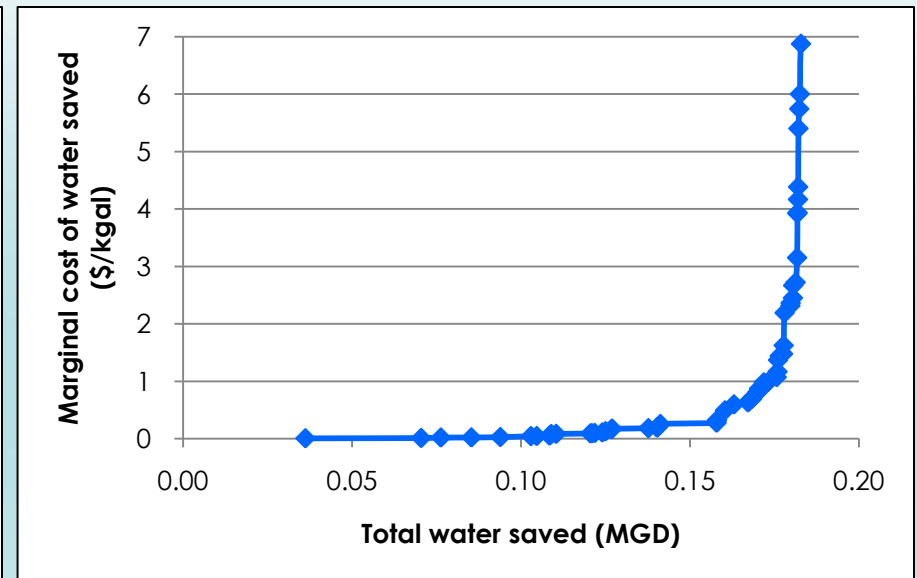
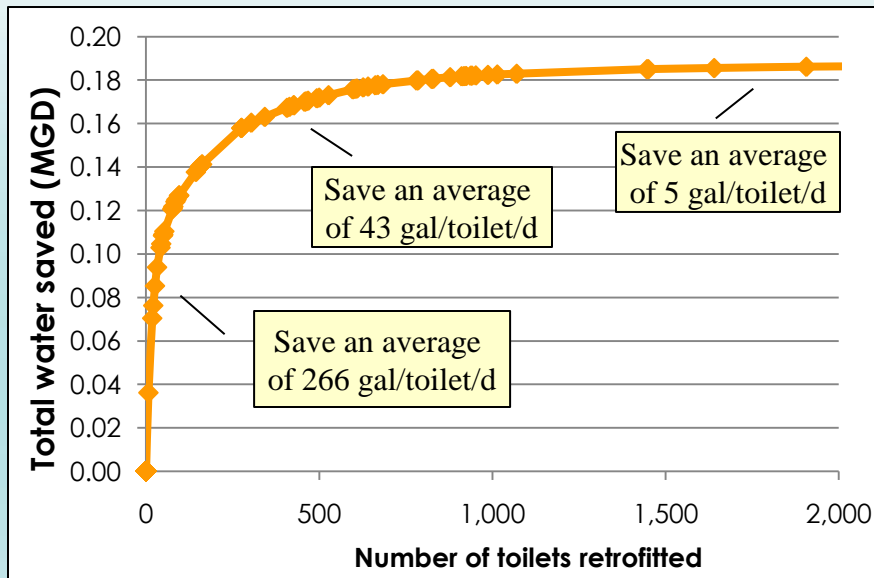
From FL-specific impact fee studies

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