Runoff Characteristics and EMC Values

By: Harvey H. Harper

January 2026

Runoff Characteristics

- Runoff concentrations are characterized by a high degree of variability:
  - From event to event
  - During storm events
- Variability is caused by variations in:
  - Rainfall Intensity
  - Rainfall Frequency
  - Soil Types
  - Land Use
  - Intensity of Land Use
  - Weather Patterns
- Variability must be included in the monitoring protocol for runoff collection to determine annual emc values
- NPDES data should not be used since these data reflect runoff characteristics for specific rain event conditions
  - NPDES data are useful for comparing different sites because the data are collected in a similar manner

Highway Runoff

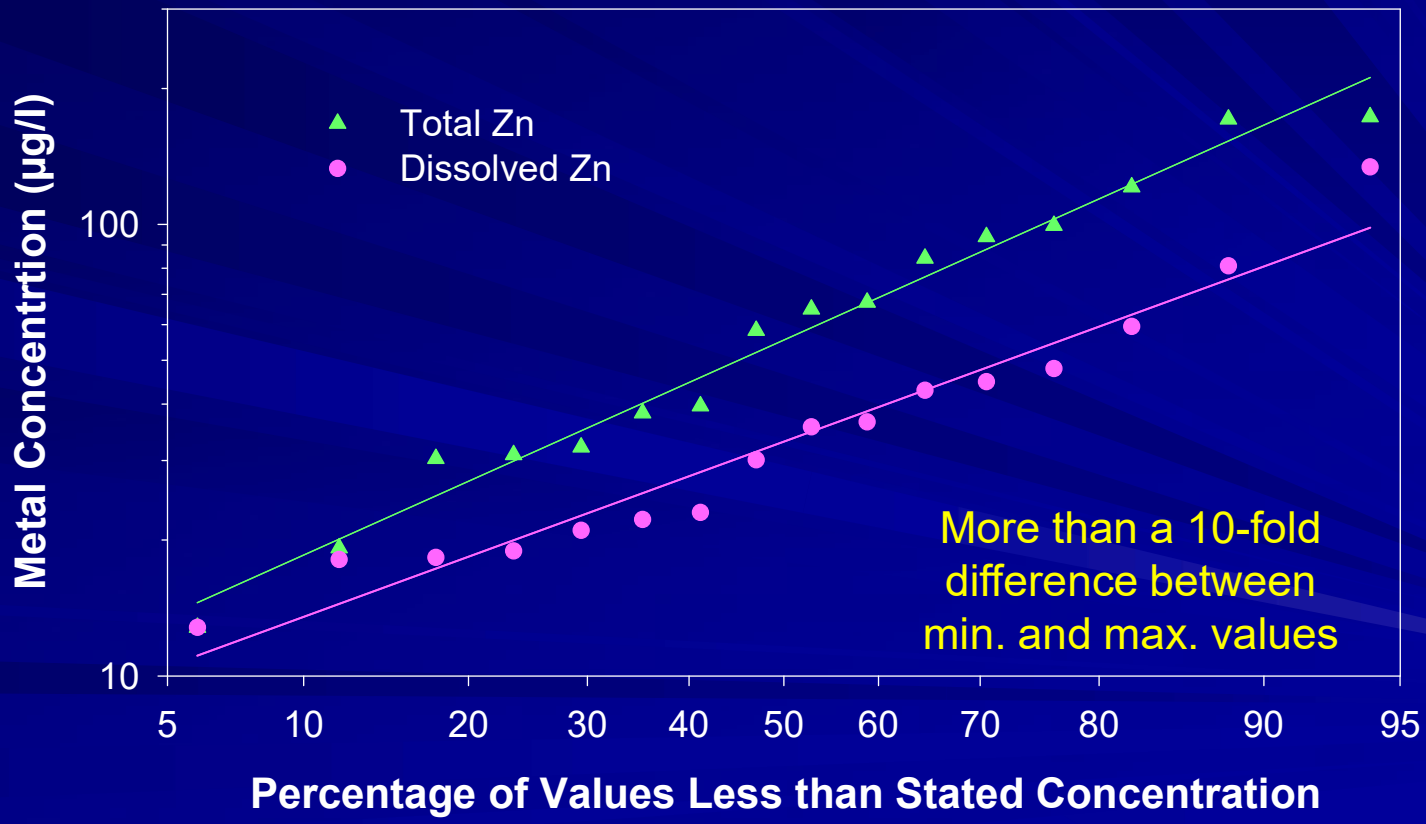
(I-4 and Maitland Ave from 1980-82)

Zinc

Runoff Variability

- Runoff concentrations exhibit a log-normal distribution (geometric mean)

- Normal arithmetic means are not the appropriate measure of central tendency



Runoff Characteristics and Loadings

- Runoff characteristics are used in many engineering analyses:
  - Pollutant loading analyses
  - TMDL calculations
  - Pre/post loading evaluations
- Runoff concentrations are expressed as an event mean concentration (EMC). The EMC concentration is the result of this equation:

$$EMC = \frac{\text{pollutant loading}}{\text{runoff volume}}$$

- An annual EMC value is determined by evaluating event EMC values over a range of rainfall depths and seasons
  - Generally determined based on field monitoring
  - Usually requires a minimum of 7-10 events collected over a range of conditions
- Annual mass loadings are calculated by:

Annual mass loading = annual runoff volume x annual EMC

History of Florida EMC Database

- The original database of Florida runoff characteristics was developed by ERD in 1990 in support of the Tampa Bay SWIM Plan
  - A literature review was conducted to identify runoff EMC values for single land use categories in Florida
  - Approximately 100 studies were identified
    - Each study was evaluated for adequacy of the data, length of study, number of monitored events, completeness, and monitoring protocol
  - Original selection criteria
    - Monitoring site included a single land use category – most difficult criterion
    - At least 1 year of data collection; minimum of 5 events monitored in a flow-weighted fashion
    - Wide range of rainfall depths and antecedent dry periods included in monitored events
    - Seasonal variability included in monitored samples
  - Approximately 40 studies were selected for inclusion in the data base
  - Values were summarized by general land use category
  - First known compilation of emc data for Florida
  - EMC values calculated as simple arithmetic means

History of Database – cont.

- Based on the literature survey, common land use categories were developed based on similarities in anticipated runoff characteristics:
  - Pre-Development
    - Agriculture (pasture, citrus, row crops)
    - Open Space / Forests
    - Mining
    - Wetlands
    - Open Water / Lake
  - Post-Development
    - Low-Density Residential
    - Single-Family Residential
    - Multi-Family Residential
    - Low-Intensity Commercial
    - High-Intensity Commercial
    - Industrial
    - Highway

Runoff Characterization Data Availability

Parameter Group	Species	Data Availability	Available Land Uses
Suspended Solids	TSS	Good	All
Nutrients	Total N Total P	Good	All
	NH_3 NO_x TKN Ortho-P	Limited	Limited
Metals	Zinc Lead Copper	Fair to Good	Commercial Residential Highway
	Cadmium Nickel Diss. Metals	Poor to Fair	Commercial Residential Highway

Runoff Characterization Data Availability – cont.

Parameter Group	Species	Data Availability	Available Land Uses
Oxygen Demanding Substances	BOD	Fair to Good	Commercial, Residential, Highway
	COD	Poor to Fair	Commercial, Residential, Highway
Oils, Greases And Hydrocarbons	Oil and Grease TRPH	Poor	Commercial, Residential, Highway
	Specific Compounds	Extremely Poor	Commercial, Residential, Highway
Pathogens	Total Coliform Fecal Coliform	Poor to Fair	Commercial, Residential, Highway
	E. Coli	Extremely Poor	Commercial, Residential, Highway

Land Use Categories

- Land use category descriptions:
  - Low Density Residential (LDR) – rural residential with less than one unit per acre
  - Single Family Residential (SFR) – typical detached family home with lot <1 acre, includes duplexes in 1/3 to 1/2 acre lots, golf courses
  - Multi-Family Residential (MFR) – residential units consisting of apartments, condominiums, and cluster-homes
  - Low Intensity Commercial (LIC) – commercial areas with low traffic levels, cars parked for extended periods, includes schools, offices, and small shopping centers
  - High Intensity Commercial (HIC) – commercial areas with high traffic volumes, includes downtown areas, malls, commercial offices
  - Industrial (Ind.) – manufacturing, shipping and transportation services, municipal treatment plants
  - Highway (HW) – major road systems and associated ROW, including interstate highways, major arteries
  - Agriculture (Ag) – includes cattle, grazing, row crops, citrus, general ag.
  - Recreation/Open Space - includes parks, ball fields, open space, barren land, does not include golf courses
  - Mining (M) – general mining activities such as sand, lime rock, gravel, etc.

- Categories were developed based on similarities in runoff EMC values and may not correspond to land use categories used in FLUCCS codes and property appraiser data bases

Original Stormwater Loading Rate Publication

- In October 1994, ERD published a non-funded summary of the results of the runoff data collected as part of the Tampa Bay SWIM study
  - Titled "Stormwater Loading Rate Parameters for Central and South Florida"
- Publication included all data from the 1990 collection effort
  - Addition of loading rate information for highway/transportation land use
  - Divided agriculture into pasture, citrus, row crops, and general ag
  - Added new references for previous landuses
- Included EMC values for wetlands based on available existing wetland data for central and south Florida
  - TP = 0.10 mg/l (100 ug/l)
  - TN = 1.00 mg/l (1,000 ug/l)
- Introduced and included areal loading rates for stormwater parameters:
  - kg/acre-yr
  - ERD no longer supports the areal loading methodology

Summary of Runoff Characterization Data

Land Use Category	No. of Studies			
	1994	2003	2007	2012
1. Low-Density Residential	0 – calc.[1]	0 – calc.[1]	0 – calc.[1]	0 – calc.[1]
2. Single-Family Resid.	9	16	17	17
3. Multi-Family Residential	6	6	6	6
4. Low-Intensity Comm.	5	9	9	9
5. High-Intensity Comm.	3	4	4	4
6. Light Industrial	2	2	4	4
7. Highway	6	10	11	15
8. Agricultural a. Pasture b. Citrus c. Row Crops	 3 7 7	 3 7 8	 3 7 8	 4 7 8
9. Undeveloped/Rangeland/ Forest	4	3	4	33
10. Mining	1	1	1	1

1. Calculated as mean of SFR and undeveloped land

Single Family Residential Runoff Characterization Data (n = 17)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Pompano Beach	Mattraw,et.al.,(1981)	2.00	0.310	7.9	26.0			0.008	0.298		0.167	0.086
Tampa-Charter St.	US EPA (1983)	2.31	0.400	13.0	33.0						0.490	0.053
Maitland (3 sites)	German (1983)	2.20	0.340	7.1	43.0			0.014	0.350	0.008	0.230	0.016
St. Pete-Bear Creek	Lopez,et.al. (1984)	1.50	0.200	4.7				0.009			0.128	0.083
Tampa-Kirby St.	Lopez,et.al. (1984)	2.20	0.250	4.5							0.050	
Tampa-St. Louis St.	Lopez,et.al. (1984)	3.00	0.450	6.1				0.016			0.213	0.133
Orlando-Duplex	Harper (1988)	4.62		9.5	63.2	0.005	0.015	0.033	0.464	0.020	0.058	0.089
Orlando-Essex Pointe	Harper (1988)	1.85	0.200	6.5	30.1	0.002	0.017	0.027	0.420	0.029	0.132	0.045
Palm Beach-Springhill	Greg,et.al. (1989)	1.18	0.307		3.5							
Tampa-102nd Ave.	Holtkamp (1998)	2.62	0.510	13.4	36.8			0.019			0.005	0.060
Bradfordville	ERD (2000)	1.30	0.280	2.7	57.1							
Fl. Keys-Key Colony	ERD (2002)	1.20	0.281	2.0	26.9	0.002	0.003	0.010	0.067		0.001	0.020
Tallahassee-Woodgate	COT & ERD (2002)	1.29	0.505	15.0	76.0			0.007			0.007	0.039
Sarasota Co.	ERD (2004)	1.17	0.506	4.4	10.1							
Orlando-Krueger St.	ERD (2004)	3.99	0.182	17.1	41.8							
Orlando-Paseo St.	ERD (2004)	1.02	0.102	4.0	12.0							
Windemere	ERD (2007)	1.69	0.402		65.0							
Mean Value		2.07	0.327	7.9	37.5	0.003	0.012	0.016	0.320	0.019	0.004	0.062
Geometric Mean:		1.87	0.301	6.6	29.3	0.002	0.009	0.014	0.267	0.017	0.003	0.052

not included in mean or median value due to dramatic reductions in lead from removal of lead n gasoline on 1/1/996

Commercial Runoff Characterization Data

Low Intensity Commercial Land Use Runoff Characterization Data (n=9)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Orlando Area wide	ECFRPC (1978)	0.89	0.160	3.6	146						0.068	
Coral Ridge Mall	Miller (1979)	1.10	0.100	5.4	45.0			0.015			0.387	0.128
Norma Park-Tampa	US EPA (1983)	1.19	0.150	12.0	22.0						0.046	0.037
Internat. Market	Harper (1988)	1.53	0.190	11.6	111	0.008	0.013	0.031	1.100	0.028	0.136	0.168
DeBary	Harper & Herr (1993)	0.76	0.260	6.9	79.1	0.0005	0.003	0.010	0.582		0.009	0.028
Bradfordville	ERD (2000)	2.14	0.160	9.0	38.3							
Cross Creek-Tall.	COT & ERD (2002)	0.93	0.150	8.0	15.0			0.008			0.002	0.045
Sarasota Co.	ERD (2004)	0.88	0.310	4.3	39.9							
Fla. Aquarium-Tampa	Teague,et.al.(2005)	0.76	0.215		42.4	0.003		0.019	1.170		0.008	0.090
Mean Value		1.13	0.188	7.6	59.9	0.004	0.008	0.017	0.951	0.028	0.006	0.083
Log-Normal Mean:		1.07	0.179	7.0	47.5	0.002	0.006	0.015	0.908	0.028	0.005	0.067

High Intensity Commercial Land Use Runoff Characterization Data (n=4)

Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Broward County	Mattraw,et.al.,(1981)	1.10	0.100	5.4	45.0	0.009		0.015	0.334		0.387	0.128
Orlando-Downtown	Wanielista, (1982)	2.81	0.310	17.2	94.3						0.056	0.165
Dade Co.	Waller (1984)	3.53	0.820								0.187	0.183
Broward County	Howie,et.al.(1986)	2.15	0.150								0.241	0.162
Mean Value		2.40	0.345	11.3	69.7	0.009		0.015	0.334			0.160
Log-Normal Mean:		2.20	0.248	9.6	65.1	0.009		0.015	0.334			0.158

not included in mean value due to reductions from removal of lead in gasoline on 1/1/1996

Highway Runoff Characterization Data (n=15)

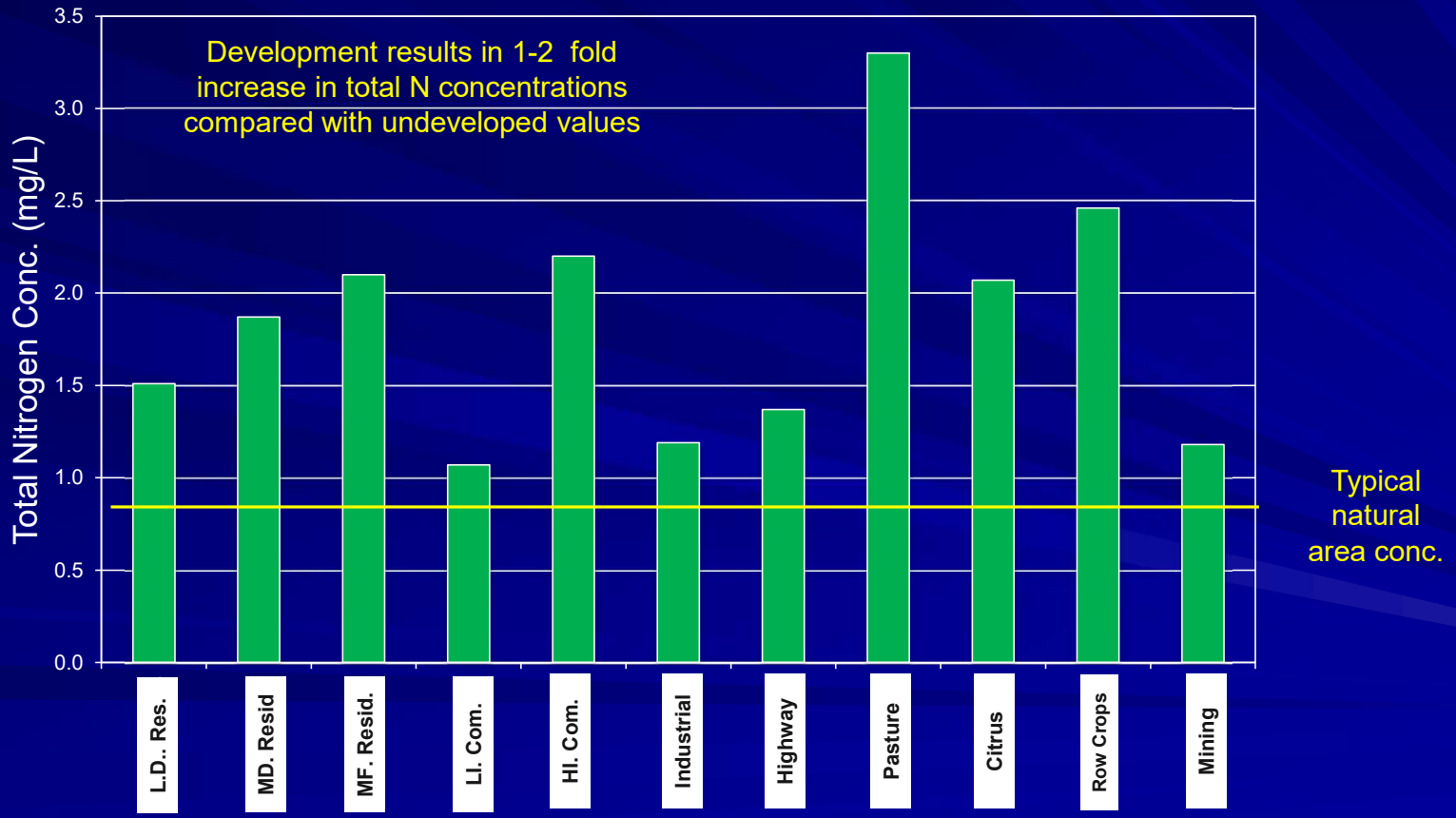
Location	Reference	Reported EMC (mg/l)										
		TN	TP	BOD	TSS	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Broward Co. (6 lane)	Mattraw,et.al.,(1981)	0.96	0.080	9.0	15.0	0.007		0.007	0.207		0.282	0.090
Miami I-95	McKenzie,et.al.(1983)	3.20	0.160		42.0	0.001	0.010	0.040			0.590	0.330
Maitland	German (1983)	1.30	0.240		27.0			0.012	0.350	0.009	0.092	0.055
Maitland I-4	Harper (1985)	1.40	0.170			0.003	0.004	0.038	0.341	0.003	0.163	0.071
Maitland Blvd.	Yousef,et.al.(1986)	1.40	0.170			0.002	0.004	0.039	0.354	0.004	0.181	0.074
I-4 EPCOT	Yousef,et.al.(1986)	3.16	0.420			0.002	0.003	0.024	0.205	0.003	0.026	0.024
Winter Park I-4	Harper (1988)	1.60	0.230	6.9	34.0	0.008	0.013	0.050	1.120	0.046	0.224	0.170
Orlando I-4	Harper (1988)	2.15	0.550	4.2	66.5	0.008	0.014	0.067	1.450	0.020	0.343	0.272
Bayside Bridge	Stoker (1996)	1.10	0.100		20.0	0.000	0.003	0.008	0.530	0.003	0.011	0.050
Tallahassee (6 lane)	ERD (2000)	1.10	0.166	1.9	70.6							
Orlando US 441	ERD (2007)	0.68	0.085	4.2	23.1							
Flamingo Dr. Collier, County	Johnson Eng. (2009)	0.94	0.060		18.5	0.0008	0.001	0.002	0.277	0.002	0.001	0.029
SR-80, Hendry County	Johnson Eng. (2009)	1.31	0.168		120	0.0003	0.001	0.011	1.235	0.004	0.008	0.155
Richard Rd, Lee Co.	Johnson Eng. (2006)	1.60	0.282		76.0	0.0003	0.002	0.010	1.244	0.001	0.007	0.130
US 41, Lee County	Johnson Eng. (2008)	0.82	0.120		39.0	0.0000	0.003	0.012	0.341	0.001	0.002	0.061
Mean Value		1.515	0.200	5.2	46.0	0.003	0.005	0.025	0.638	0.009	0.006	0.116
Geometric Mean		1.371	0.167	4.8	38.1	0.001	0.004	0.017	0.498	0.004	0.004	0.087

not included in mean value due to reductions from removal of lead in gas on 1/1/1996

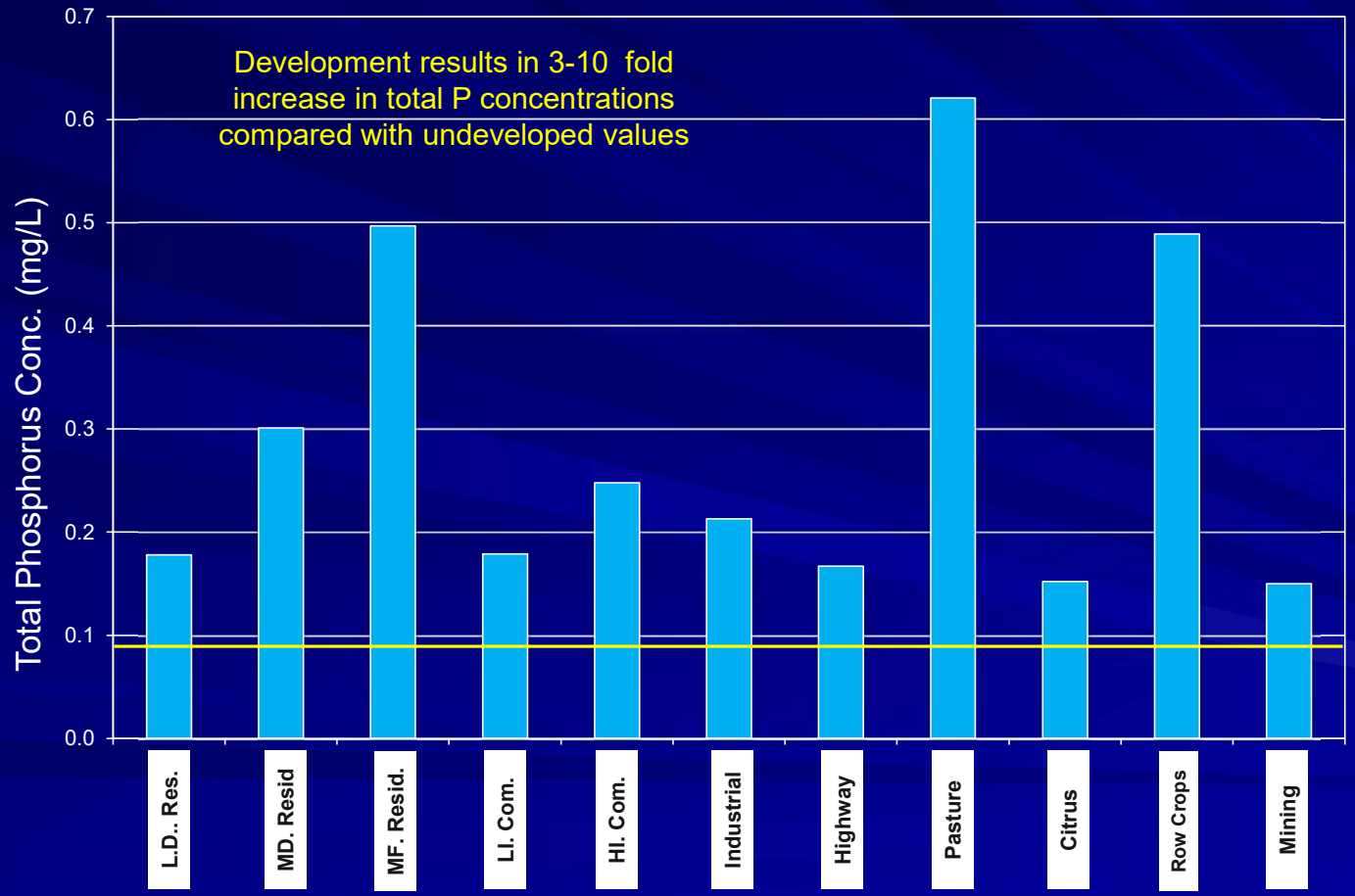
Comparison of Developed Land Use EMC Values

Land Type	Mean Values EMC database (mg/l)		AH – Vol. 1 Statewide Rule (mg/l)	
	Total N	Total P	Total N	Total P
Low Density Residential	1.74	0.180	1.65	0.270
Single Family	2.32	0.340	1.77	0.327
Multi-Family	2.65	0.520	1.84	0.520
Low Intensity Commercial	1.13	0.188	0.93	0.190
High Intensity Commercial	2.40	0.345	2.40	0.345
Light Industrial	1.20	0.260	1.20	0.260
Highway	1.48	0.201	1.25	0.173

Typical Total N Concentrations in Stormwater



Typical Total P Concentrations in Stormwater



Natural Area Monitoring Project

Objectives

- FDEP funded project to ERD to characterize runoff quality from common natural undeveloped upland vegetative communities in Florida
- Data to be used to support pre-development runoff quality for Statewide Stormwater Rule
- State parks used for natural area monitoring

Work Efforts

- Total of 33 automated monitoring sites established in 10 State parks throughout Florida
- Monitoring conducted over 14-month period from July 2007 – August 2008 to include variety of seasonal conditions
- Total of 318 samples collected and analyzed for general parameters, nutrients, demand parameters, fecal coliform and heavy metals

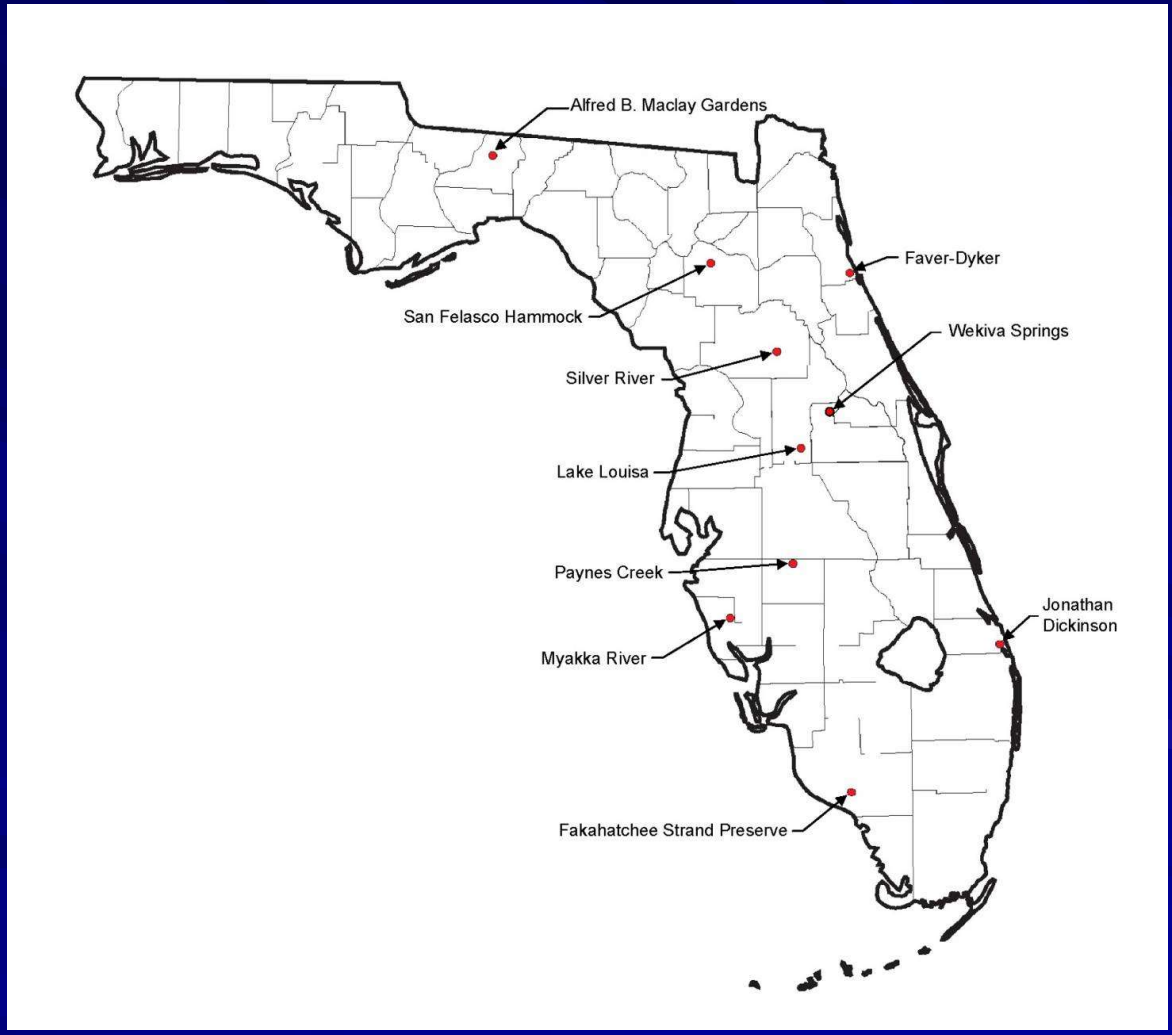
Summary of Florida Upland Land Use Classifications

(Source: FFWCC)

Classification	Area (acres)	Percent of Total
Coastal Strand	15,008	0.1
Dry Prairie	1,227,697	11.4
Hardwood Hammock/Forest	980,612	9.1
Mixed Pine/Hardwood Forest	889,010	8.3
Pinelands	6,528,121	60.7
Sand Pine Scrub	194,135	1.8
Sandhill	761,359	7.1
Tropical Hardwood Hammock	15,390	0.1
Xeric Oak Scrub	146,823	1.4
Totals:	10,758,155	100.0

Monitored natural areas include more than 92% of upland land covers in Florida

Monitored State Parks



Alfred B. Maclay Gardens State Park

Mixed Hardwood Forest

Community Characteristics

- Well-developed, closed canopy upland hardwood forest on rolling hills

- Common in northern panhandle Florida

- Generally, lack shortleaf pine, American beech and other more northern species

-Occur on rolling hills that often have limestone or phosphatic rock near the surface






Faver-Dykes State Park

Mesic Flatwoods/Pinelands

Community Characteristics

- Characterized as an open canopy forest of widely spaced pine trees with dense ground cover of herbs and shrubs

- Occur on relatively flat, moderately to poorly drained

- Soils typically consist of 1-3 feet of acidic sands generally overlying an organic hardpan or clayey subsoil

- Most widespread biological community in Florida

- 30 to 50% of the State's uplands

Synonyms: Pine flatwoods, pine savannah, pine barrens

Jonathan Dickinson State Park

Wet Flatwoods

Synonyms: Low flatwoods, moist pine barren, hydric flatwoods, pond pine flatwoods, cabbage palm/pine savannah/flatwoods

Community Characteristics

- Relatively open-canopy forests of scattered pine trees or cabbage palms

- Relatively flat, poorly drained terrain

- Soils consist of 1 to 3 feet of acidic sands overlying an organic hardpan or clay layer






Silver River State Park

Upland Hardwood Forest

Synonyms: Mesic hammock, climax hardwoods, upland hardwoods, beech-magnolia climax, oak-magnolia climax, pine-oak-hickory association, southern mixed hardwoods, clay hills hammocks, Piedmont forest

Community Characteristics

- Well-developed, closed canopy forests of upland hardwoods on rolling hills

- Most common in northern and central peninsula Florida






Silver River State Park
Monitoring Site Natural Communities

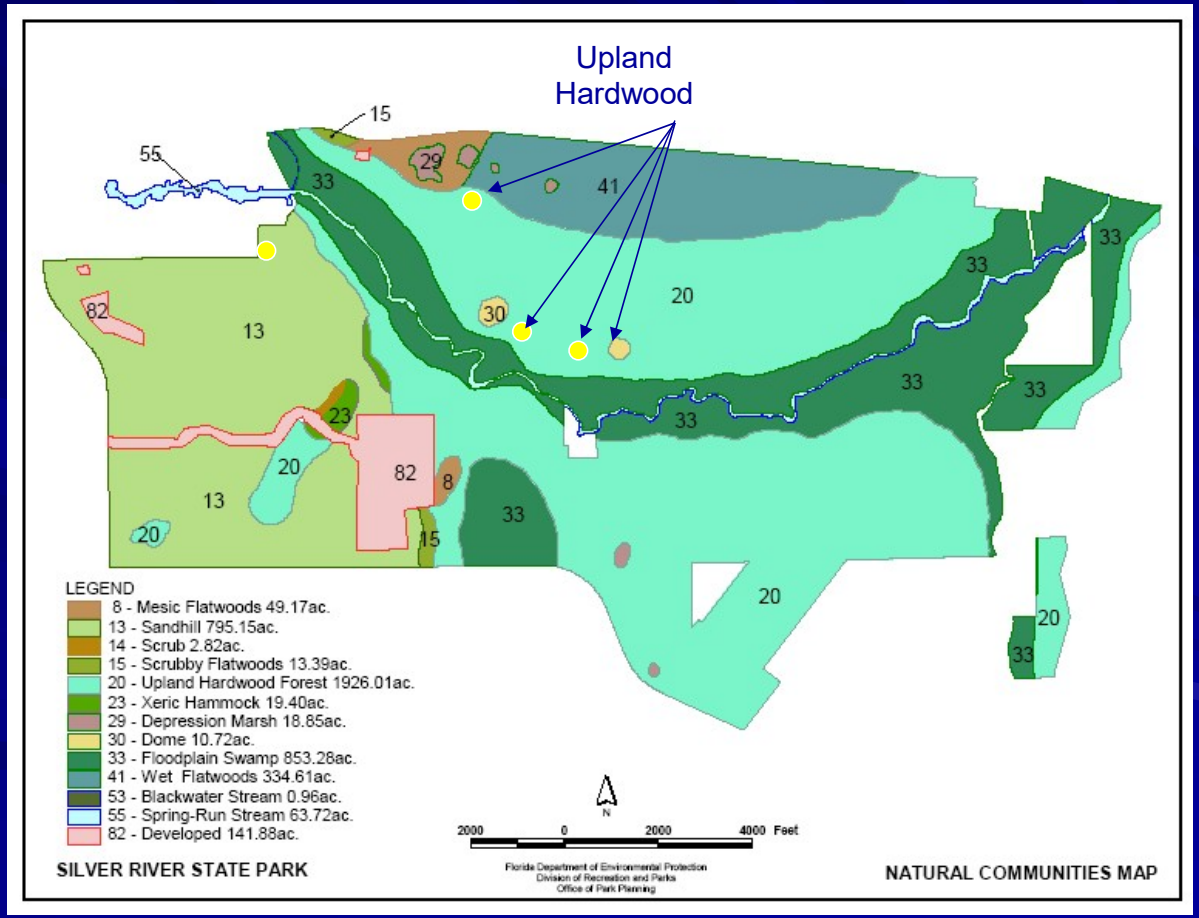
Site Selection

- Natural communities are mapped in all State parks

- Potential monitoring sites were identified in community of interest

- Sites selected where runoff converges in a conveyance channel to accommodate field monitoring

- Site coordinates plotted on GIS map of community areas developed by FDEP to verify



Lake Louisa State Park

Ruderal/Upland Pine Forest

Synonyms: Longleaf pine upland forest, loblolly-shortleaf upland forest, clay hills, high pineland

Community Characteristics

- Rolling forest of widely spaced pines with few understory shrubs and a dense ground cover of grasses and herbs

- Occurs on the rolling hills of extreme northern Florida

- Soils are composed of sand with variable amounts of Miocene clays






Fakahatchee Strand State Park
Strand Swamp

Synonyms: Cypress strand, stringer

Community Characteristics

- Shallow, forested, usually elongated depressions or channels dominated by bald cypress

- Situated in troughs in a flat limestone plain

- Soils are peat and sand over limestone

- Occur mainly in Collier County






San Felasco Hammock Preserve State Park

Upland Mixed Forest

Synonyms: Mesic hammock, climax hardwoods, upland hardwoods, beech-magnolia climax, oak-magnolia climax, pine-oak-hickory association, southern mixed hardwoods, clay hills hammocks, Piedmont forest

Community Characteristics

- Well-developed, closed canopy forests of upland hardwoods on rolling hills

- Most common in northern and central peninsula Florida north of Ocala

- Generally, lack shortleaf pine, American beech and other more northern species






Myakka River State Park

Dry Prairie

Synonyms: Palm Savannah, palmetto prairie

Community Characteristics

- Nearly treeless plain with a dense ground cover of wiregrass, saw palmetto, and other grasses, herbs, and low shrubs

- Relatively flat, moderately to poorly drained terrain

- 1 to 3 feet of acidic sands generally overlying an organic hardpan or clayey subsoil

Wekiva River State Park
Xeric Scrub

Synonyms: Sand pine scrub, Florida scrub, sand scrub, rosemary scrub, oak scrub

Community Characteristics

- Closed to open canopy forest of sand pines with dense clumps or vast thickets of scrub oaks and other shrubs dominating the understory

- Occurs on sand ridges along former shorelines

- Well washed deep sands






Measured Natural Land Use Runoff Characteristics

(Geometric Mean Values)

Land Type	N	Total N (µg/l)	Total P (µg/l)	Iron (mg/l)	Fecal Coli. (cfu/100ml)
Dry Prairie	12	1,950	107	1.259[1]	72
Hydric Hammock	17	1,072	26	0.537	43
Marl Prairie	3	603	10	0.162	83
Mesic Flatwoods	26	1,000	34	0.598	363[1]
Mixed Hardwood Forest	39	288	501	1.479[1]	166
Ruderal/Upland Pine	2	1,318	347	3.311[1]	17
Scrubby Flatwoods	17	1,023	27	0.741	295[1]
Upland Hardwood	79	891	269	0.776	155
Upland Mixed Forest	16	676	2,291	0.437	372[1]
Wet Flatwoods	77	1,175	15	0.347	117
Wet Prairie	9	776	9	0.069	68
Xeric Hammock	1	1,318	2,816	0.814	108
Xeric Scrub	3	1,158	96	0.060	1533[1]

1. Values which exceed Class III criterion

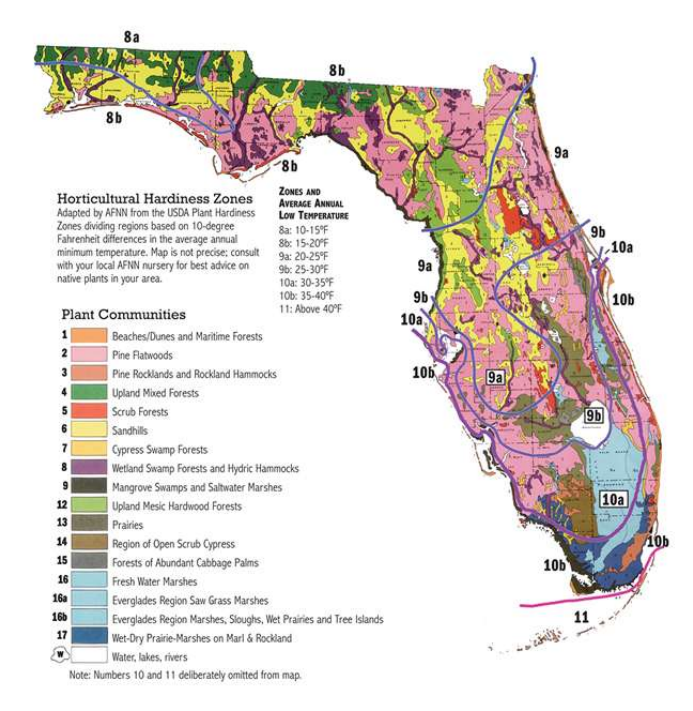
- Natural areas had frequent violations of Class III criteria for both iron and fecal coliform

- Total P concentrations in several natural areas with deciduous forests exceeded developed EMC values

Natural Community Indices

1. Florida Vegetation and Land Cover (FFWCC)

- Part of Florida's Natural Heritage Program at FSU
- Reflects existing land cover based on aerial photography – both developed and natural areas
- Original survey conducted in 1990s included:
  - 17 natural and semi-natural cover types
  - 4 land cover types reflecting disturbed land
  - 1 water class
- Survey updated using aerial photography (2003) and included:
  - 26 natural and semi-natural cover types
  - 16 land cover types reflecting disturbed land
  - 1 water class
- Coverage maps are available for all of Florida
- Subject to limitations of aerial photography
- Digital GIS version released in 2004



Natural Community Indices – cont.

2. Florida Natural Areas Inventory (FNAI)

- Developed by Florida Department of Natural Resources (DNR)
- Reflects original, natural vegetation associations in Florida
- Natural communities are characterized and defined by a combination of physiognomy, vegetation structure and composition, topography, landform, substrate, soil moisture condition, climate, and fire
- Named for their most characteristic biological or physical feature
- Grouped into 6 Natural Community Categories with 13 Natural Community Groups and 66 sub-groups based on hydrology and vegetation
- FNAI is system used by State Park system
- Coverage maps are not available for all of Florida
- This coverage index selected for natural area characterization study

- http://fnai.org/PDF/AA_Short_Descriptions_Final_2010.pdf

Natural Community Indices – cont.

3. Florida Cooperative Land Cover Map

- Released in July 2010
- Combined aspects of the Florida Vegetation and Land Cover (FFWCC) and the Florida Natural Areas Inventory (FNAI)
- Version 3.5 released in November 2021
- Available in GIS
- Primary responsibility is assigned to FWC with assistance from FNAI

- Home - Florida Natural Areas Inventory (fnai.org)

Update to Natural Community Indices

4. Florida Land Cover Classification System (2012, 2018)

- FDEP has begun an evaluation to develop a unified lake cover classification system
- 22 terrestrial and wetland types
- More robust classification system that accounts for spatial differences within classifications
- Revision of GIS layers
- Numbered classification system similar to FLUCCS, but different numbers
- Updated frequently

Statewide Land Use Land Cover | Florida Department of Environmental Protection Geospatial Open Data

Use of FLUCCS Codes in Loading Calculations

Problems:

- FLUCCS codes contain too much detail and often misclassify land use activities

- Runoff emc data are not available for all listed land use categories

- FLUCCS codes have been converted to the closest general categories based on anticipated runoff characteristics

- Available in BMPFast Model

FLUCCS Code	Description
1100	Residential, Low Density-Less than 2 du/acre
1200	Residential, Medium Density-Two-five du/acre
1300	Residential, High Density
1400	Commercial and Services
1700	Institutional
1820	Golf Course
2110	Improved Pasture
2120	Unimproved Pastures
2130	Woodland Pasture
2210	Citrus groves
3100	Herbaceous Dry Prairie
3200	Shrub and Brushland
3300	Mixed Rangeland
4110	Pine flatwoods
4340	Hardwood Conifer Mixed
6120	Mangrove swamp
6170	Mixed wetland hardwoods
6420	Saltwater marshes
6460	Mixed scrub-shrub wetland
7410	Rural land in transition w/o indicators of intended activity

Runoff Characteristics and EMC Values

By: Harvey H. Harper

January 2026