PM and Nutrient Load Recovery, Credits and Economics for MS4 Maintenance Activities: Phase III (w/review of the 2011 Phase II results)

University of Florida, Environmental Engineering Sciences (EES)
Engineering School of Sustainable Infrastructure and Environment (ESSIE) Draft Presentation

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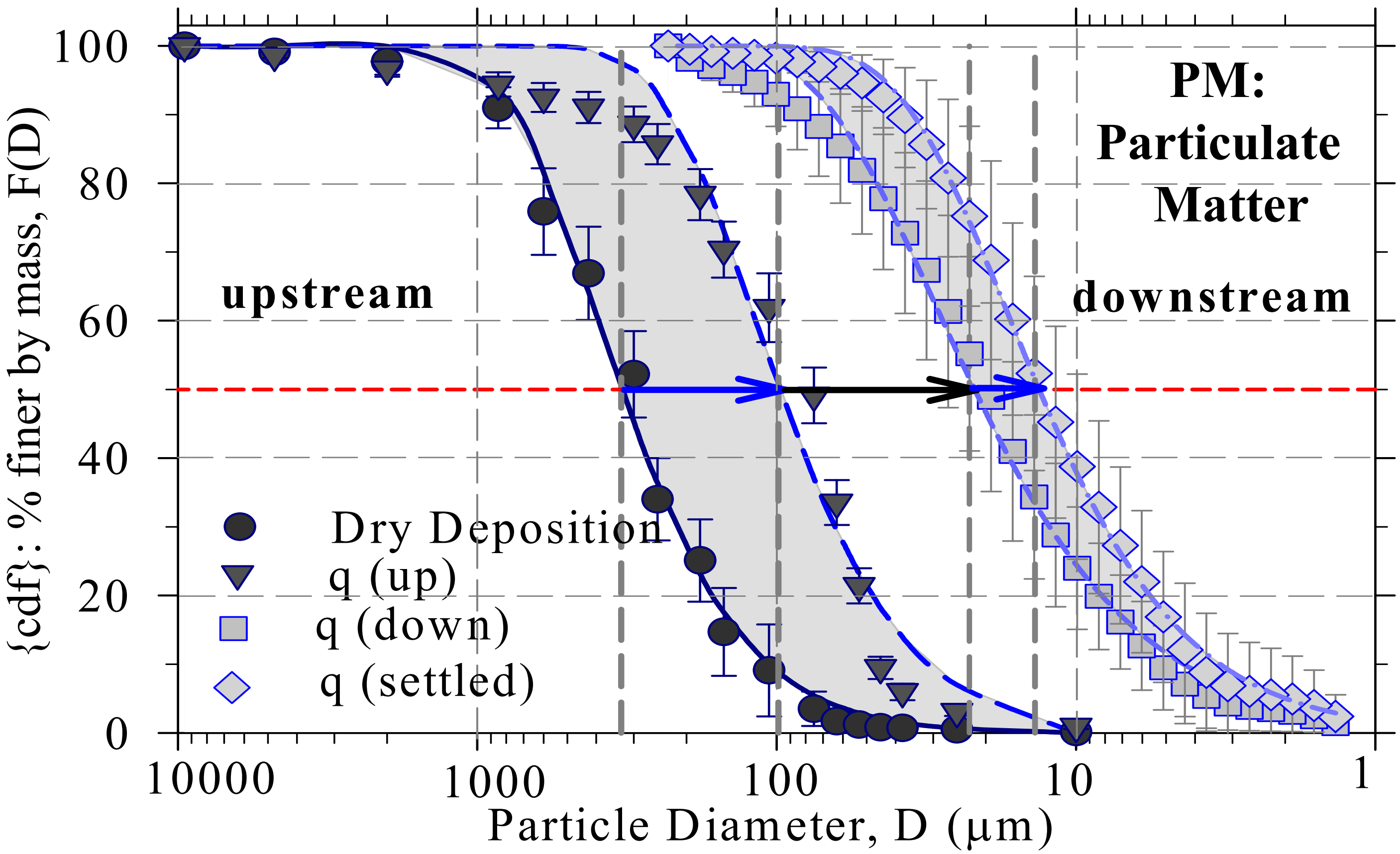
Urban Particulate Matter (PM)

- **PM is the predominate sink and source of nutrients (P, N)**
- **Management of PM = Control of chemical (nutrient) load, [C]**
- Myths regarding PM is a function of how we sample and analyze
  - *samplers are designed for steady wastewater flows and organic PM*
  - *analysis based on sub-aliquot methods (TSS) without particle size data*
- Particle size distributions (PSD), particle number density PND:
  - *Required for modeling PM, solute and microbiological fate*
  - *Required for load inventories of PM and nutrients, maintenance*
- **The cost of PM and nutrient recovery by maintenance (street, CB cleaning) is much lower than using conventional BMPs**

The drainage system modifies PM: Through transport of pavement deposition to catch basins to "BMP" influent and effluent PM



PSD gamma model

$$f(D) = \frac{(D/\beta)^{\gamma-1} e^{(-D/\beta)}}{\beta \cdot \Gamma(\gamma)}$$

$$F(D) = \Gamma_D(\gamma) / \Gamma(\gamma)$$

$$\Gamma(\gamma) = \int_0^\infty x^{\gamma-1} e^{(-x)} dx$$

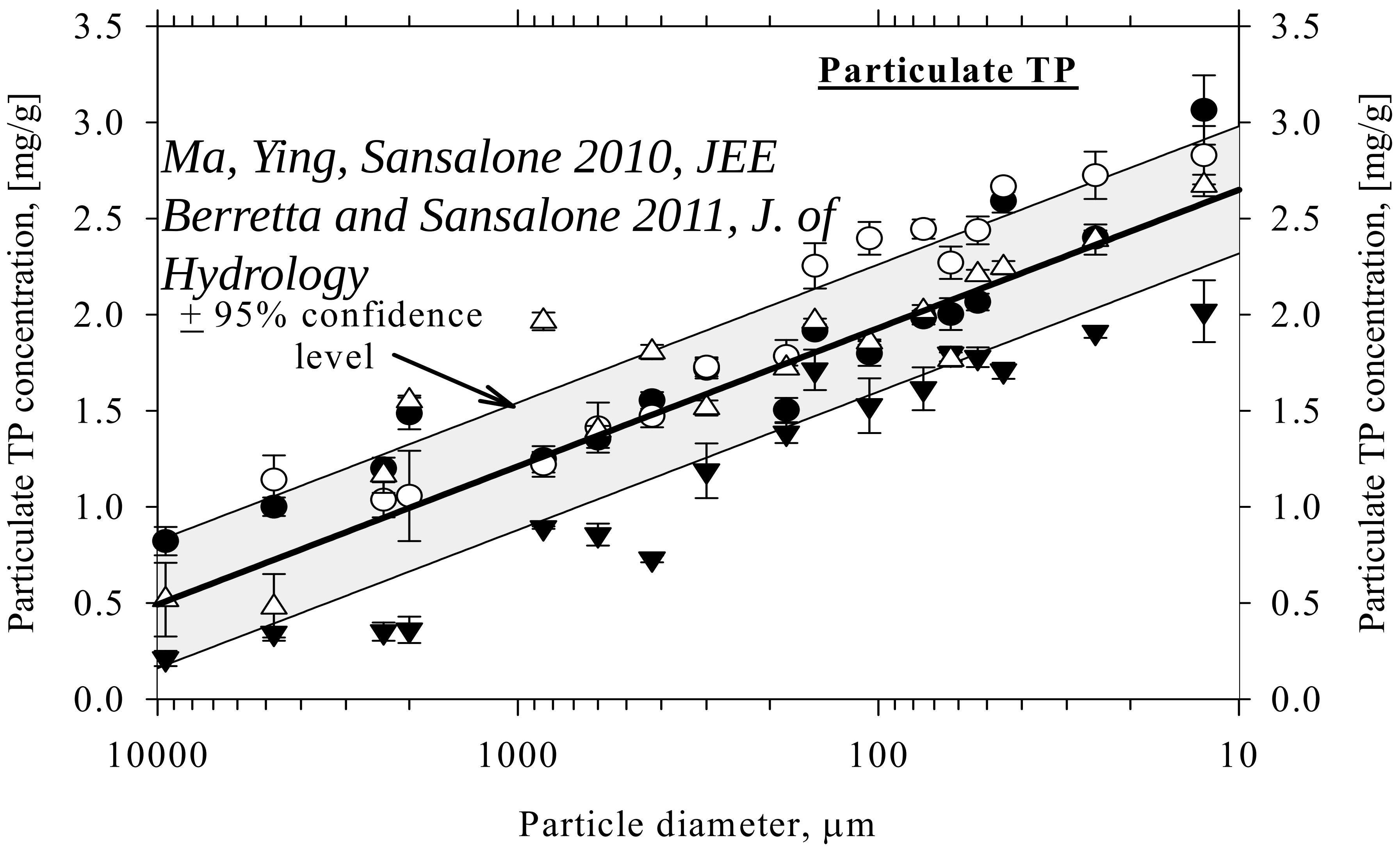
$$\Gamma_D(\gamma) = \int_0^D x^{\gamma-1} e^{(-x)} dx$$

BMP: Clarifier with 1 hr. of quiescent settling

Location	(γ, β)
DD	(2.06, 187.7)
q (up)	(1.90, 61.9)
q (down)	(1.23, 23.6)
q (settled)	(1.51, 11.1)

PSD of PM	DD Pavement ***Deposition***	q (up) CB or inlet ***Runoff***	q (down) BMP influent ***Runoff***	q (settled) BMP effluent ***Runoff***
D_{50m}	331 μm	99 μm	23 μm	14 μm

Relationship between granulometry (PM size) and particulate TP based on University of Florida rainfall-runoff event datasets



What were Phase II Project Objectives and Outcomes ?

The primary project objective (Phase II and III) is a ***<u>Florida-based</u>*** "yardstick" or metrics allowing an MS4 to quantify nutrient (TN and TP) loads through ***separation*** then ***recovery*** of ***<u>particulate matter</u>*** (PM) for common urban hydrologic functional units (HFUs):

1. Pavement systems cleaning (pavement street sweeping), (II and III)

2. Catch basins (inlets), (II and III)

3. "BMP " (the most utilized and cleaned BMPs for an MS4) (II and III).

- All Phase II and III outcomes are Florida-based metrics (a statistic of the resulting probability distributions: i.e. median) based on all MS4s
- Outcomes allow ***<u>dry-equiv.</u>*** load of PM ***separated*** (i.e. a BMP) and then ***recovered*** by maintenance to be converted to TN, TP loads
- Outcomes quantified by land use or independent of land use
- Outside vs. inside wastewater reuse areas preliminary analysis (Phase II)

Brief Review of Phase II Project Methodology

1. The experimental design of Phase II was for maintenance practices outside (OUT) of wastewater reclaimed areas,
2. Any examination for maintenance practices inside (IN) of wastewater reclaimed areas was preliminary and ad-hoc for Phase II, representing only 3 of the 14 MS4s,
3. Phase III, in contrast to Phase II, had an experimental design to test IN vs. OUT of wastewater reclaimed areas as a primary objective; all 12 MS4s had an equivalence of IN and OUT maintenance-recovered PM samples,
4. As part of Phase III an examination was conducted to statistically compare Phase II and III results of maintenance-recovered PM for TN and TP.

Participating Florida MS4s in Phase II

1. Gainesville (GNV) ***[IN + OUT]***
2. Hillsborough County (HC)
3. Jacksonville (JAX)
4. Lee County (LC)
5. Miami-Dade County (MDC)
6. Orange County (OC)
7. Orlando (MCO)
8. Pensacola/Escambia County (PEC)
9. Sarasota County (SAC) ***[IN + OUT]***
10. Seminole County (SEC)
11. St. Petersburg/Pinellas County (SPP)
12. Stuart (ST)
13. Tallahassee (TAL)
14. Tampa (TPH) ***[IN + OUT]***

MCO-CB-R-OUT-2

TPH-BMP-C-OUT-1

HC-CB-R-OUT-2

MDC-BMP-C-OUT-9

JAX-SS-R-OUT-1

ST-BMP-C-OUT-1

Project Process Flow

Sampling Process → **UF Lab Analysis** → **Future Application**

1. The objective was to develop a ‘yardstick’ to quantify the nutrient load recovered through regular maintenance of BMPs, CBs and pavements (street sweeping or cleaning).
2. 14 MS4s, each collected 27 samples with detailed field information for every sample.
3. 3 locations each, in 3 land uses – commercial, highway and residential; for the 3 maintenance practices.
4. 3 MS4s also collected 27 samples from within areas with reclaimed wastewater usage, to compare nutrient loads.

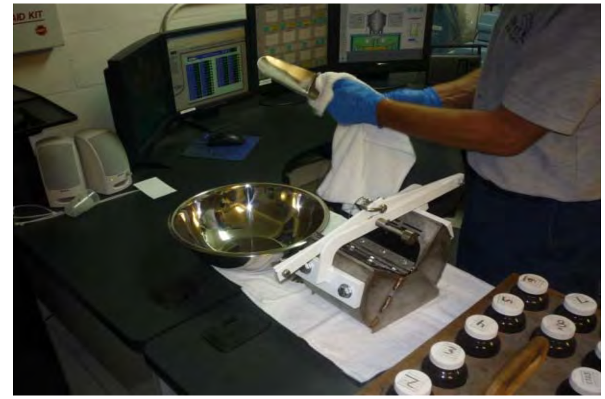
Projects (II and III) sampled a diversity of "BMPs"

(Diversity provided a robust FL-based metric and valuable debate)

BMP Classification (Phase II only)	IN	OUT
Pond (Basin)	10	11
Baffle Box	1	27
Swale, Ditch or Sediment Accumulation	11	35
Manufactured BMP (i.e. hydrodynamic separators)	5	28
Drainage or Sump Box (i.e. "French drains")	0	23
Total	**27**	**124**

Cleaning, Sampling, Packing, Shipping, Receiving

1. QAPP specified sampling, site information needed
2. Cleaning of equipment is very important to prevent cross contamination
3. Samples have to be collected in 2 L bottles
4. Samples had to be stored on ice after collection or refrigerated and delivered or shipped to UF within 24 hours unless dry; along with detailed chain of custody (COC)
5. Samples need to have considerable amount of particulate matter (PM)
6. Study utilized dry/moist samples ***(representative moisture content (MC) is a simple and critical requirement for credits)***



Sample Identification:
City/County Code – HFU – Land use – In/Out of reclaimed water usage area – Dry/Moist/Wet – Sample Location number
i.e. GNV – SS – H – IN – D – 1

Collection of Field Information: 1 Tallahassee Sample

FIELD INFORMATION - TALLAHASSEE (TAL - CB - C - OUT - 1)

Sample identification
- TAL – CB – C – OUT – 1

Jurisdiction
- Tallahassee

Land use zoning

Condition
- Needs maintenance attention

Condition of PM residuals
- Dry

FIELD INFORMATION - TALLAHASSEE (TAL - CB - C - OUT - 1)

Sample identification
- TAL – CB – C – OUT – 1

Jurisdiction
- Tallahassee

Land use zoning
- Commercial, Restaurant, Hotel, Small Businesses

Location
- University; NE Corner of Tennessee and Dewey Streets

Co-ordinates
- 30.44504 N and 84.29451 W

Date and time (with previous dry hours)
- 06/15/2009 11:23 AM

Condition
- Needs maintenance attention

Condition of PM residuals
- Dry

Dimensions and volume
- 25 in (w) x 25 in (d) x 40 in (l)

Description of flow to catch basin
- Direct run-off

Description of sampling method
- Stainless steel scoop

Traffic estimate (ADT)
- 39509

- Anthropogenic

Description of catch basin

Type
- Catch basin

Approximate age
- Older (brick lined)

Previous cleaning activity
- Unknown

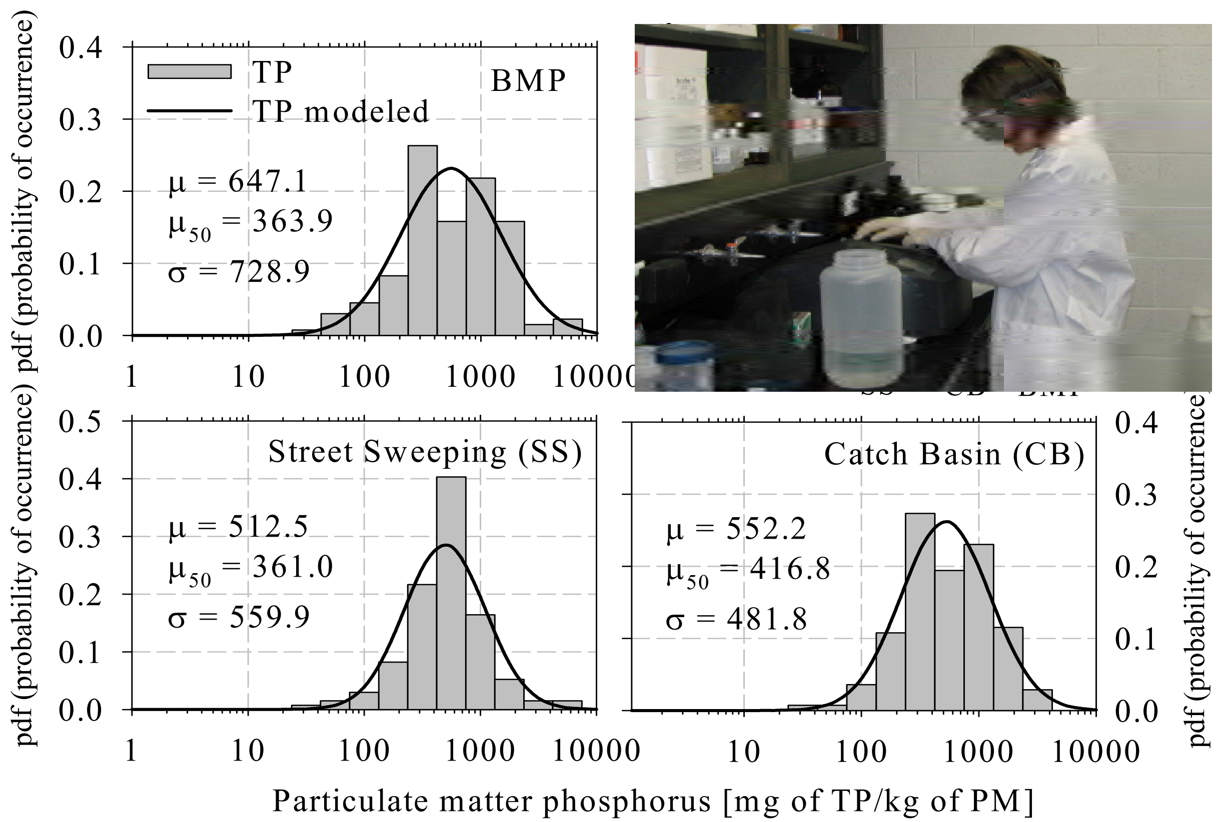
OUT : outside reclaimed water area
R/W : right of way
TAL : Tallahassee

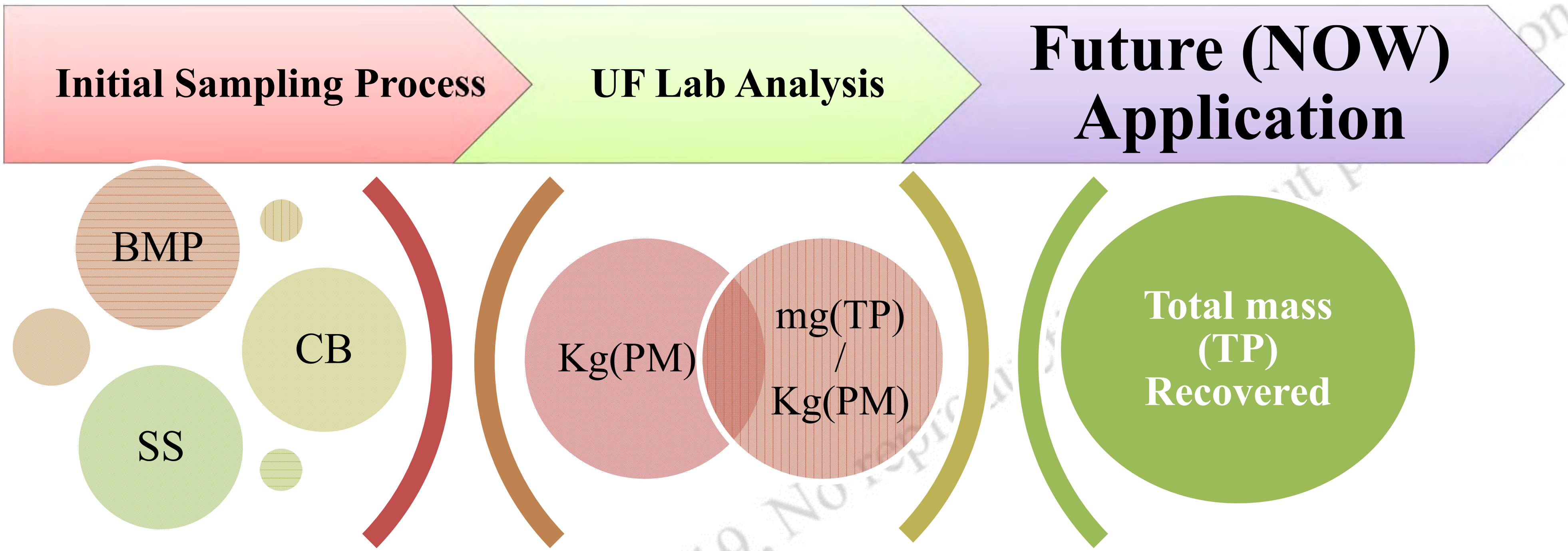
Initial Sampling Process → **UF Lab Analysis** → **Future Application**

UF Lab Analysis

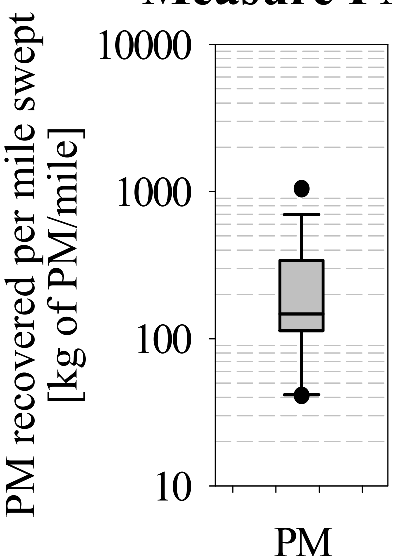
1. U. of Florida analyzed samples for N (as TN) and P (as TP) in NELAC certified labs.
2. TP, TN, and extractable P, moisture content and particle size distribution (PSD) analyses were performed.
3. Based on results, probability distributions (and statistical indices) generated for N, P.
4. Distributions and indices generated on Florida-basis with/without land use, HFU or reclaimed wastewater.

For example, distribution statistics are in Table 8 of Phase I report (land use results are lumped)

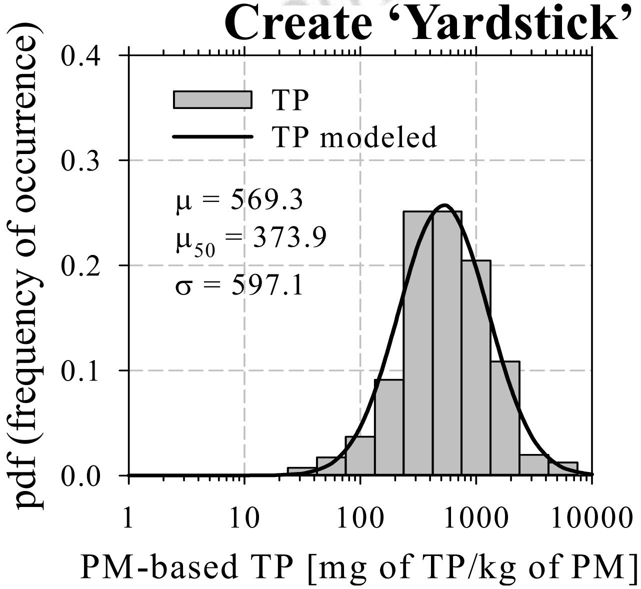




Measure PM



Create 'Yardstick'



Nutrient (N, P) Credit

<u>Documentation and validation reqr. for dry-equivalent PM recovery</u>

Sample Analysis Flow Chart: MC, dry PM, N, P

50 g
Sub-sample

50 g
Sub-sample

50 g
Sub-sample

40 ~ 60 g
PM analysis

10 g
Moisture content (MC)

Volatile PM
Fraction

2.5 g
Extractable P

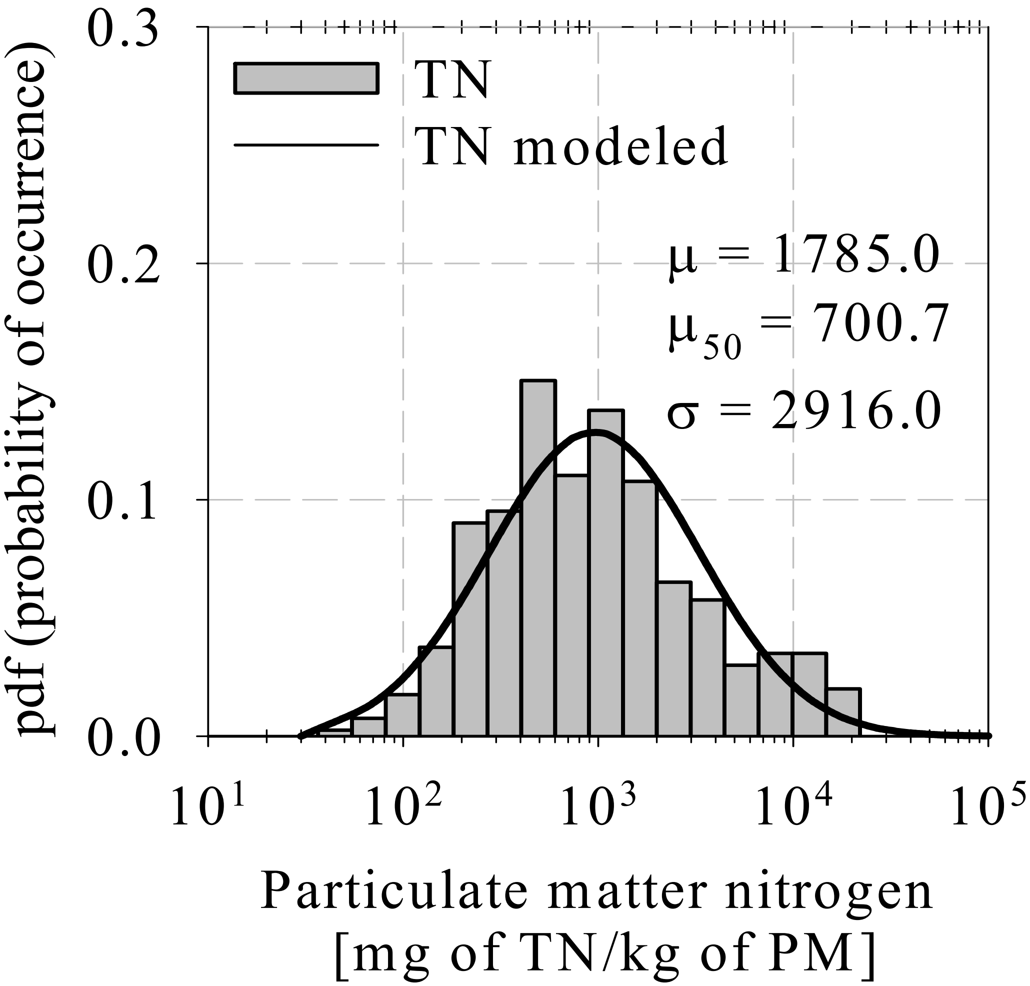
1.0 g
TP

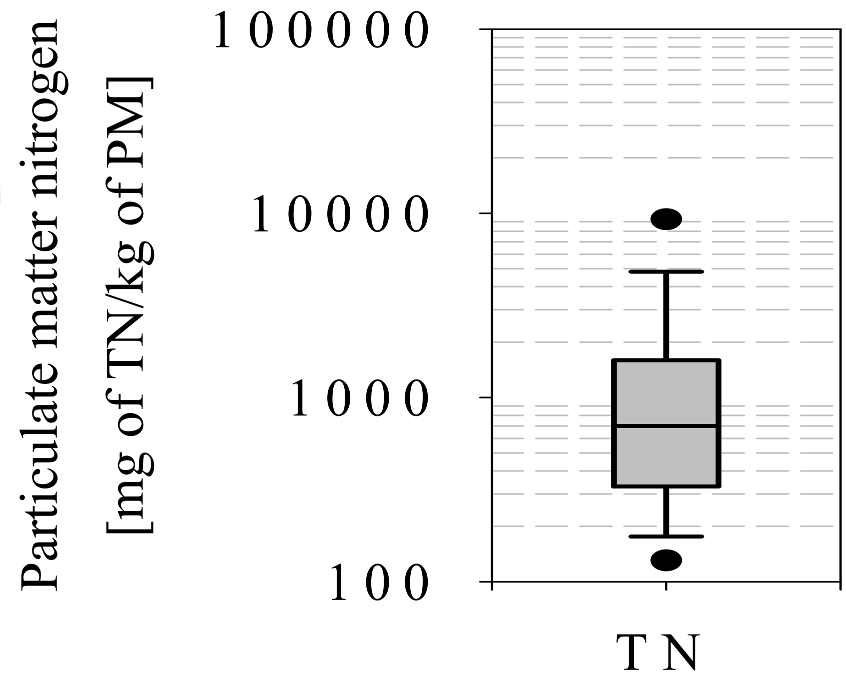
5.0 g
TN

Review of Primary Project Results (Phase II)

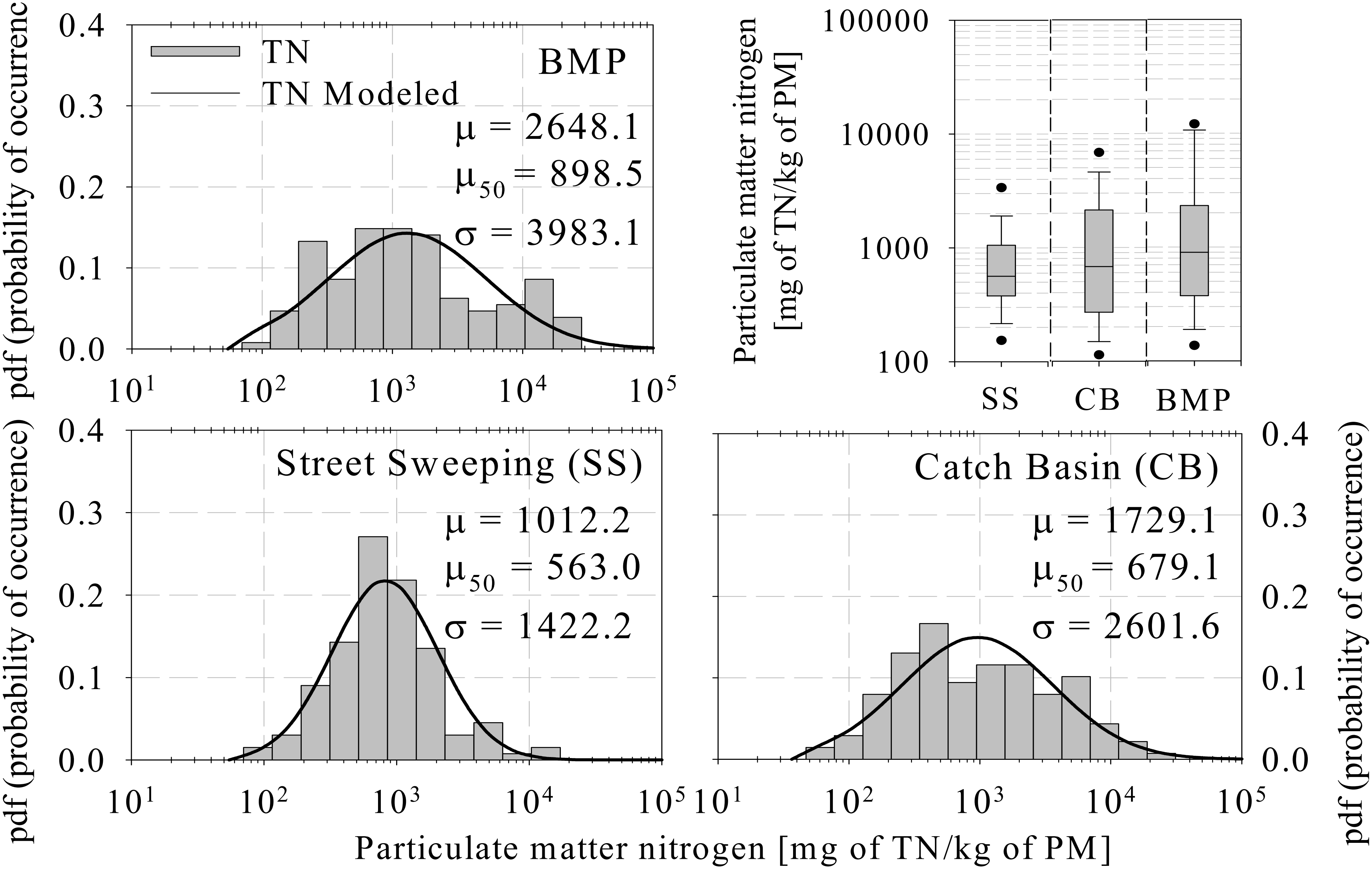
1. Results presented are from outside (OUT) reclaimed wastewater areas, unless inside (IN) reclaimed area results are specifically identified.
2. Results are either composited by combining separate land use results or combining separate HFU results or both, OR results are delineated as a function of land use and HFU
3. Land use:
   - "Highway" (H) {major transportation R/W}
   - Residential (R)
   - Commercial (C)

Florida-Based Result: Distribution of N (as TN) (Land Uses Composited and HFUs Composited)

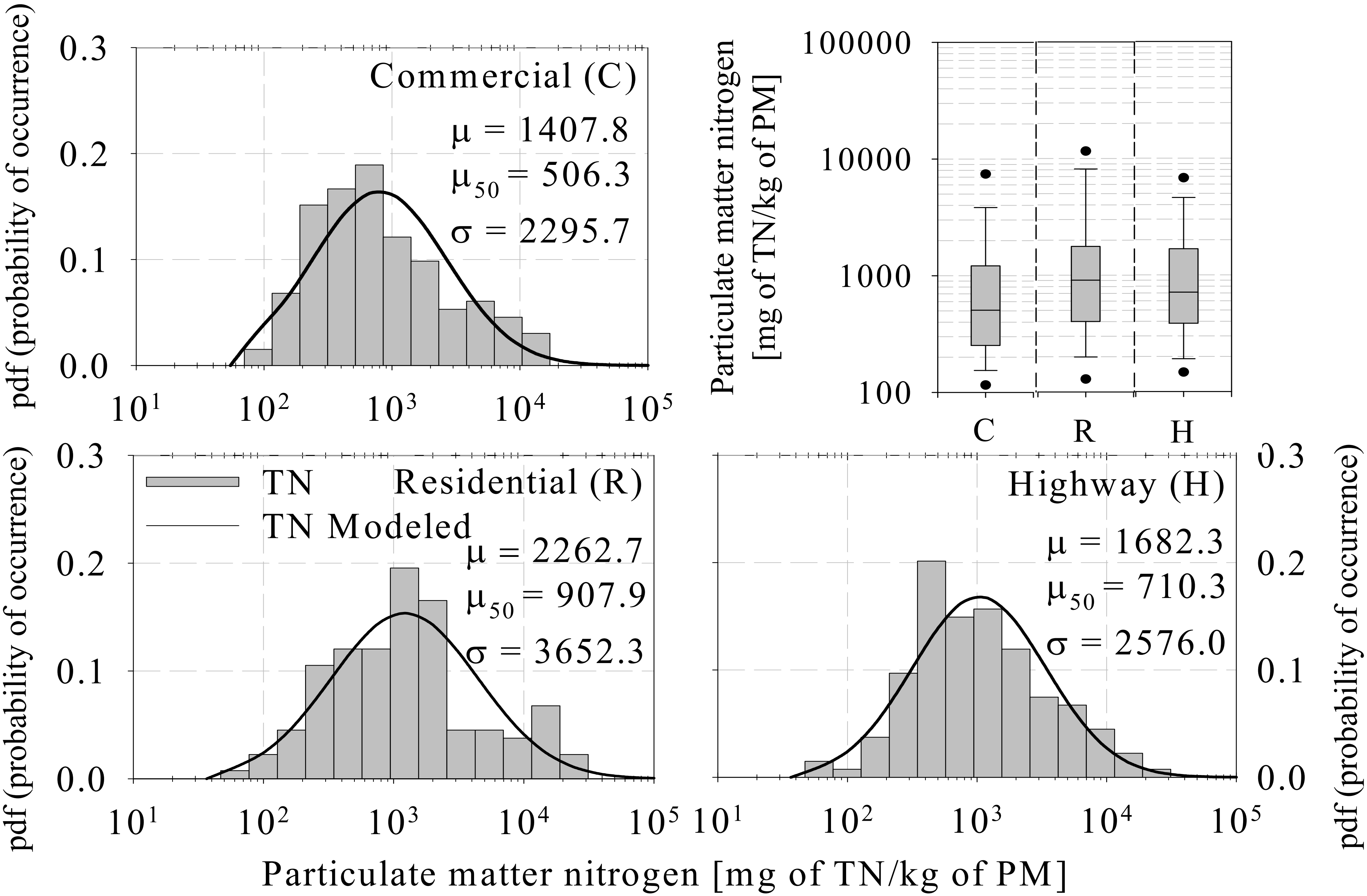




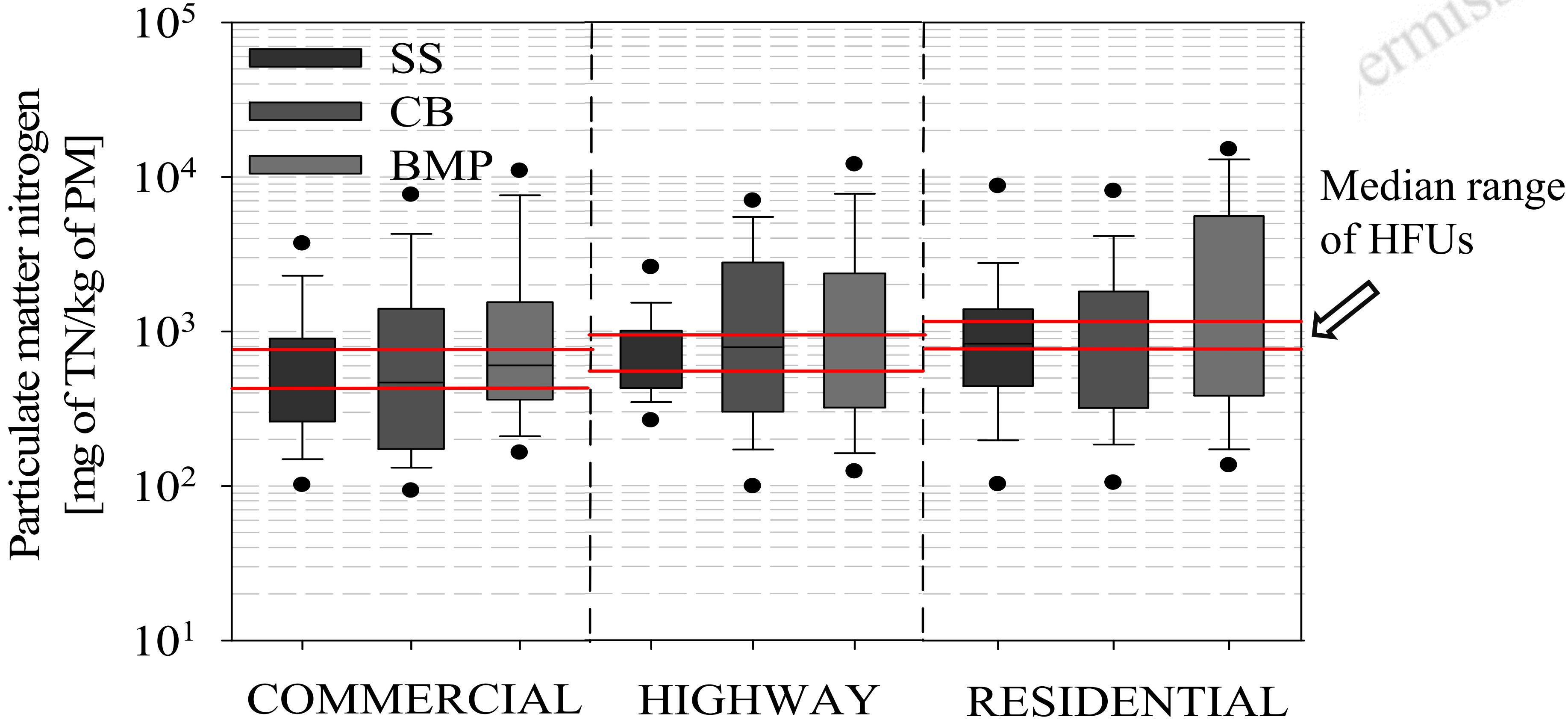
TN Results – Distribution by HFUs



TN Results – Distribution by Land Use



TN Results by Land Use and HFU (Table 6 or S1)

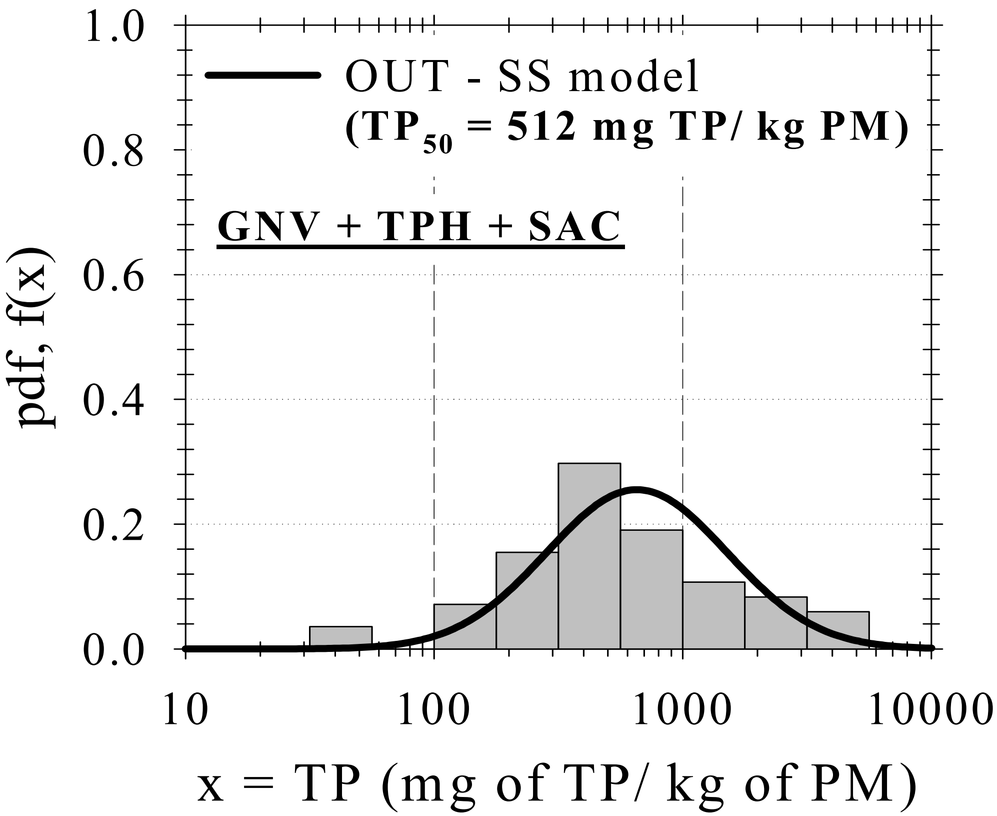


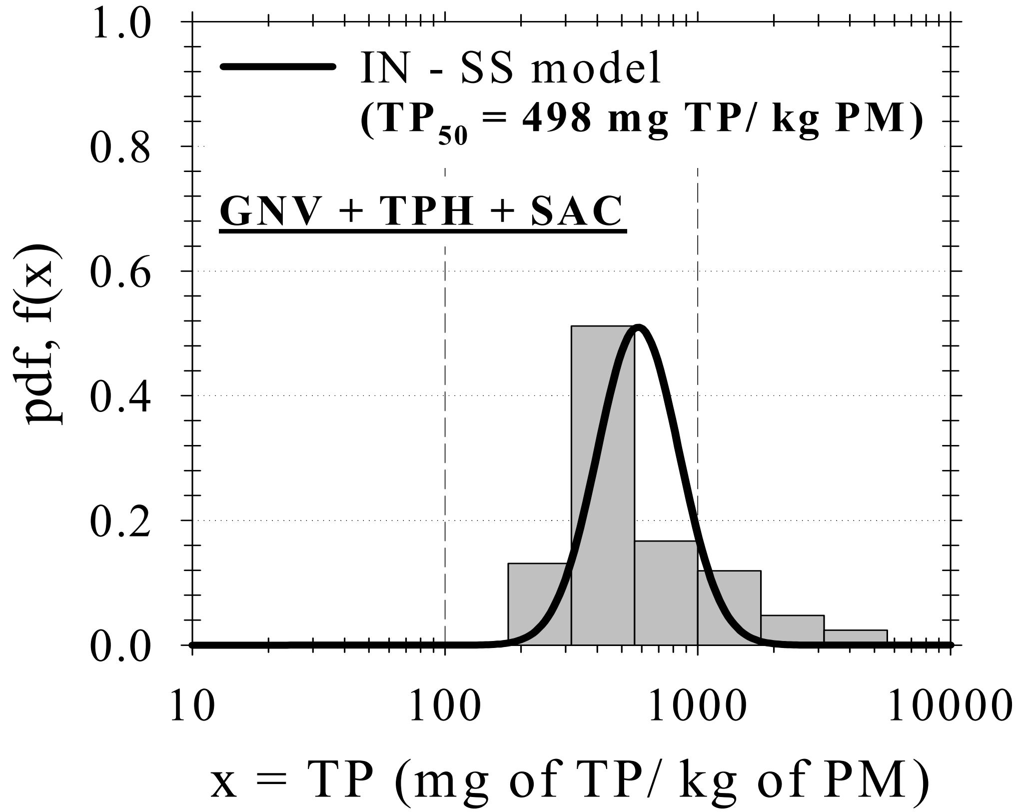
TN [mg/kg]	Street Sweeping (SS)			Catch Basin (CB)			BMP		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.	Mean	Median	St. Dev.
C	789.1	429.6	944.2	1459.7	467.2	2237.8	1999.0	602.1	3104.1
R	1439.0	832.4	2169.9	1803.9	773.8	2955.8	3587.7	1169.0	4991.9
H	826.6	546.4	654.8	1926.3	785.4	2587.8	2342.4	939.2	3496.6

“In” vs. “Out” numerical offset results: N and P load offsets for MS4 areas that irrigate with reclaimed wastewater

Should there be a numerical offset for loads recovered inside reclaimed wastewater irrigation areas of MS4s? (Preliminary results further expanded in Phase III)

Comparing nutrient loadings inside and outside areas with reclaimed wastewater usage: **TP for SS**

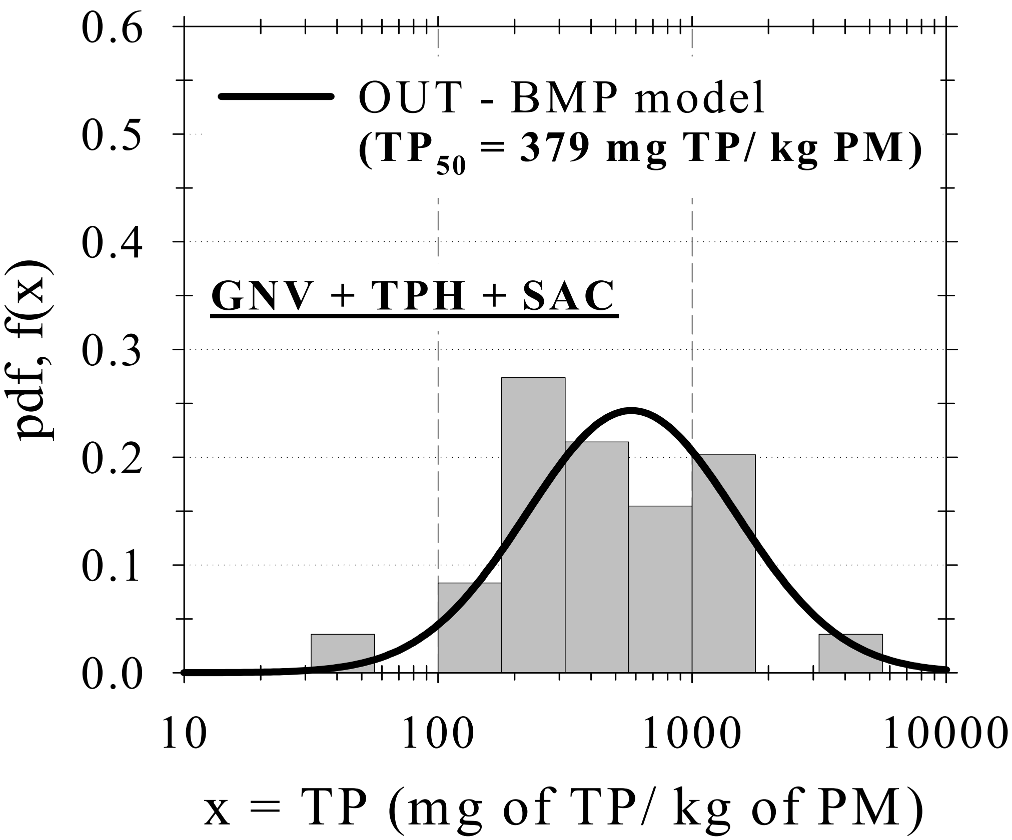


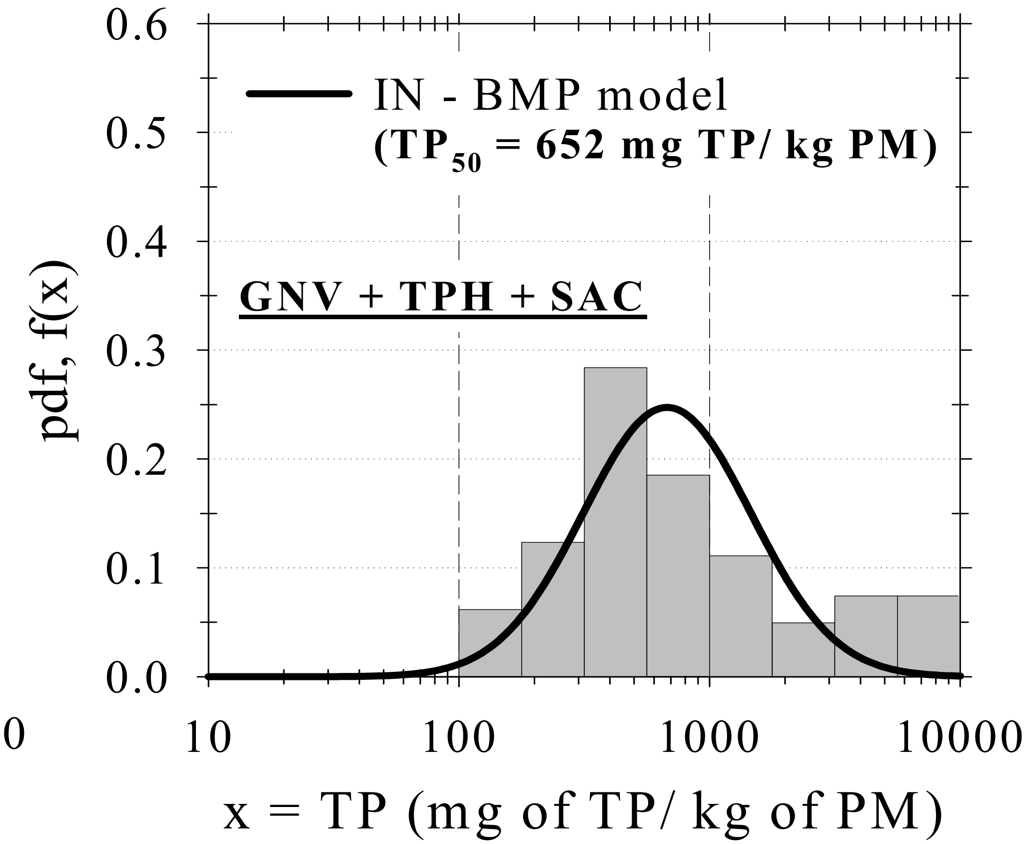


Total Phosphorus (TP) for Street Sweepings (SS)

No statistically significant difference between collected datasets at 95% C.L.

Comparing nutrient loadings inside and outside areas with reclaimed wastewater usage: **TP for BMPs**

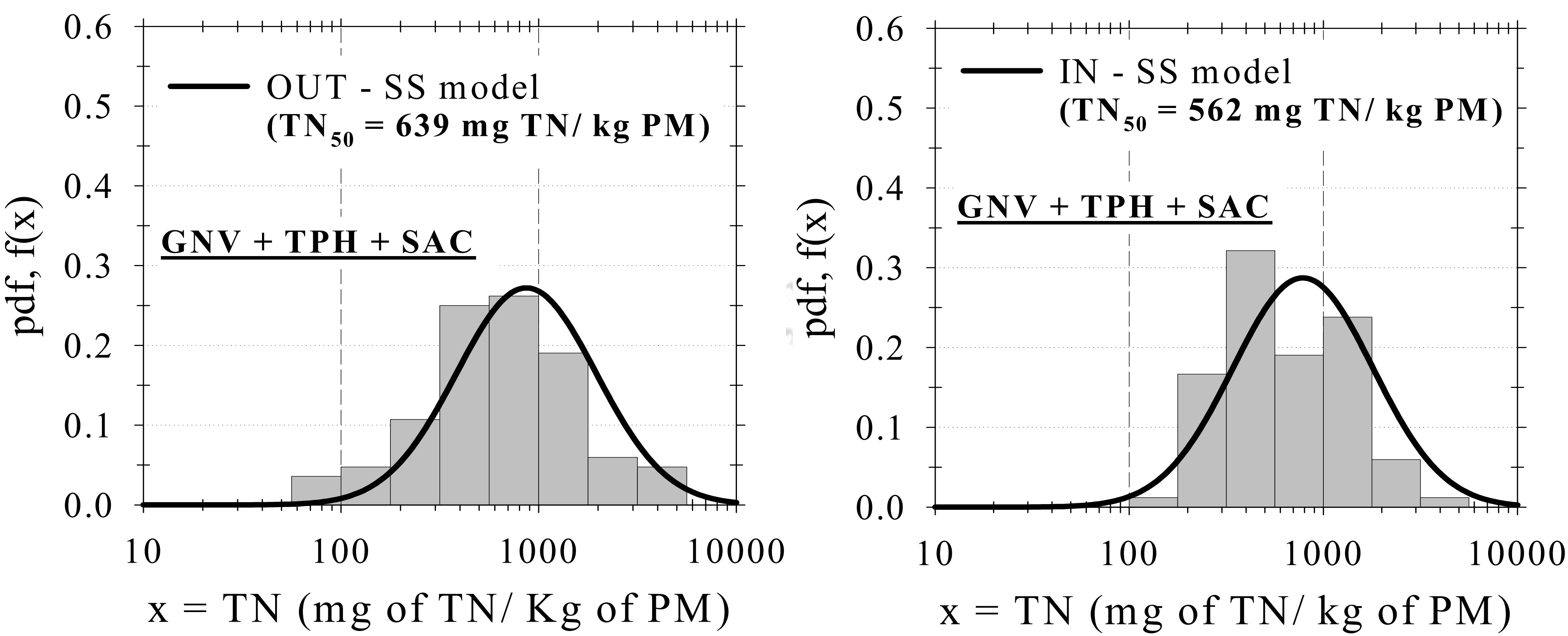




Total Phosphorus (TP) for BMPs

Statistically significant difference between collected datasets at 95% C.L.

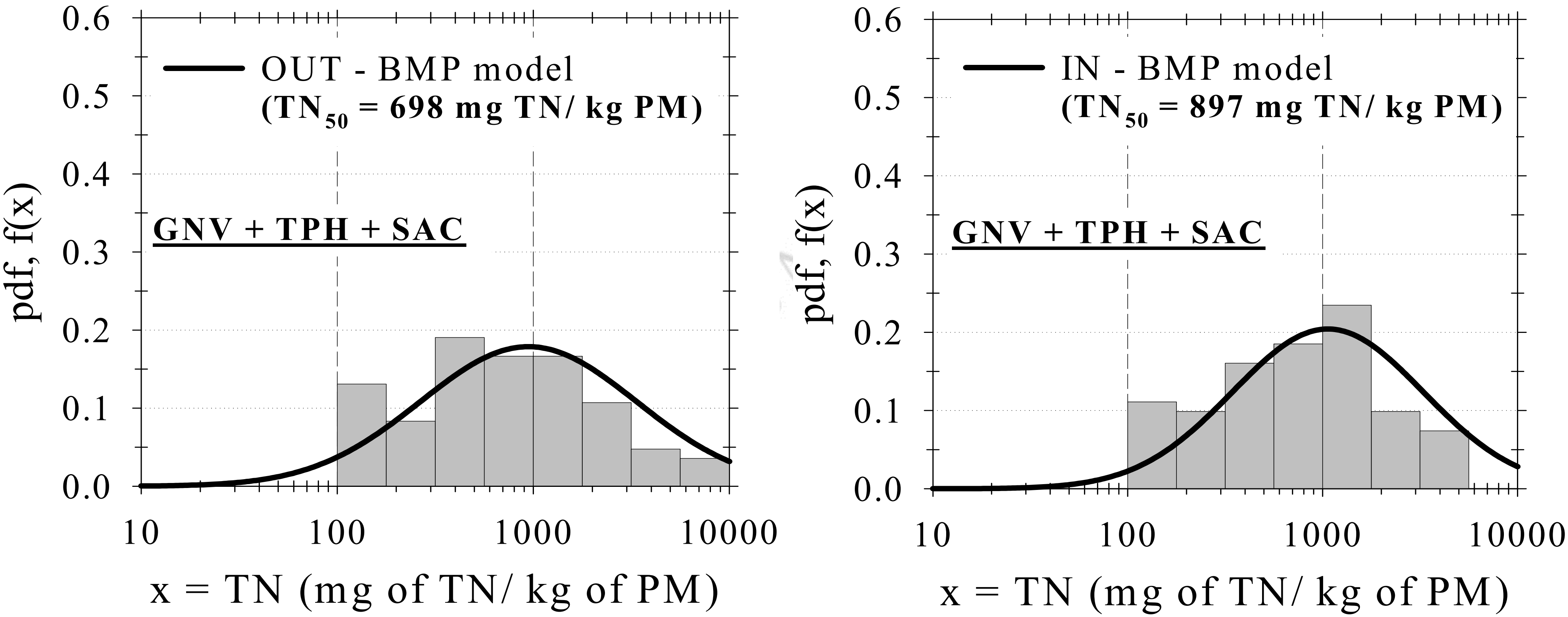
Comparing nutrient loadings inside and outside areas with reclaimed wastewater usage: **TN for SS**



Total Nitrogen (TN) for Street Sweepings (SS)

No statistically significant difference between collected datasets at 95% C.L.

Comparing nutrient loadings inside and outside areas with reclaimed water usage



Total Nitrogen (TN) for BMPs

No statistically significant difference between collected datasets at 95% C.L.

Moisture Content (MC) and Bulk Density (ρ_b)

Moisture Content (MC):

1. PM recovered in a maintenance operation **is never** dry ("Dry" ≡ 0% MC)
2. MC will be generally lowest for street sweeping PM, and MC will generally be highest for PM recovered from BMPs
3. Project metrics and FDEP credits are based on dry mass of PM; all results (including future) must be on a dry (MC = 0%) basis

Bulk Density (ρ_b):

1. All PM has intra- and inter-particle porosity that is occupied by fluids (gases or liquids) and the ρ_b is a non-linear function of MC, densification, granulometry,…
2. The **preferred method** to generate dry PM mass is gravimetric: to measure moist PM mass and convert the measurement(s) to dry mass with MC measurement(s)
3. Recognizing that PM is often (**and less preferably**) measured volumetrically, the volume of a PM deposit (wet or dry) must be converted to dry PM mass
4. This conversion requires ρ_b (dry mass/volume of a PM deposit)

What is a representative moisture content (MC) associated with collected PM deposits ?

Moisture content (%)	Range	Max.	Min.	Median	25%	75%
BMP	768.2	768.3	0.1	34.1	19.2	63.4
CB	759.6	759.9	0.3	26.9	16.3	40.3
SS	314.3	314.3	< 0.1	5.9	2.2	18.7

- Representative nutrient load credit requires MC of PM: measured and eventually modeled *(Recall that the study samples were sampled as moist)*
  - BMPs have highest MC: BMPs predominately have wet sumps
  - CBs have an intermediate MC: CBs by design should be free-draining
  - SS have the lowest MC: SS are in equilibrium with atmospheric MC

For the first year that each MS4 is involved in the load credit process, each MS4 requesting credit will provide to FDEP supporting MC and ρ_b data in a physically and statistically defensible manner as part of their verification process for load credits.

Example: Street Sweeping Costs from Phase II (2011)

- Cost of street sweeping is based on utilizing a street sweeping contractor, a common practice in Florida

Street Sweeping Cost: $30.14 per mile (City of Oakland Park, Florida by FDOT in 2011)
(Cost range by Florida MS4s = $17.20 – $28.30)

1 pound of TP → 8.5 pavement miles → $257/lb TP

1 pound of TN → 5.5 pavement miles → $165/lb TN

- These costs do not include solid waste landfill disposal (on the order of $80 to $95/ton)
- Note: Recovery costs for maintenance of each HFU or BMP type does not include solid waste landfill costs

Example: BMP Separation and Recovery: PM, TP, TN

- This examples utilizes a common screened **hydrodynamic separator (screened HS)** and monitored data for the performance of a screened HS subject to actual storm events
- HS units and comparison of HS units subject to controlled and uncontrolled loadings (actual events) are well-documented:
- (Kim and Sansalone 2008; Sansalone and Ying 2008; Sansalone and Pathapati 2009; Dickenson and Sansalone 2009, Pathapati and Sansalone 2011).

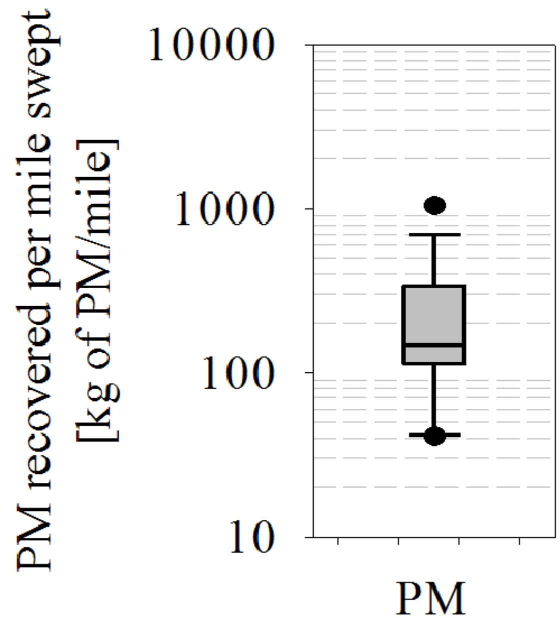
Parameters: (Note: in this case knowledge of runoff loads must be used)

1. Drained urban area of 2000 m^2
2. Annual removal efficiency of 50% for PM
3. No washout and scour from screened HS (Hydro-fantasy !)
4. A yearly rainfall depth of 1270 mm (for GNV, from NOAA)
5. Based on 22 monitored rainfall-runoff events for GNV
6. Watershed-based 400 mg/L PM (suspended + settleable + sediment)
7. Hydrology: Berretta and Sansalone, 2011a; Berretta and Sansalone 2011b

Why measure [kg of PM/mile] and not just miles swept?

<u>A pavement cleaning (street sweeping) metric [kg of PM/mile] depends on:</u>

1. how loaded with PM is the pavement
2. frequency swept
3. inter-event rainfall time
4. previous rainfall frequency/intensity/duration
5. equipment type
6. how the equipment is operated, i.e. speed
7. location on the pavement
8. PSD (particle size distribution): more work is required to differentiate PSDs



However, [mg of N,P/kg of PM] is not dependent on 1 to 7 but dependent on 8 (at this time there is no substitute for load verification based on kg of PM/mile)

Impact of maintenance interval on PM removal efficiency

(Results validated with actual events of return periods at ~ 1 month)

Treatment Train:

- Primary (Type I) settling followed by secondary filtration

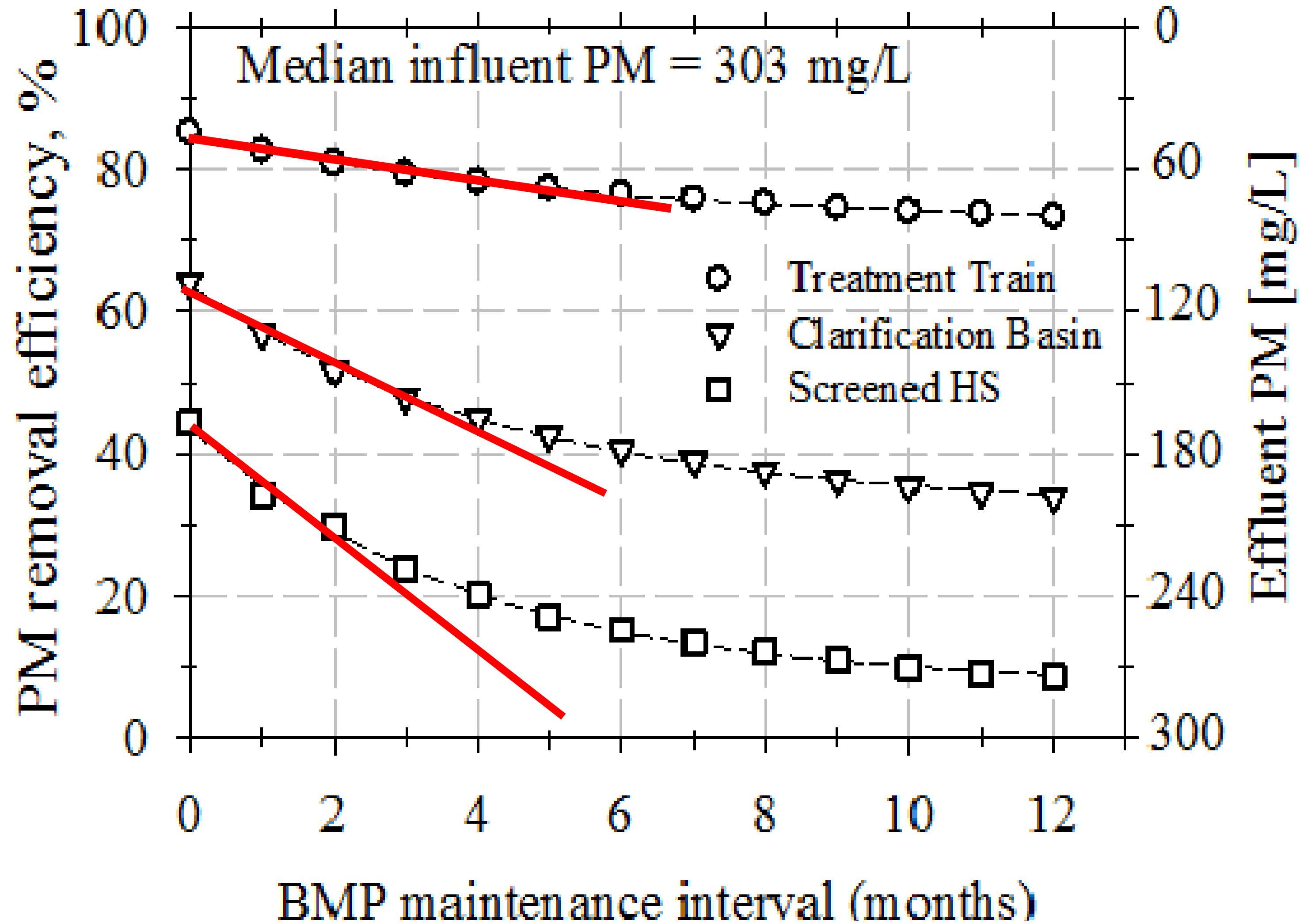
Clarification Basin:

- Primary (Type I) setting

Screened HS:

- Primary (Type I) setting and size exclusion by screen

Screened HS function governed by cleaning interval, whereas treatment train can be governed by head loss



Example: PM, TN, TP Recovery from BMPs

- Utilizing example parameters and peer-reviewed scientific literature:

627 lb of PM (284 Kg) separated yearly by a screened HS (BMP)

627 lb PM → 0.23 lb TP and 0.56 lb TN separated for one BMP

To recover 1 pound of TP → 4.4 BMPs need to be maintained

To recover 1 pound of TN → 1.8 BMPs need to be maintained

- While example uses annual maintenance frequency, most BMPs need more frequent maintenance to reduce PM washout and changing inter-event sump water chemistry

<u>Excerpt from Table 8:</u>

HFU	TP [mg/kg]			TN [mg/kg]		
	Mean	Median	St. Dev.	Mean	Median	St. Dev.
Street Sweeping (SS)	512.5	361.0	599.9	1012.2	563.0	1422.2
Catch Basin (CB)	552.2	416.8	481.8	1729.1	679.1	2601.6
BMP	647.1	363.9	728.9	2648.1	898.5	3983.1

Example: BMP Costs (2011)

1. Catch basin have only a maintenance cost (not designed or intended for PM separation)
2. BMP costs include the capital cost for the BMP (designed and purchased for PM separation) and the cost of maintenance
3. For this example utilizing a screened HS and GNV hydrology:
    - Median capital costs (\$25K) (range is \$20K to \$30K) at 4% interest
    - BMP design life is 25 years → Annualized capital cost ~ \$1600
    - With an annual frequency → Annualized maintenance cost ~ \$500
4. 1 pound of TP → 4.4 BMPs → \$9.2K/pound of TP (3.2K – 36.7K)
5. 1 pound of TN → 1.8 BMPs → \$3.7K/pound of TN (1.3K – 14.9K)
6. The bracketed ranges allow for parameter variability of:
    - Annual interest rate from 0 to 6% and capital costs from \$20 to 30K
    - PM separation efficiency from 90% to 20%
    - Maintenance frequency of once per year to twice per year

Cost $/Pound (2011): PM, TP, TN Separation or Recovery

Separation or Recovery Method	Cost ($/lb) (excluding SW landfill costs) TN	TP	PM
BMP Treatment Train[a]	935	**32,600**	26
FL Database for BMPs[b]	1,900	10,500	**41**
Screened Hydrodynamic Separator[c]	**3,730 (1,280 - 14,860)**	9,210 (3,170 - 36,680)	4 (1 - 13)
Baffled Hydrodynamic Separator[c]	3,020 (1,280 - 14,860)	7,450 (3,170 - 36,680)	3 (1 - 13)
Street Cleaning (lowest cost)	**165**	**257**	**0.10**
Catch Basin Cleaning[d] (2nd lowest)	1,016	1,656	0.70

[a] Wet basin sedimentation followed by granular media filtration, UF, 2010.

[b] TMDL database for FL Best Management Practices, 2009

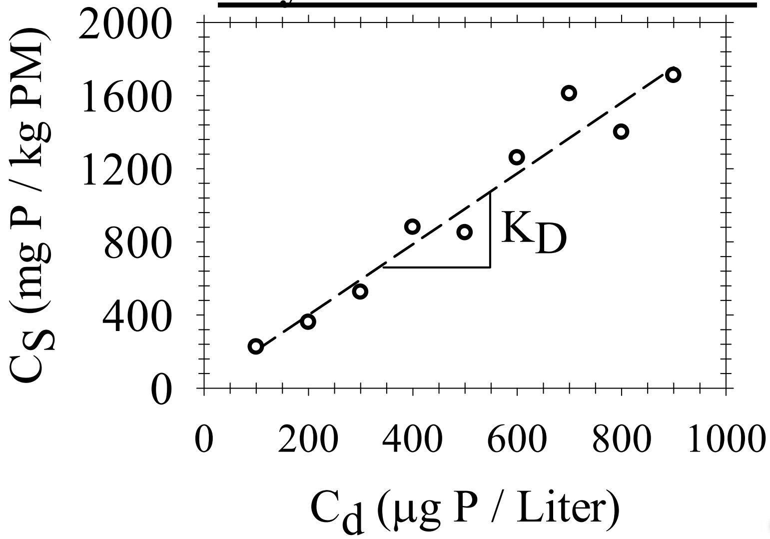
[c] Based on 2000 m^2 urban catchment draining to a screened hydrodynamic separator (HS) with 50% PM annual removal efficiency ***based on clean sump conditions***

[d] Based on 100 dry pounds of PM recovery with an annual cleaning frequency

Is it scientific heresy to include Florida basins in the same "population" as other BMPs in this study?

For the metrics of Phase II are BMPs created equal?

Physical-chemical basis:



- Different BMP classes provide significantly different treatment levels for the aqueous phase. However, in all BMPs an equilibrium is established between aqueous and PM phases that is dependent on influent PM and dissolved concentration [C_d].
- μ_{50} runoff P: f_d is 25 to 35%, K_D: 10^4 to > 10^6 L/kg
- μ_{50} runoff N: f_d is 55 to 65%, K_D: 10^2 to > 10^4 L/kg

Statistical basis (at 95% C.L.):

FL BMP Population (w/ or w/o basins)	P-value	Median	25%	75%
TP [mg/kg] (all BMPs with basins)	0.69	363.9	239.8	914.4
TP [mg/kg] (BMPs without basins)		382.7	258.9	941.3
TN [mg/kg] (all BMPs with basins)	0.65	898.5	377.1	2283.3
TN [mg/kg] (BMPs without basins)		940.0	405.2	2356.9

- For a given watershed and land use the [mg N,P/kg PM] recovered from BMPs **are not statistically different**. This does not imply that manufactured BMPs are equal to FL basins.

Conclusions from Phase II Florida-based MS4 study

1. The consistent log-normality of TN and TP results leads to the recommendation of a median (50^{th} percentile) concentration [mg/kg] from each TN and TP distribution.

2. This result is important for **allocation of load credits** because the results are not represented by a singular concentration [mg/kg] but by log-normal distributions

3. From 3 MS4s, results illustrate reclaimed wastewater potentially enrich urban PM/detritus with P and likely other constituents (not measured herein). Results have physical basis.

4. The cost of load recovery for PM, TP and TN by maintenance practices, in particular for street sweeping, is significantly lower than current manufactured BMPs, even assuming such BMPs are maintained annually and do not scour or washout. (See following $/pound slide)

5. Moisture content (MC) is a critical parameter for load credits. This study recommends that a MS4 measure MC for a year in order to develop a MC factor as a function of HFU.

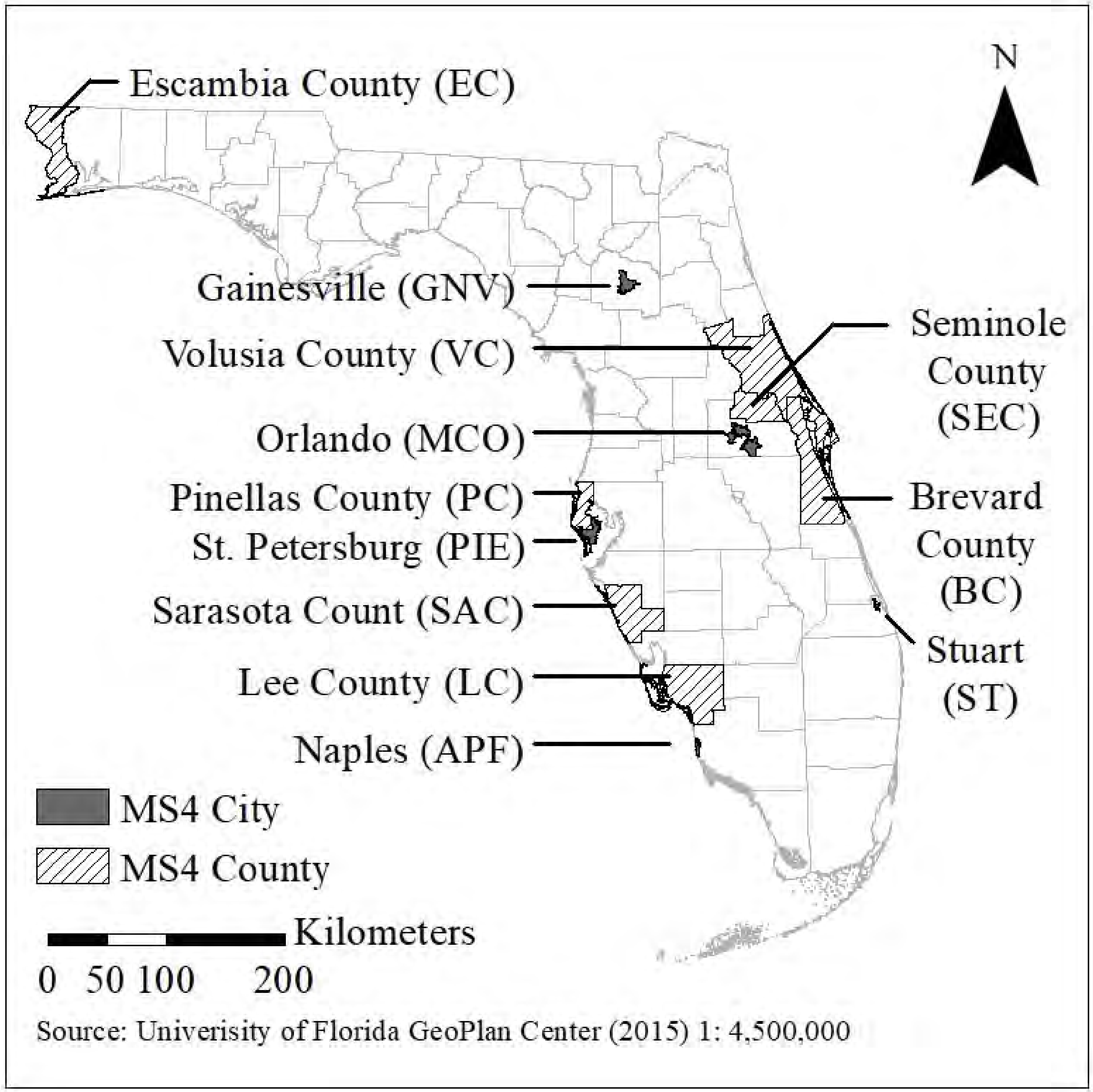
6. For PM-based nutrient concentrations (not loads), basins are statistically equivalent to manufactured BMPs despite far superior aqueous treatment and hydrologic benefits of basins

7. Study results provide a Florida-wide basis and is not intended to compare MS4s

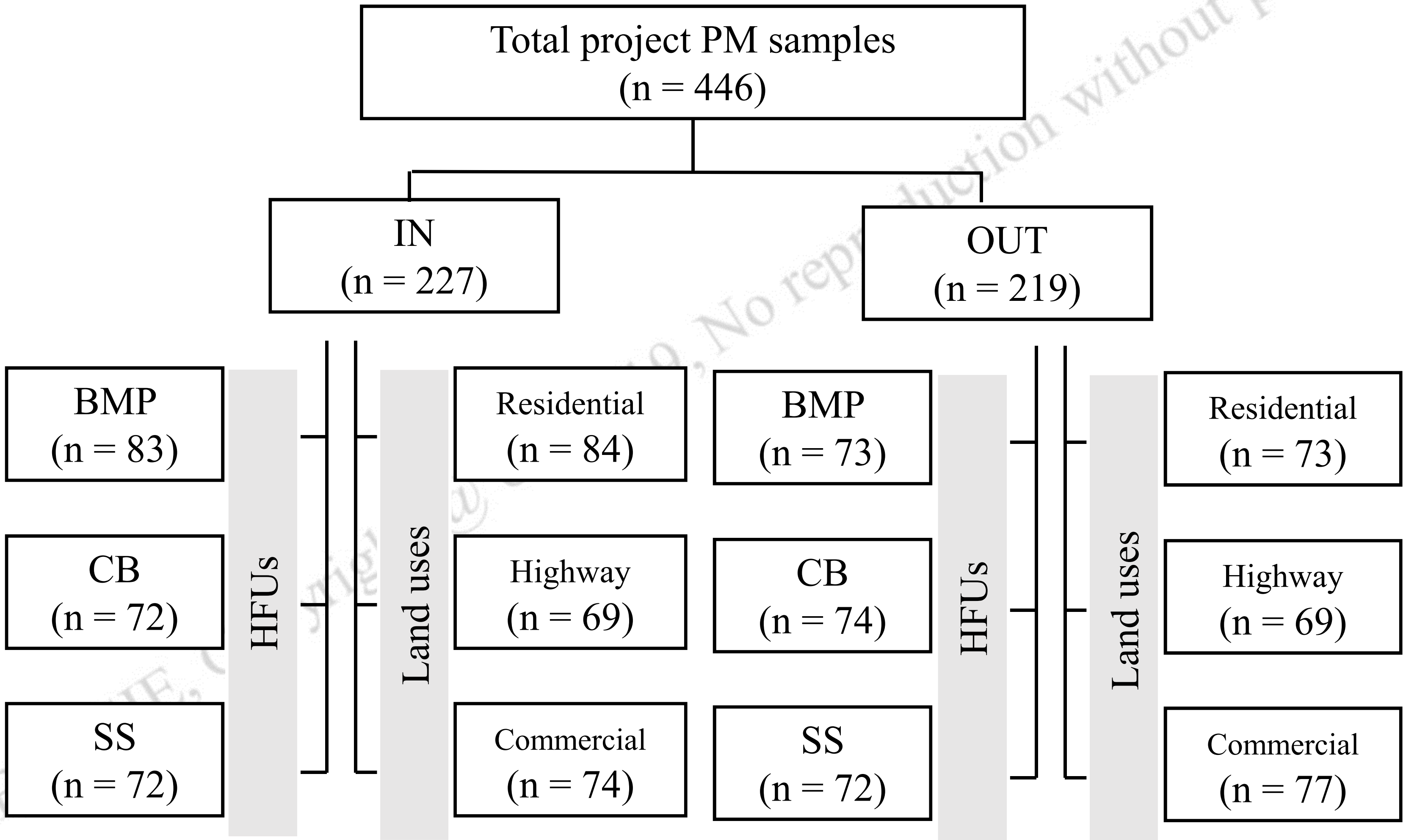
Phase III Summary

1. Phase II vs. Phase III results
2. Inside vs. Outside wastewater reclaimed area enrichment of PM
3. The economics of BMPs for load recovery

Florida distribution of 12 MS4 locations (Phase III)



Phase III sampling matrix and sample numbers



Test of difference between Phase II and Phase III

Method to compare difference:

Mann-Whitney U (MW) test is a nonparametric test that compares the medians of two groups (Phase II and III).

> Note:
> Nonparametric = no assumption of distribution of data;
> H_0 = null hypothesis;
> H_1 = alternative hypothesis.

Two-sided hypothesis test: (α = 0.05, 95% C.I.)

H_0: Phase II and III have equal medians.

H_1: Phase II and III have different medians.

test if Phase II = III

Right-tailed hypothesis test: (α = 0.05, 95% C.I.)

H_0: the median of Phase II is less or equal to the median of Phase III.

H_1: the median of Phase II is greater than the median of Phase III.

test if Phase II $\leq$ III

Left-tailed hypothesis test: (α = 0.05, 95% C.I.)

H_0: the median of Phase II is greater or equal to the median of Phase III.

H_1: the median of Phase II is less than the median of Phase III.

test if Phase II $\geq$ III

Possible outcomes:

$x_1 = x_2$

$x_1 < x_2$

$x_1 \leq x_2$

$x_1 > x_2$

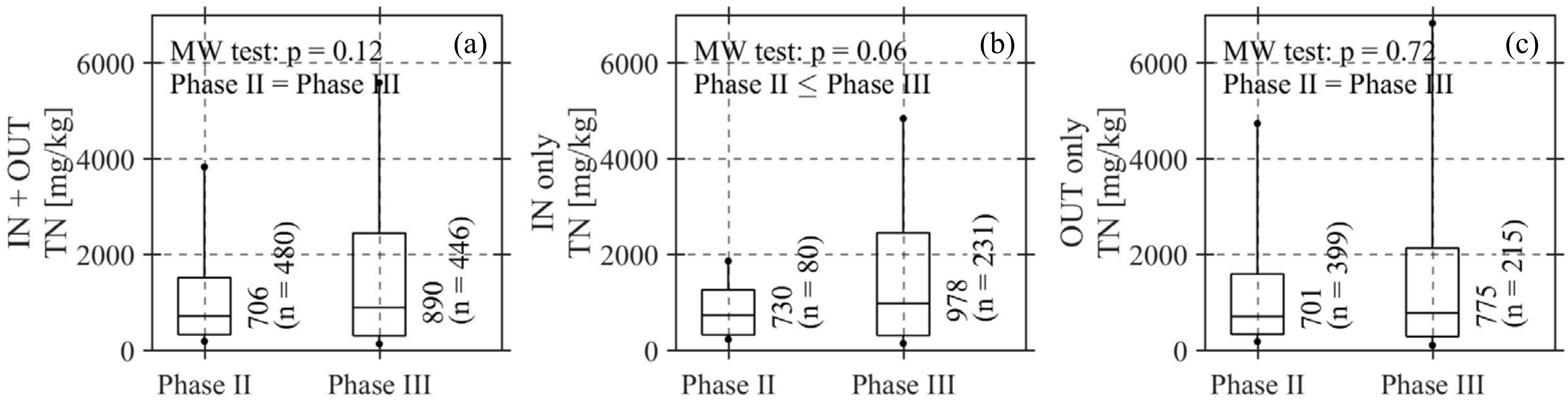
$x_1 \geq x_2$

Numbers of samples from Phase II and III:

	Phase II MS4s	IN	OUT			Phase III MS4s	IN	OUT
GNV	Alachua County - Gainesville	27	27	↔	GNV	Alachua County - Gainesville	29	30
EC	Escambia County - Pensacola	0	28	↔	EC	Escambia County	18	18
LC	Lee County	0	28	↔	LC	Lee County	18	18
ST	Martin County - Stuart	0	27	↔	ST	Martin County - Stuart	18	18
MCO	Orange County - Orlando	0	30	↔	MCO	Orange County - Orlando	18	18
OC	Orange County	0	27		OC	Orange County	0	0
PIE	Pinellas County - St. Petersburg	0	27	↔	PIE	Pinellas County - St. Petersburg	12	12
PC	Pinellas County	0	0		PC	Pinellas County	18	18
SAC	Sarasota County	27	29	↔	SAC	Sarasota County	17	18
SEC	Seminole County	0	26	↔	SEC	Seminole County	14	14
JAX	Duval County - Jacksonville	0	27		BC	Brevard County	29	19
HC	Hillsborough County	0	27		APF	Collier County - Naples	22	14
TPH	Hillsborough County - Tampa	27	27		VC	Volusia County	18	18
TAL	Leon County - Tallahassee	0	27					
MDC	Miami-Dade County	0	42					
SUM	(IN + OUT = 480)	81	399	↔	SUM	(IN + OUT = 446)	231	215

Note: IN = sampled from reclaimed-IN area; OUT = sampled from reclaimed-OUT area.

Comparison between Phase II and III: TN (overall and subsets)



Note: $p > 0.05$ indicates TN for Phase II is equal to Phase III.

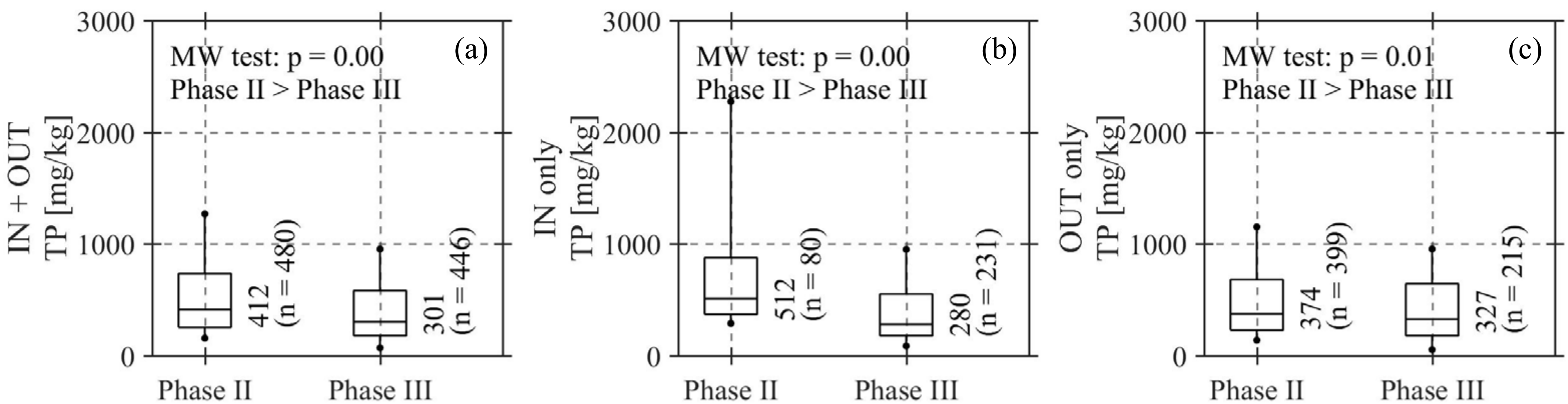
Conclusions:

1) For total nitrogen (TN), Phase II has a consistently equivalent median to Phase III, whether comparing (a) IN+OUT data, (b) IN data only, or (c) OUT data only.
2) MW test of plot (b) as follows:

test of 1st H_0: Phase II = Phase III Result: p-value = 0.06, fail to reject H_0;
test of 2nd H_0: Phase II ≤ Phase III Result: p-value = 0.97, fail to reject H_0;
test of 3rd H_0: Phase II ≥ Phase III Result: p-value = 0.03, reject H_0;

⇒ Phase II ≤ Phase III

Comparison between Phase II and III: TP (overall and subsets)

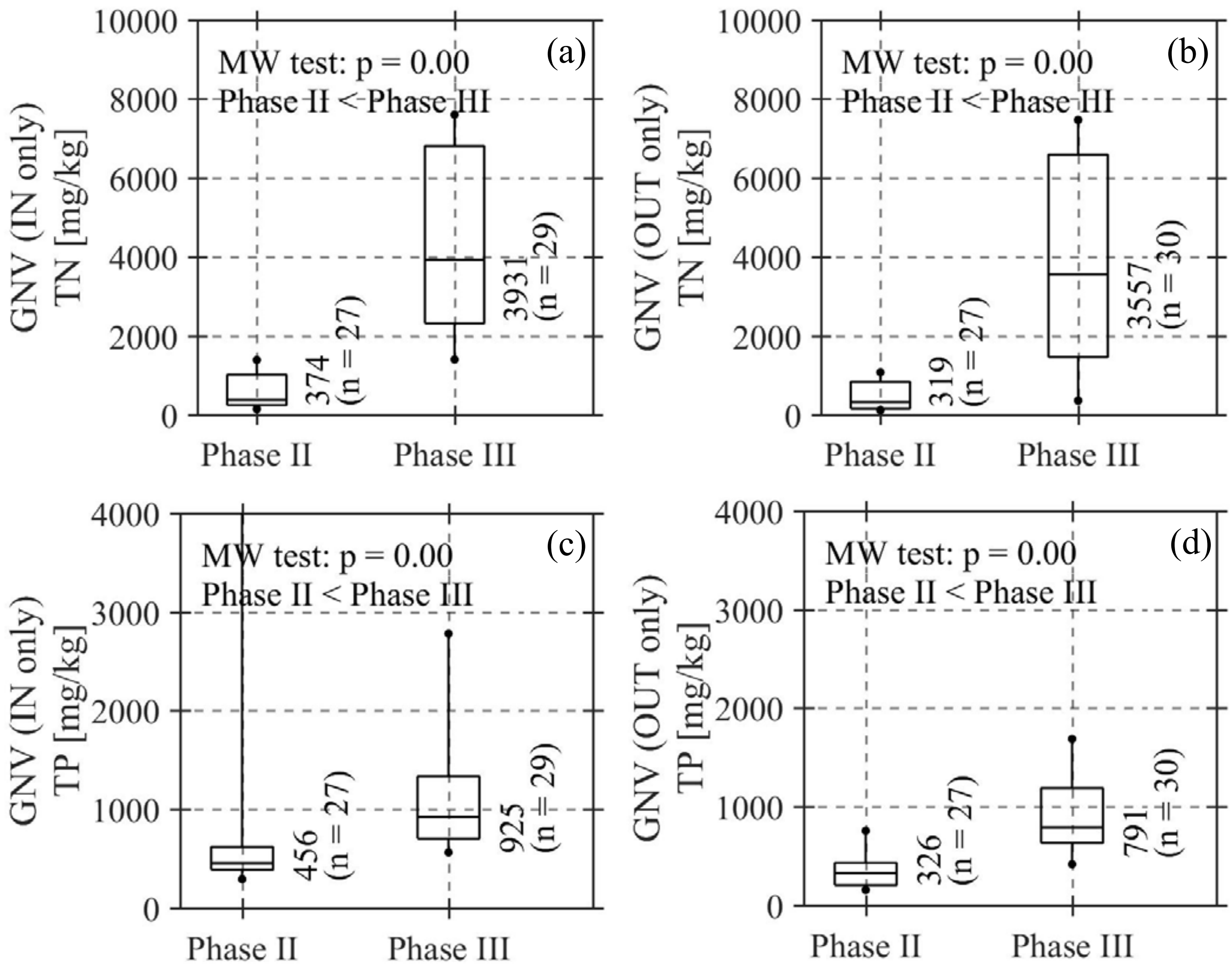


Note: if p > 0.05 indicates Phase II is equal to Phase III.

Conclusions:

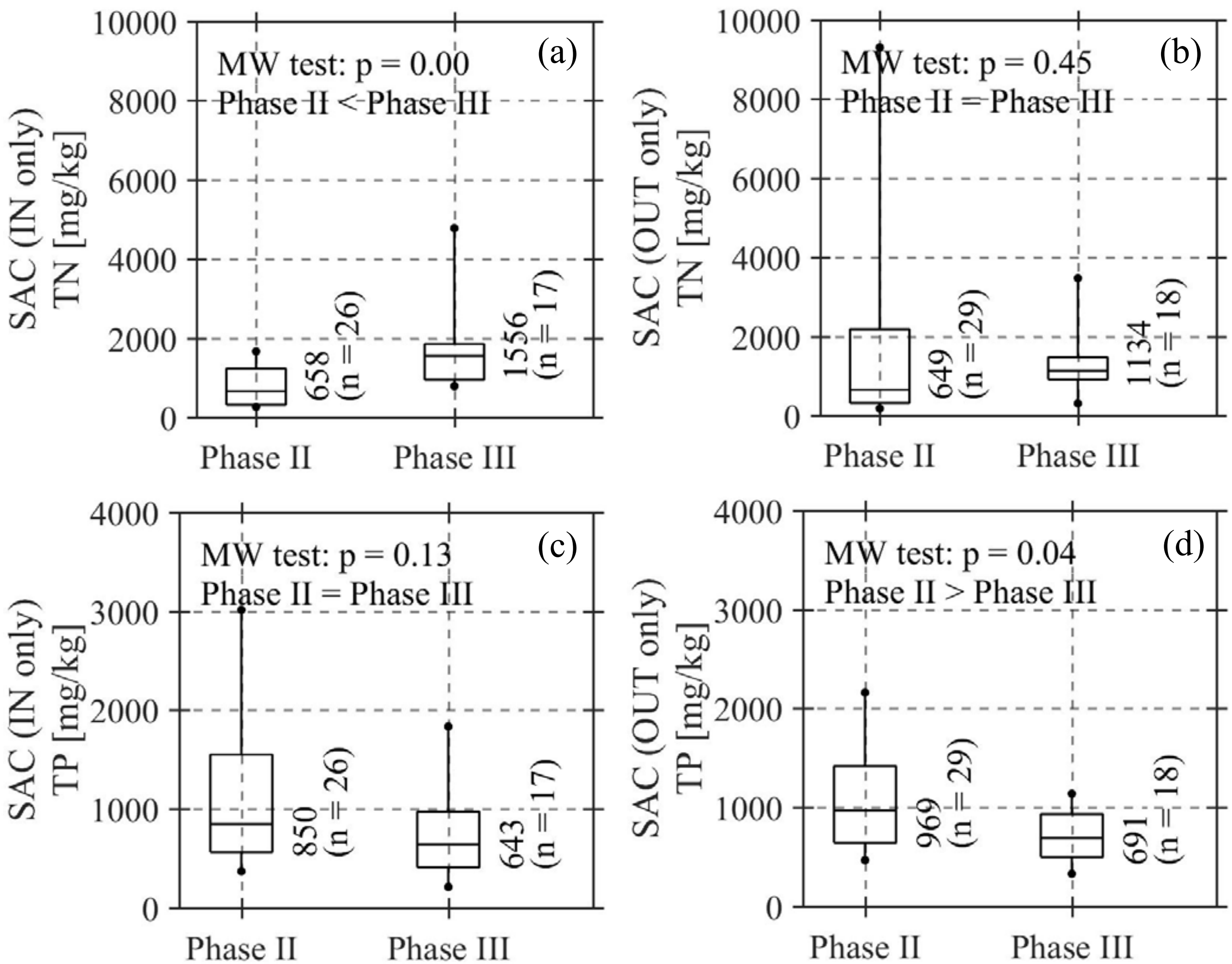
1) For total phosphorus (TP), Phase II has a consistently greater median than Phase III, whether comparing (a) IN+OUT data, (b) IN data only, or (c) OUT data only.
2) Even though there is a statistically significant difference for (a), (b), and (c), a reduction in enrichment is difficult to infer because of unpaired sampling locations and seasonality (see later result).

Example: Comparison Phase II vs. III: Gainesville (GNV) only



1. Gainesville (1 MS4) has a consistently smaller median from Phase II than Phase III, whether for IN vs OUT area for both TN and TP analyses.
2. There is TN and TP apparent "enrichment" for Gainesville from 2011 to 2018.
3. The enrichment occurred for both IN and OUT areas.
4. **Seasonality** at the time of sampling is likely the most probable physically-based explanation for this enrichment. For Gainesville, Phase II was sampled in July 2010, and Phase III was sampled in March 2017.

Example: Comparison Phase II vs. III: Sarasota County (SAC) only



1. Sarasota has enrichment of TN from Phase II to III for reclaimed-IN area only.
2. No enrichment of TN observed for outside (OUT) reclaimed wastewater areas.
3. There is no enrichment of TP for reclaimed–IN areas.
4. There is a decrease of TP from Phase II to Phase III for reclaimed-OUT area.

Note: Sarasota was sampled in September 2010 for Phase II, and August 2017 for Phase III (**same season sampling**).

Comparison between Phase II and III: other MS4s

TN from reclaimed-OUT area					
MS4	Phase II		Phase III		MW test
	n	median	n	median	
EC	28	419.06	18	136.85	Phase II > Phase III
LC	28	483.59	18	610.20	Phase II = Phase III
ST	27	814.77	18	313.27	Phase II > Phase III
MCO	30	1659.78	18	1006.32	Phase II = Phase III
PIE	27	614.23	12	683.35	Phase II = Phase III
SEC	26	1229.75	14	2009.36	Phase II = Phase III

TP from reclaimed-OUT area					
MS4	Phase II		Phase III		MW test
	n	median	n	median	
EC	28	96.22	18	36.00	Phase II > Phase III
LC	28	407.48	18	354.40	Phase II = Phase III
ST	27	286.72	18	183.65	Phase II > Phase III
MCO	30	552.50	18	425.28	Phase II = Phase III
PIE	27	249.08	12	265.52	Phase II = Phase III
SEC	26	350.54	14	333.72	Phase II = Phase III

1. Under the analyses with no inside reclaimed area samples, 4 out of 6 MS4s show no statistical different between Phase II and Phase III data for the outside reclaimed area samples.
2. The other 2 MS4s (EC and ST) both have a greater median from Phase II than Phase III.
3. The results stated above are consistent for both TN and TP analytes.

Sampling date		
MS4	Phase II	Phase III
EC	Jul-2009	Nov-2017
LC	Jul-2010	Feb-2017
ST	Oct-2009	Aug-2017
MCO	Aug-2010	Aug-2017
PIE	Apr-2009	Mar-2018
SEC	May-2010	Dec-2017

Conclusion: is there an enrichment between Phase II and III?

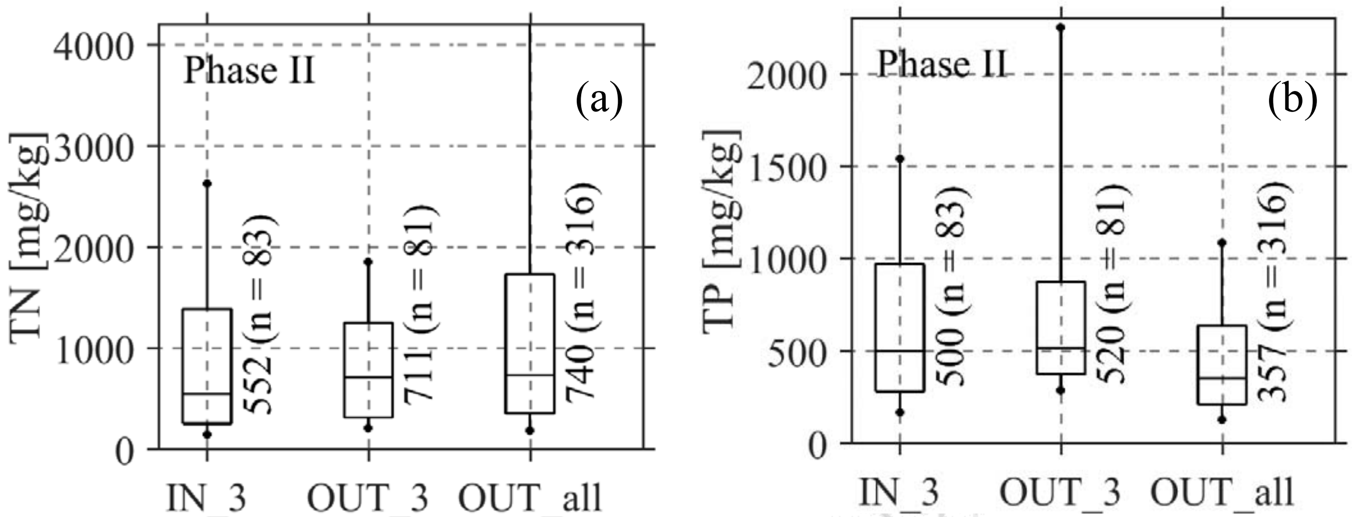
1) A comparison between Phase II and III using overall data are shown in the following table; however, this result is not evidence of enrichment given different sampling locations and seasonality during sampling.

Analyte	IN+OUT data	IN data only	OUT data only
TN	Phase II = Phase III	Phase II ≤ Phase III	Phase II = Phase III
TP	Phase II > Phase III	Phase II > Phase III	Phase II > Phase III

2) To answer the question that if there is an enrichment between Phase II and III, only two sets of data are available. GNV and SAC are the only two MS4s that were sampled both in 2011 and 2017 for both IN and OUT samples.
3) Result of GNV shows Phase III is significantly larger than Phase II for either TN or TP, from either IN or OUT area; but different sampling seasons (spring and summer) is the most probable explanation for this significant difference, instead of enrichment during time. Actual enrichment is not probable for GNV.
4) Result of SAC verifies there is an enrichment of TN between Phase II and III only for reclaimed-IN area. No enrichment is found for reclaimed-OUT area. There is no enrichment for TP.
5) **As a conclusion, only one set of data supports the enrichment of TN from 2011 to 2017(8) within reclaimed wastewater areas. Due to the limited dataset size, more sampling in a timely manner (seasonality issue) and the use of identical sampling locations is needed to demonstrate enrichment.**

Test of difference between reclaimed IN and OUT area in Phase II and III

Comparison between IN and OUT: Phase II



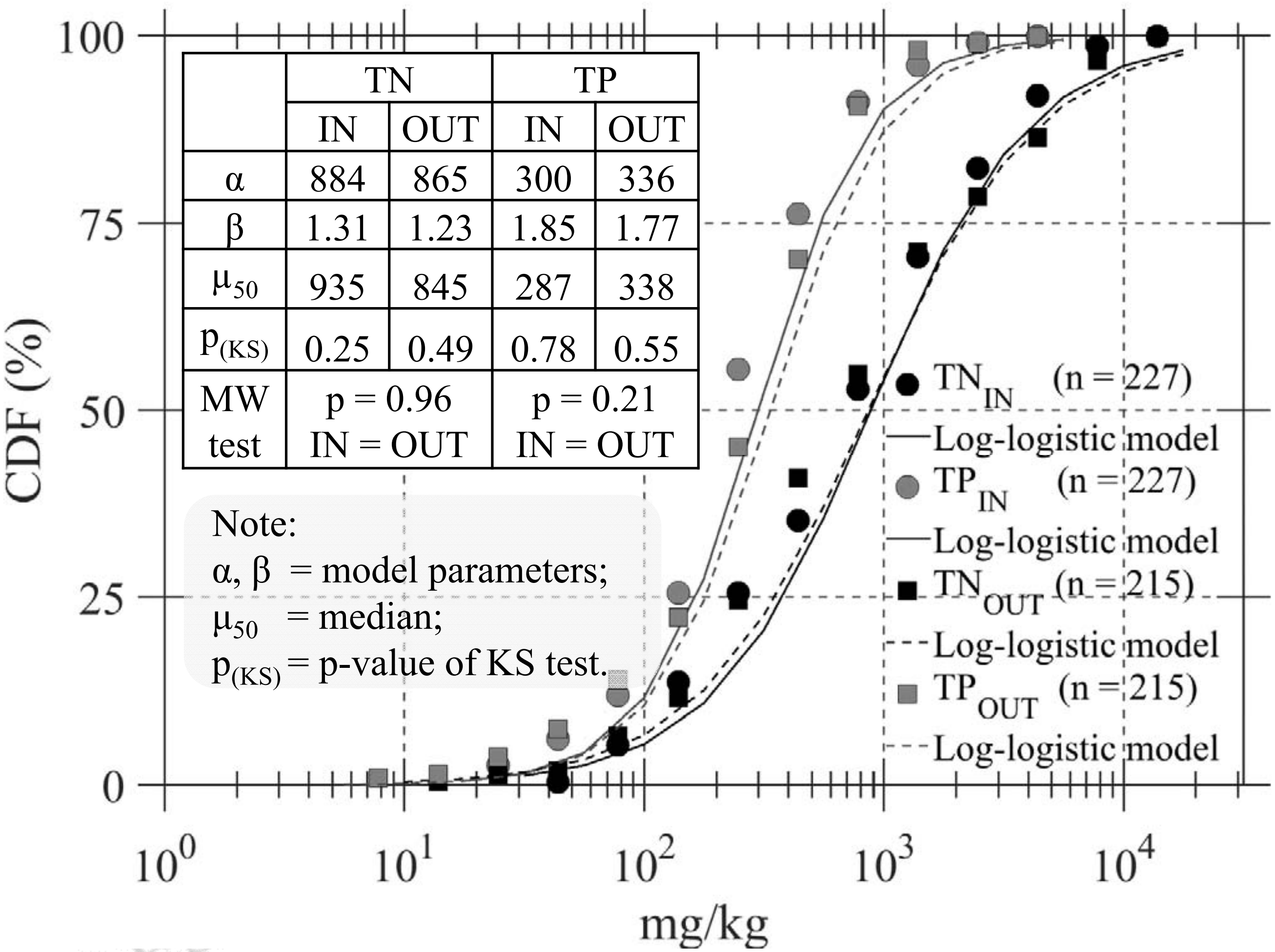
Label	Description	MW test For TN	MW test For TP
IN_3	Reclaimed-IN data from GNV, SAC, TPH	p = 0.46 IN_3 = OUT_3	p = 0.22 IN_3 = OUT_3
OUT_3	Reclaimed-OUT data from GNV, SAC, TPH		
OUT_all	Reclaimed-OUT data from all 14 MS4s		

Since there're only 3 MS4s sampled both IN and OUT samples in Phase II, the comparison is conducted only between IN_3 and OUT_3.

Conclusion:

No significant difference is found between IN and OUT samples from Phase II, for both TN and TP.

Comparison between IN and OUT: Phase III



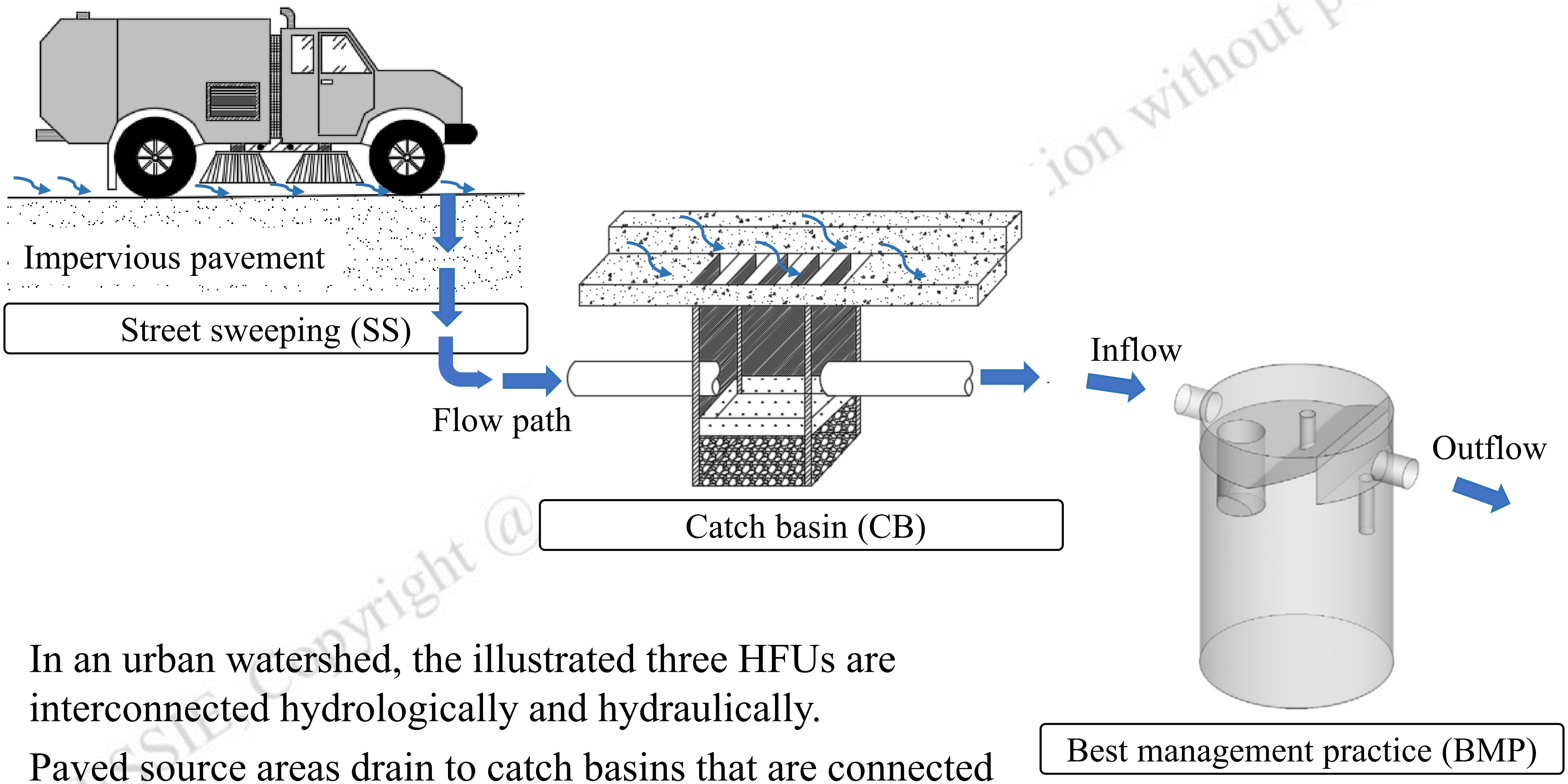
	TN		TP	
	IN	OUT	IN	OUT
α	884	865	300	336
β	1.31	1.23	1.85	1.77
μ_{50}	935	845	287	338
$p_{(KS)}$	0.25	0.49	0.78	0.55
MW test	p = 0.96 IN = OUT		p = 0.21 IN = OUT	

1. Phase III was designed to collect equivalent samples from reclaimed IN and OUT area for each MS4. Therefore, the entire dataset (all MS4s) is available for the difference test.
2. Kolmogorov–Smirnov (KS) test is adopted to test the goodness of fit of log-logistic model for TN or TP distributions to measurements, while the difference between IN and OUT is still conducted using MW test.

Conclusion:

No significant difference is found between IN and OUT samples from Phase III. This result is consistent for both TN and TP.

Illustration of hydrologic functional units (HFUs)



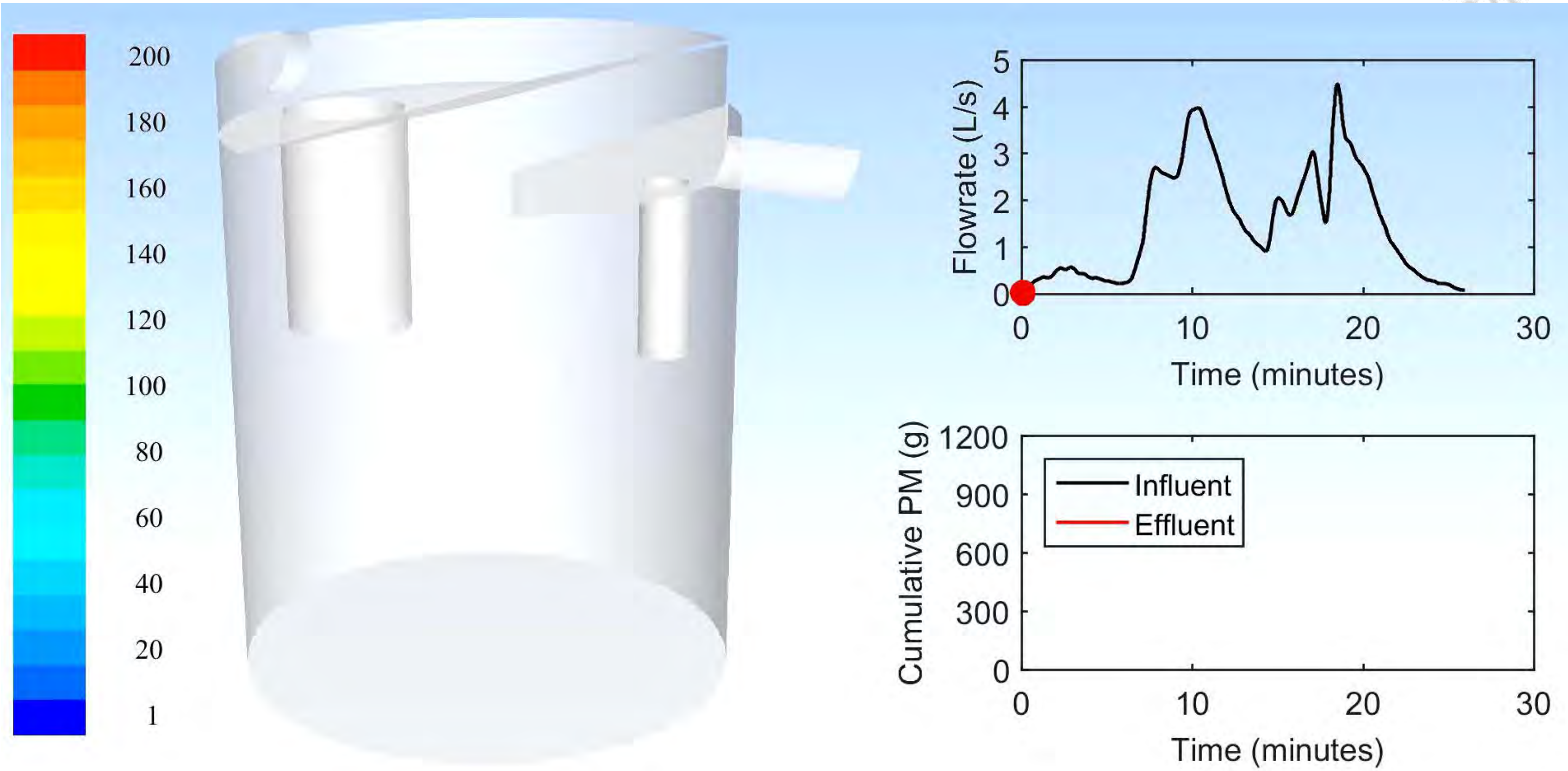
1. In an urban watershed, the illustrated three HFUs are interconnected hydrologically and hydraulically.
2. Paved source areas drain to catch basins that are connected with BMPs.

Projects (II and III) sampled a diversity of "BMPs"

(Diversity provided a robust FL-based metric and valuable debate)

BMP Classification (Phase III only)	IN	OUT
Pond (Basin)	18	20
Baffle Box	3	15
Swale, Ditch or Sediment Accumulation	32	22
Manufactured BMP (i.e. hydrodynamic separators)	13	10
Drainage or Sump Box (i.e. "French drains")	8	6
Total	**74**	**73**

Storm-driven Computational Fluid Dynamics for BMP Behavior



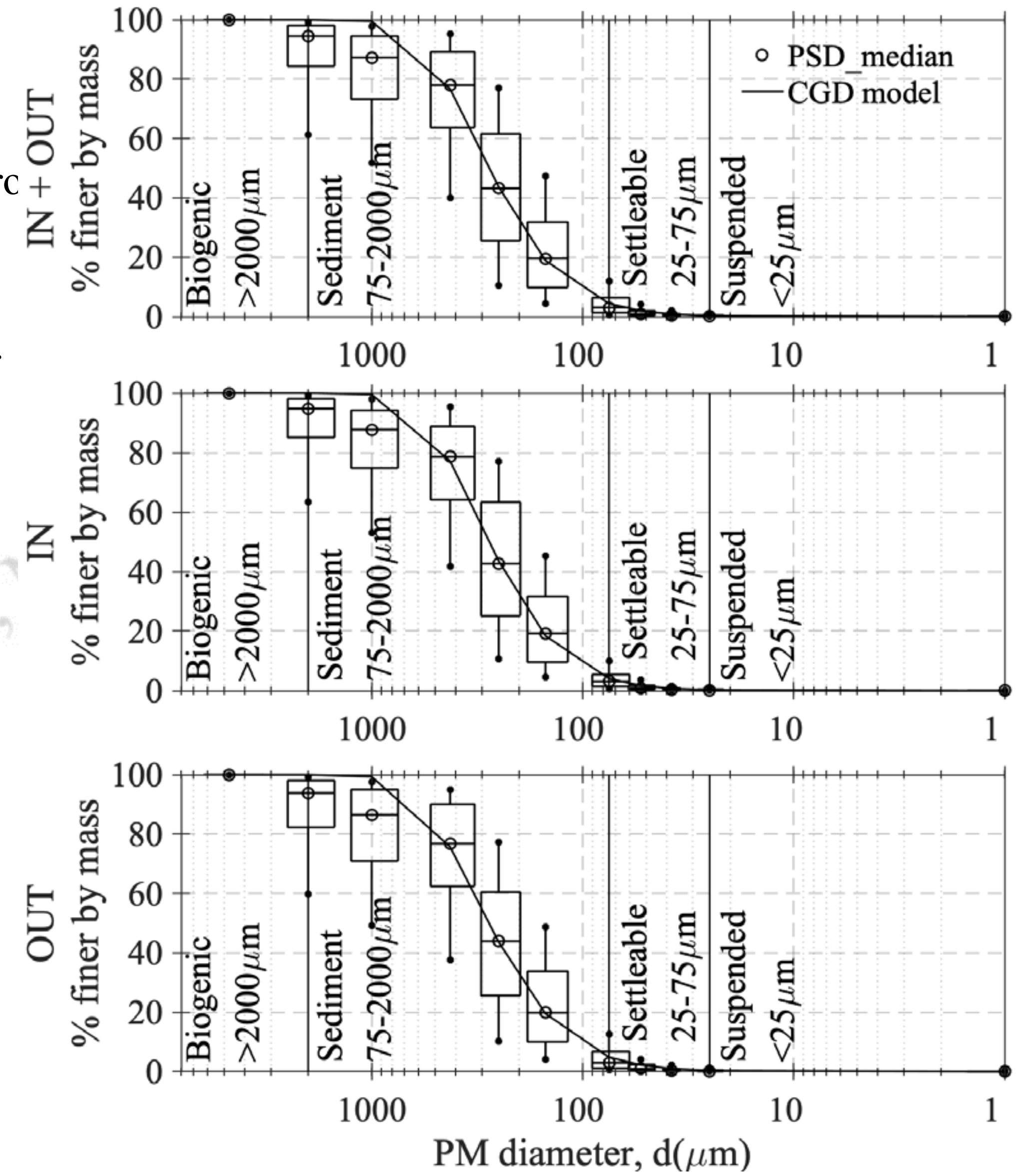
Particle diameter (µm)

FlowTime (minutes) 0.01

Sedimentation tank, UF campus
11 July 2010 storm event

PSD comparison between IN and OUT

1. No statistically difference of PSDs between samples frc IN and OUT of reclaimed water areas ($\alpha = 0.05$).
2. Reclaimed water has no effect on dry deposition PSD.
3. Therefore, sample data from IN and OUT are lumped for the PSD, TN, and TP distribution data analysis.



Statistics	Reclaimed/Non-reclaimed		
	IN + OUT	IN	OUT
Sample number	450	232	218
m_median (g)	2903.4	2879.5	2929.8
d_{10} (μm)	106.6	107.0	106.1
d_{50} (μm)	284.3	285.6	282.4
d_{90} (μm)	1389.6	1319.0	1475.8
CGD-α	2.8	2.9	2.6
CGD-β	113.1	108.4	121.7
R^2_{adj}	0.987	0.988	0.986

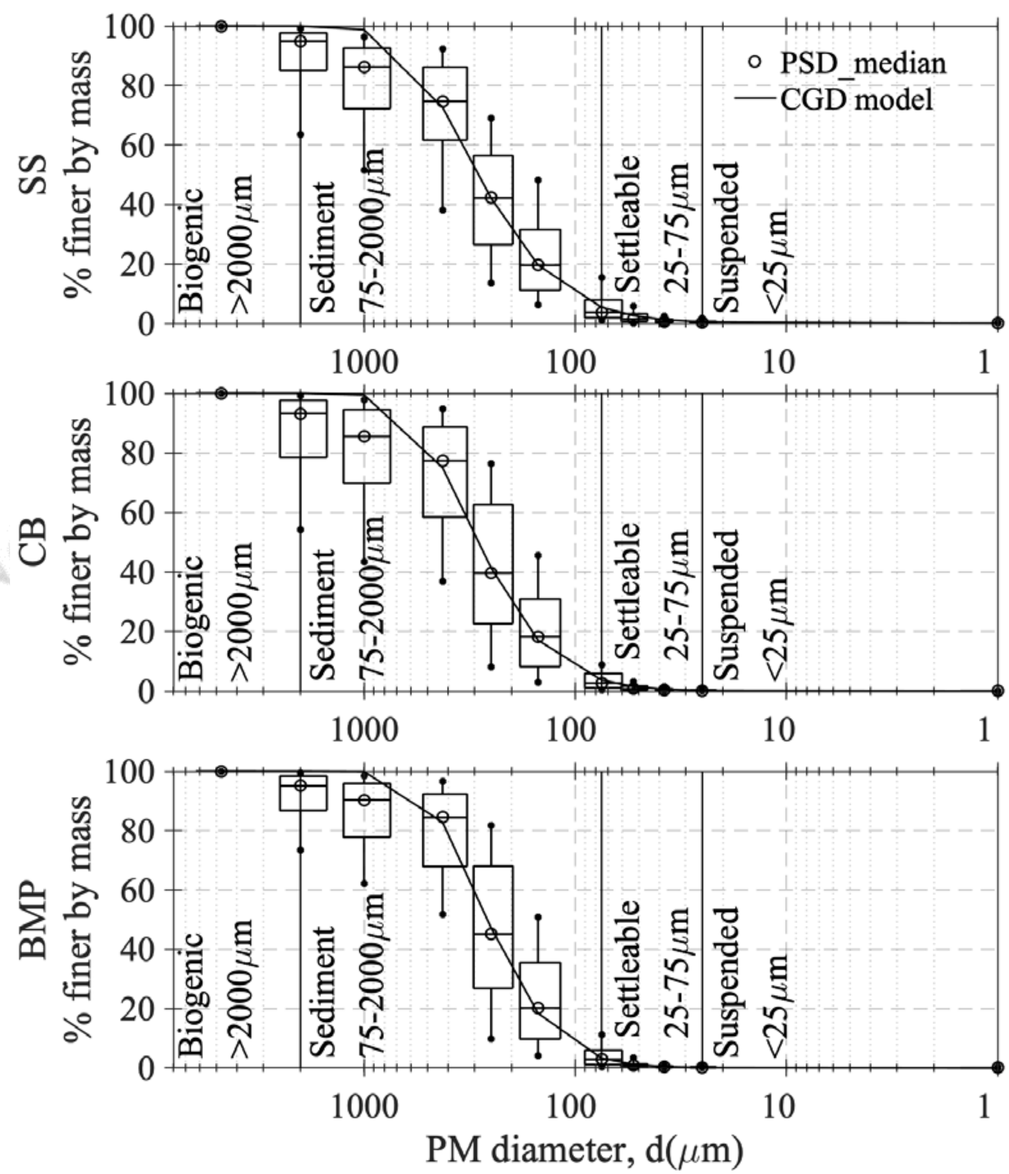
Note: CGD = cumulative gamma distribution

PSD comparison between HFUs based on PSDs

1. No statistically difference of PSDs between samples from IN and OUT of reclaimed water areas ($\alpha = 0.05$).
2. Reclaimed water has no effect on dry deposition PSD.
3. Therefore, sample data from IN and OUT are lumped for the PSD, TN, and TP distribution data analysis.

Statistics	HFU		
	SS	CB	BMP
Sample number	142	148	160
m_median (g)	3428.9	2807.4	2534.2
d_{10} (μm)	104.7	110.2	105.9
d_{50} (μm)	291.9	298.2	271.7
d_{90} (μm)	1433.2	1587.9	969.1
CGD-α	2.4	2.9	3.4
CGD-β	140.6	112.5	83.9
R^2_{adj}	0.987	0.982	0.992

Note: CGD = cumulative gamma distribution



PSD comparison among HFUs based on PM class

PM class	Gradations (µm)	Mann–Whitney test HFU (α = 0.05)		
Biogenic	> 4750	SS = CB	CB = BMP	BMP = SS
	2000 - 4750	SS = CB	CB < BMP	BMP = SS
Sediment	1000 - 2000	SS = CB	CB < BMP	BMP > SS
	425 - 1000	SS = CB	CB < BMP	BMP > SS
	250 - 425	SS = CB	CB = BMP	BMP = SS
	150 - 250	SS = CB	CB = BMP	BMP = SS
	75 - 150	SS > CB	CB = BMP	BMP < SS
Settleable	53 - 75	SS > CB	CB = BMP	BMP < SS
	38 - 53	SS > CB	CB = BMP	BMP < SS
	25 - 38	SS > CB	CB = BMP	BMP < SS
Suspended	1 - 25	SS = CB	CB = BMP	BMP < SS

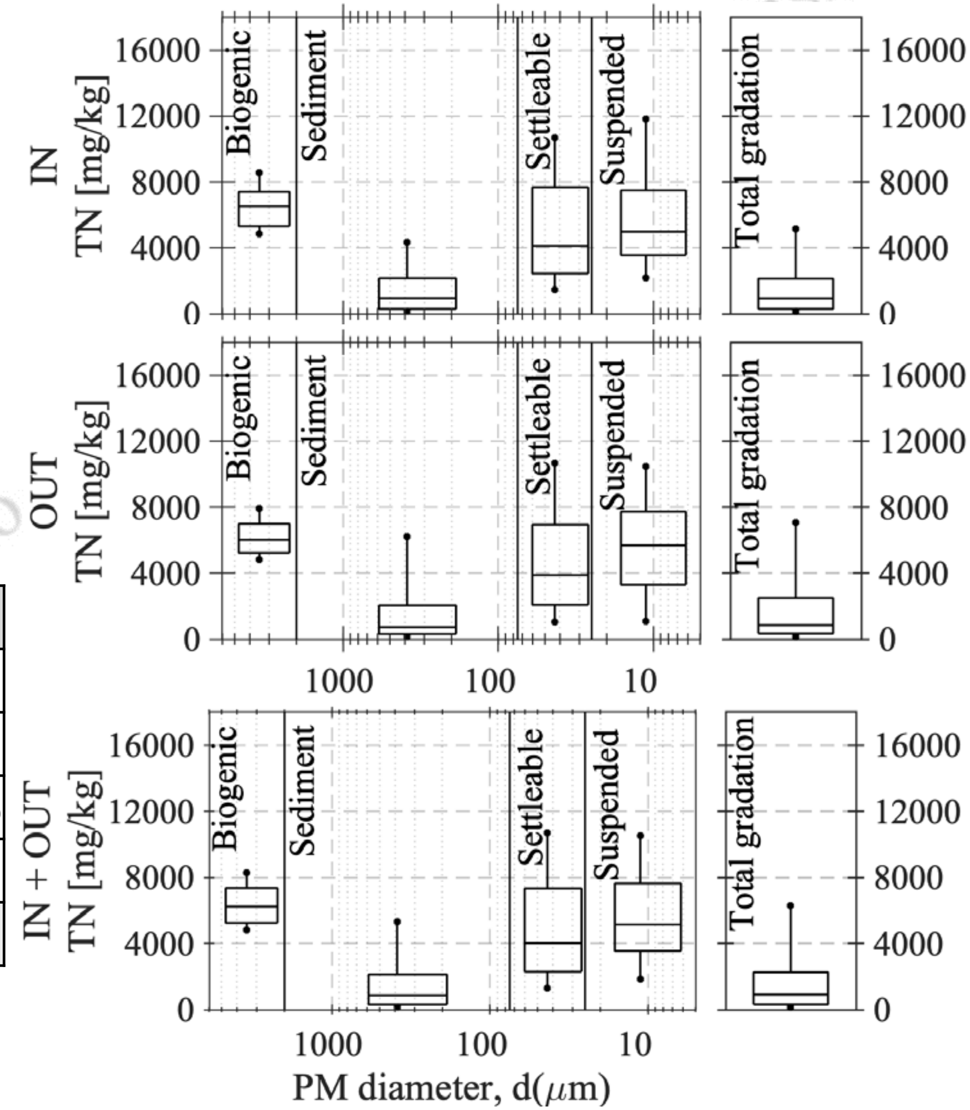
1. For biogenic fraction, SS, CB, and BMP are not significantly different.
2. For sediment PM, SS and CB are not statistically different, except the fraction between the particle diameter of 75 - 150 µm; CB and BMP, BMP and SS does not perform the consistent relationship, depending on gradation.
3. For settleable PM, SS is consistently greater than CB; CB and BMP are no difference; BMP is larger than SS.
4. For suspended PM, SS and CB, CB and BMP are no difference, but BMP is statistically smaller than SS.
5. Overall PM gradations, BMP is consistently smaller than SS for particles finer than 150 µm while BMP is greater or equal to SS for coarse particles (> 150 µm) indicating that BMP do not have the potential to remove the finer particles.

TN comparison between IN and OUT

1. There is no statistically difference of TN gradations between samples from inside (IN) and outside (OUT) reclaimed water areas (α = 0.05).
2. Reclaimed water has no effect on TN across gradations.

TN [mg/kg]	IN + OUT	IN	OUT
Biogenic PM	6229 (N=54)	6522 (N=28)	6023 (N=26)
Sediment PM	855 (N=431)	947 (N=220)	724 (N=211)
Settleable PM	4016 (N=373)	4128 (N=192)	3890 (N=181)
Suspended PM	5147 (N=86)	4996 (N=39)	5679 (N=47)
Total gradation	900 (N=442)	935 (N=227)	845 (N=215)

Note: median value (N = # of samples)



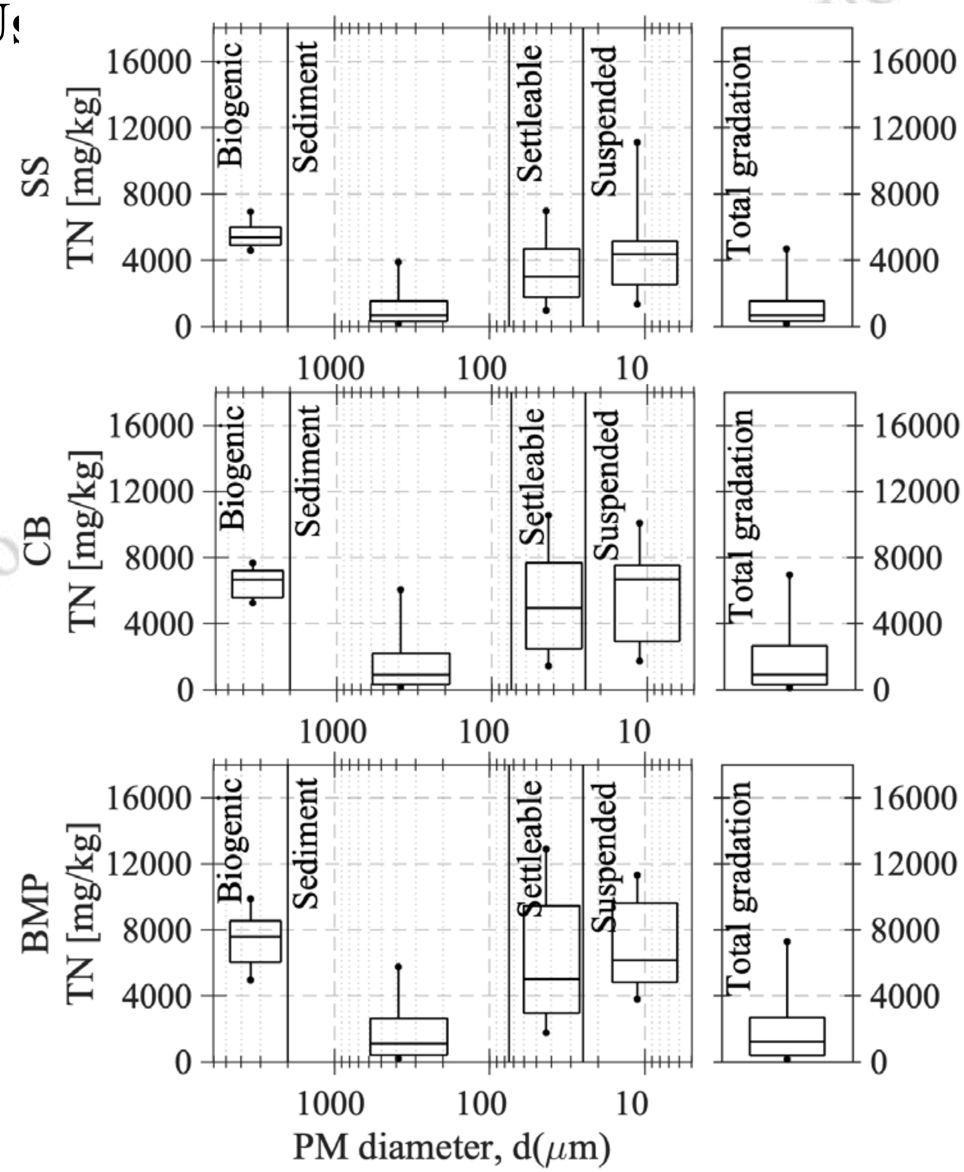
TN comparison and TN distribution of HFUs

1. BMP is consistently greater than SS for TN gradations.
2. CB and BMP, SS and CB are not significantly different.
3. Biogenic materials could be a higher potential TN enrichment that need more attention; TN is enhanced as particle diameter decreases for inorganic fractions.

Mann–Whitney test	HFU (α = 0.05)		
Biogenic PM	SS = CB	CB = BMP	BMP > SS
Sediment PM	SS < CB	CB <= BMP	BMP > SS
Settleable PM	SS = CB	CB = BMP	BMP > SS
Suspended PM	SS < CB	CB = BMP	BMP > SS
Total gradation	SS <= CB	CB = BMP	BMP > SS

TN [mg/kg]	SS	CB	BMP
Biogenic PM	5374 (N=20)	6656 (N=19)	7576 (N=15)
Sediment PM	655 (N=138)	887 (N=141)	1106 (N=152)
Settleable PM	3001 (N=127)	4929 (N=116)	5009 (N=130)
Suspended PM	4362 (N=31)	6668 (N=26)	6154 (N=29)
Total gradation	656 (N=142)	891 (N=145)	1209 (N=155)

Note: median value (N=# of samples)

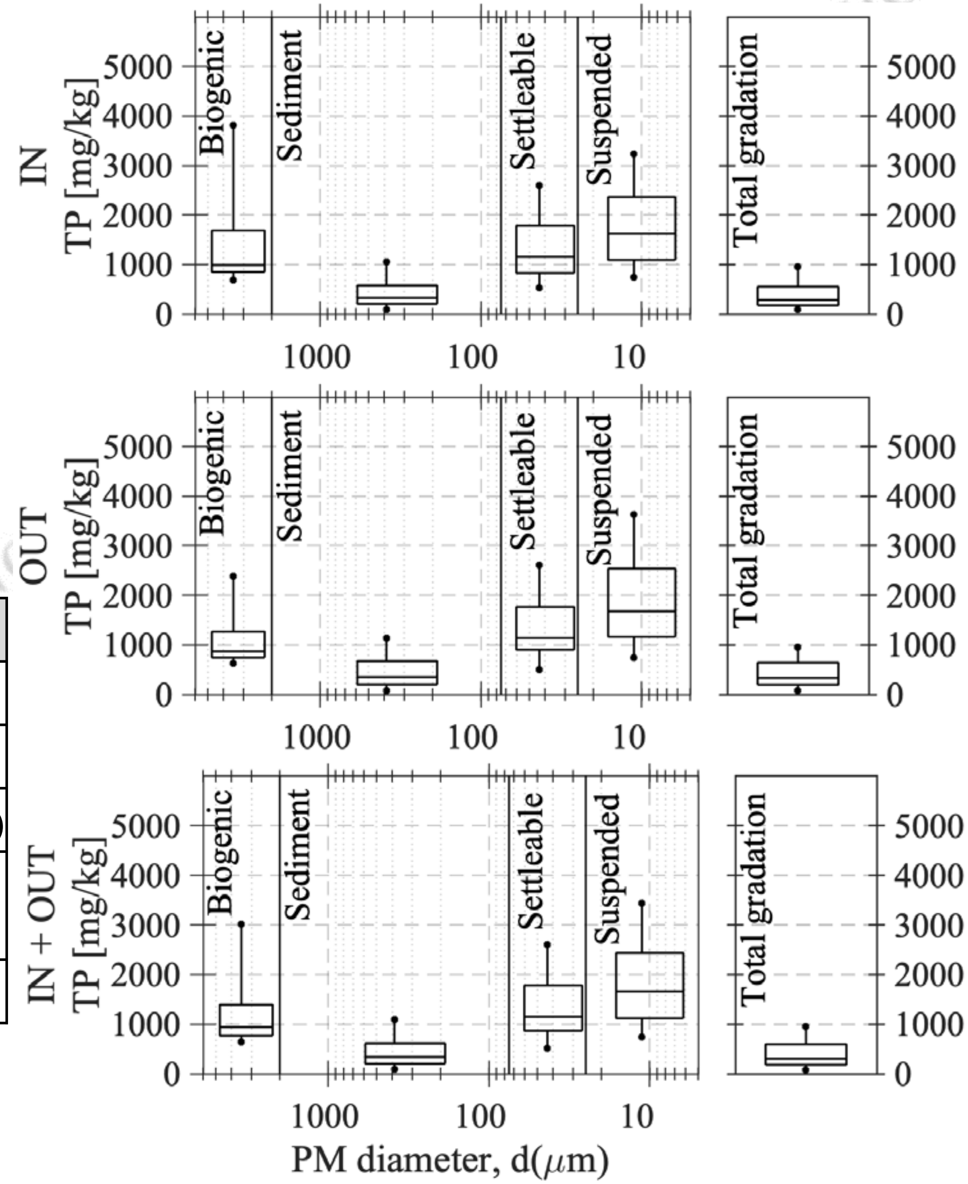


TP comparison between IN and OUT

1. There is no statistically difference of TP gradations between samples from inside (IN) and outside (OUT) reclaimed water areas ($\alpha = 0.05$).
2. Reclaimed water has no effect on TP across PM gradations.

TP [mg/kg]	IN + OUT	IN	OUT
Biogenic PM	940 (N=68)	990 (N=32)	872 (N=36)
Sediment PM	339 (N=439)	328 (N=226)	355 (N=213)
Settleable PM	1149 (N=419)	1156 (N=215)	1141 (N=204)
Suspended PM	1664 (N=325)	1624 (N=170)	1681 (N=155)
Total gradation	396 (N=442)	287 (N=227)	338 (N=215)

Note: median value (N = # of samples)



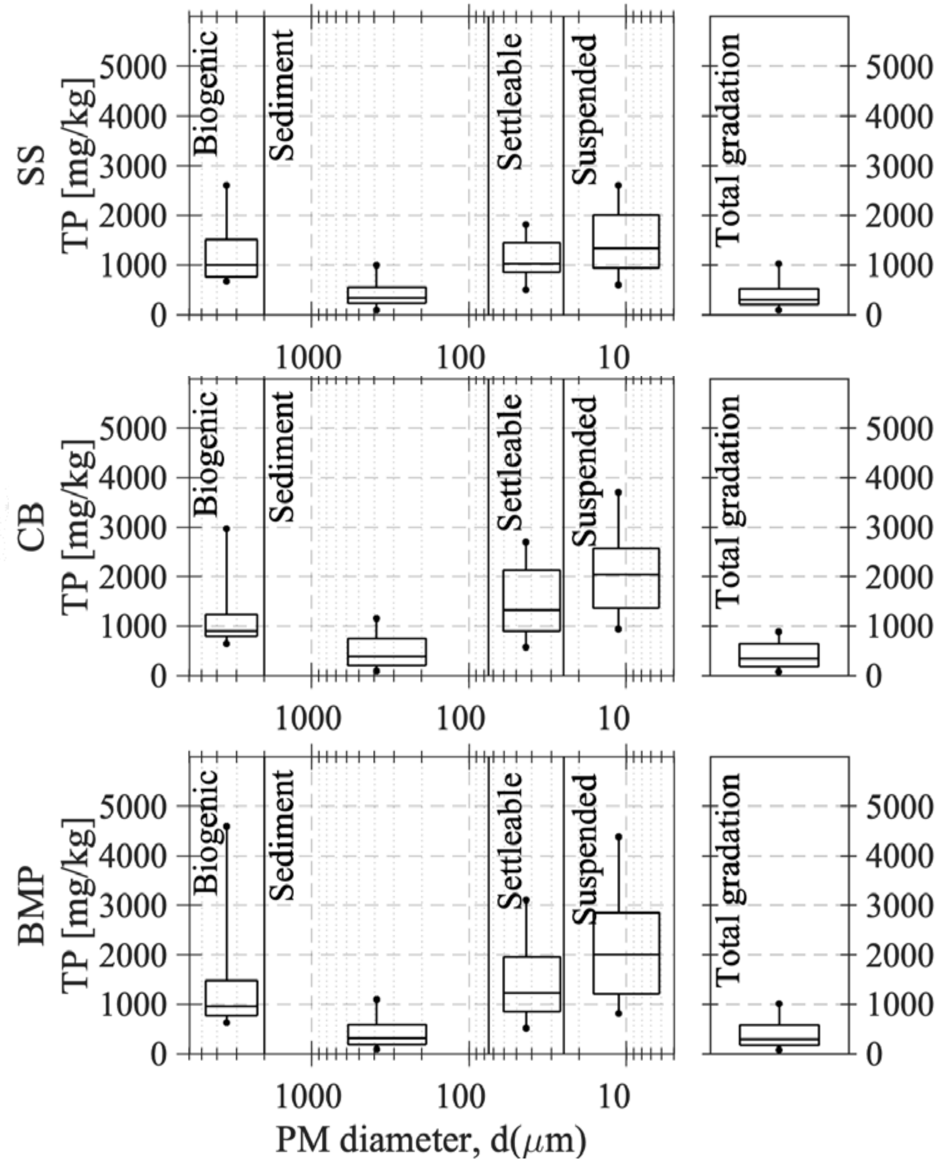
TP comparison and TP distribution of HFUs

1. BMP is greater than SS for suspended PM, but not for other gradations; CB and BMP are not significantly different.
2. Biogenic materials could be a higher potential TP enrichment; TP is enhanced as particle diameter decreases for inorganic fractions.

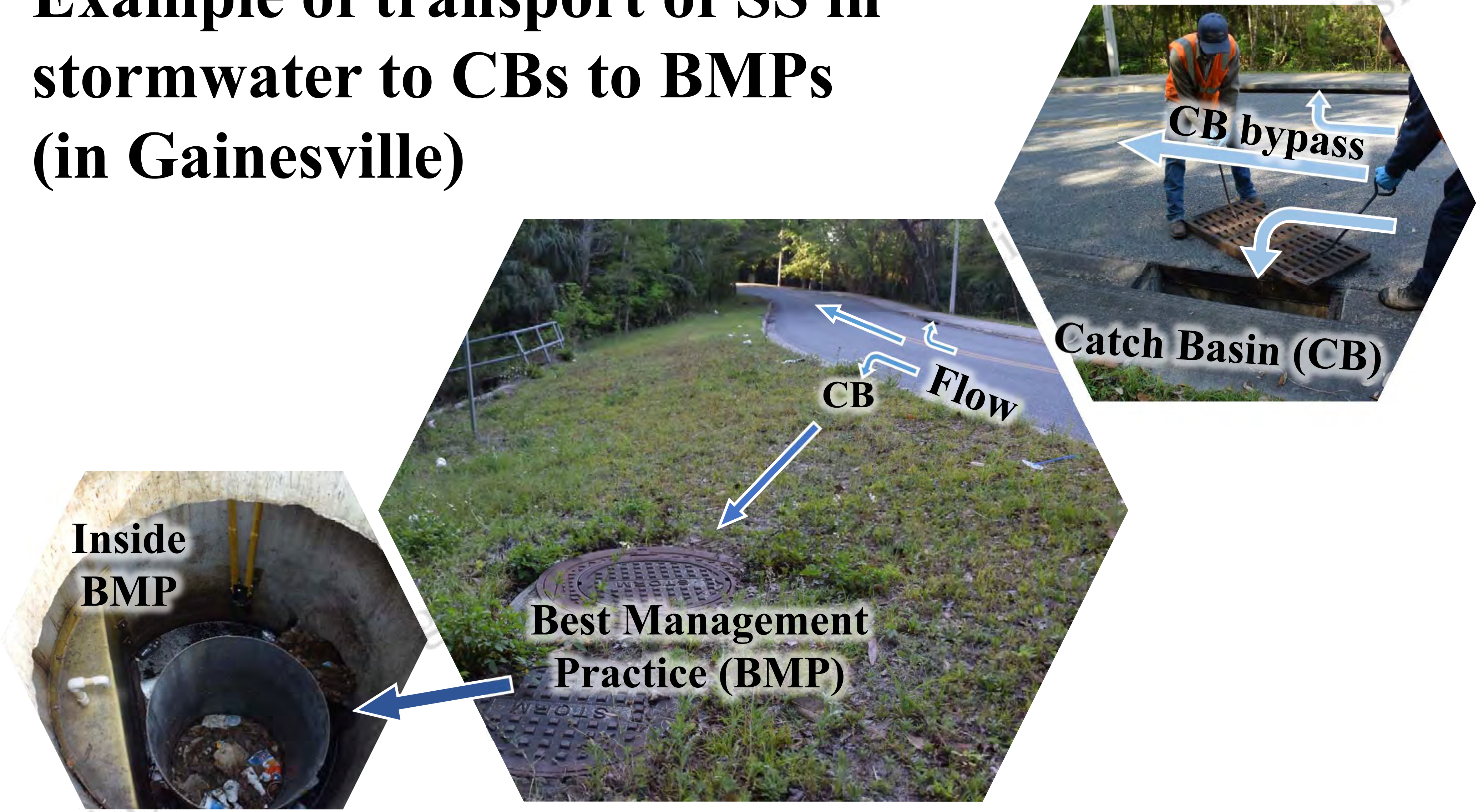
Mann–Whitney test	HFU ($\alpha = 0.05$)		
Biogenic PM	SS = CB	CB = BMP	BMP = SS
Sediment PM	SS = CB	CB = BMP	BMP = SS
Settleable PM	SS = CB	CB = BMP	BMP = SS
Suspended PM	SS < CB	CB = BMP	BMP > SS
Total gradation	SS < CB	CB = BMP	BMP > SS

TP [mg/kg]	SS	CB	BMP
Biogenic PM	997 (N=20)	899 (N=26)	955 (N=22)
Sediment PM	341 (N=142)	384 (N=144)	315 (N=153)
Settleable PM	1023 (N=138)	1325 (N=135)	1231 (N=146)
Suspended PM	1336 (N=116)	2043 (N=97)	2005 (N=112)
Total gradation	303 (N=142)	339 (N=145)	291 (N=155)

Note: median value (N = # of samples)



Example of transport of SS in stormwater to CBs to BMPs (in Gainesville)



Economics of maintenance for HFUs (example is GNV)

1. Nutrient (total nitrogen, TN; total phosphorus, TP) concentration is represented as mg/kg **dry PM** recovered from street sweeping (SS), catch basin (CB) and best management practices (BMP).

2. Conversion from wet PM to dry PM characterized by water content (WC).

3. By lumping the effect of land use and with no statistical difference between IN and OUT, the median value of nutrient recovery concentrations in the above table is solely as a function of hydrological function unit (HFU).

4. An example of **<u>annual</u>** economics for Gainesville (GNV) is demonstrated by using the Florida-based metrics.

Phase III Results for PM (all results combined):

Median value	TN	TP	WC
	[mg/kg PM_{dry}]	[mg/kg PM_{dry}]	(%)
SS	656	303	3.90
CB	891	339	24.12
BMP	1209	291	33.41

Phase II Unit Economic Costs:

Maintenance median cost (Phase II, 2011)	TN	TP
	[$/lb]	[$/lb]
SS	165	257
CB	1016	1656
BMP	1900	10500

Estimate: GNV annual SS load recovery of TN and cost

	PM mass recovered[1]	Water content	Concentration of Nutrients	Annual-based swept distance[2,3]	Maintenance median cost

Dry-equivalent PM mass $= \dfrac{147 \text{ kg PM}}{1 \text{ mile}} \times (100-3.90)\%$

TN mass per mile $= \dfrac{147 \text{ kg PM}}{1 \text{ mile}} \times (100-3.90)\% \times \dfrac{656 \text{ mg TN}}{1 \text{ kg PM}_{dry}}$

TN load recovery $= \dfrac{147 \text{ kg PM}}{1 \text{ mile}} \times (100-3.90)\% \times \dfrac{656 \text{ mg TN}}{1 \text{ kg PM}_{dry}} \times (880 \times 12) \text{ mile}$

Cost of TN recovery $= \dfrac{147 \text{ kg PM}}{1 \text{ mile}} \times (100-3.90)\% \times \dfrac{656 \text{ mg TN}}{1 \text{ kg PM}_{dry}} \times (880 \times 12) \text{ mile} \times \dfrac{\$165}{1 \text{ lb TN}} \times \dfrac{1 \text{ lb}}{453592 \text{ mg}}$

=$ 355,981

Notes:
1. Phase II reported a median of 147 kg PM recovered by SS per mile (Berretta et al., 2011);
2. Total length of major road within Gainesville jurisdiction is 880 mile based on GNV road and streets 2016, credit to Alachua County Fire Rescue.
3. Sweeping frequency is assumed to be 1 time per month.

Estimate: GNV annual SS load recovery of TP and cost

	PM mass recovered[1]	Water content	Concentration of Nutrients	Annual-based swept distance[2,3]	Maintenance median cost

Dry-equivalent PM mass
$$= \frac{147\ \text{kg PM}}{1\ \text{mile}} \times (100\% - 3.90\%)$$

TP mass per mile
$$= \frac{147\ \text{kg PM}}{1\ \text{mile}} \times (100\% - 3.90\%) \times \frac{303\ \text{mg TP}}{1\ \text{kg PM}_{dry}}$$

TP load recovery
$$= \frac{147\ \text{kg PM}}{1\ \text{mile}} \times (100\% - 3.90\%) \times \frac{303\ \text{mg TP}}{1\ \text{kg PM}_{dry}} \times (880 \times 12)\ \text{mile}$$

Cost of TP recovery
$$= \frac{147\ \text{kg PM}}{1\ \text{mile}} \times (100\% - 3.90\%) \times \frac{303\ \text{mg TP}}{1\ \text{kg PM}_{dry}} \times (880 \times 12)\ \text{mile} \times \frac{\$257}{1\ \text{lb TP}} \times \frac{1\ \text{lb}}{453592\ \text{mg}}$$

$$= \$\ \mathbf{256{,}103}$$

Note:
1. Phase II reported a median of 147 kg PM recovered by SS per mile (Berretta et al., 2011);
2. Total length of major road within Gainesville jurisdiction is 880 mile based on GNV road and streets 2016, credit to Alachua County Fire Rescue.
3. Sweeping frequency is assumed to be 1 time per month.

Estimate: GNV annual CB load recovery TN/TP and cost

1. 100 lb PM_{dry} is recovered per CB once a year as suggested in Phase II report (Berretta et al., 2011);
2. Based on GIS database of Gainesville, the number of CB is around 18,000. (GNV_dDropInlet 2016)

PM_{dry} mass recovered | TN concentration | # of CB | Maintenance median cost

$$\text{TN mass per CB} = \frac{100\ \text{lb}\ PM_{dry}}{1\ \text{CB}} \times \frac{891\ \text{mg TN}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}}$$

$$\text{TN load recovery} = \frac{100\ \text{lb}\ PM_{dry}}{1\ \text{CB}} \times \frac{891\ \text{mg TN}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}} \times 18000\ \text{CB}$$

$$\text{Cost of TN recovery} = \frac{100\ \text{lb}\ PM_{dry}}{1\ \text{CB}} \times \frac{891\ \text{mg TN}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}} \times 18000\ \text{CB} \times \frac{\$1016}{1\ \text{lb TN}} = \mathbf{\$\ 1{,}629{,}461}$$

PM_{dry} mass recovered | TP concentration | # of CB | Maintenance median cost

$$\text{TP mass per CB} = \frac{100\ \text{lb}\ PM_{dry}}{1\ \text{CB}} \times \frac{339\ \text{mg TP}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}}$$

$$\text{TP load recovery} = \frac{100\ \text{lb}\ PM_{dry}}{1\ \text{CB}} \times \frac{339\ \text{mg TP}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}} \times 18000\ \text{CB}$$

$$\text{Cost of TP recovery} = \frac{100\ \text{lb}\ PM_{dry}}{1\ \text{CB}} \times \frac{339\ \text{mg TP}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}} \times 18000\ \text{CB} \times \frac{\$1{,}656}{1\ \text{lb TP}} = \mathbf{\$\ 1{,}010{,}491}$$

Estimate: GNV annual BMP load recovery of TN and cost

Assumptions:

1. One BMP with a drainage area of 2000 m^2;
2. Treatment with annual PM removal efficiency of 50% based on clean sump conditions;
3. No scouring and washout PM;
4. Annual rainfall depth of 50 inches;
5. Volumetric rainfall runoff coefficient (C) is 0.75;
6. Total PM concentration is 200 mg/L;
7. Two catch basins connecting to one BMP, and the number of BMP is approximately 5000.
8. Maintenance frequency is assumed to be once a year.

$$\text{PM recovered per BMP} = 2000\ \text{m}^2 \times 50\ \text{inch} \times \frac{1\ \text{m}}{39.37\ \text{inch}} \times 0.75 \times \frac{200\ \text{mg}}{\text{L}} \times \frac{1000\ \text{L}}{\text{m}^3} \times 50\% \times \frac{1\ \text{lb}}{453592\ \text{mg}} = 420\ \text{lb}$$

	PM_{dry} mass recovered	TN concentration	# of BMP	Maintenance median cost	
TN mass per BMP	$= \frac{420\ \text{lb}\ PM_{dry}}{1\ \text{BMP}} \times$	$\frac{1209\ \text{mg TN}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}}$			
TN load recovery	$= \frac{420\ \text{lb}\ PM_{dry}}{1\ \text{BMP}} \times$	$\frac{1209\ \text{mg TN}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}}$	$\times 5000$ BMP		
Cost of TN recovery	$= \frac{420\ \text{lb}\ PM_{dry}}{1\ \text{BMP}} \times$	$\frac{1209\ \text{mg TN}}{1\ \text{kg}\ PM_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}}$	$\times 5000$ BMP $\times$	$\frac{\$1{,}900}{1\ \text{lb TN}}$	$=$ **\$ 4,823,910**

Estimate: GNV annual BMP load recovery of TP and cost

Assumptions:

1. One BMP with a drainage area of 2000 m^2;
2. Treatment with annual PM removal efficiency of 50% based on clean sump conditions;
3. No scouring and washout PM;
4. Annual rainfall depth of 50 inches;
5. Volumetric rainfall runoff coefficient (C) is 0.75;
6. Total PM concentration is 200 mg/L;
7. Multiple catch basins connecting to one BMP, and the number of BMP is approximately 5000.
8. Maintenance frequency is assumed to once a year.

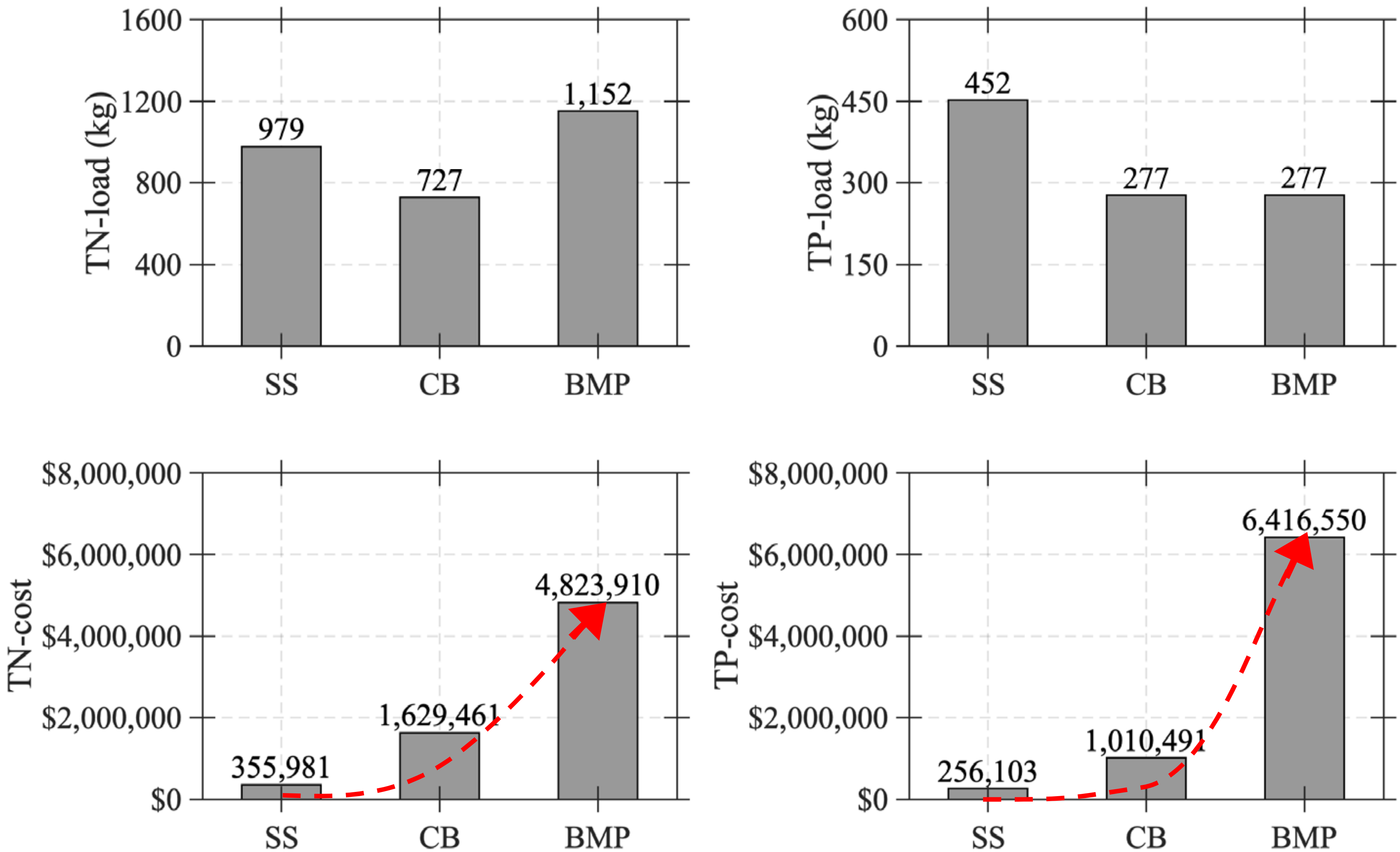
$$\text{PM recovered per BMP} = 2000\ \text{m}^2 \times 50\ \text{inch} \times \frac{1\ \text{m}}{39.37\ \text{inch}} \times 0.75 \times \frac{200\ \text{mg}}{\text{L}} \times \frac{1000\ \text{L}}{\text{m}^3} \times 50\% \times \frac{1\ \text{lb}}{453592\ \text{mg}} = 420\ \text{lb}$$

$$\text{TP mass per BMP} = \underbrace{\frac{420\ \text{lb PM}_{dry}}{1\ \text{BMP}}}_{\text{PM}_{dry}\text{ mass recovered}} \times \underbrace{\frac{291\ \text{mg TP}}{1\ \text{kg PM}_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}}}_{\text{TP concentration}}$$

$$\text{TP load recovery} = \frac{420\ \text{lb PM}_{dry}}{1\ \text{BMP}} \times \frac{291\ \text{mg TP}}{1\ \text{kg PM}_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}} \times \underbrace{5000\ \text{BMP}}_{\#\text{ of BMP}}$$

$$\boxed{\text{Cost of TP recovery} = \frac{420\ \text{lb PM}_{dry}}{1\ \text{BMP}} \times \frac{291\ \text{mg TP}}{1\ \text{kg PM}_{dry}} \times \frac{1\ \text{kg}}{1000000\ \text{mg}} \times 5000\ \text{BMP} \times \underbrace{\frac{\$10{,}500}{1\ \text{lb TP}}}_{\text{Maintenance median cost}} = \mathbf{\$\ 6{,}416{,}550}}$$

Annual cost estimation of TN and TP recovered by SS, CB, and BMP in GNV



Conclusions from seminar

1. Maintenance Matters !!
2. The most effective and economical maintenance practice is documented street sweeping/cleaning for PM, TN, TP load control and the difference is very significant compared to all "BMPs",
3. BMPs that provide hydrologic/hydraulic control as well as load control are important but typically require retrofits to significantly improve economy and performance, maintenance still required,
4. State of practice tools that are used to provide improved economy and performance are SWMM, CFD and monitoring guided by these tools,
5. Phase III results are not statistically different than Phase II on a Florida basis, confounding parameters are location and seasonality,
6. At this point based on Phase III results, PM is not significantly enriched with TN or TP; IN and OUT load enrichment offsets (i.e. > 1.0) are not different.