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Optimal Outdoor Urban Irrigation Conservation Methodology

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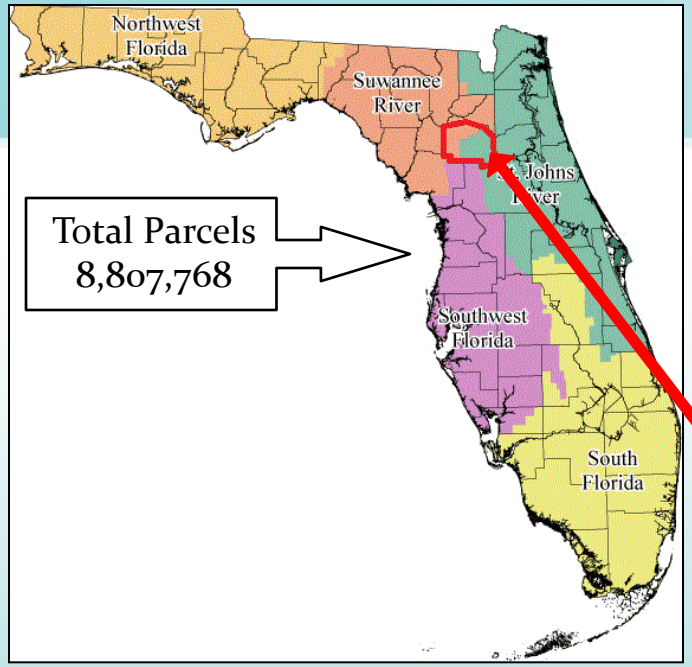
UF | Environmental Engineering Sciences

Conserve Florida Water Clearinghouse

Topics to Cover

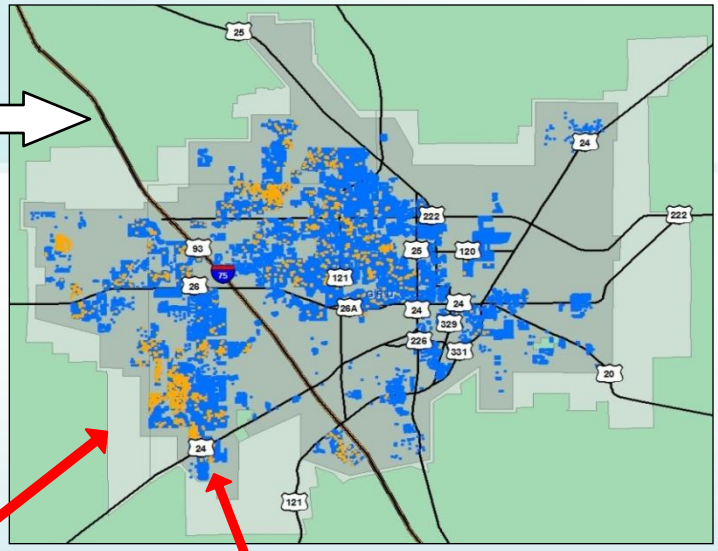
- Urban water systems parcel level database
- Parcel level irrigation demand analysis
  - Determination of irrigators from potable system
  - Irrigable area distribution and trends
  - Application rate distribution and trends
- Predicted savings from outdoor conservation BMPs
  - Soil moisture sensors, irrigation audits, reuse
- Optimal outdoor BMP strategy
  - Nonlinear programming approach
- Incorporation into EZ Guide
  - Florida water conservation and planning online tool

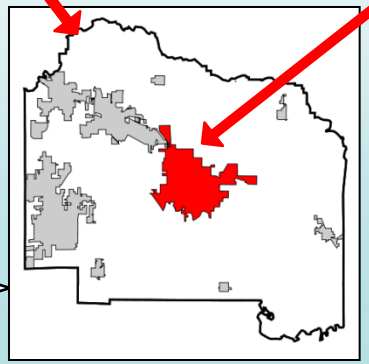
Urban Water Systems Parcel Level Database



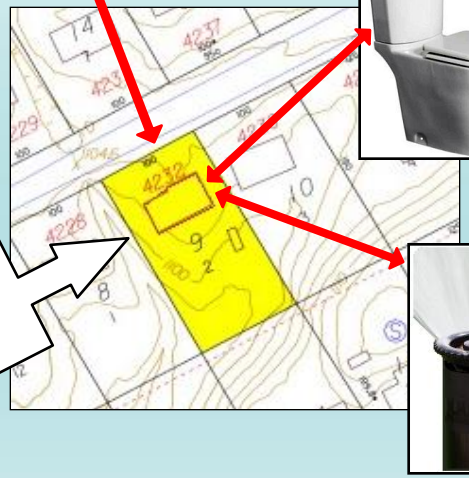
Total Parcels
8,807,768

Total Parcels GRU
55,551





Parcels Alachua
99,305



SFR parcels GRU
30,910

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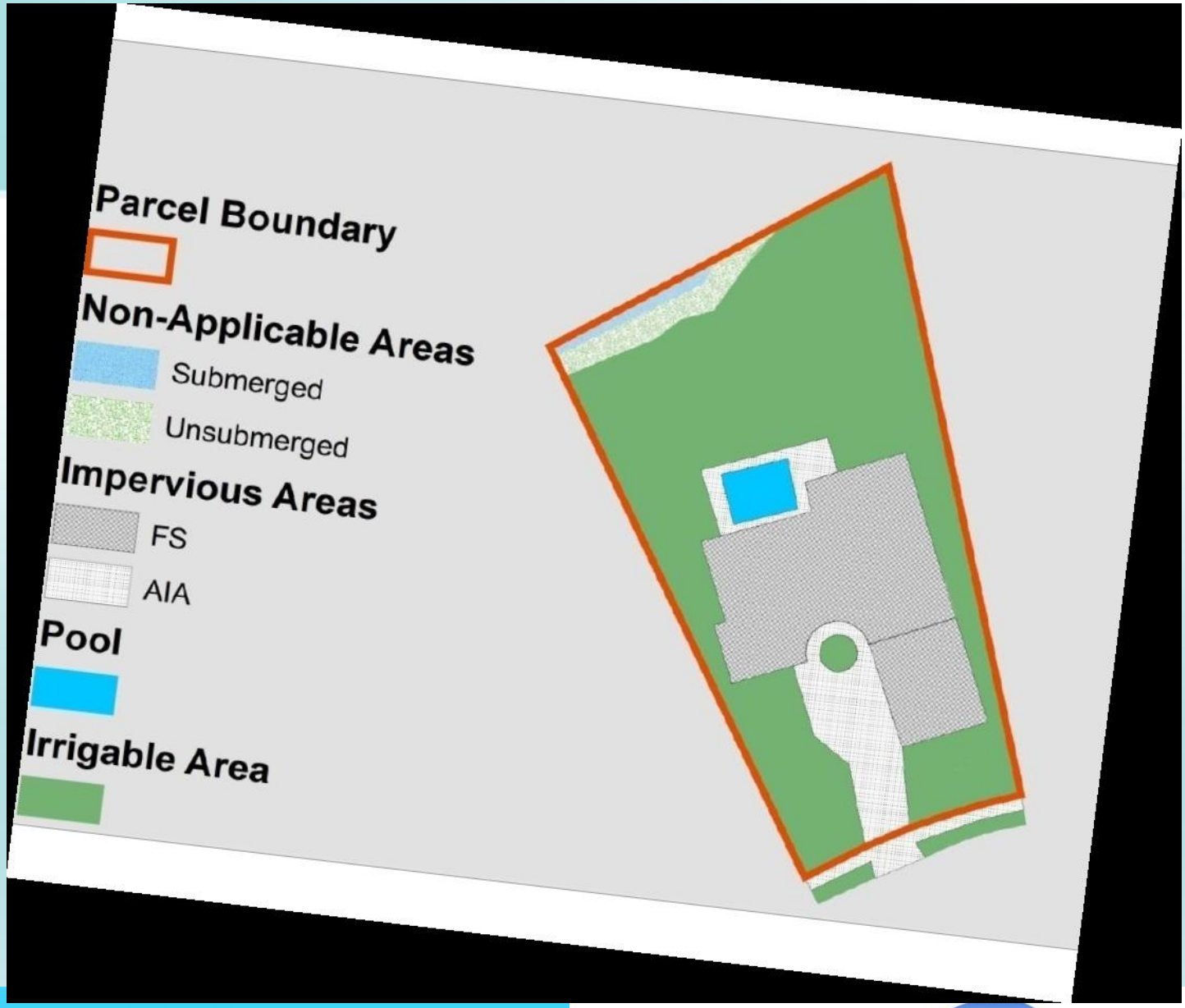
Irrigable area mass balance

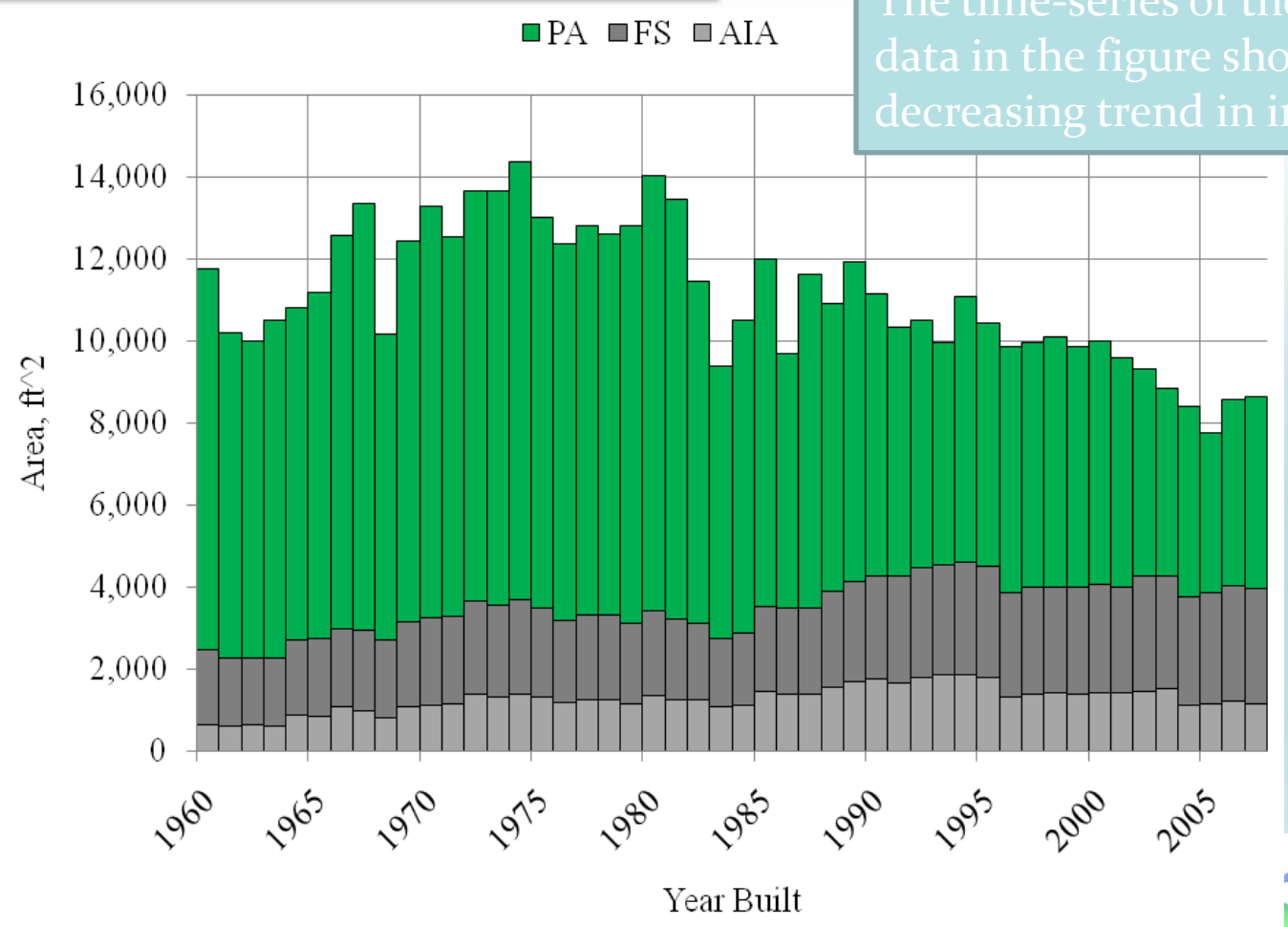
Direct IA data from parcel level database



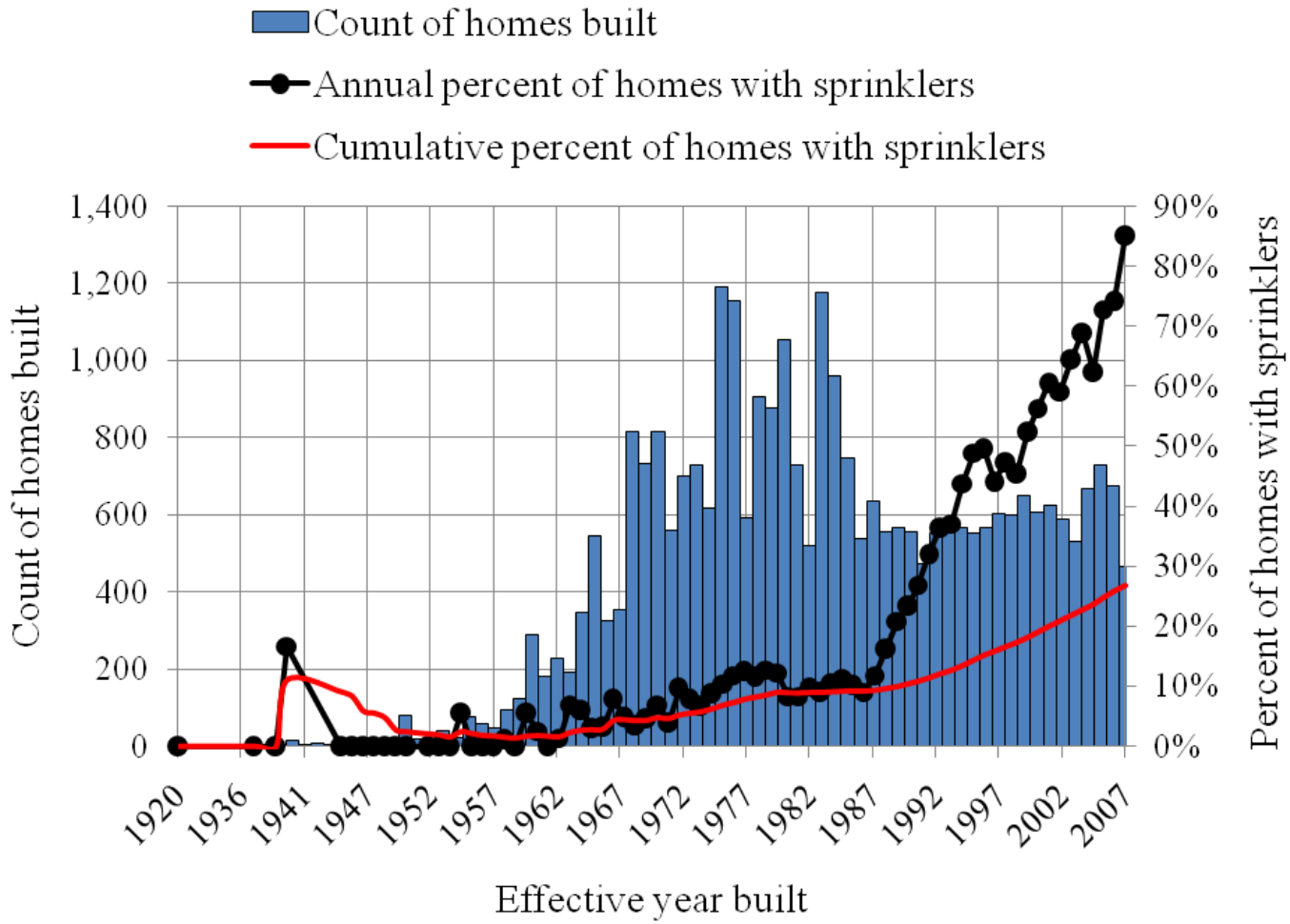
Irrigable or pervious area (*PA*)-GRU

$A_{irrigable} = PA = TA - (FS + AIA)$

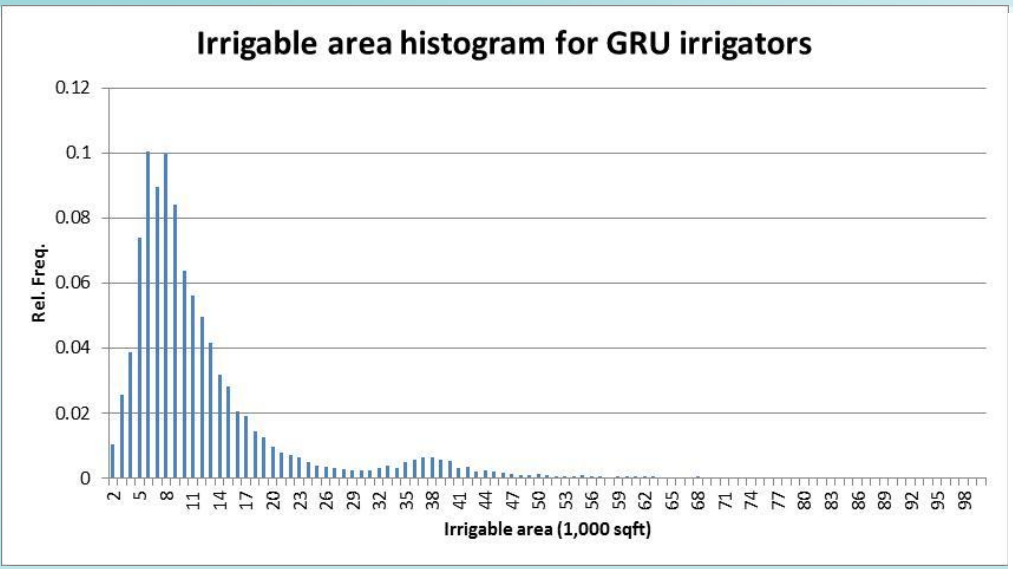
The time-series of the calculated data in the figure shows the decreasing trend in irrigable area

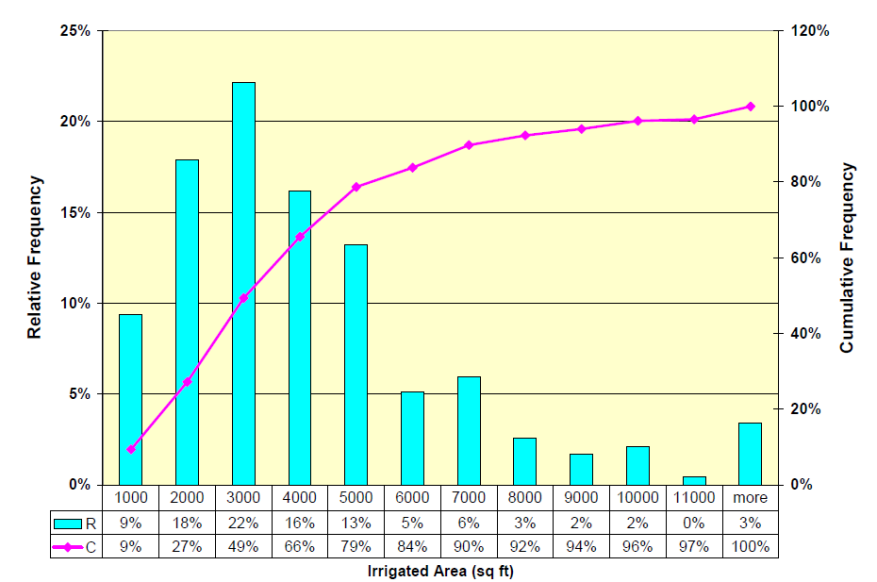


Major Increase in Popularity of In-ground Irrigation Systems Since 1987 in Gainesville



Irrigable Area Distribution





	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	more
R	9%	18%	22%	16%	13%	5%	6%	3%	2%	2%	0%	3%
C	9%	27%	49%	66%	79%	84%	90%	92%	94%	96%	97%	100%

- IA distribution appears lognormal
- Avg. IA (**of irrigators**) = 12.31ksf
- Std. dev. = 11.30 ksf

DeOreo and Mayer 2011 California SFR IA Data

http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282011%29-Analysis-of-Water-Use-in-New-Single-Family-Homes.pdf

Parcel Level Irrigation Demand Estimation

1. Hydrograph separation utilized to determine monthly outdoor usage for each SFR parcel
   - Total monthly usage from customer billing data
   - Indoor usage estimated from property appraisal data
   - Indoor usage consistent across country (Mayer et al. 1999, REUWS)

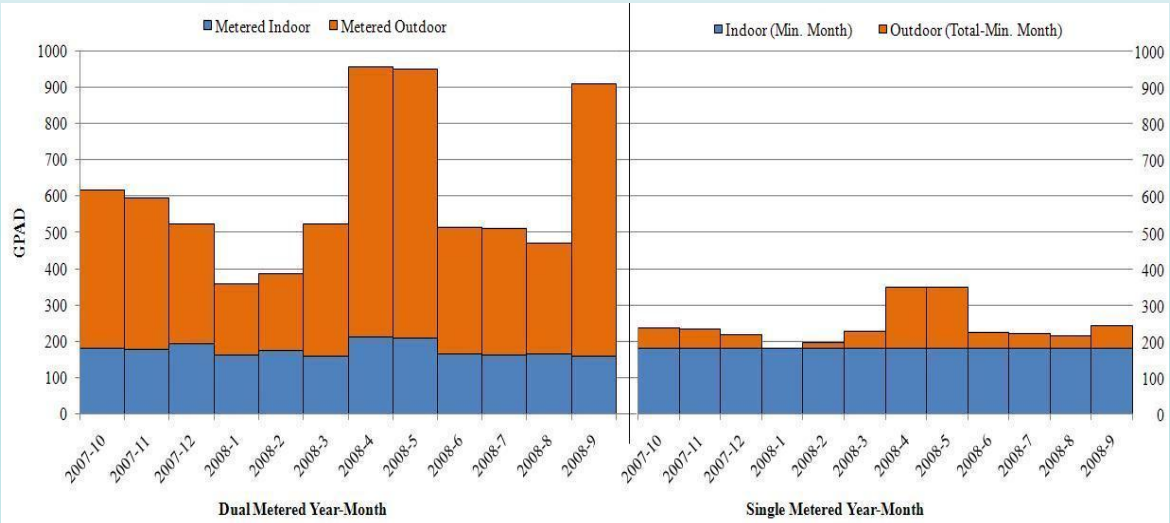
$$\overline{Q}_{out} = \overline{Q}_{tot} - \overline{Q}_{in}$$

Where:

$\overline{Q}_{out}$ = single family residential outdoor usage (gal/mo)

$\overline{Q}_{in}$ = single family residential indoor usage (gal/mo)

$\overline{Q}_{tot}$ = single family residential total usage (gal/mo)



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Parcel Level Irrigation Demand Estimation

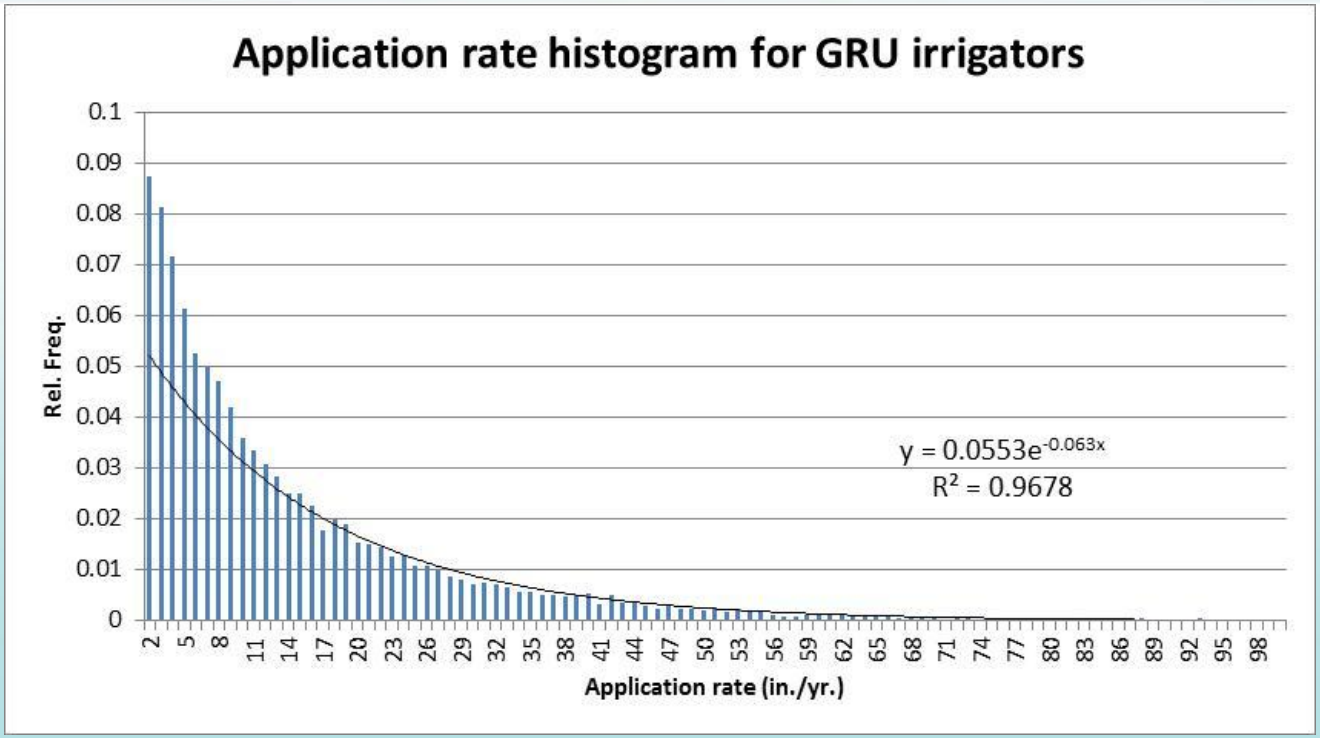
2. Estimate application rate from calculated Qout and IA

$$\overline{Q}_{out} = k * AR * IA$$

Where:
AR = average application rate for a given parcel (in. /yr.)
$\overline{Q}_{out}$ = average monthly outdoor usage (gal/mo)
IA = irrigable area (1,000 ft^2)
k = conversion factor

3. Determine which parcels irrigate from the potable system
   - Irrigates from potable if: 1≤ IA ≤100 and 1≤ AR ≤100
   - Removes outliers, and non-irrigators

Application Rate Distribution



- Avg AR (**of irrigators**)= 14.24 in./yr., std. dev.= 14.60 in./yr.
- Number of irrigators from potable = 16,303 of 30,903 total SFR (53%)

Predicted Savings From Outdoor Conservation BMPs

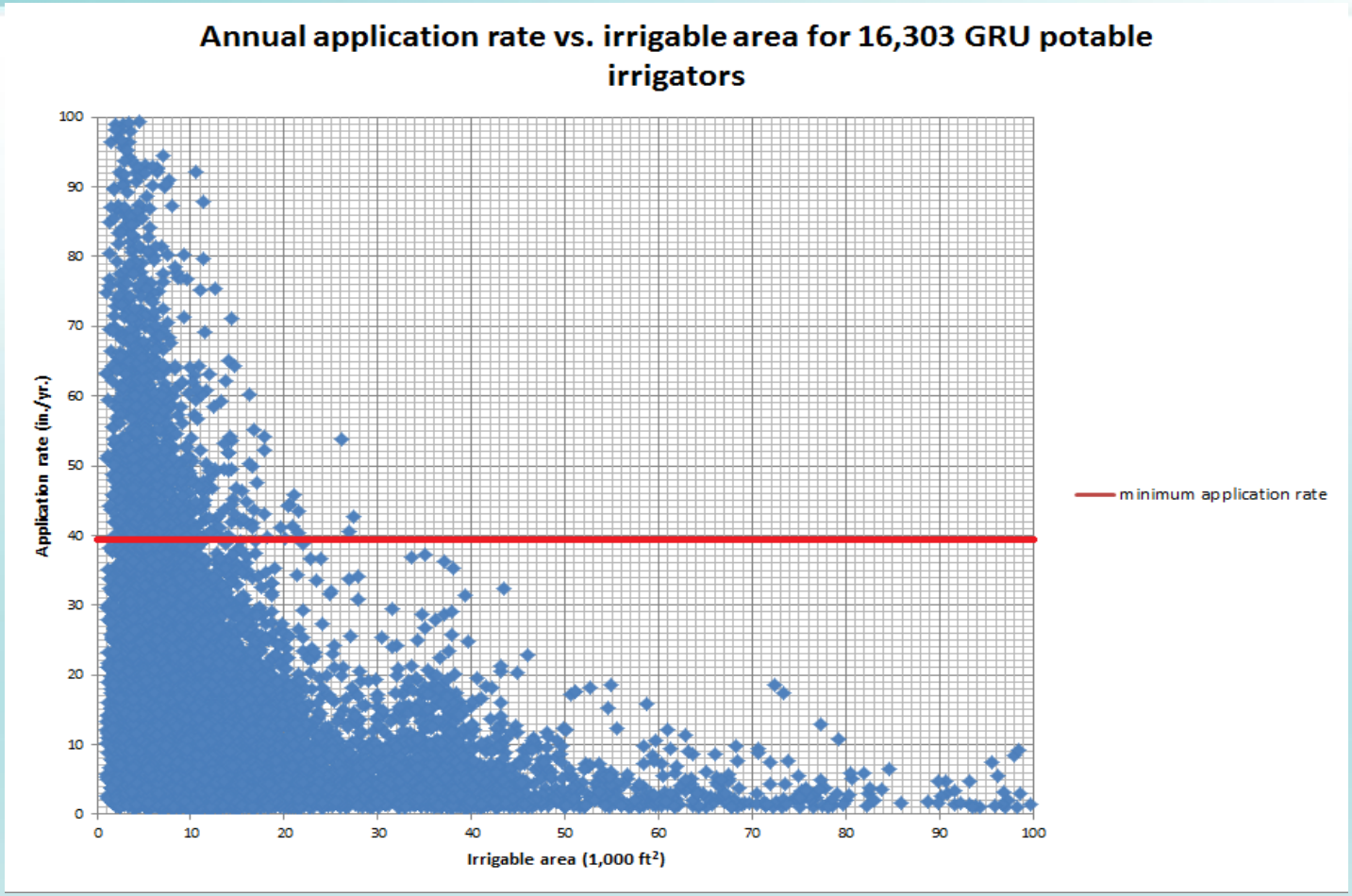
$$\Delta Q_{out} = k * IA * (AR_i - AR_{\min})$$

Where:

ΔQ_{out} = change in total irrigation water use per parcel (gpad)
AR_i = current irrigation application rate (in/yr)
IA = irrigable area (sf)
AR_{min} = minimum required irrigation application rate (in/yr)
k = conversion factor

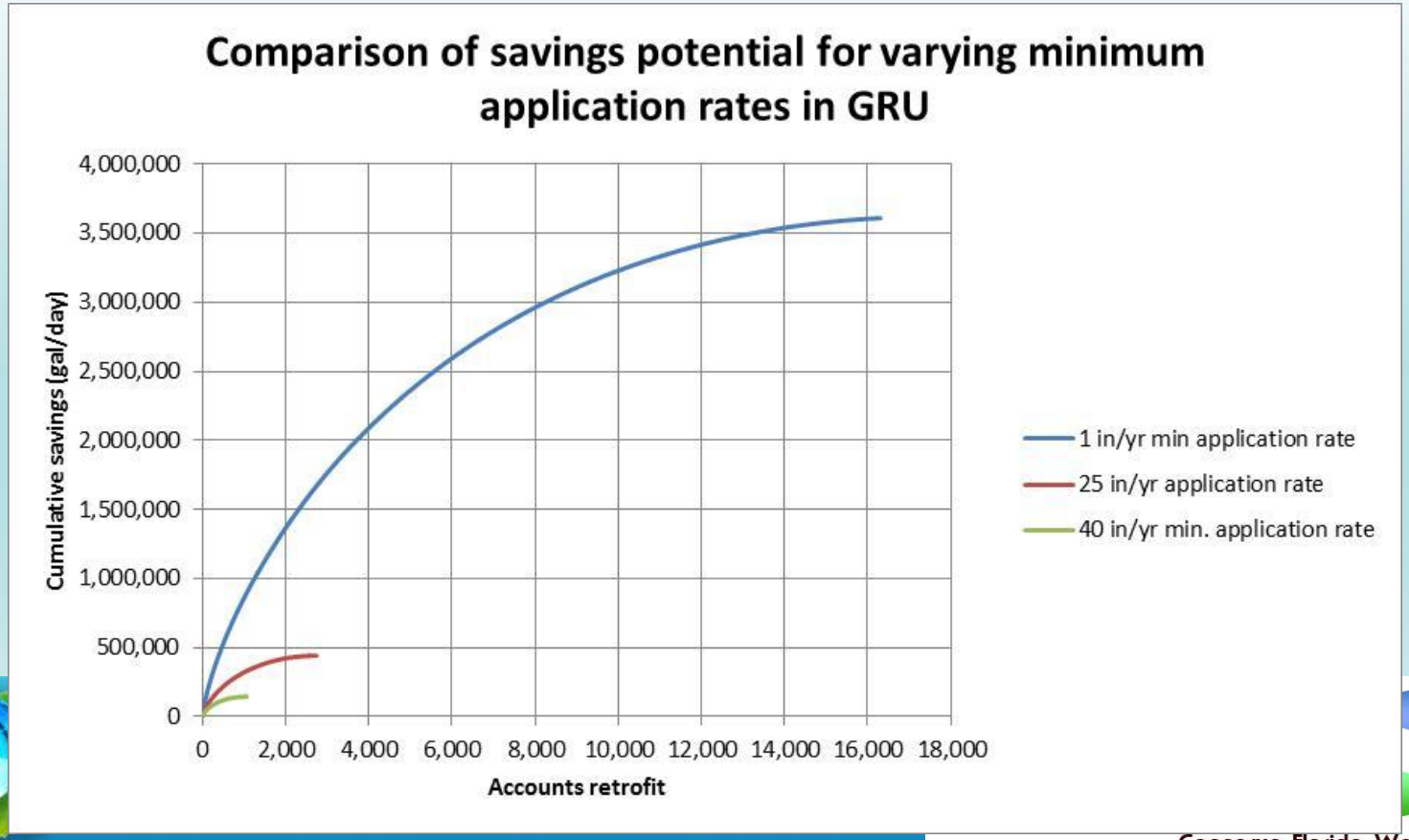
- Savings directly calculated as difference between current and "minimum required application rate (MAR)"
- MAR reflects a desired threshold application achieved with implementation of an outdoor BMP
- Assume IA remains constant
- Only reasonable to target SFR's that irrigate **above MAR**

Joint distribution of AR vs. IA for GRU

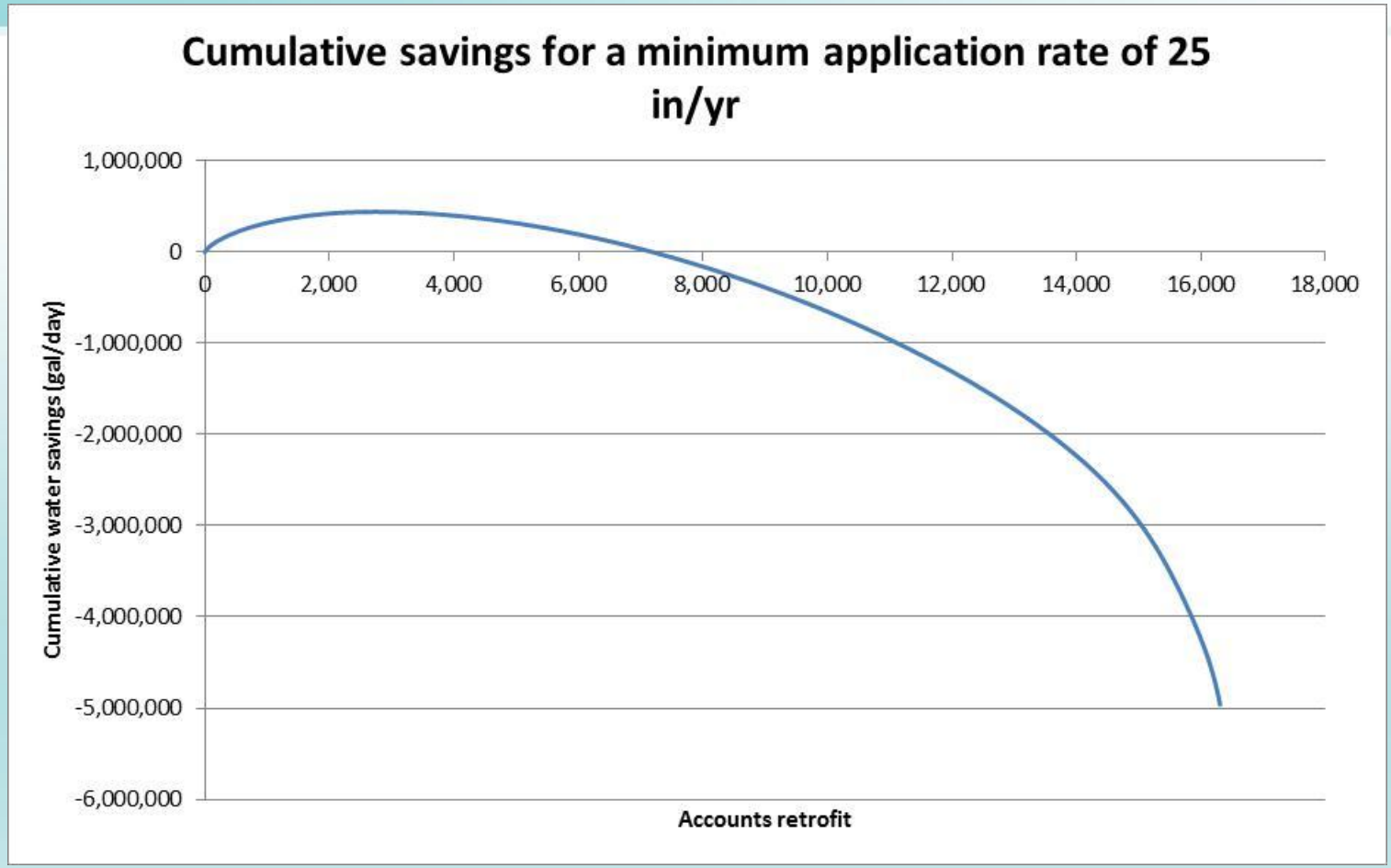


Water Savings Production Function for Soil Moisture Sensors in GRU

MAR, in./yr.	N	avg. IA, ksf	avg. AR above MAR , in./yr.	Maximum Savings Potential, gal./day
1	16,303	12.31	14.24	3,265,116
25	2,746	6.95	15.72	440,119
40	1,070	5.87	15.31	144,145



Consequences of Including Irrigators Below MAR



Optimal Mix of Outdoor BMPs can be Found Using Nonlinear Programming

The least cost mix of soil moisture sensor retrofits, irrigation audits, and reuse to achieve a desired reduction in water use (gal/day) can be found by solving following the nonlinear program:

Minimize $Z = c_1 * x_1 + c_2 * x_2 + c_3 * x_3$
Subject to:

$$y = \sum_{i=1}^{3} y\max_i \cdot (1 - e^{-k_i x_i})$$

$x_i \leq xmax_i$
$y \geq Q$
$x \geq 0$

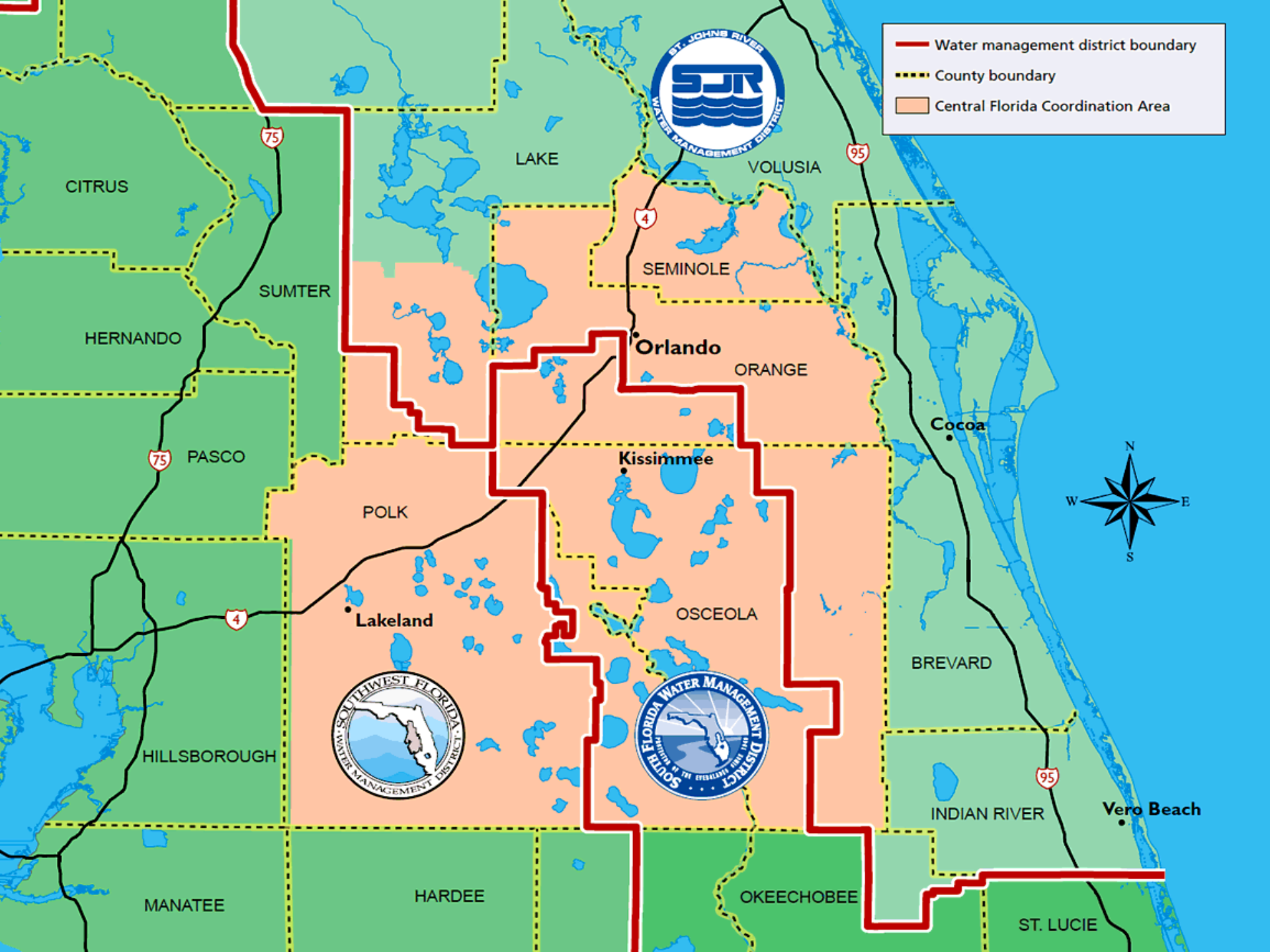
Where:
Z= total costs, $/day
y= quantity of water saved, gal/day
Q= water savings target, gal/day
c=unit cost of bmp, $/account/day
x=number of accounts to retrofit with an upper bound of xmax

Recent Application of Methodology

- Applied to a 6 county planning region in Central Florida (CFWI)
- An estimated 50% (304,214 of 610,536) of SFR parcels irrigate from potable system
- MAR for reuse assumed to be 0 in/yr
- MAR for irrigation audits and soil moisture sensors requested to be set at 40 in/yr
  - Audits assumed to reduce demand by 0.25*ΔAR
- Assumed 10% of irrigators (30,214) could be hooked up to reuse

Parameters for the outdoor BMP optimization

BMP	c_i	$ymax_i$	k_i	$xmax_i$
Soil moisture sensors (x1)	0.22	3,494,087	2.241E-4	28,119
Irrigation audits (x2)	0.06	873,522	2.241E-4	28,119
Reuse (x3)	0.36	5,493,904	1.9401E-4	30,421
Total	n/a	9,861,513	n/a	86,659

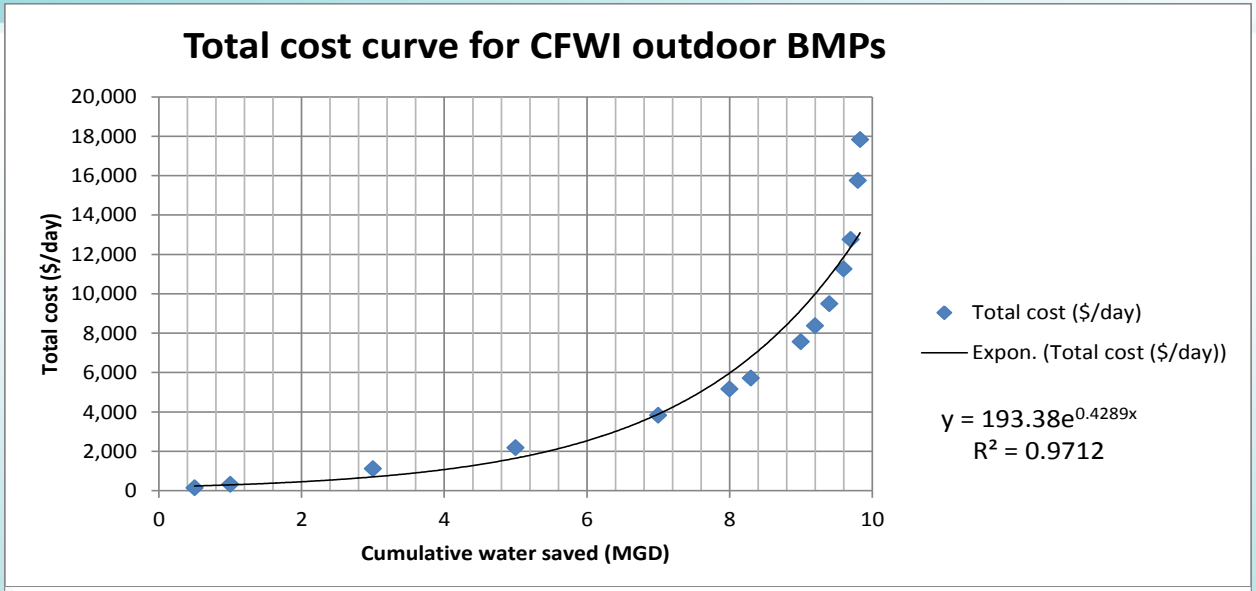

Water management district boundary
County boundary
Central Florida Coordination Area
CITRUS
LAKE
VOLUSIA
SUMTER
HERNANDO
SEMINOLE
Orlando
ORANGE
Cocoa
PASCO
Kissimmee
POLK
Lakeland
OSCEOLA
BREVARD
HILLSBOROUGH
INDIAN RIVER
Vero Beach
MANATEE
HARDEE
OKEECHOBEE
ST. LUCIE
75
4
95
N
S
E
W

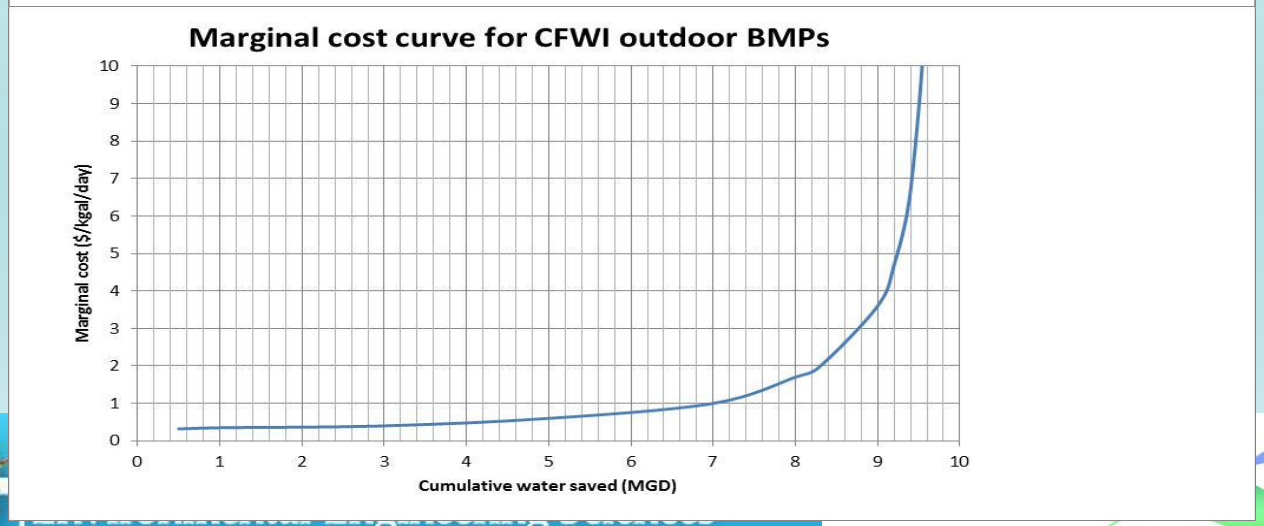
Least costly combination of the three outdoor BMPs to meet a specified target savings for CFWI.

Target conservation savings, Q (MGD)	Total cost ($/d)	Accounts to retrofit			Total accounts	Marginal cost ($/kgal)*
		Soil moisture sensors	Irrigation audits	Reuse		
0.5	$ 151	623	235	0	858	$ 0.32
1	$ 321	986	599	189	1774	$ 0.35
3	$ 1,115	2,127	1,739	1,508	5374	$ 0.40
5	$ 2,185	3,661	3,280	3,285	10226	$ 0.60
7	$ 3,830	6,029	5,641	6,016	17686	$ 1.00
8	$ 5,166	7,948	7,560	8,232	23740	$ 1.70
8.3	$ 5,711	8,730	8,342	9,139	26211	$ 1.99
9	$ 7,558	11,378	10,999	12,208	34585	$ 3.60
9.2	$ 8,378	12,567	12,176	13,563	38306	$ 4.70
9.4	$ 9,496	14,175	13,768	15,420	43363	$ 6.70
9.6	$ 11,260	16,703	16,331	18,348	51382	$ 12.00
9.7	$ 12,756	18,855	18,457	20,834	58146	$ 19.00
9.8	$ 15,753	23,162	22,777	25,808	71747	$ 50.50
9.83	$ 17,829	26,119	25,807	29,263	81189	$ 99.00

#Marginal cost is the shadow price (dual variable) with the respect to the specified minimum amount of water.

Total and Marginal Cost Curves for CFWI Outdoor BMPs





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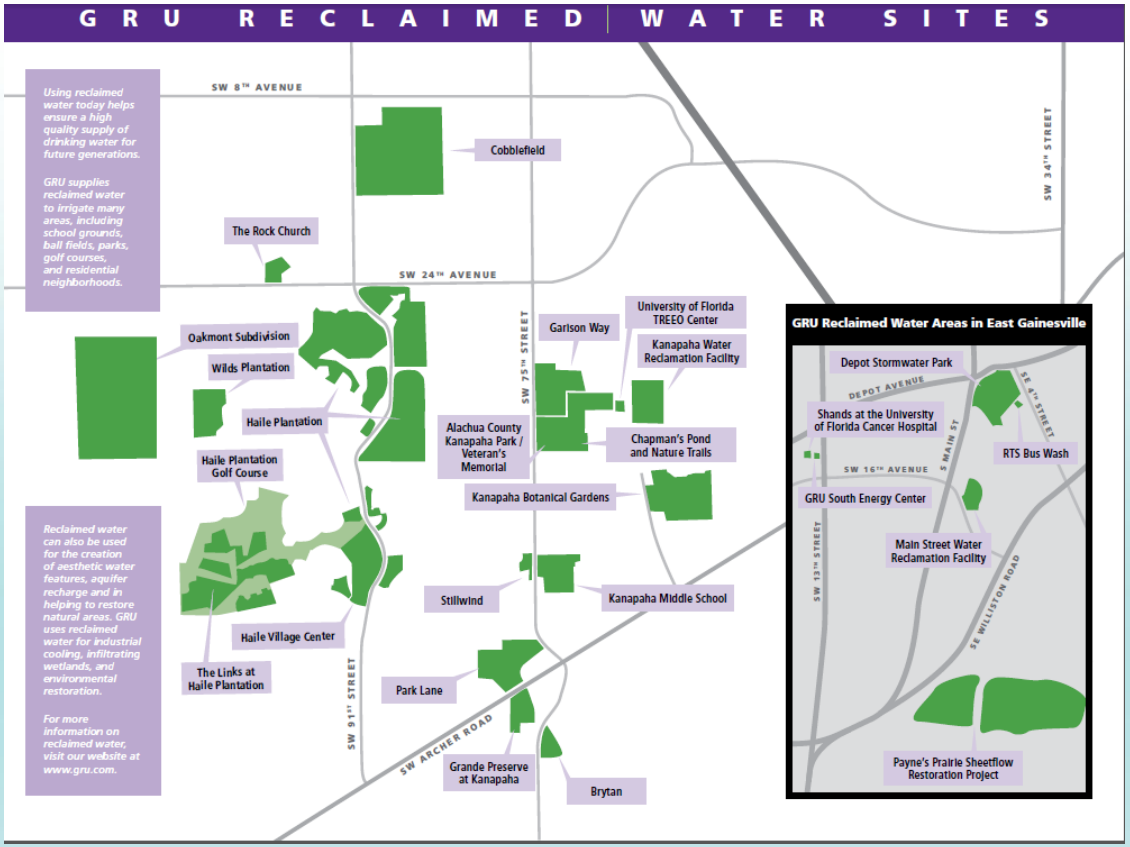
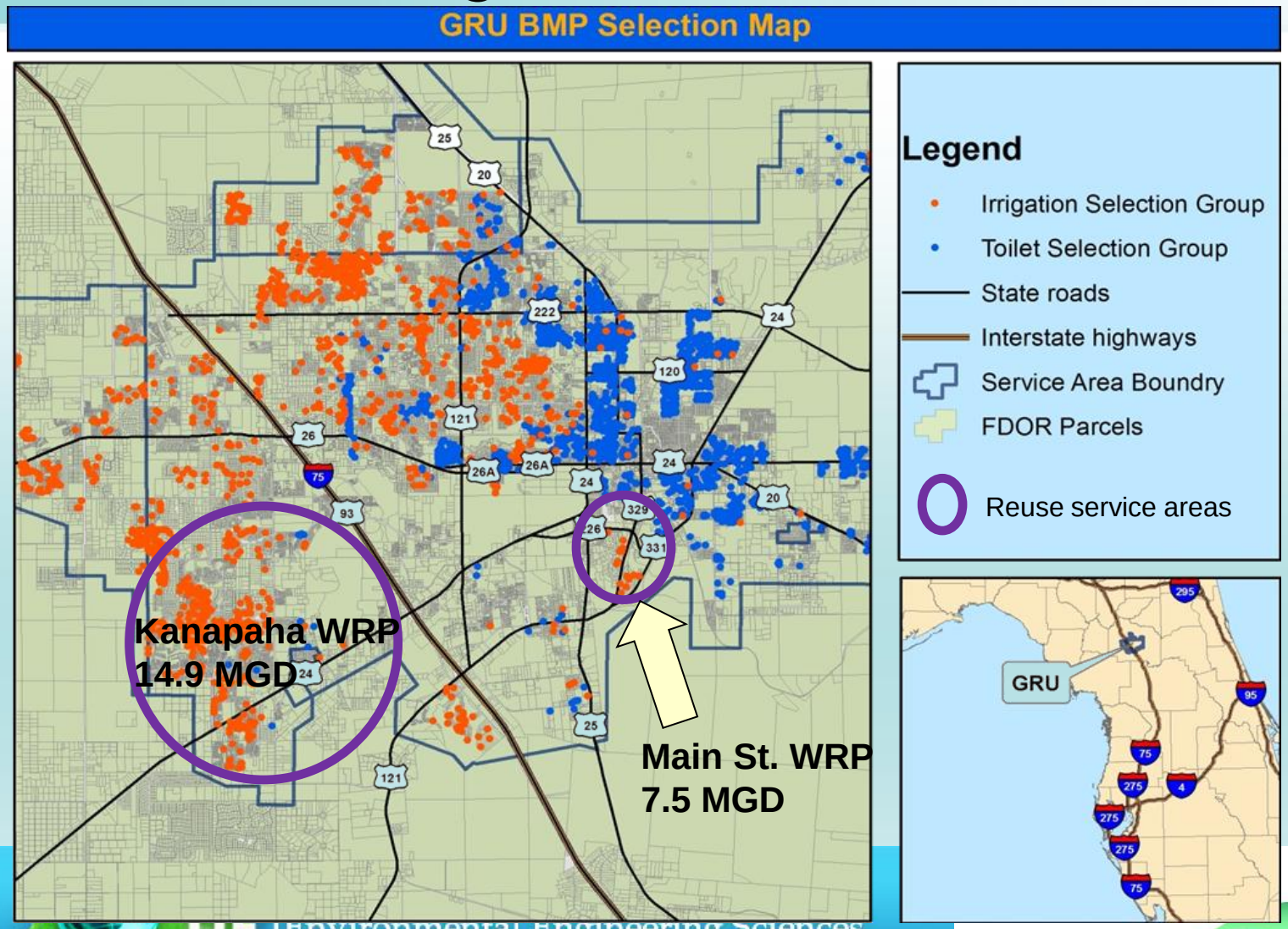
Ongoing Methodology Enhancements



- Reuse market potential and cost per account highly variable and utility specific
- Depends on existing reuse network and reclaimed water treatment plant locations

https://www.gru.com/Pdf/Reclaimed%20Water%20brochure.pdf

Combining with other BMPs



Summary And Conclusions

- Outdoor water usage can be estimated at the parcel level using property appraisal and customer billing data
- Trending toward smaller irrigable area with increasing percentage of in ground sprinklers
- Need to focus outdoor BMPs on only those homes which "over irrigate"
- Optimal mix of outdoor BMPs can be found using nonlinear programming
  - Can be extended to BMPs from other sectors
- Reuse opportunities depend on current infrastructure
- Incorporation into EZ Guide planning tool

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Promoting Conservation in Our Public Water Supplies

Home | Profile | Water Supply Analysis | Audit | Water Budget | BMP Analysis | Planning | Summary Report | BMP Tracking

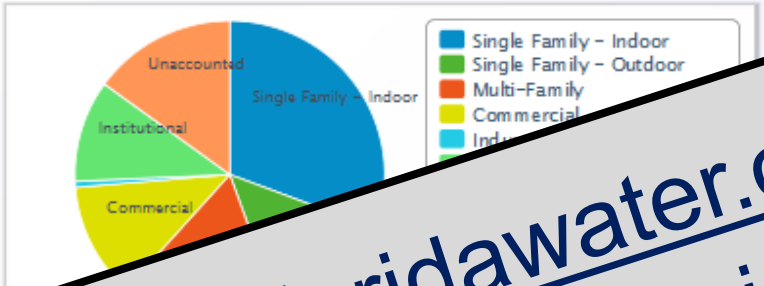
GRU 011812

- Historical Conservation Programs (BMPs)
- Historical Conservation Programs (Measures)
- Calibration
- Summary

Water Budget Configurables

Analysis Year: 2009 - To change the Analysis Year return to Water Supply Analysis page

Calibrated Water Budget By Sector



							fference
							11.01%
						11,368.70	36.32%
					128	157	23%

www.conservefloridawater.org

http://ezguide.conservefloridawater.org

	Water Use	Residential GPCD	Gross GPCD	Population	% Total Population	Average Gallons Per Heated Square Foot Per Month	Links
Single Family	44.5%	116	70	117,946	60%	4.97	
Single Family - Indoor	30.7 %	80	48	---	---	3.43	Details
Single Family - Outdoor	13.8 %	36	22	---	---	1.54	Details
Multi-Family	17.2%	67	27	80,025	40%	4.65	Details
CII	23.4%	--	37	---	---	4.37	Details
Commercial	12.0 %	--	19	---	---	5.18	Details
Industrial	0.6 %	--	1	---	---	0.87	Details
Institutional	10.7 %	--	17	---	---	4.66	Details
Unaccounted	15.0%	--	24	---	---	--	
Total	**100.0%**	--	**157**	**197,971**	**100%**	**5.56**	