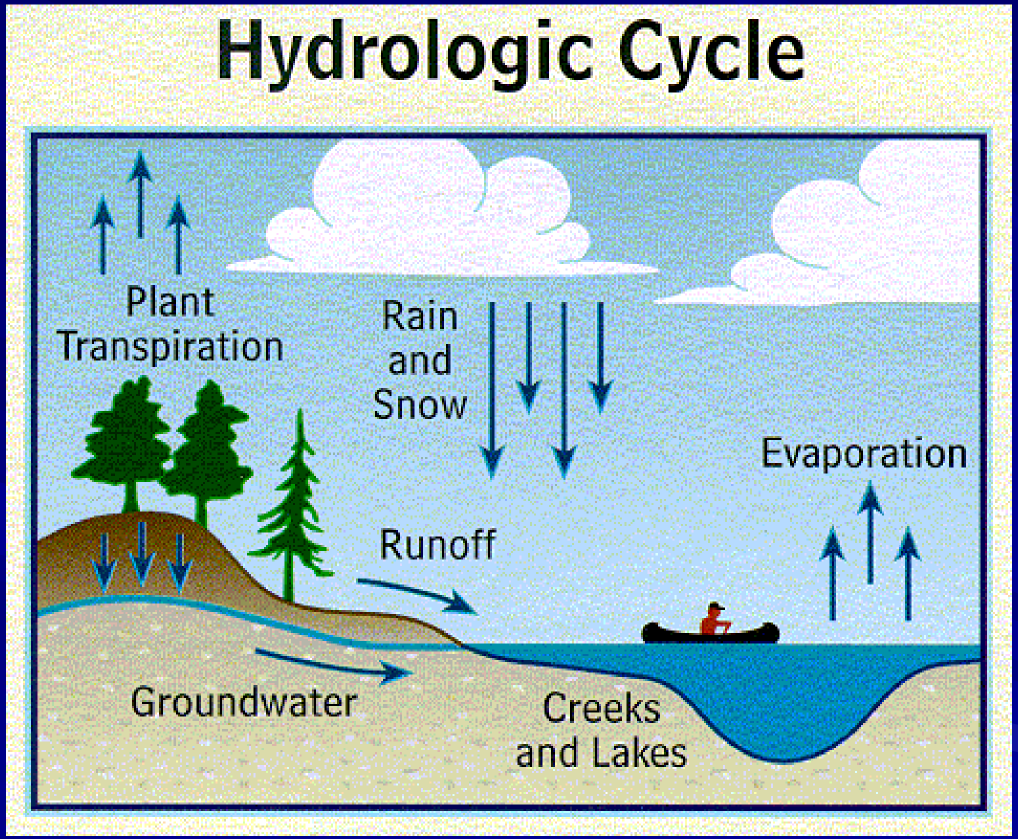
BMPTRAINS MODEL:
RAINFALL CHARACTERISTICS

BY: HARVEY H. HARPER, PHD, P.E.

Precipitation

- Precipitation drives the hydrologic cycle
- The runoff component must be conveyed and treated
- Understanding precipitation is essential to understanding and quantifying runoff

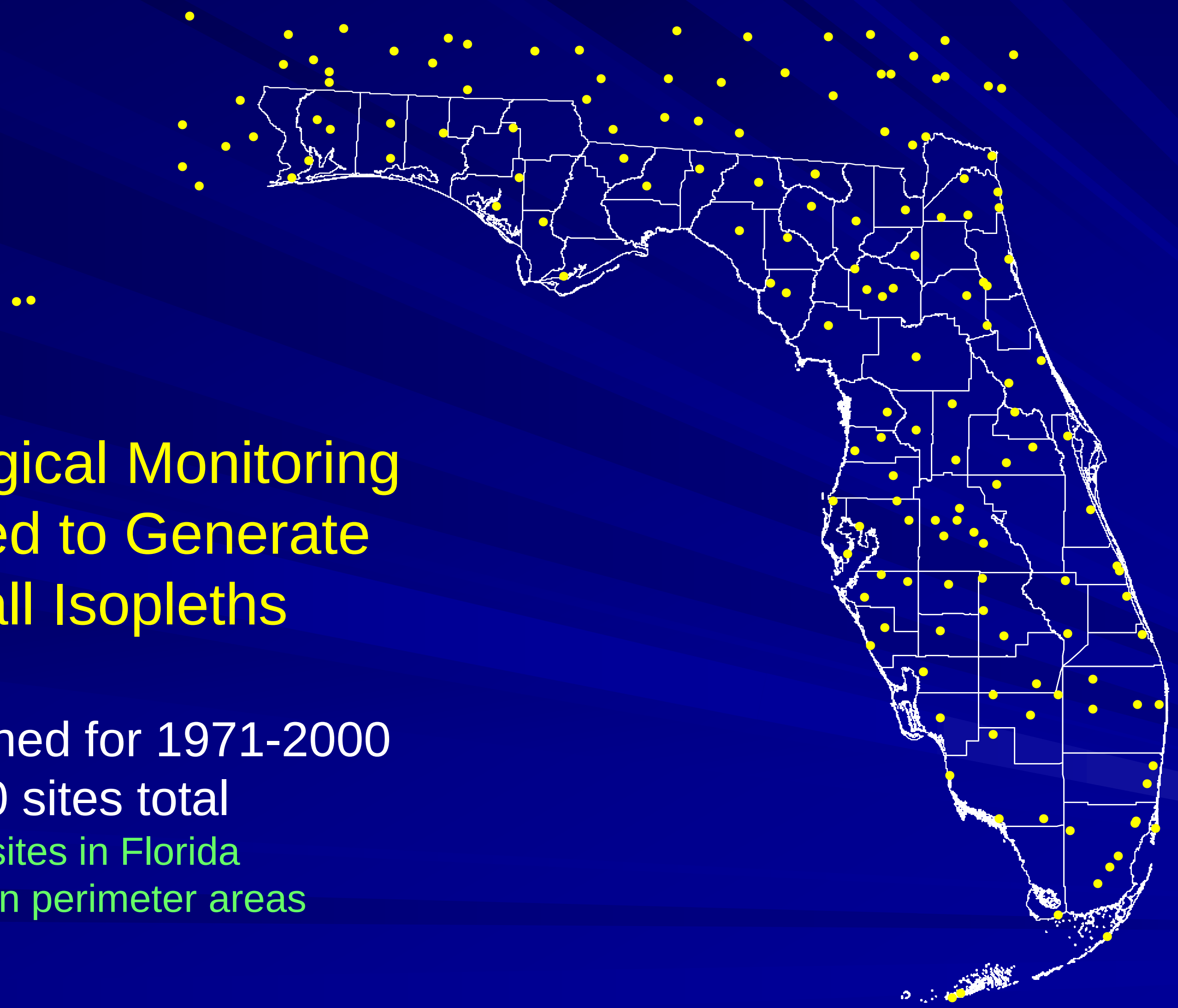


BMPTRAINS Rainfall Data

- Rainfall data included in the BMPTRAINS Model are based on an evaluation conducted by Harper and Baker (2007) for FDEP which is summarized in the document titled “Evaluation of Current Stormwater Design Criteria within the State of Florida”

- Study included an evaluation of rainfall characteristics throughout the State, including
  - Rainfall depths
  - Rainfall variability
  - Inter-event dry periods

Available Meteorological Data



Meteorological Monitoring Sites Used to Generate Rainfall Isopleths

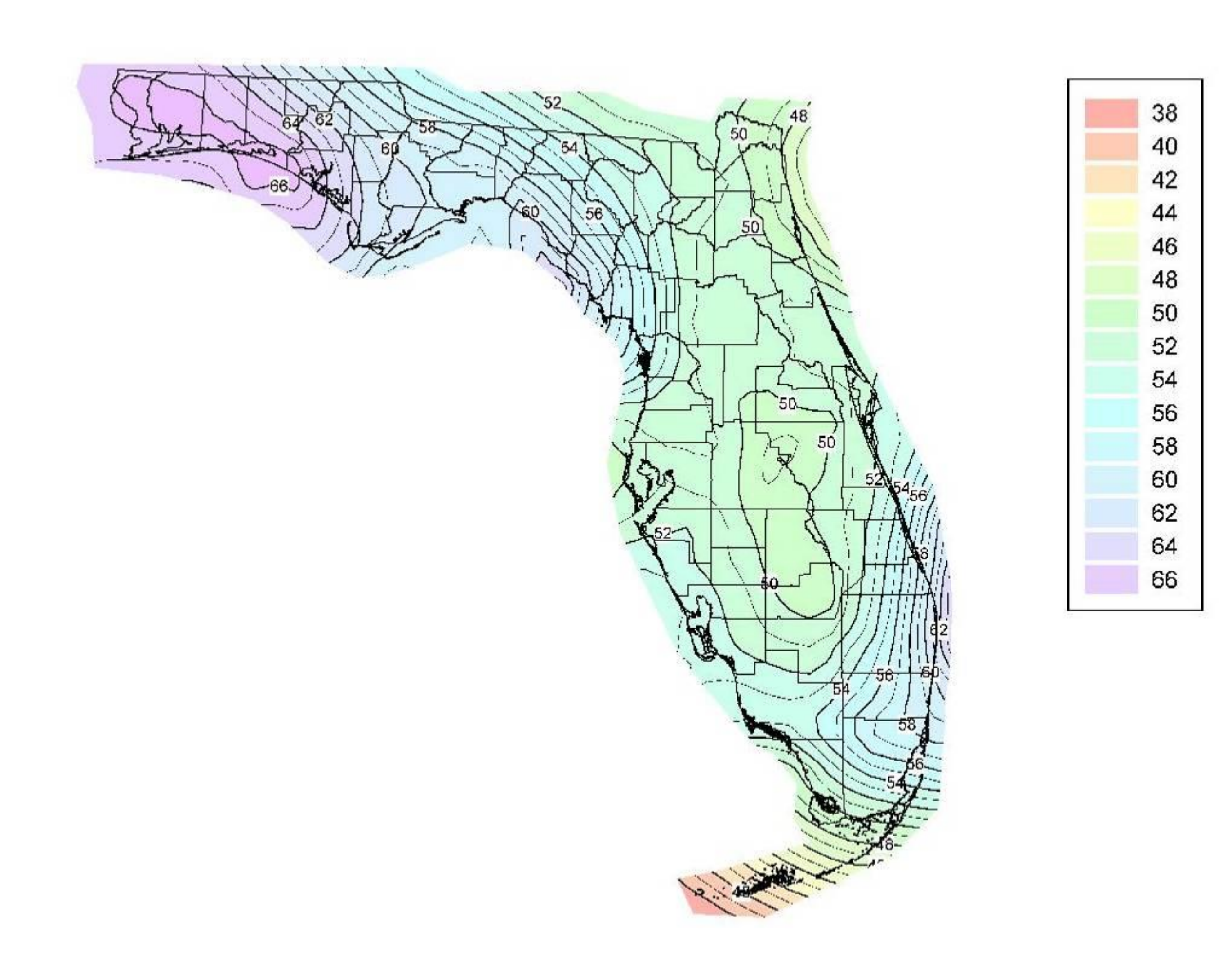
- Data obtained for 1971-2000
- 160 sites total
  - 111 sites in Florida
  - 49 sites in perimeter areas

Average Annual Florida Precipitation 1971 – 2000

- Rainfall isopleths were developed for 1971 – 2000 based on the historical data

- Florida rainfall is highly variable ranging from ~ 38 – 66 in/yr, depending on location

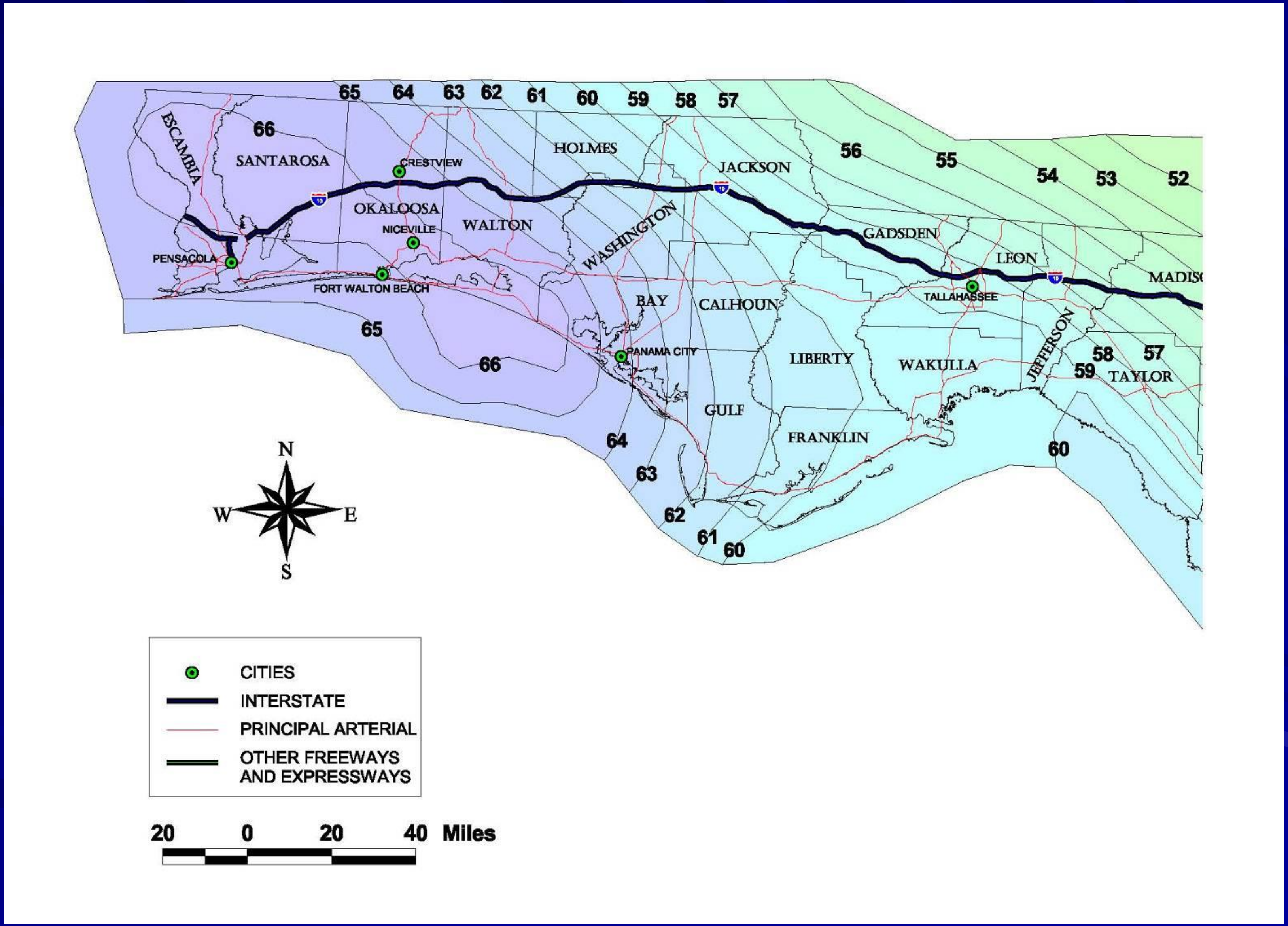
- Isopleths are used to determine project rainfall in BMPTRAINS



Expanded View of Rainfall Isopleths

- Expanded view plots are available in BMPTRAINS for the entire State

- Use expanded plots to determine annual rainfall for project site



Meteorological Evaluation

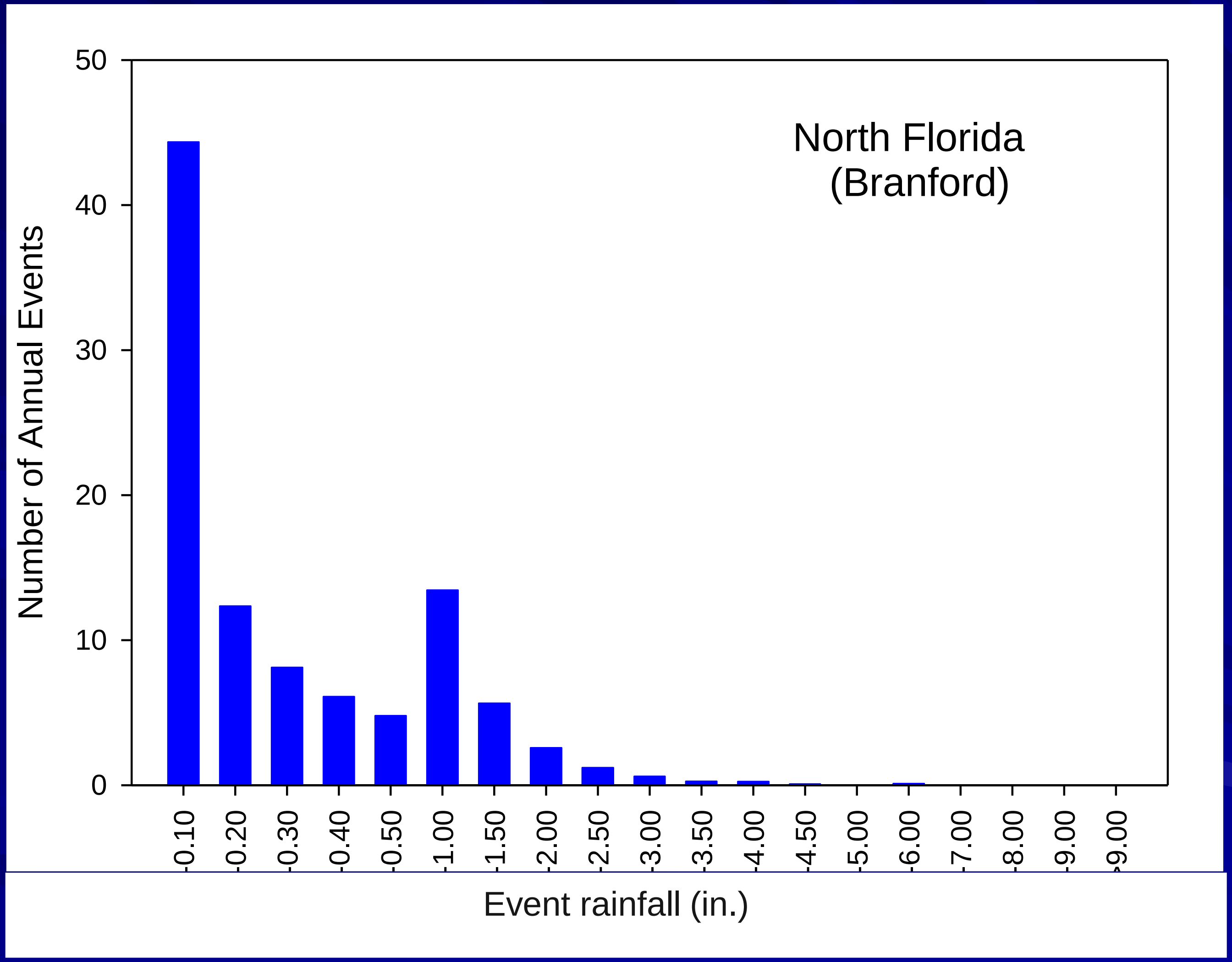
- Obtained historical 1 hour rainfall data from the National Climatic Data Center (NCDC) for each available meteorological station
  - Data available at 45 of 111 Florida stations
  - Period of record ranged from 25 – 59 years per site
- Grouped data into individual rain events
  - Used 3 hour separation to define individual events
- Created historical data set of daily rain events over period of record for each site
- Developed annual frequency distribution of individual rain events for each monitoring site

Typical Rainfall Frequency Distribution

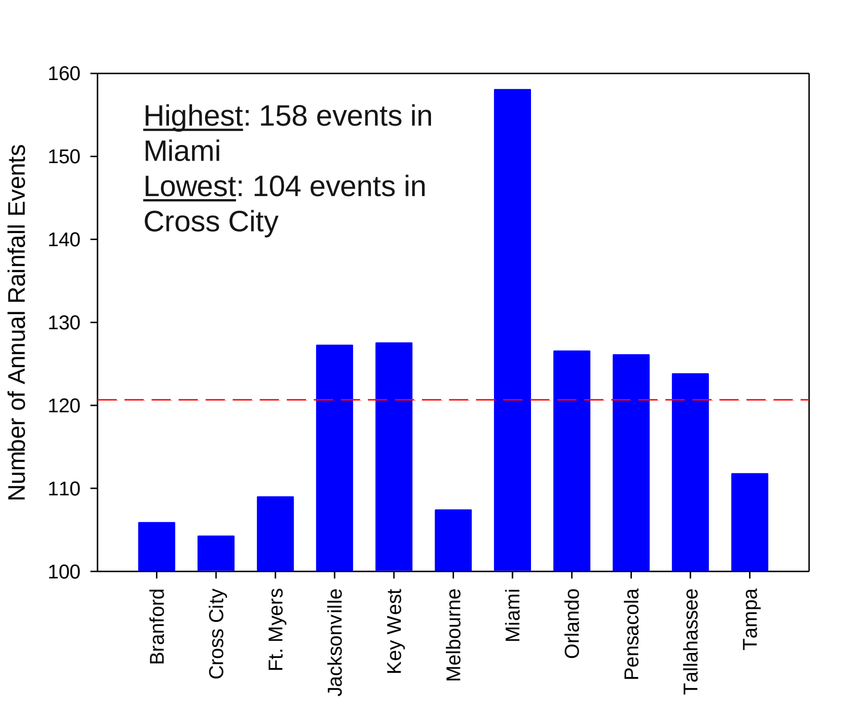
- A large number of annual rain events are small depths

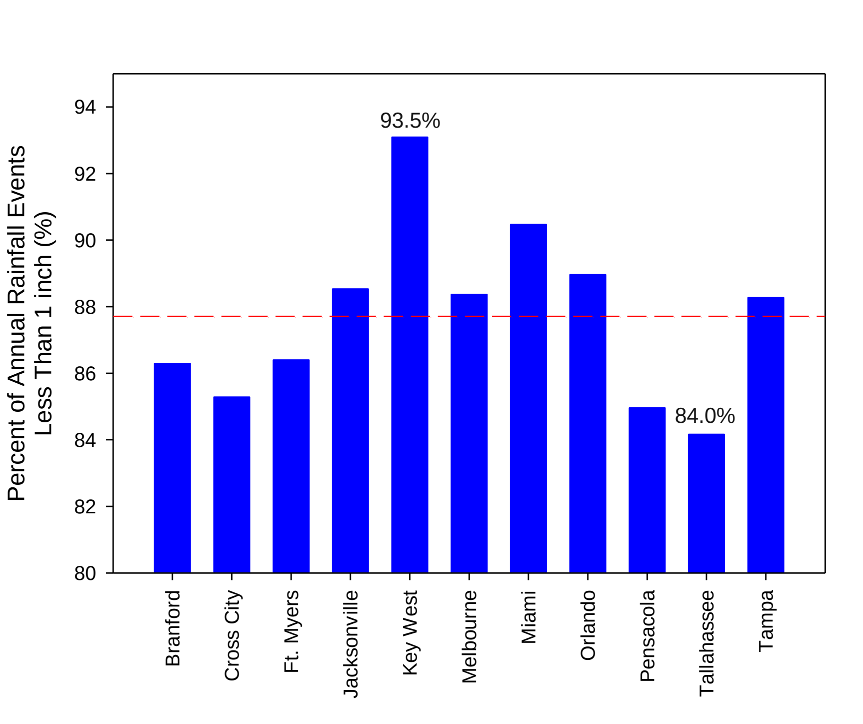
- A relatively small number of annual events are large depth

- Similar, but variable, patterns for stations throughout Florida



Characteristics of Rainfall Events at Selected Meteorological Sites





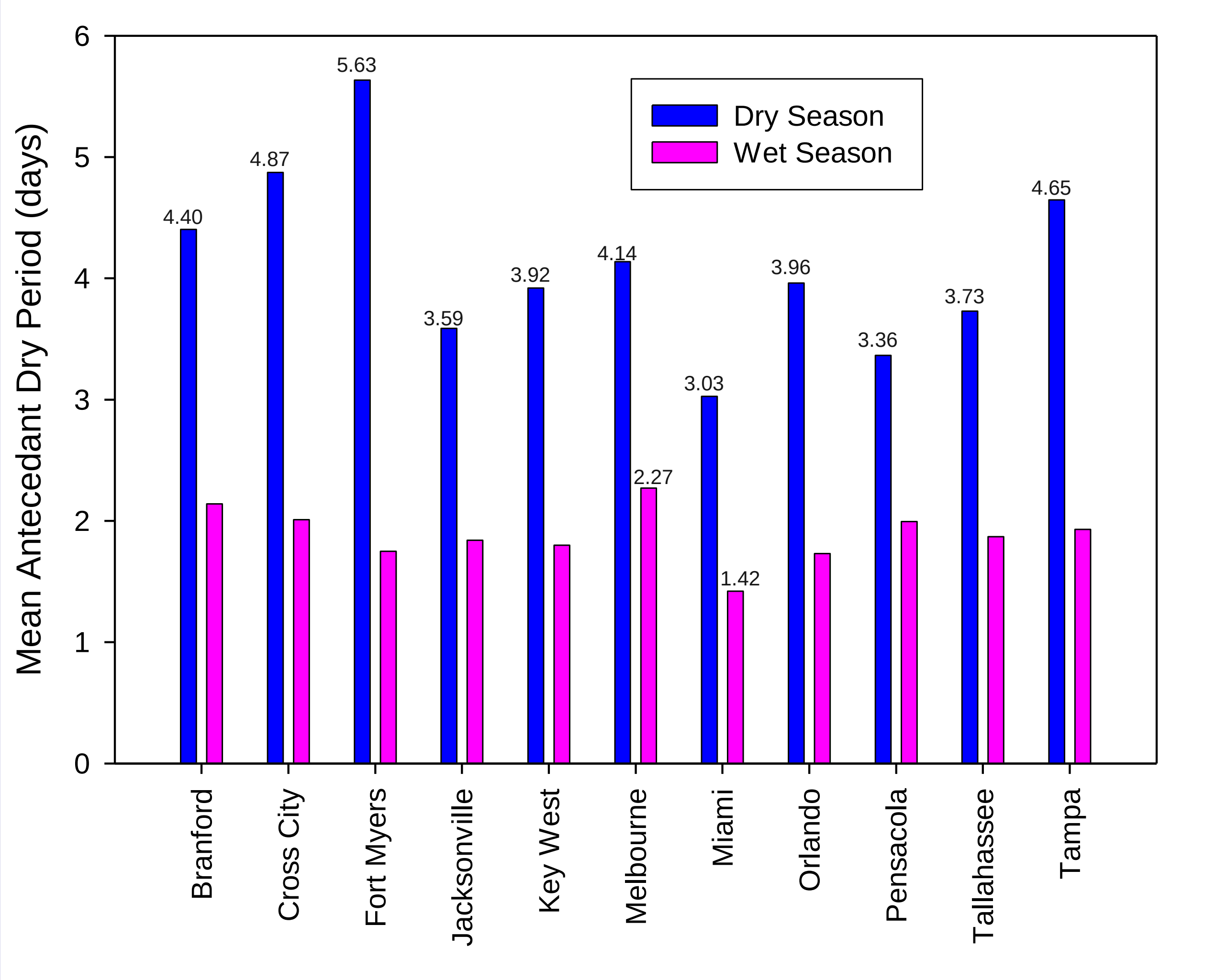
- Rainfall is highly variable in the number of “small” and “large” events at sites around the state

-This impacts both runoff generation as well as treatment system performance efficiency

Variability in Inter-Event Dry Period

Variability in rainfall frequency impacts:

- Runoff C values
- Recovery and performance efficiency of stormwater management systems, especially dry retention



Summary

- Rainfall in Florida is highly variable
  - Annual rainfall
    - Ranges from 38in/yr in Key West to 68 in/yr in Tallahassee and Pensacola
  - Number of annual rain events
    - Ranges from 104 events/yr in Cross City to 158 events/yr in Miami
  - Rain event depths
    - Most rain events in Florida are less than 0.5 inch
    - Approximately 84 – 94% are less than 1 inch
  - Inter-event dry period
    - Wet season – 1.42 days (34 hrs.) – 2.27 days (54 hrs.)
- Rainfall variability impacts runoff volumes and BMP efficiencies throughout the State

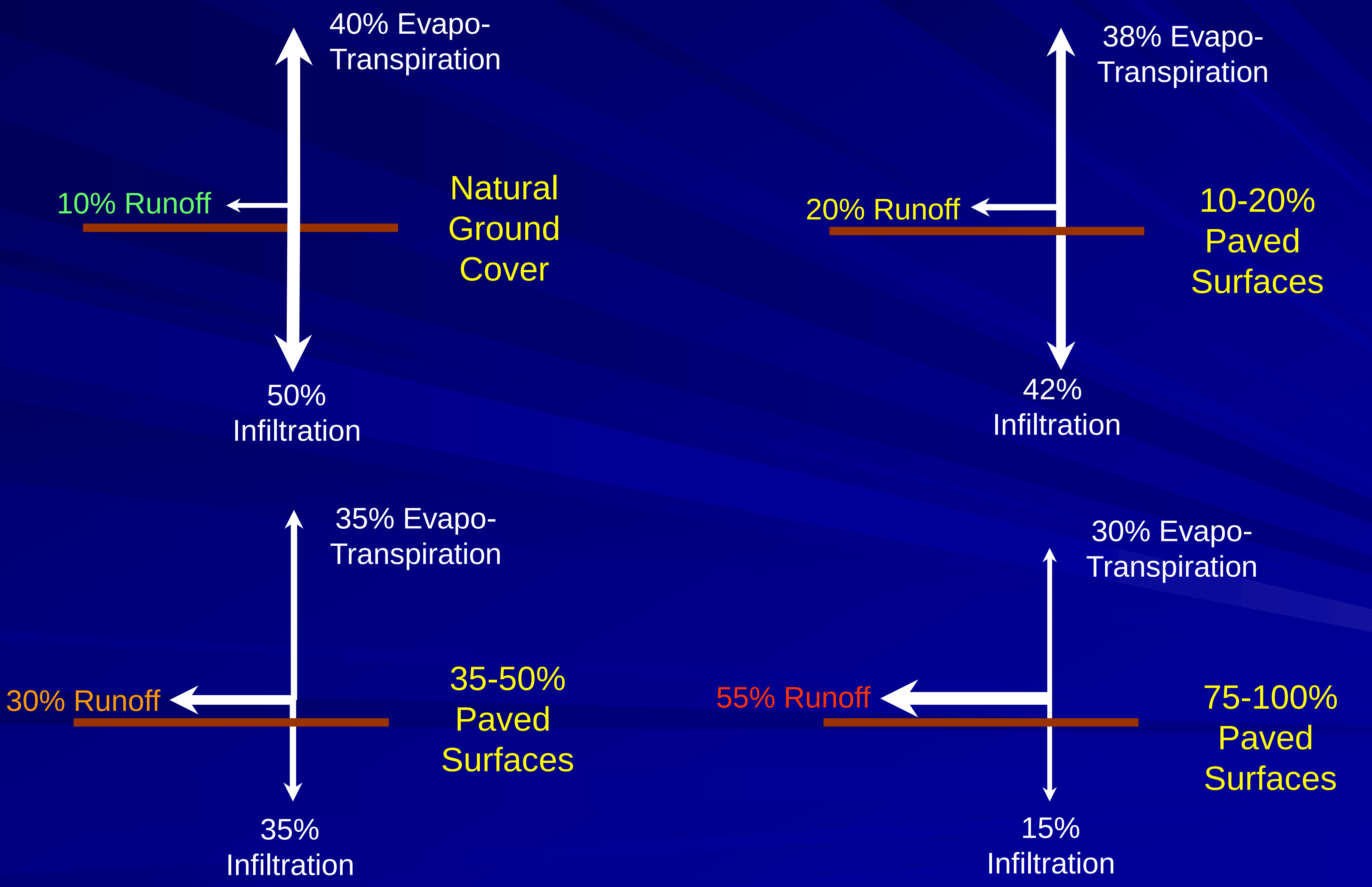
BMPTRAINS MODEL:
RUNOFF GENERATION AND ESTIMATION

BY: HARVEY H. HARPER, PHD, P.E.

Runoff Generation

- Runoff generation is a function of:
  - Precipitation
  - Soil types
  - Land cover
- Understanding precipitation is essential to understanding and quantifying runoff

Typical Hydrologic Changes Resulting From Development



Runoff Volume Estimation

- Runoff generation is a function of a variety of factors, including:
  - Land use
  - Impervious surfaces
  - Soil types
  - Topography –
    - Basin slope
    - Depressional areas
  - Precipitation amount and event characteristics
- Model must be capable of incorporating each of these factors

BMPTRAINS Runoff Estimation

- Runoff estimation in the BMPTRAINS Model is based on relationships developed by Harper and Baker (2007) for FDEP summarized in the document titled “Evaluation of Current Stormwater Design Criteria within the State of Florida”

- Modeling was conducted using the SCS Curve Number (CN) methodology
  - Common method used by most civil engineers
  - Model used to calculate annual runoff coefficients (C values) for meteorological sites throughout Florida

Runoff Coefficients

Runoff coefficients (C values)

- Runoff coefficients reflect the proportion of rainfall that becomes runoff under specified conditions

- Tabular C values are used to size pipes using the Rational Formula:

$$Q = C \times i \times A$$

Where: C = estimate of runoff proportion for a design storm event (typically 10 yr)

- Runoff coefficients are often improperly used for estimation of runoff volumes for non design storm conditions

- Tabular runoff coefficients were never intended to reflect estimates of annual rainfall/runoff relationships

Common Rational Formula Runoff Coefficients

Area	Runoff Coefficient
Business (Downtown)	0.70 to 0.95
Business (Neighborhood)	0.50 to 0.70
Residential (Single-Family)	0.30 to 0.50
Residential (Multi-Units, Detached)	0.40 to 0.60
Residential (Suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial (Light)	0.50 to 0.80
Industrial (Heavy)	0.60 to 0.90
Parks, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Unimproved, Natural Areas	0.10 to 0.30

- Common C values reflect runoff potential under design storm event conditions
- Rational runoff coefficients <u>do not</u> reflect the proportion of annual rainfall which becomes runoff

SCS Curve Number Methodology

- SCS Curve Number (CN) methodology
  - Outlined in NRCS document TR-55 titled “Urban Hydrology for Small Watersheds”
  - Common methodology used in many public and proprietary models
  - Curve numbers are empirically derived values which predict runoff as a function of soil type and land cover
  - Can be used to predict event specific runoff depths and volumes
  - Runoff generation based on impervious area, soil types and land cover
  - Model incorporates two basic parameters:
    - Directly connected impervious area (DCIA)
      - Percentage of impervious area with a direct hydraulic connection to the drainage system (0 – 100%)
    - Curve Number (CN)
      - Measure of the runoff generating potential of the pervious areas (grass, landscaping, etc.) and impervious areas which are not DCIA (0 – 100)

Typical Curve Numbers (TR-55)

Cover Type and Hydrologic Condition	Curve Number			
	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%) …………………….......…	68	79	86	89
Fair condition (grass cover 50% to 75%) ……………................	49	69	79	84
Good condition (grass cover > 75%) ……………………...........	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc. (excl. ROW)	98	98	98	98
Streets and roads:				
Paved; curbs and storm (excl. ROW) ………………….. ……….	98	98	98	98
Paved; open ditches (including right-of-way) …………………...	83	89	92	93
Gravel (including right-of-way) …...	76	85	89	91
Dirt (including right-of-way) ………………..............................	72	82	87	89
Pasture, grassland, or range:				
Poor condition ..………………………………………..............	68	79	86	89
Fair condition ..…………………………………………………..	49	69	79	84
Good condition …………………………………………………	39	61	74	80
Brush—brush-weed-grass mixture:				
Poor ………………………………………………….............	48	67	77	83
Fair …………………………………………………………….	35	56	70	77
Good …………………………………………………………...	30	48	65	73
Woods:				
Poor …………………………………………………………….	45	66	77	83
Fair …………………………………………………………….	36	60	73	79
Good …………………………………………………………...	30	55	70	77

Typical Curve Numbers (TR-55)

Cover Type and Hydrologic Condition	Imp. (%)	Curve Number			
		A	B	C	D
Residential					
Lot size: 1/8 acre or less ………………………........…	65	77	85	90	92
Lot size: 1/4 acre ……………............................	38	61	75	83	87
Lot size: 1/3 acre …………………………..............	30	57	72	81	86
Lot size: 1/2 acre	25	54	70	80	85
Lot size: 1 acre	20	51	68	79	84
Lot size: 2 acre	12	46	65	77	82
Water/wetlands	0	0	0	0	0

- General curve numbers for available for residential areas
  - General CN values reflect runoff potential for the pervious and impervious areas combined
    - Do not directly address DCIA
    - Should not be used in BMPTRAINS model
- Water areas are assigned a CN and C-value of zero since precipitation and evaporation are approximately equal over an annual cycle

Directly Connected Impervious Areas (DCIA)

- Definition varies depending on the type of analysis
  - Flood routing – Major events
    - DCIA includes all impervious areas from which runoff discharges directly into the drainage system
    - Also considered to be DCIA if runoff discharges as a concentrated shallow flow over pervious areas and then into the drainage system
      - Ex. – Shallow roadside swales
    - Often generously estimated to provide safety factor for design
  - Annual runoff estimation – Common daily events
    - DCIA includes all impervious areas from which runoff discharges directly into the drainage system during small events
    - Does not include swales
    - Generally results in a lower DCIA value than used for flood routing

SCS Curve Number Parameters

- Non-Directly Connected Impervious Areas (non-DCIA):
  - Includes pervious areas + impervious areas which are not considered to be DCIA

- Non-DCIA Curve Number (non-DCIA CN Value):

$$\text{Non-DCIA CN Value} = \frac{(\text{Area}_{\text{perv.}}) \times (\text{CN}_{\text{perv.}}) + (\text{Area}_{\text{non-DCIA}}) \times 98}{(\text{Area}_{\text{perv.}}) + (\text{Area}_{\text{non-DCIA}})}$$

- The Non-DCIA CN Value is then used to calculate the soil storage:

$$Soil\ Storage,\ S = \left(\frac{1000}{nDCIA\ CN} - 10 \right)$$

Curve Number Adjustments

CN values were adjusted based on Antecedent Moisture Condition (AMC

Antecedent Moisture Condition (AMC)	Total Antecedent 5-Day Rainfall (inches)	
	Dormant Season (October – February)	Growing Season (March – September)
I – Dry Conditions	< 0.5	< 1.4
II – Normal	0.5 – 1.1	1.4 – 2.1
III – Wet Conditions	> 1.1	> 2.1

Typical CN adjustments for varying AMC conditions

CN for Condition II	Corresponding CN for Condition	
	I	II
100	100	100
90	78	98
80	63	94
70	51	87
60	40	79
50	31	70
40	23	60
30	15	50

Calculation of Runoff Volumes

Separate calculations are conducted for the DCIA and non-DCIA areas

- Using an overall CN value for the area would lead to significant errors in estimating runoff

1. Runoff from non-DCIA areas is calculated by:

$$Q_{nDCIA_i} = \frac{(P_i - 0.2S)^2}{(P_i + 0.8S)}$$

CN = curve number for pervious area

Imp. = percent impervious area

DCIA = percent directly connected impervious area

non-DCIA CN = curve number for non-DCIA area

P_i = rainfall depth for event (i)

R_{nDCIAi} = rainfall excess for non-DCIA for event **(i)**

2. Runoff from DCIA is calculated as:

$$Q_{DCIAi} = (P_i - 0.1)$$

When P_i is less than 0.1, Q_{DCIAi} is equal to zero

Impacts of Rainfall Variability on Annual Runoff Coefficients

- Continuous simulation of runoff from a hypothetical 1 acre site using SCS curve number methodology and historical rainfall data set for 45 rainfall sites with hourly data
  - Data ranged from 13 – 64 years per site, but most contained 30+ years of data per site (mean of 4,685 events/site)
  - Data separated into individual events using 3 hour separation
- Runoff modeled for each event at each site for (mean of 4,685 events/site) :
  - DCIA percentages from 0-100 in 5 unit intervals
  - Non-DCIA curve numbers from 25-95 in 5 unit intervals
  - 350 model combinations per rainfall site x 45 sites = 15,750 separate models
- Total generated runoff depth compared with rainfall depth to calculate runoff coefficient:

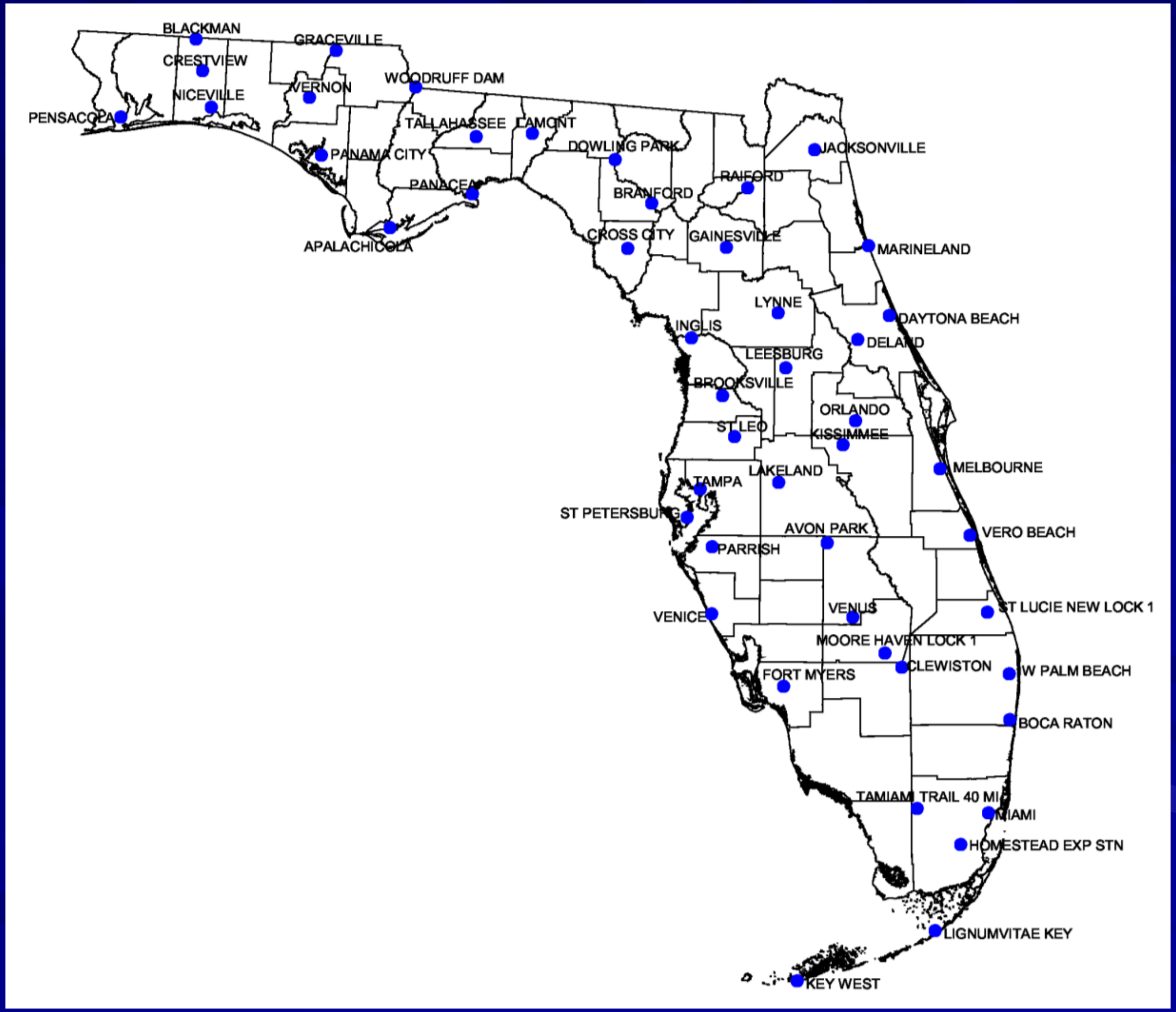
$$\text{C Value} = \frac{\text{Total Runoff Depth}}{\text{Total Rainfall Depth}}$$

Meteorological Sites Included in Runoff Modeling

Hourly Rainfall Sites Used for Runoff Modeling

- 45 sites total

- Runoff modeling conducted for each rain event at each site over available period of record



Modeled C Values for Various Combinations of CN and DCIA

Modeled C values for Miami – 64 years from 1942 - 2005

NDCIA	Percent DCIA																				
CN	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.008	0.048	0.088	0.128	0.168	0.208	0.248	0.288	0.328	0.368	0.408	0.448	0.488	0.528	0.568	0.608	0.648	0.688	0.728	0.768	0.808
35	0.012	0.052	0.092	0.132	0.171	0.211	0.251	0.291	0.331	0.370	0.410	0.450	0.490	0.529	0.569	0.609	0.649	0.689	0.728	0.768	0.808
40	0.018	0.057	0.097	0.136	0.176	0.215	0.255	0.294	0.334	0.373	0.413	0.452	0.492	0.531	0.571	0.611	0.650	0.690	0.729	0.769	0.808
45	0.025	0.064	0.103	0.142	0.182	0.221	0.260	0.299	0.338	0.377	0.417	0.456	0.495	0.534	0.573	0.612	0.651	0.691	0.730	0.769	0.808
50	0.034	0.072	0.111	0.150	0.189	0.227	0.266	0.305	0.343	0.382	0.421	0.460	0.498	0.537	0.576	0.614	0.653	0.692	0.731	0.769	0.808
55	0.044	0.082	0.121	0.159	0.197	0.235	0.273	0.312	0.350	0.388	0.426	0.464	0.502	0.541	0.579	0.617	0.655	0.693	0.732	0.770	0.808
60	0.057	0.095	0.132	0.170	0.207	0.245	0.282	0.320	0.357	0.395	0.433	0.470	0.508	0.545	0.583	0.620	0.658	0.695	0.733	0.770	0.808
65	0.073	0.110	0.147	0.183	0.220	0.257	0.294	0.330	0.367	0.404	0.441	0.477	0.514	0.551	0.588	0.624	0.661	0.698	0.735	0.771	0.808
70	0.093	0.129	0.165	0.201	0.236	0.272	0.308	0.344	0.379	0.415	0.451	0.486	0.522	0.558	0.594	0.629	0.665	0.701	0.737	0.772	0.808
75	0.120	0.155	0.189	0.223	0.258	0.292	0.327	0.361	0.395	0.430	0.464	0.498	0.533	0.567	0.602	0.636	0.670	0.705	0.739	0.774	0.808
80	0.157	0.189	0.222	0.254	0.287	0.319	0.352	0.385	0.417	0.450	0.482	0.515	0.547	0.580	0.613	0.645	0.678	0.710	0.743	0.775	0.808
85	0.209	0.239	0.269	0.299	0.329	0.359	0.389	0.419	0.449	0.479	0.509	0.538	0.568	0.598	0.628	0.658	0.688	0.718	0.748	0.778	0.808
90	0.292	0.318	0.343	0.369	0.395	0.421	0.447	0.472	0.498	0.524	0.550	0.576	0.602	0.627	0.653	0.679	0.705	0.731	0.756	0.782	0.808
95	0.445	0.464	0.482	0.500	0.518	0.536	0.554	0.572	0.590	0.609	0.627	0.645	0.663	0.681	0.699	0.717	0.736	0.754	0.772	0.790	0.808
98	0.614	0.624	0.633	0.643	0.653	0.662	0.672	0.682	0.692	0.701	0.711	0.721	0.730	0.740	0.750	0.760	0.769	0.779	0.789	0.798	0.808

- This process was repeated for each of the 45 meteorological sites

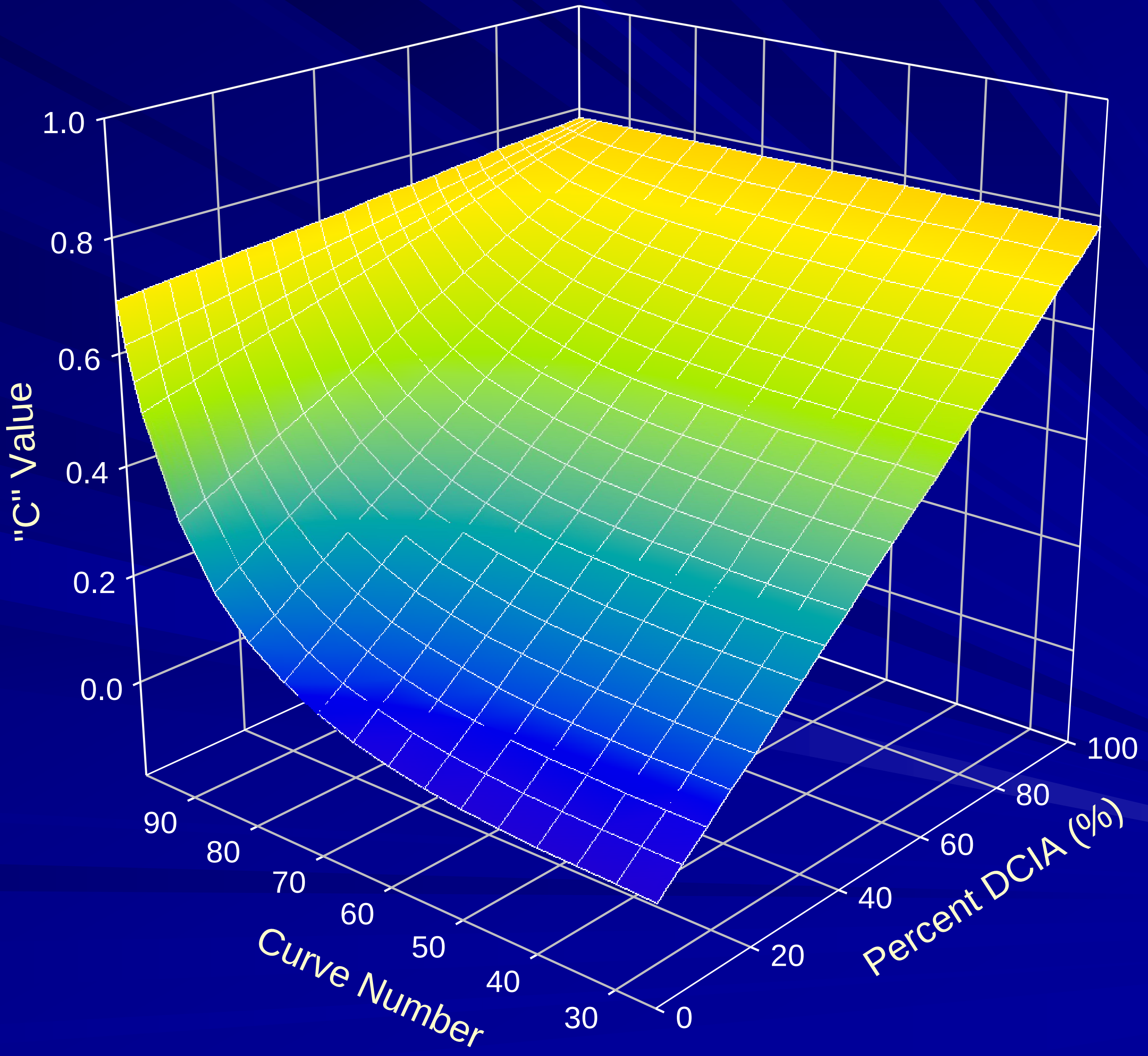
Relationship Between Curve Number, Percent DCIA, and C Value

- Linear relationship between C Value and DCIA

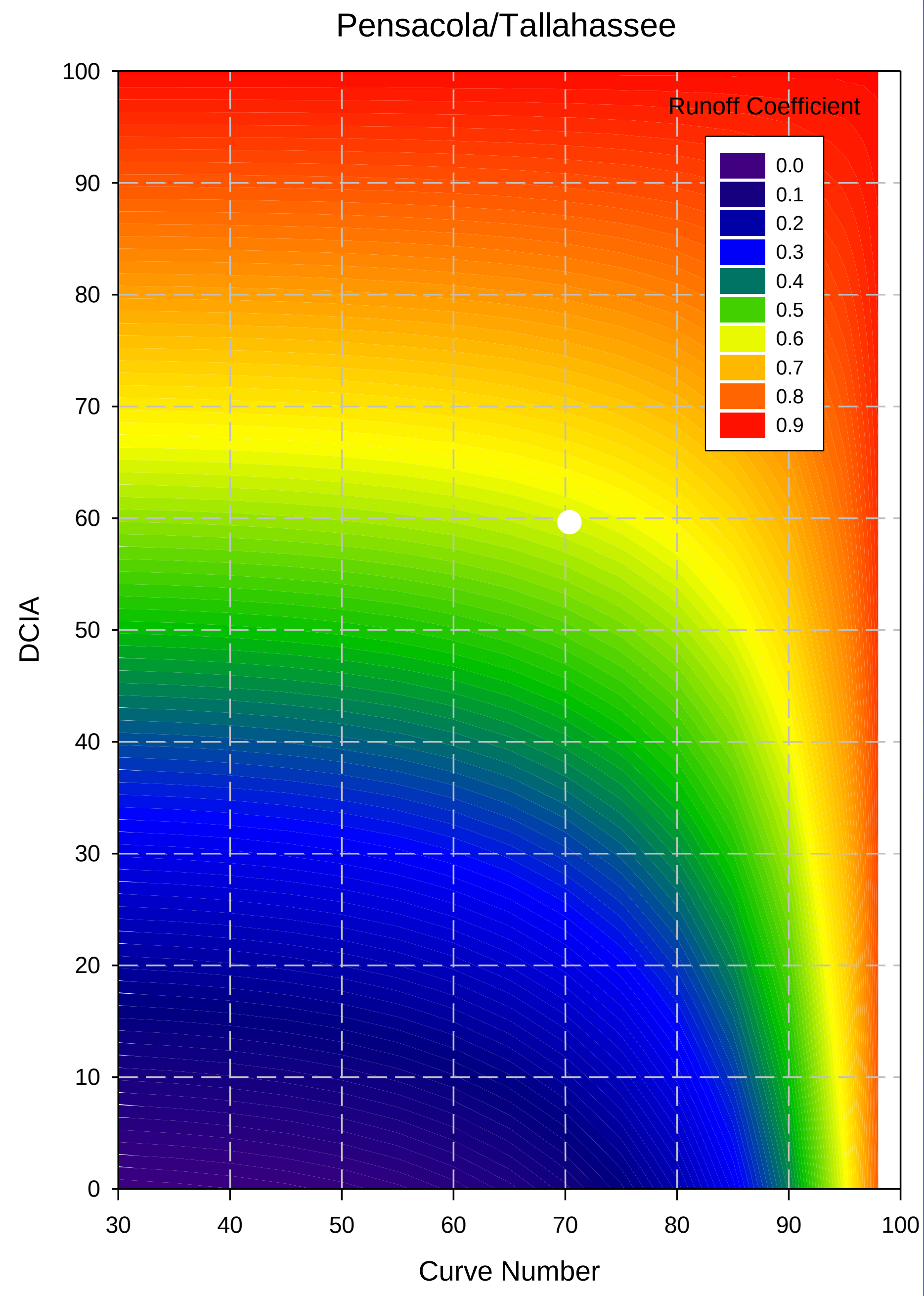
- Exponential relationship between C Value and CN value

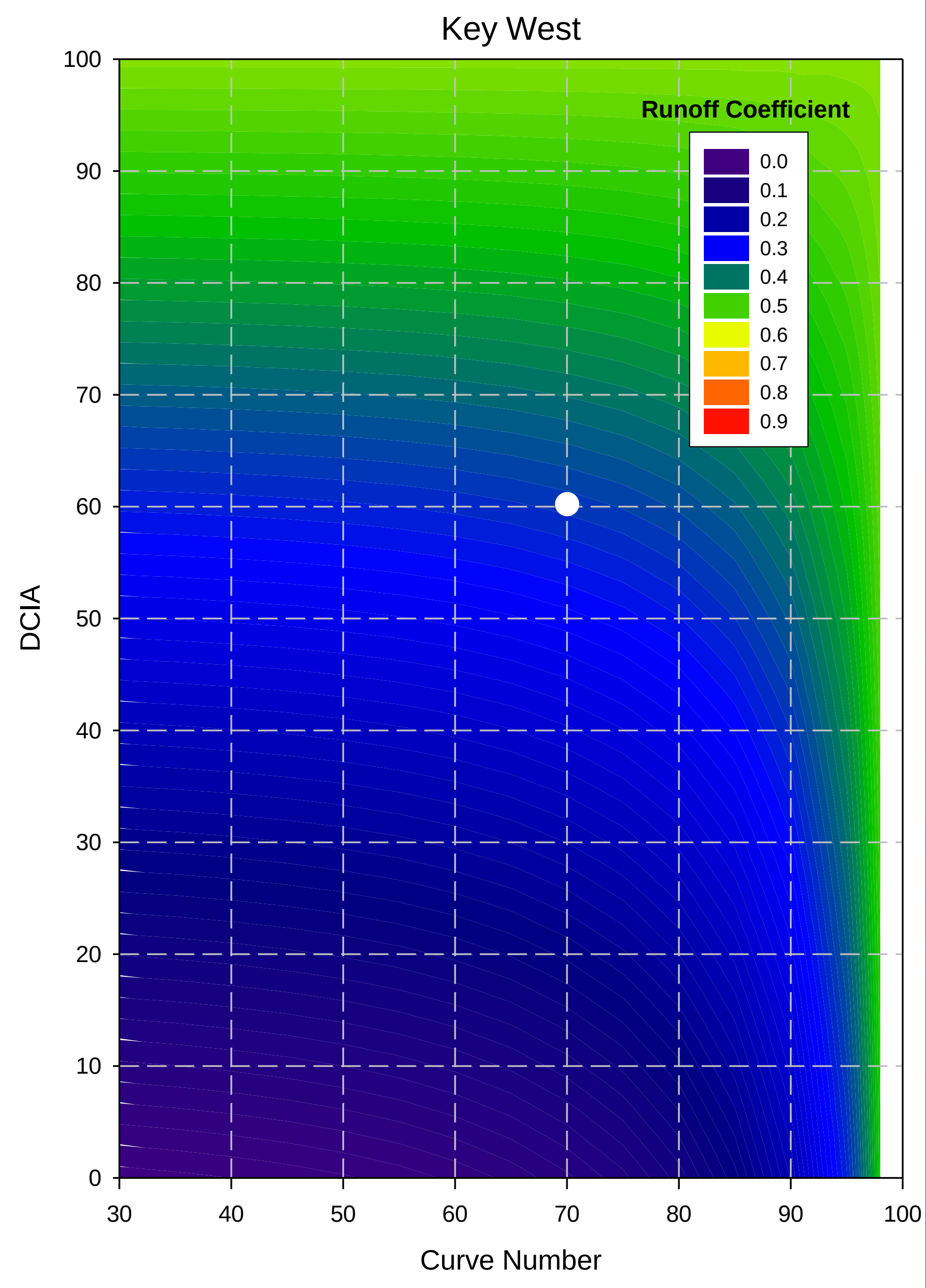
- Implies that averaging CN values is statistically invalid and leads to over-estimation of runoff volume

Parameter	Area 1	Area 2	Combined Area
CN Value	40	80	60
Modeled C Value	0.018	0.157	0.057
Mean C value		0.088	+35
CN Value	60	80	70
Modeled C Value	0.057	0.157	0.093
Mean C value		0.088	-13

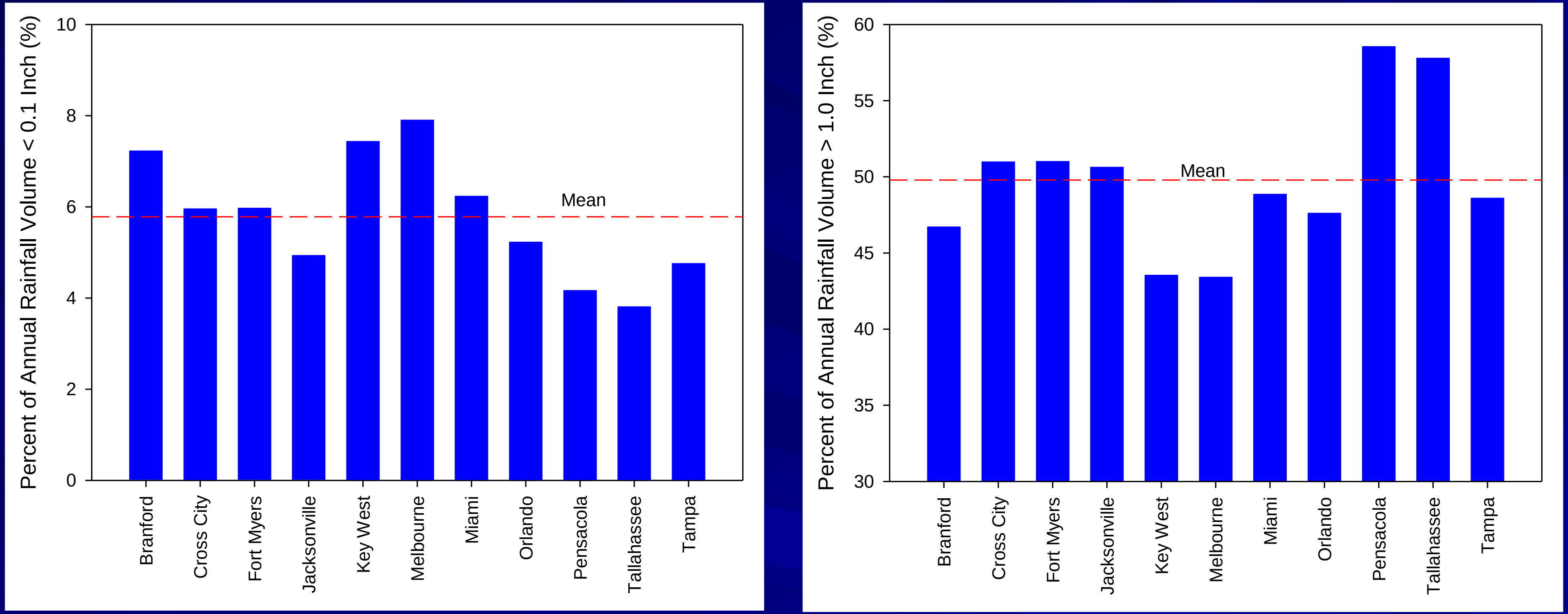


Annual C Values as a Function of DCIA and non-DCIA Curve Number



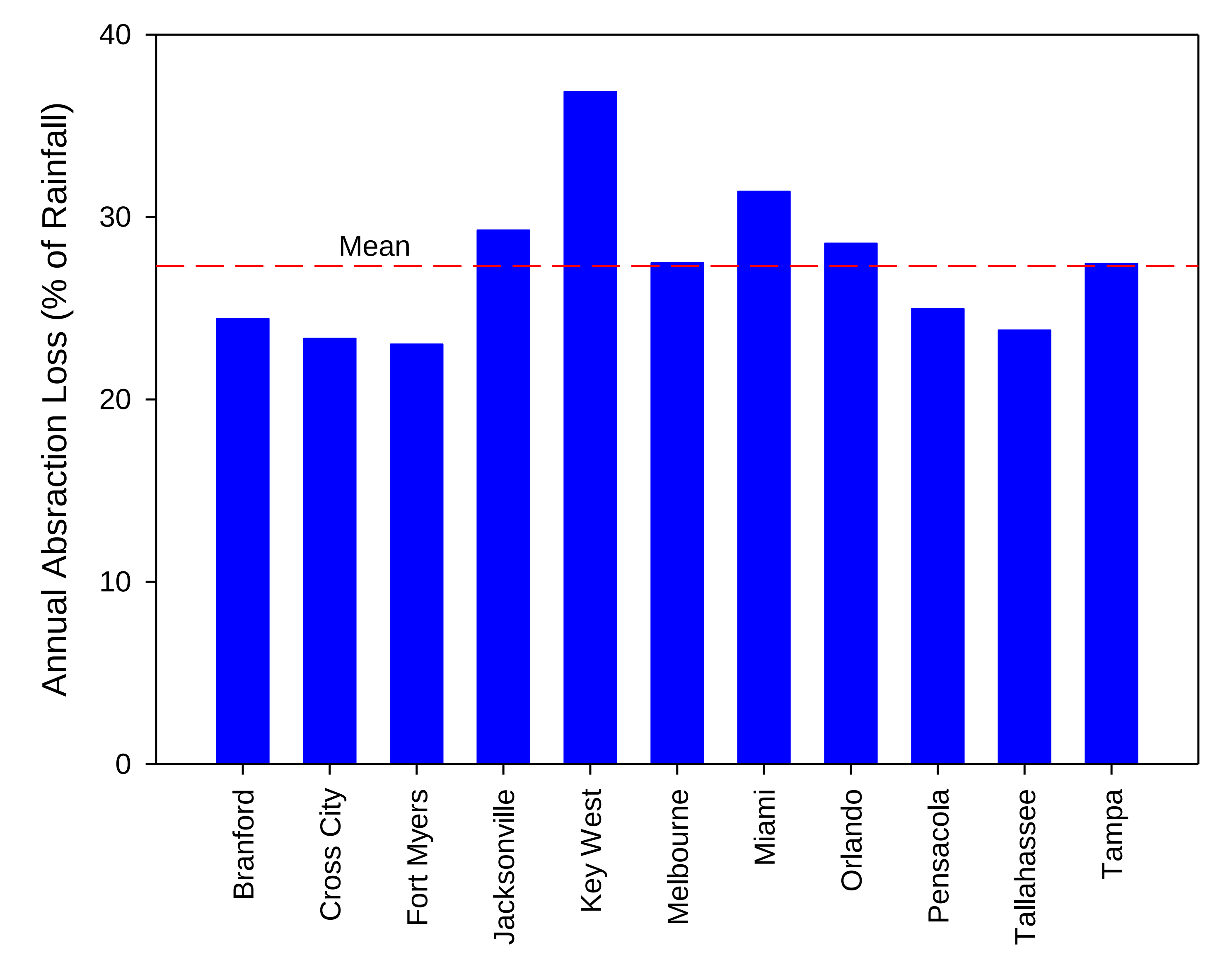


Impacts of Rainfall Characteristics on Runoff Generation



- Key West and Melbourne have a higher percentage of small rain events and a lower percentage of large rain events
  - Results in less annual runoff volume
- Pensacola and Tallahassee have a lower percentage of small events and a higher percentage of large events
  - Results in more annual runoff volume

Comparative Abstraction from Impervious Areas for Meteorological Sites

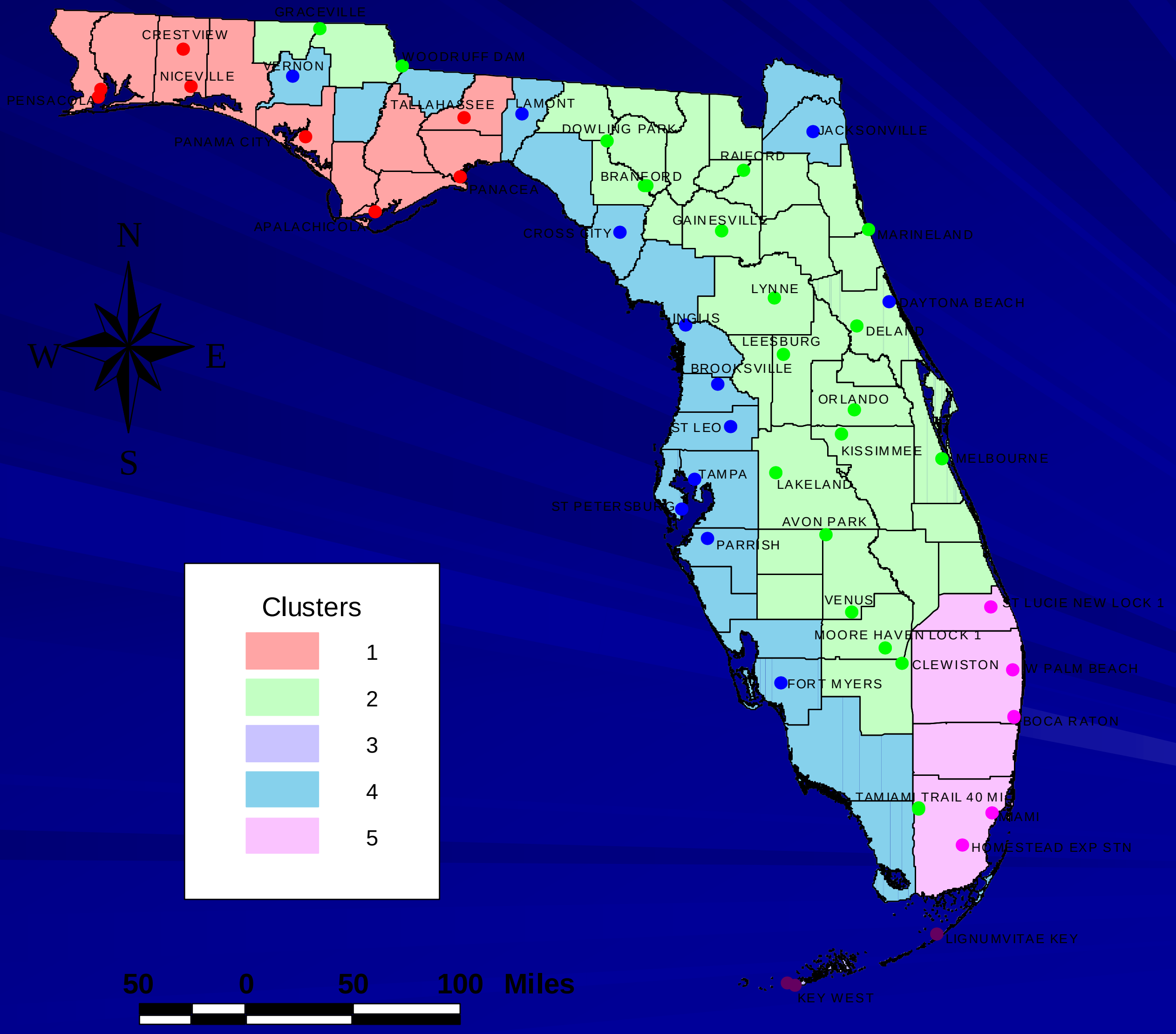


Similar Meteorological Zones

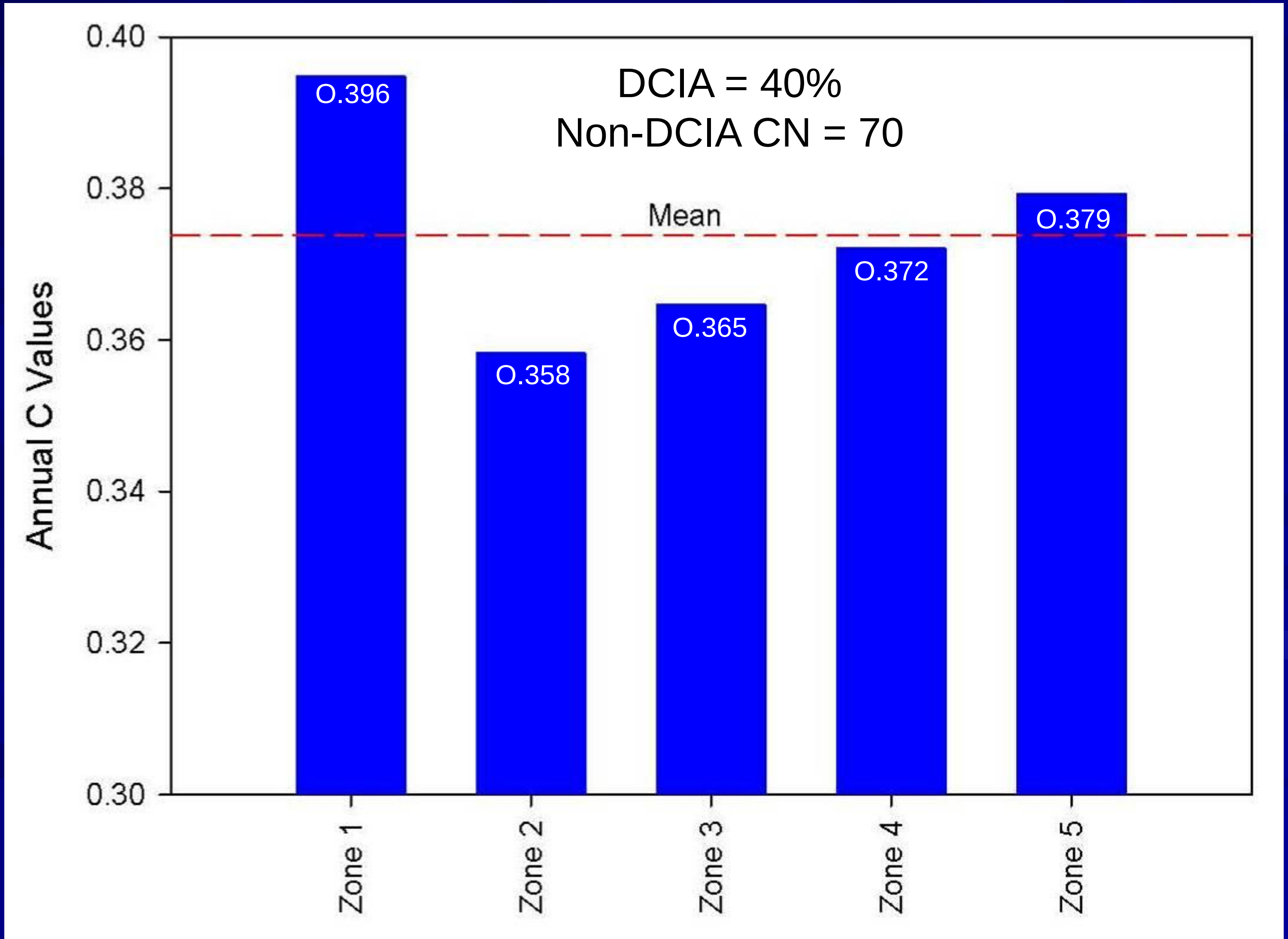
- Cluster analysis used to identify areas with similar annual rainfall/runoff relationships (C values)

- Analysis identified 5 significantly different areas

- Differences due to rainfall distribution rather than annual rainfall depth



Comparison of State-Wide Annual C Values for A Hypothetical Residential Development



BMPTRAINS Runoff Input Data

- Calculation of runoff in the BMPTRAINS model uses the tabular rainfall/runoff relationships developed by Harper and Baker (2007) for each meteorological zone (5 separate tables – Appendix C)

Zone 1 - Panhandle

NDCIA	Percent DCIA																				
CN	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.006	0.048	0.090	0.132	0.175	0.217	0.259	0.301	0.343	0.386	0.428	0.470	0.512	0.554	0.596	0.639	0.681	0.723	0.765	0.807	0.849
35	0.009	0.051	0.093	0.135	0.177	0.219	0.261	0.303	0.345	0.387	0.429	0.471	0.513	0.555	0.597	0.639	0.681	0.723	0.765	0.807	0.849
40	0.014	0.056	0.098	0.139	0.181	0.223	0.265	0.307	0.348	0.390	0.432	0.474	0.515	0.557	0.599	0.641	0.682	0.724	0.766	0.808	0.849
45	0.020	0.062	0.103	0.145	0.186	0.228	0.269	0.311	0.352	0.394	0.435	0.476	0.518	0.559	0.601	0.642	0.684	0.725	0.767	0.808	0.849
50	0.029	0.070	0.111	0.152	0.193	0.234	0.275	0.316	0.357	0.398	0.439	0.480	0.521	0.562	0.603	0.644	0.685	0.726	0.767	0.808	0.849
55	0.039	0.079	0.120	0.161	0.201	0.242	0.282	0.323	0.363	0.404	0.444	0.485	0.525	0.566	0.606	0.647	0.687	0.728	0.768	0.809	0.849
60	0.052	0.092	0.132	0.172	0.212	0.252	0.291	0.331	0.371	0.411	0.451	0.491	0.531	0.570	0.610	0.650	0.690	0.730	0.770	0.810	0.849
65	0.069	0.108	0.147	0.186	0.225	0.264	0.303	0.342	0.381	0.420	0.459	0.498	0.537	0.576	0.615	0.654	0.693	0.732	0.771	0.810	0.849
70	0.092	0.130	0.167	0.205	0.243	0.281	0.319	0.357	0.395	0.433	0.471	0.508	0.546	0.584	0.622	0.660	0.698	0.736	0.774	0.812	0.849
75	0.121	0.158	0.194	0.230	0.267	0.303	0.340	0.376	0.412	0.449	0.485	0.522	0.558	0.595	0.631	0.667	0.704	0.740	0.777	0.813	0.849
80	0.162	0.196	0.230	0.265	0.299	0.334	0.368	0.402	0.437	0.471	0.506	0.540	0.574	0.609	0.643	0.678	0.712	0.746	0.781	0.815	0.849
85	0.220	0.252	0.283	0.315	0.346	0.378	0.409	0.441	0.472	0.503	0.535	0.566	0.598	0.629	0.661	0.692	0.724	0.755	0.787	0.818	0.849
90	0.312	0.339	0.366	0.393	0.419	0.446	0.473	0.500	0.527	0.554	0.581	0.608	0.634	0.661	0.688	0.715	0.742	0.769	0.796	0.823	0.849
95	0.478	0.496	0.515	0.533	0.552	0.571	0.589	0.608	0.626	0.645	0.664	0.682	0.701	0.719	0.738	0.757	0.775	0.794	0.812	0.831	0.849
98	0.656	0.666	0.676	0.685	0.695	0.705	0.714	0.724	0.734	0.743	0.753	0.763	0.772	0.782	0.792	0.801	0.811	0.821	0.830	0.840	0.849

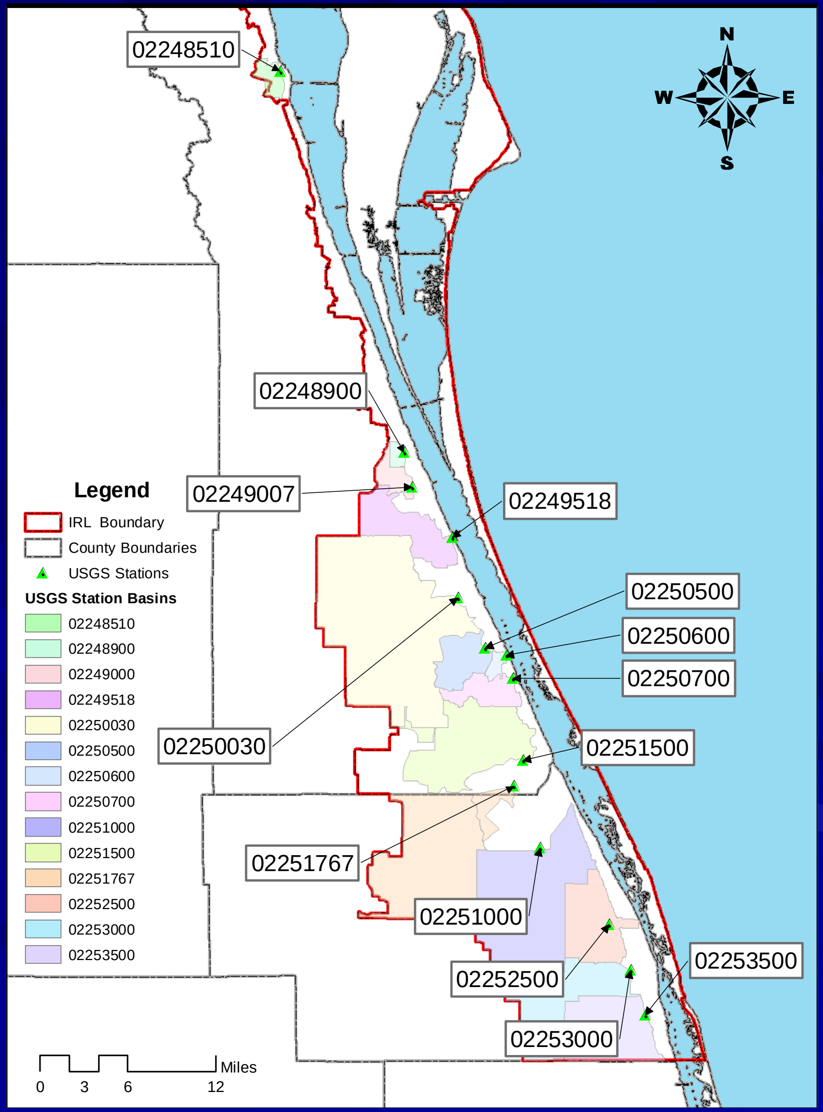
- Required input data include:
  - Rainfall meteorological zone based on rainfall zone map
  - Annual rainfall depth from isopleth maps
  - Project DCIA
  - Non-DCIA curve number
- BMPTRAINS conducts iterations for uneven values of DCIA and CN
  - Calculates annual runoff coefficient (C value) and annual runoff volume

User Defined C Values in BMPTRAINS

USGS Tributary Gauging Sites and Associated Watershed Areas in the Central and Southern IRL

~ 42% of Overall Basin Area

- Most of the watersheds are agriculture and natural areas

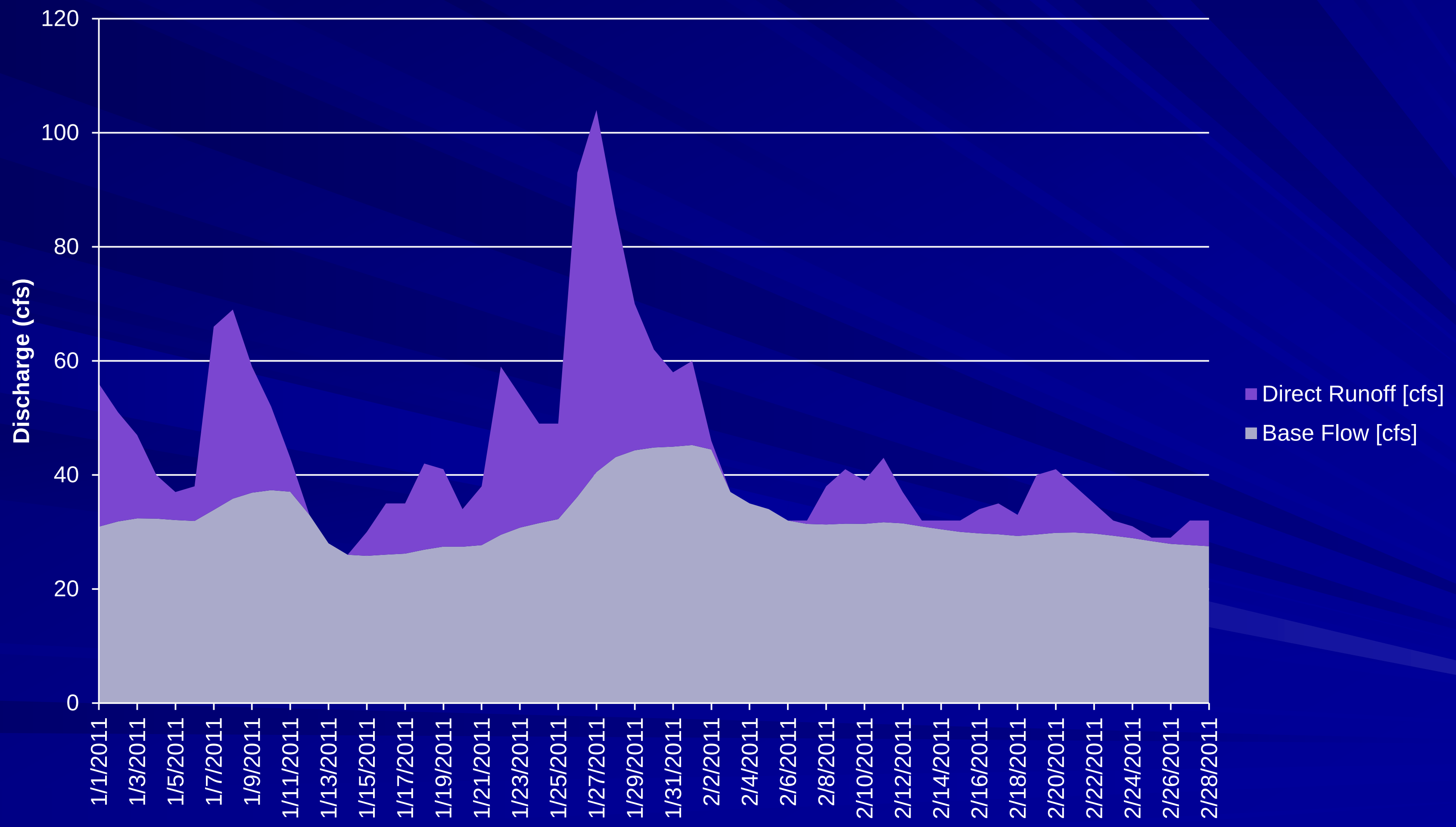


Comparison of Runoff and Baseflow at USGS Station 02251767

- Runoff and baseflow separation conducted using the WHAT program from Purdue University

- Approx 33% of total discharge is runoff with 67% baseflow

- C value obtained from this station would include both runoff and baseflow



Example Calculations

1. Land Use: 90 acres of single-family residential
   5 acres of stormwater management systems
   5 acres of preserved wetlands

2. Ground Cover/Soil Types

   A. Residential areas will be covered with lawns in good condition
   B. Soil types in HSG D

3. Impervious/DCIA Areas

   A. Residential areas will be 25% impervious, 75% of which will be DCIA
      Impervious Area = 25% of developed site = 90 ac x 0.25 = 22.50 acres
      DCIA Area = 22.50 acres x 0.75 = 16.88 acres
      DCIA Percentage = (16.88 ac/90.0 ac) x 100 = 18.7% of developed area

4. Calculate composite non-DCIA curve number from TR-55:

Curve number for lawns in good condition in HSG D = 80
Areas of lawns = 90 acres total – 22.50 ac impervious area = 67.50 acres pervious area
Impervious area which is not DCIA = 22.50 ac – 16.88 ac = 5.62 ac
Assume a curve number of 98 for impervious areas

$$\text{Non-DCIA curve number} = \frac{67.50\ ac\ (80) + 5.62\ ac\ (98)}{67.50\ ac + 5.62\ ac} = 81.4$$

Example Calculations – cont.

5. Calculate annual runoff volume for developed area

The proposed developed area for the project is 90 ac. Estimation of runoff volumes is not included for the 5-acre stormwater management area since runoff generated in these areas is incorporated into the performance efficiency estimates for the stormwater system.

a. **Pensacola (Zone 1) Project**: The BMPTRAINS model calculates the annual runoff coefficient based on the meteorological zone and the hydrologic characteristics.

Pensacola = Zone 1, DCIA = 18.75%, and non-DCIA CN = 81.4

Annual C value = 0.304
The annual rainfall for the Pensacola area = 65.5 inches (From Isopleth Map)
Annual generated runoff volume = 90 ac x 65.5 in/yr x 1 ft/12 in x 0.304 = **149.3 ac-ft/yr**

b. **Key West (Zone 3) Project**: The BMPTRAINS model calculates the annual runoff coefficient based on the meteorological zone and the hydrologic characteristics.

Key West = Zone 3, DCIA = 18.75%, and non-DCIA CN = 81.4

Annual C value = 0.266
The annual rainfall for the Key West area = 40.0 inches (From Isopleth Map)
Annual generated runoff volume = 90 ac x 40.0 in/yr x 1 ft/12 in x 0.266 = **79.8 ac-ft/yr**

Summary

- Like rainfall, runoff in Florida is highly variable
  - Impervious area
    - Direct relationship between runoff and impervious percentage
  - Non-DCIA CN value
    - Exponential relationship between CN value and runoff
  - Characteristics of rain events
- BMPTRAINS Model calculates annual C value and runoff volume based on hydrologic and meteorological characteristics of the project site

BMPTRAINS MODEL:

RUNOFF CHARACTERISTICS AND LOADINGS

BY: HARVEY H. HARPER, PHD, P.E.

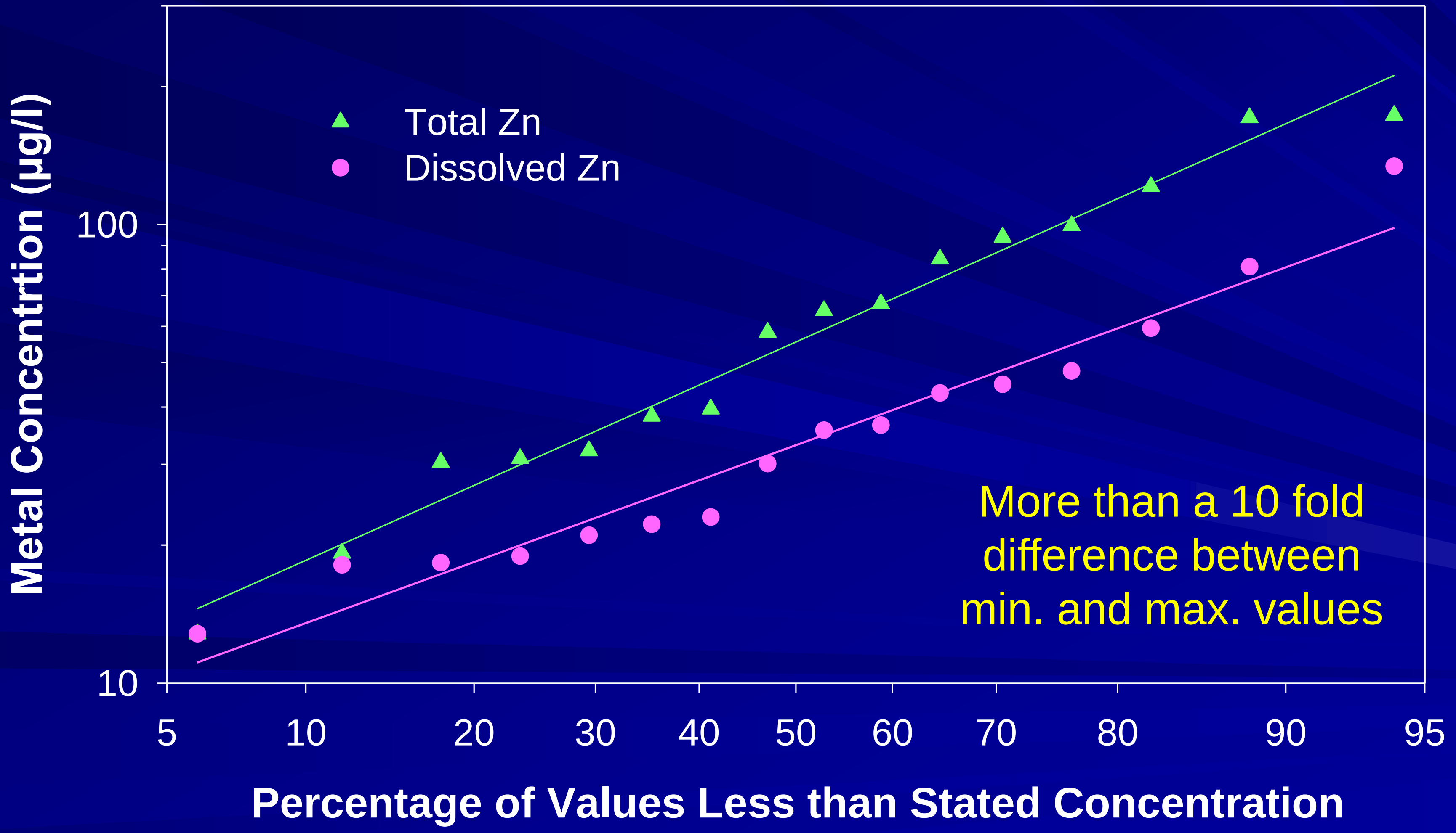
Runoff Characteristics

- 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 should be included in the monitoring protocol for runoff collection
- 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 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

Runoff Characteristics and Loadings

- Runoff characteristics are used in many engineering analyses, including:
  - Pollutant loading analyses
  - TMDL calculations
  - Pre/post loading evaluations

- Runoff concentrations are commonly expressed in terms of an event mean concentration (emc):

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

- An annual emc value is generally determined by evaluating event emc values over a range of rainfall depths and seasons
  - Generally estimated 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 emc Database

- The original database 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 <u>simple arithmetic means</u>

History of emc 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
- FLUCCS (Florida Land Use Cover Classification System) codes contain too much detail and often misclassifies land use activities
  - Insufficient characterization data exist to provide emc values for all FLUCCS codes
  - FLUCCS codes can be converted to the general categories based on anticipated runoff characteristics
    - Ex. Mobile home parks, recreational areas (golf courses)

General Land Use Categories

- Land use category descriptions:
  - Low Density Residential (LDR) – rural residential with lot sizes >1 acre or 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.

Florida Land Use and Cover Classification System (FLUCCS)

-Very detailed land use breakdown

Problems:

- Loading calculations require runoff characteristics for all identified land use categories

- Runoff characterization data are not available for all of the listed land use categories

- General runoff categories are based on anticipated similarities in runoff characteristics

FLUCCS	Description	FLUCCS	Description
1200	Residential, Medium Density-Two-five dwellingunits per acre	8330	Water supply plants
3200	Shrub and Brushland	8200	Communications
2210	Citrus groves	6500	Non-vegetated Wetland
4110	Pine flatwoods	1620	Sand and Gravel Pits
6170	Mixed wetland hardwoods	2200	Tree Crops
6420	Saltwater marshes	1800	Recreational
1100	Residential, Low Density-Less than 2 du/acre	6110	Bay swamps
4340	Hardwood Conifer Mixed	1530	Mineral Processing
1300	Residential, High Density	1460	Oil and Gas Storage
6460	Mixed scrub-shrub wetland	1520	Timber Processing
2110	Improved Pasture	6172	Mixed Shrubs
1400	Commercial and Services	1830	Race Tracks (horse, dog, car, motorcycle)
6120	Mangrove swamp	7200	Sand other than beaches
6410	Freshwater marshes	1540	Oil and Gas Processing
3100	Herbaceous Dry Prairie	1870	Stadiums
2120	Unimproved Pastures	3210	Palmetto Prairies
3300	Mixed Rangeland	1320	Mobile Home Units
5400	Bays and estuaries	8180	Auto parking facilities
6300	Wetland Forested Mixed	2610	Fallow cropland
5430	Enclosed saltwater ponds within a salt marsh	5250	Marshy Lakes
4200	Upland Hardwood Forest	1110	Fixed Single Family Units
6430	Wet prairies	2320	Poultry feeding operations
4210	Xeric oak	4280	Cabbage palm
1750	Governmental	2420	Sod farms
5300	Reservoirs	8130	Bus and truck terminals
6181	Cabbage palm hammock	1562	Pre-stressed concrete plants
8140	Roads and Highways	5410	Embayments opening directly to the Gulf or Ocean
1700	Institutional (Educational,religious,health and military facilities)	1310	Fixed Single Family Units
1820	Golf Course	1590	Industrial Under Construction
1180	Residential, Rural < or = 0.5 dwelling units/acre	2500	Specialty Farms
1900	Open Land	8115	Grass Airports
6210	Cypress	5710	Atlantic Ocean
8110	Airports	5120	Channelized waterways, canals
5100	Streams and waterways	2220	Fruit Orchards
2130	Woodland Pasture	8330	Water supply plants
7410	Rural land in transition without positive indicators of intended activity	8200	Communications
1550	Other Light Industrial	6500	Non-vegetated Wetland
2600	Other Open Lands – Rural	1620	Sand and Gravel Pits
1290	Medium Density Under Construction	2200	Tree Crops
1730	Military	1800	Recreational
1850	Parks and Zoos	6110	Bay swamps

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
Median Value		1.85	0.309	6.5	34.9	0.002	0.015	0.014	0.350	0.020	0.005	0.057
Log-Normal 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 in gasoline

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**
Median Value		**0.93**	**0.160**	**7.5**	**42.4**	**0.003**	**0.008**	**0.015**	**1.100**	**0.028**	**0.008**	**0.068**
Log-Normal Mean:		**1.07**	**0.179**	**7.00**	**47.51**	**0.002**	**0.006**	**0.015**	**0.908**	**0.028**	**0.005**	**0.067**

not included in mean value due to reductions from removal of lead in gasoline

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**
Median Value		**2.48**	**0.230**	**11.3**	**69.7**	**0.009**		**0.015**	**0.334**			**0.164**
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

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**
Median Value		**1.310**	**0.168**	**4.2**	**36.5**	**0.001**	**0.003**	**0.012**	**0.352**	**0.003**	**0.007**	**0.074**
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 gasoline

Summary of emc Database Studies for Significant Revisions

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	3	3	3	4
b. Citrus	7	7	7	7
c. Row Crops	7	8	8	8
9. Undeveloped/Rangeland/ Forest	4	3	4	33
10. Mining	1	1	1	1

1. Calculated as mean of SFR and undeveloped land

Comparison of 2007 and Current (2012) emc Values

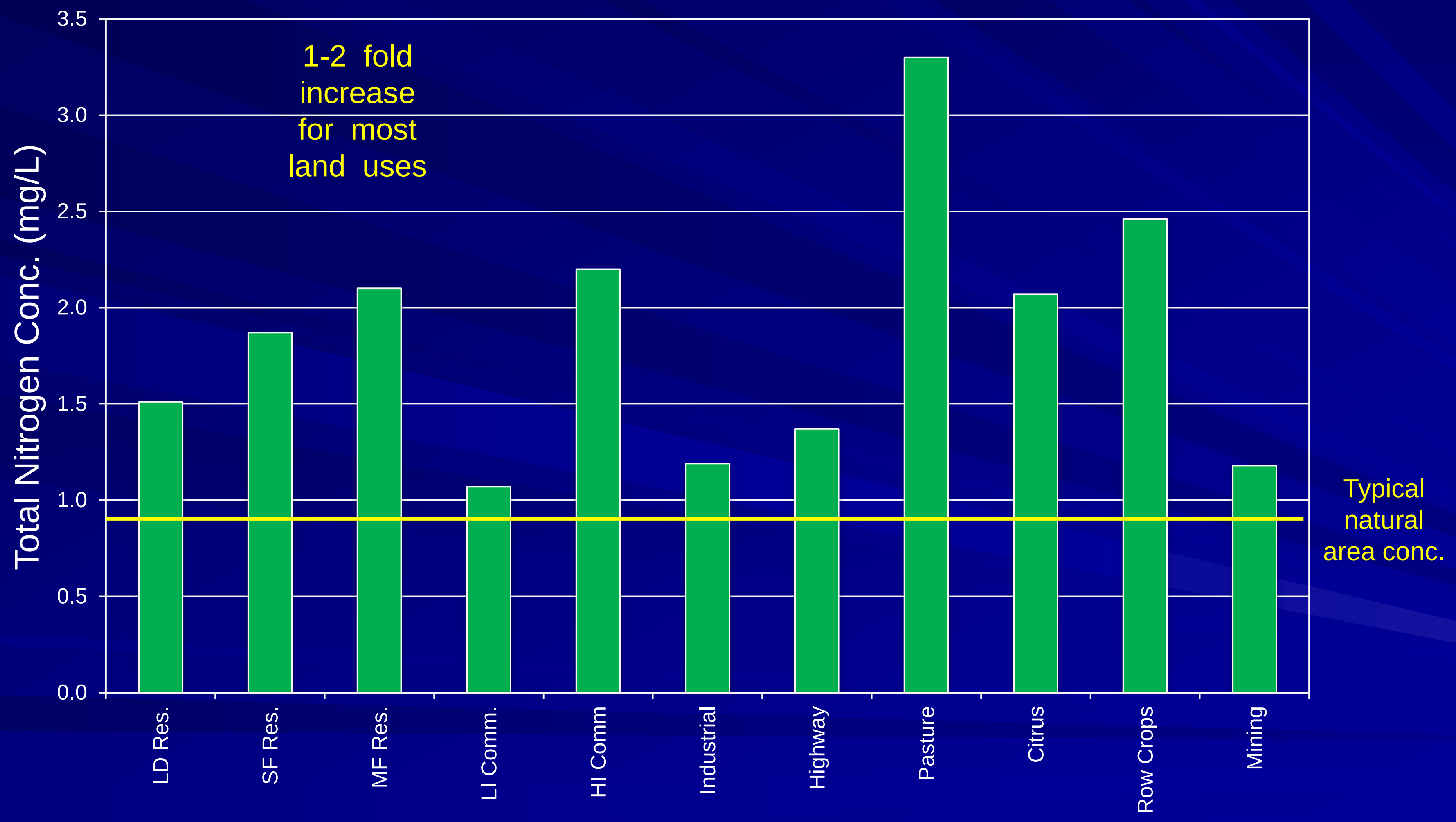
Land Use Category	2007 Values (mg/l)		Revised (2012) Values (mg/l)	
	Total N	Total P	Total N	Total P
Low Density Residential[1]	1.61	0.191	1.51	0.178
Single Family	2.07	0.327	1.87	0.301
Multi-Family	2.32	0.520	2.10	0.497
Low Intensity Commercial	1.18	0.179	1.07	0.179
High Intensity Commercial	2.40	0.345	2.20	0.248
Light Industrial	1.20	0.260	1.19	0.213
Highway	1.64	0.220	1.37	0.167
Agricultural				
Pasture	3.47	0.616	3.30	0.621
Citrus	2.24	0.183	2.07	0.152
Row Crops	2.65	0.593	2.46	0.489
Undeveloped/Rangeland/Forest	1.15	0.055	Natural Area Values	
Mining/Extractive	1.18	0.150	1.18	0.150

Changes from 2007 to 2012 datasets:

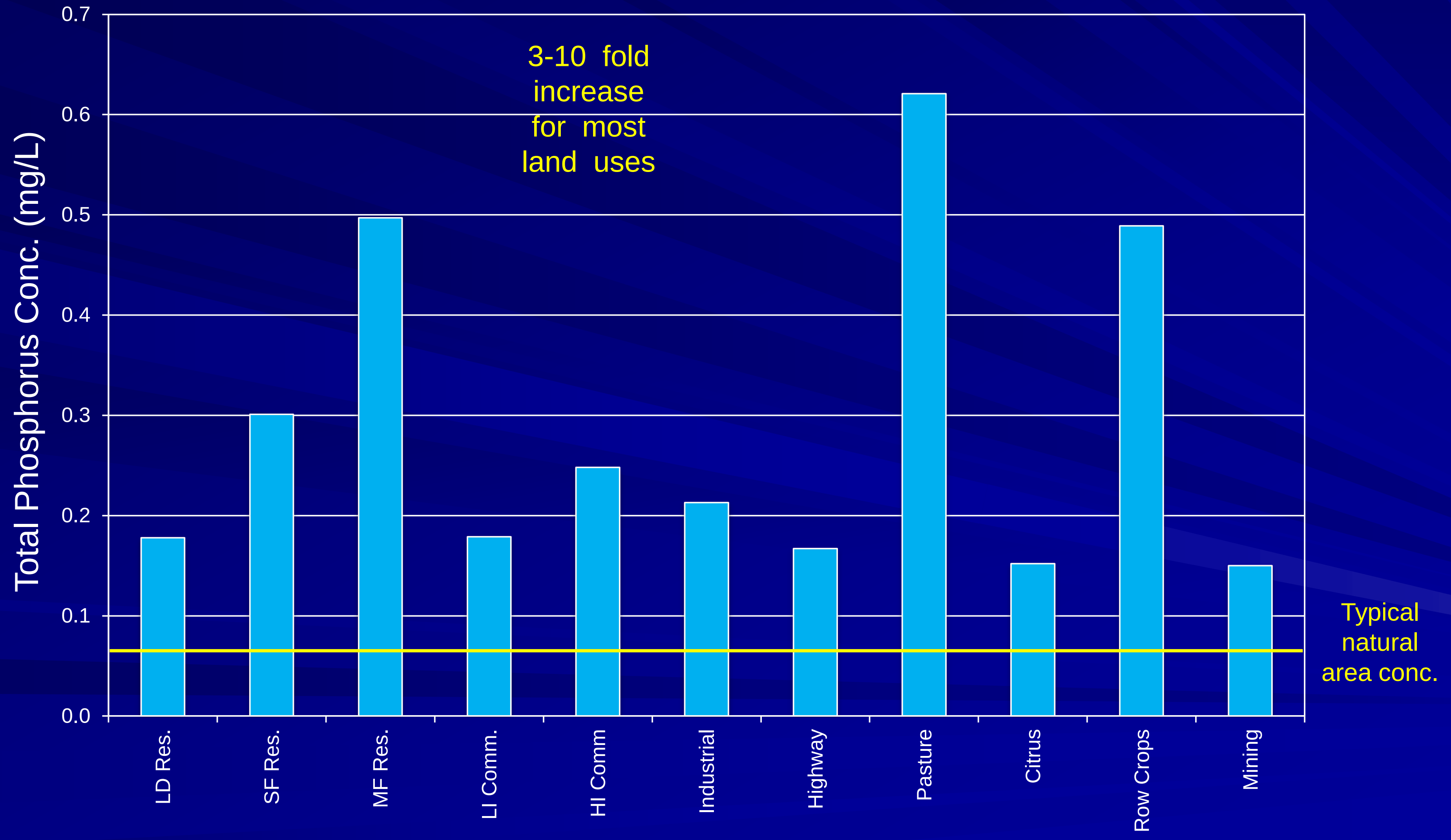
- Central tendency expressed as geometric (log-normal) means rather than arithmetic means
- Additional emc values added for highway and natural areas

- Values reflect end-of-pipe concentrations without any pre-treatment

Comparison of Typical Nitrogen Concentrations in Stormwater



Comparison of Typical Phosphorus Concentrations in Stormwater



Impacts of Reuse Irrigation on Runoff Characteristics

- The chemical characteristics of reuse water are highly variable, depending on location and level of treatment

- Characteristics of secondary effluent – minimum level of treatment
  - Nitrogen ~ 4-20 mg/l, mostly as NO_3^- and organic N (2-15 times higher than urban runoff)
  - Phosphorus ~ 2-15 mg/l (8-60 times higher than runoff)
  - On average, secondary reuse water is similar in characteristics to septic tank leachate
  - No requirement to measure nutrient levels, except NO_x
  - Approximately 2/3 of WWT plants in Florida provide secondary treatment

- Characteristics of tertiary effluent – adds nutrient removal
  - Nitrogen - < 3 mg/l
  - Phosphorus - <1 mg/l
  - Tertiary reuse is similar in characteristics to HDR stormwater runoff
  - Approximately 1/3 of WWT plants in Florida provide tertiary treatment

- Impact assessments for reuse only give a cursory look at nutrient impacts
  - Most simply state that the presence of nutrients will increase the value of the water

Comparison of Mean Stormwater Characteristics of Basin Areas with and without Reuse Irrigation (ERD, 1994)

Parameter	Units	Without Reuse[1]	With Reuse[1]	Enrichment By Reuse (%)
Alkalinity	mg/L	40.5	58.1	44
Ammonia	µg/L	87	537	520
NOx	µg/L	218	456	109
Total N	µg/L	1,526	2,355	54
SRP	µg/L	192	241	25
Total P	µg/L	376	569	51
BOD	mg/L	4.8	7.7	59

1. Geometric mean values

Conclusion: Secondary reuse irrigation increases concentrations of nutrients by approximately 50%

Natural Area Monitoring Project

Objectives

- FDEP funded project to characterize runoff quality from common natural undeveloped upland vegetative communities in Florida

- Data to be used to define pre-development emc data for Statewide Stormwater Rule

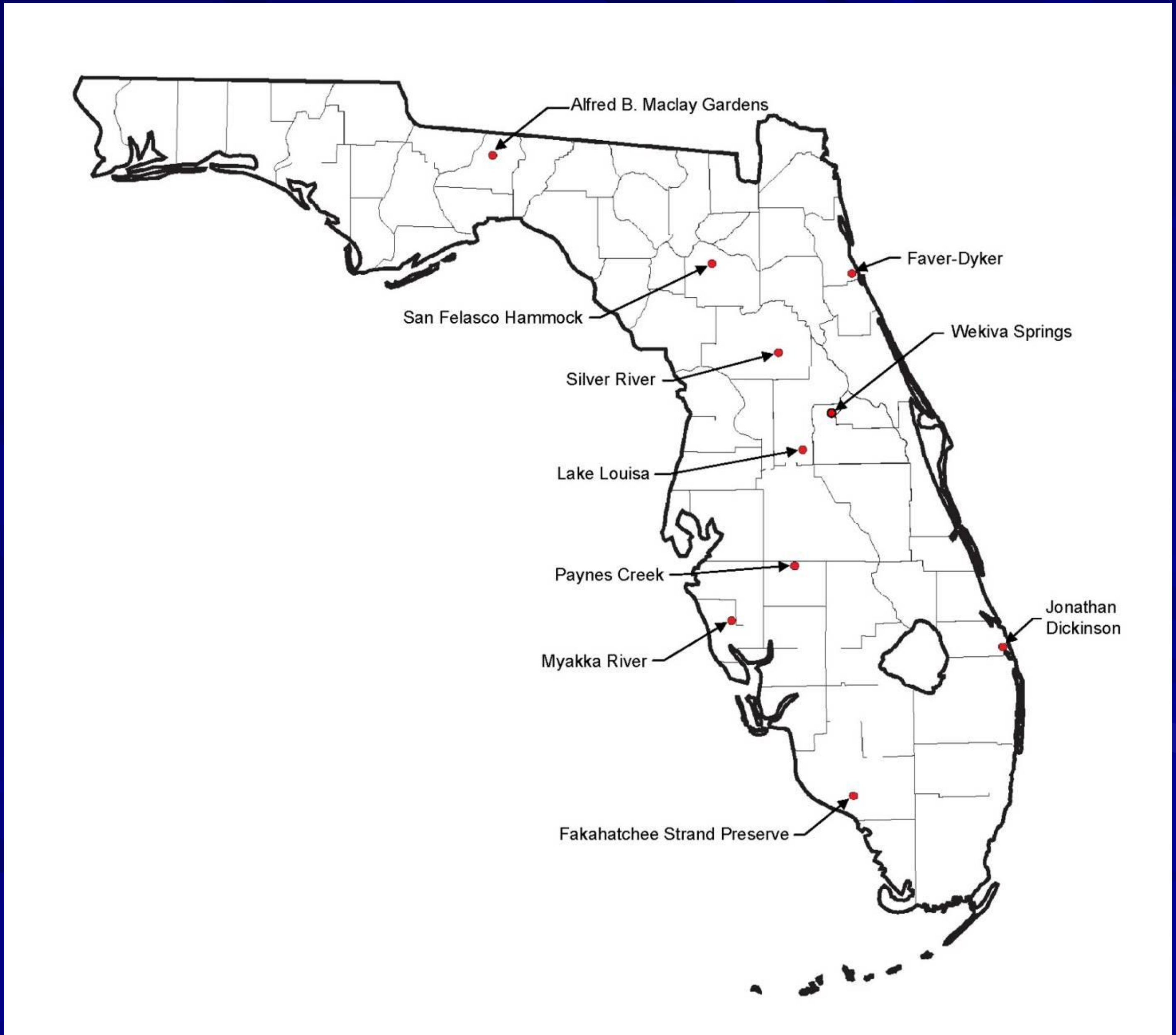
Work Efforts

- 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

Monitored State Parks Used for Natural Area Project



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

Alfred B. Maclay Gardens State Park

Monitoring Site Natural Communities

<u>Community Characteristics</u>

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

- Most 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

Mixed Hardwood Forest

Faver-Dykes State Park
Monitoring Site Natural Communities

<u>Community Characteristics</u>

- Synonyms: pine flatwoods, pine savannahs, pine barrens

- 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

Mesic Flatwoods/Pinelands






Jonathan Dickinson State Park
Monitoring Site Natural Communities

Wet Flatwoods

<u>Community Characteristics</u>

- Synonyms: low flatwoods, moist pine barren, hydric flatwoods, pond pine flatwoods, cabbage palm/pine savannah or flatwoods

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

- Relatively flat, poorly drained terrain

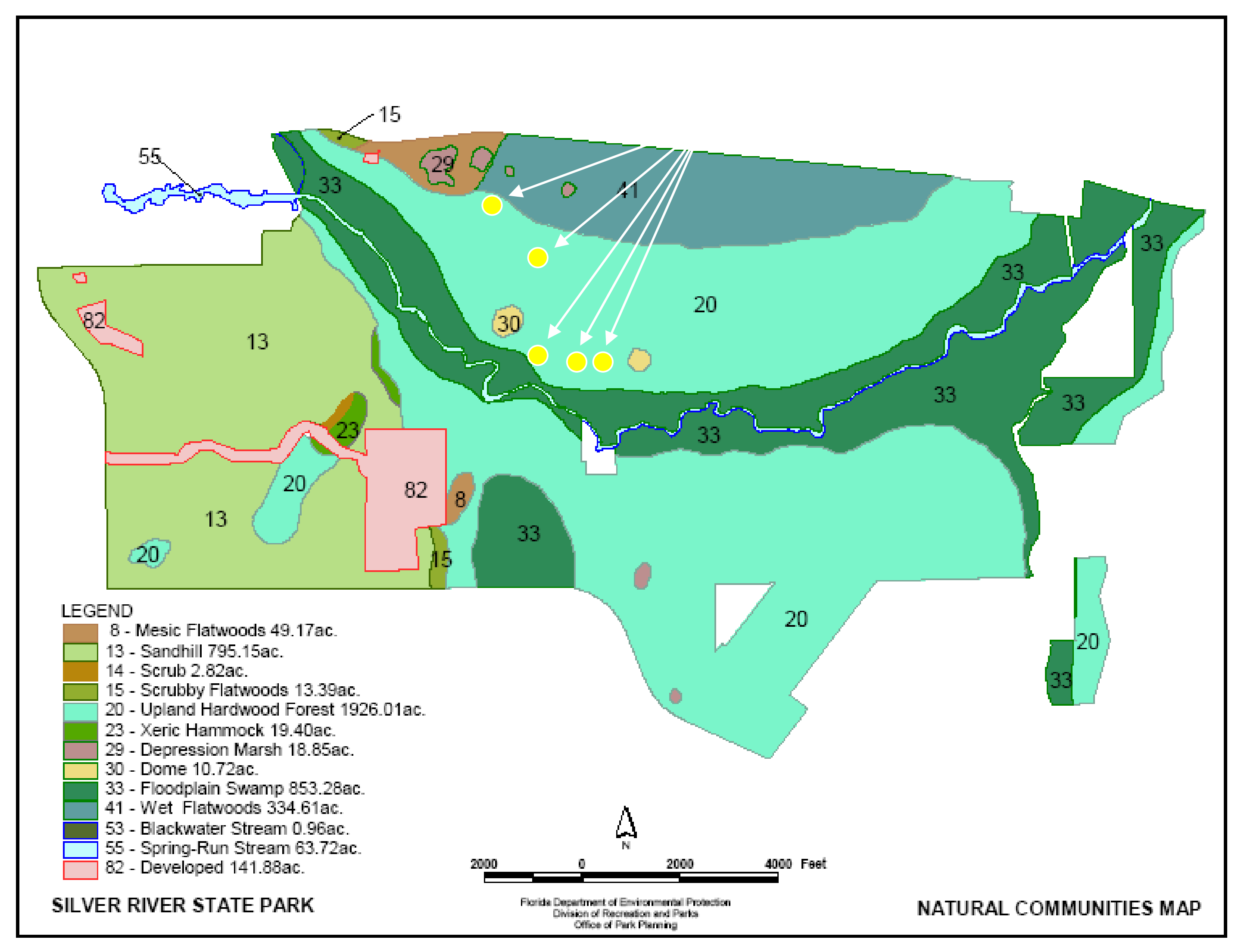
- Soils consist of 1 to 3 feet of acidic sands overlying an organic hardpan or clay layer






Silver River State Park

Monitoring Site Natural Communities



Silver River State Park
Natural Communities

Upland Hardwood Forest






<u>Community Characteristics</u>

- 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

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

- Most common in northern and central peninsula Florida

Lake Louisa State Park

Monitoring Site Natural Communities

Ruderal/Upland Pine Forest



<u>Community Characteristics</u>

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

- 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

Monitoring Site Natural Communities

Strand Swamp

<u>Community Characteristics</u>

- Synonyms: cypress strand, stringer

- 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

Monitoring Site Communities

<u>Community Characteristics</u>

- 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

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

- Most common in northern and central peninsula Florida

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

Upland Mixed Forest






Myakka River State Park

Monitoring Sites Natural Communities

Dry Prairie

<u>Community Characteristics</u>

- Synonyms: palm savannah, palmetto prairie, pineland-threeawn range

- 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
Monitoring Site Communities

Xeric Scrub

<u>Community Characteristics</u>

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

- 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






Natural Land Use Runoff Characteristics

Land Type	N	Total N (µg/l)	Total P (µg/l)	Iron (mg/l)	Fecal Coliform (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 Area Loadings

- A wide variability was observed in nutrient concentrations from natural areas
  - Natural areas with deciduous vegetation were characterized by higher runoff concentrations
- Natural areas with deciduous vegetation were characterized by higher runoff concentrations
- Natural areas had exceedances of Class III criteria for iron and fecal coliform
- After the community is identified, the annual mass loading is calculated:

Annual Loading = emc conc. for community type x annual runoff volume

Natural Community Indices

1. Florida Vegetation and Land Cover (FFWCC)
   - 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 in 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

Natural Community Indices – cont.

2. Florida Natural Areas Inventory (FNAI) - 2010

- 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, land form, 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

Example Calculations

1. Land Use: 90 acres of single-family residential
   5 acres of stormwater management systems
   5 acres of preserved wetlands

2. Ground Cover/Soil Types

   A. Residential areas will be covered with lawns in good condition
   B. Soil types in HSG D

3. Impervious/DCIA Areas

   A. Residential areas will be 25% impervious, 75% of which will be DCIA
      Impervious Area = 25% of developed site = 90 ac x 0.25 = 22.50 acres
      DCIA Area = 22.50 acres x 0.75 = 16.88 acres
      DCIA Percentage = (16.88 ac/90.0 ac) x 100 = 18.7% of developed area

4. Post Development Annual Runoff Generation

Project Location	Area (acres)	Impervious Areas		DCIA		Non-DCIA CN Value	Annual Rainfall (in)	Annual C Value	Runoff (ac-ft/yr)
		%	acres	acres	%				
Pensacola	90	25	22.5	16.68	18.75	81.4	65.5	0.304	149.3
Orlando	90	25	22.5	16.68	18.75	81.4	50.0	0.253	94.8
Key West	90	25	22.5	16.68	18.75	81.4	40.0	0.266	79.8

Example Calculations – cont.

5. Generated Loading to Stormwater Pond:

Under post-development conditions, nutrient loadings will be generated from the 90-acre developed single-family area.

Stormwater management systems are not included in estimates of post-development loadings since incidental mass inputs of pollutants to these systems are included in the estimation of removal effectiveness.

Mean emc values for total nitrogen and total phosphorus in single-family residential runoff

TN = 1.87 mg/l TP = 0.301 mg/l

a. Pensacola (Zone 1) Project

TN load from single-family area:

$$\frac{149.3 \text{ ac-ft}}{\text{yr}} \times \frac{43{,}560 \text{ ft}^2}{\text{ac}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \times \frac{3.785 \text{ liter}}{\text{gal}} \times \frac{1.87 \text{ mg}}{\text{liter}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}} = \underline{344 \text{ kg TN/yr}}$$

TP load from single-family area:

$$\frac{149.3 \text{ ac-ft}}{\text{yr}} \times \frac{43{,}560 \text{ ft}^2}{\text{ac}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \times \frac{3.785 \text{ liter}}{\text{gal}} \times \frac{0.301 \text{mg}}{\text{liter}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}} = 55.4 \underline{\text{ kg TP/yr}}$$

Location	TN Loading (kg/yr)	TP Loading (kg/yr)
Pensacola	344	55.4
Orlando	219	35.2
Key West	184	29.6

Example Calculations – cont.

6. Pre-Development Runoff and Mass Loadings:

The natural vegetation on the area to be developed (95 acres) consists of 60% mesic flatwoods and 40% wet flatwoods in fair condition on HSG D soils.

From TR-55, the CN value for wooded areas in fair condition on HSG D soils = 79

Project Location	Area (acres)	Impervious Areas		DCIA		Non-DCIA CN Value	Annual Rainfall (in)	Annual C Value	Runoff (ac-ft/yr)
		%	acres	acres	%				
Pensacola	95	0	0	0	0	79	65.5	0.154	79.9
Orlando	95	0	0	0	0	79	50.0	0.105	41.6
Key West	95	0	0	0	0	79	40.0	0.125	39.6

Mean emc values for total nitrogen and total phosphorus under pre-development conditions:

Land Cover	Percent Cover (%)	Runoff emc Values (mg/L)		Combined emc Values (mg/L)	
		Total N	Total P	Total N	Total P
Mesic flatwoods	60	1.000	0.034	1.070	0.026
Wet flatwoods	40	1.175	0.015		

Example Calculations – con't.

6. Pre-Development Runoff and Mass Loadings – cont.:

a. Pensacola (Zone 1) Project

TN load from pre-development areas:

$$\frac{79.9\ \text{ac-ft}}{\text{yr}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}} \times \frac{7.48\ \text{gal}}{\text{ft}^3} \times \frac{3.785\ \text{liter}}{\text{gal}} \times \frac{1.07\ \text{mg}}{\text{liter}} \times \frac{1\ \text{kg}}{10^6\ \text{mg}} = \underline{105.4\ \text{kg TN/yr}}$$

TP load from pre-development areas:

$$\frac{79.9\ \textit{ac-ft}}{\textit{yr}} \times \frac{43{,}560\ \textit{ft}^2}{\textit{ac}} \times \frac{7.48\ \textit{gal}}{\textit{ft}^3} \times \frac{3.785\ \textit{liter}}{\textit{gal}} \times \frac{0.026\ \textit{mg}}{\textit{liter}} \times \frac{1\ \textit{kg}}{10^6\ \textit{mg}} = \underline{2.56\ \textit{kg TP/yr}}$$

Location	TN Loading (kg/yr)	TP Loading (kg/yr)
Pensacola	105.4	2.56
Orlando	54.9	1.33
Key West	52.3	1.27

Example Calculations - cont.

7. Calculate required removal efficiencies to achieve post- less than or equal to pre-loadings:

Summary of pre- and post-loadings and required removal efficiencies

Project Location	Total Nitrogen			Total Phosphorus		
	Pre-Load (kg/yr)	Post-Load (kg/yr)	Required Removal (%)	Pre-Load (kg/yr)	Post-Load (kg/yr)	Required Removal (%)
Pensacola (Zone 1)	105.4	344	69.4	2.56	55.4	95.4
Orlando (Zone 2)	54.9	219	74.9	1.33	35.2	96.2
Key West (Zone 3)	52.3	184	71.6	1.27	29.6	95.7

Summary

- Runoff emc values are available for a wide range of landuse categories in Florida
  - Urban land uses
  - Natural land uses
- Estimation of annual runoff loadings requires
  - Estimation of annual runoff volume
  - Runoff emc value which reflects runoff characteristics
- BMPTRAINS Model calculates loadings based on user input data for
  - Location
  - Annual rainfall
  - Project physical characteristics
  - Pre/post Land use and cover
  - Soil types – CN values

BMPTRAINS MODEL:
DRY RETENTION

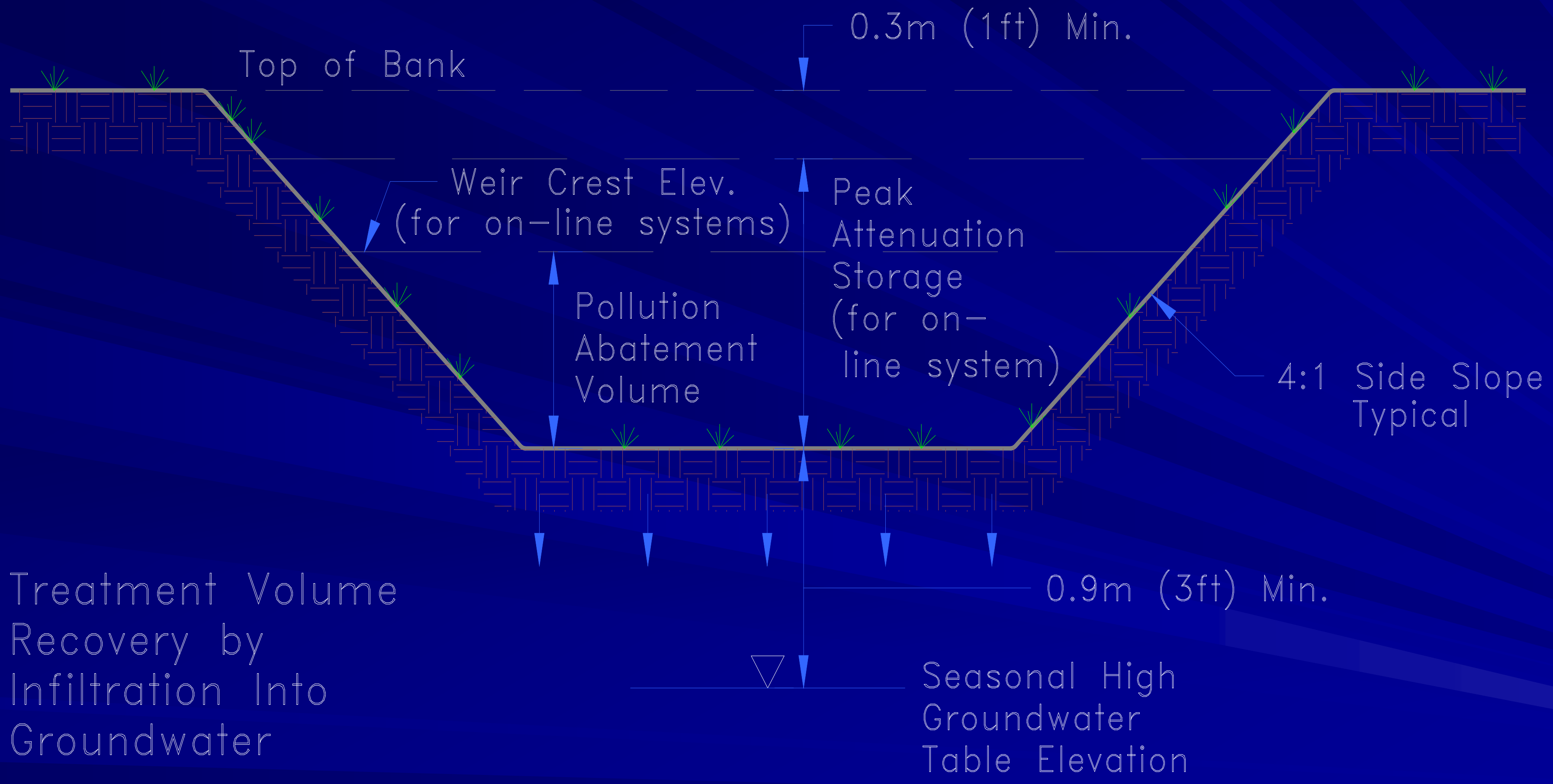
BY: HARVEY H. HARPER, PHD, P.E.

Definitions

- <u>Retention</u> - A group of stormwater practices where the treatment volume is evacuated by either percolation into groundwater or evaporation
  - No surface discharge for treatment volume
  - Substantial reduction in runoff volume

- <u>Detention</u> - A group of stormwater practices where the treatment volume is detained for a period of time before release
  - Continuous discharge of treatment volume over a period of days
  - No significant reduction in runoff volume

Schematic of Typical Dry Retention Pond
(Infiltration Pond)



Typical design volumes:
- 0.5" of runoff
- 1" of runoff
- 1" of rainfall

Dry Retention Efficiency Modeling Methods

- An evaluation of the efficiency of dry retention practices was conducted by Harper and Baker (2007) for FDEP which is summarized in the document titled “Evaluation of Current Stormwater Design Criteria within the State of Florida”
- Based on a continuous simulation of runoff from a hypothetical 1 acre site using SCS curve number methodology
- Runoff depths calculated for continuous historical rainfall data set for each of the 45 hourly Florida meteorological sites
  - Generally 30-50 years of data per site
- Analysis performed for:
  - DCIA percentages from 0-100 in 5 unit intervals
  - Non-DCIA curve numbers from 30-90 in 5 unit intervals
  - Resulted in 300 combinations of DCIA and CN for each hourly site

Efficiency Modeling Assumptions

- Performance efficiency calculated using a continuous simulation of runoff inputs into a theoretical dry retention pond based on the entire available rainfall record for all hourly meteorological stations

- After runoff enters pond:
  - A removal efficiency of 100% is assumed for all rain events with a runoff volume < treatment volume
  - For rain events with a runoff volume > treatment volume
    - 100% removal for inputs up to the treatment volume
    - 0% removal for inputs in excess of treatment volume – excess water bypasses pond

- Hypothetical drawdown curve is used to evacuate water from pond based on common drawdown requirements
  - Recovery of 50% of treatment volume in 24 hours
  - Recovery of 100% of treatment volume in 72 hours

- Modeling assumes no significant “first flush” effect from the watershed
  - Small watersheds (< 5-10 ac.) may exhibit “first flush” for certain rain events, there is no evidence that larger watersheds exhibit first-flush effects on a continuous basis

- Pond efficiency is equal to the fraction of annual runoff volume infiltrated

Modeled Dry Retention Removal Efficiencies

Tables were generated of retention efficiency for each meteorological zone in 0.25 inch intervals from 0.25 - 4.0 inches - 16 separate tables per zone, 80 tables total

Mean Annual Mass Removal Efficiencies for 0.25-inches of Retention for Zone 1

NDCIA	Percent DCIA																			
CN	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	86.2	81.3	73.3	65.5	58.7	53.0	48.3	44.2	40.8	37.9	35.3	33.1	31.1	29.4	27.8	26.4	25.1	24.0	22.9	21.9
35	81.6	78.7	71.7	64.5	58.0	52.5	47.9	44.0	40.6	37.7	35.2	33.0	31.0	29.3	27.8	26.4	25.1	23.9	22.9	21.9
40	76.4	75.5	69.6	63.1	57.1	51.9	47.4	43.6	40.3	37.5	35.0	32.9	30.9	29.2	27.7	26.3	25.1	23.9	22.9	21.9
45	70.7	71.7	67.2	61.4	55.9	51.0	46.8	43.1	40.0	37.2	34.8	32.7	30.8	29.1	27.6	26.3	25.0	23.9	22.9	21.9
50	64.7	67.5	64.2	59.4	54.5	50.0	46.0	42.6	39.5	36.9	34.6	32.5	30.7	29.0	27.5	26.2	25.0	23.9	22.9	21.9
55	58.6	62.8	60.9	57.0	52.7	48.7	45.1	41.8	39.0	36.5	34.2	32.3	30.5	28.9	27.4	26.1	24.9	23.9	22.9	21.9
60	52.8	57.8	57.1	54.2	50.7	47.1	43.9	40.9	38.3	35.9	33.8	31.9	30.2	28.7	27.3	26.0	24.9	23.8	22.8	21.9
65	47.3	52.6	53.0	51.1	48.3	45.3	42.5	39.8	37.4	35.3	33.3	31.5	29.9	28.4	27.1	25.9	24.8	23.8	22.8	21.9
70	42.2	47.3	48.6	47.6	45.6	43.2	40.8	38.5	36.4	34.4	32.6	31.0	29.5	28.1	26.9	25.7	24.7	23.7	22.8	21.9
75	37.8	42.2	43.9	43.7	42.4	40.7	38.8	36.9	35.1	33.4	31.8	30.4	29.0	27.8	26.6	25.5	24.5	23.6	22.7	21.9
80	34.0	37.5	39.1	39.4	38.8	37.7	36.4	34.9	33.5	32.1	30.8	29.5	28.3	27.2	26.2	25.2	24.3	23.5	22.7	21.9
85	30.8	33.1	34.3	34.8	34.7	34.2	33.4	32.5	31.4	30.4	29.4	28.4	27.4	26.5	25.7	24.8	24.1	23.3	22.6	21.9
90	27.9	29.2	29.9	30.3	30.3	30.2	29.8	29.3	28.8	28.2	27.5	26.8	26.2	25.5	24.9	24.2	23.6	23.0	22.5	21.9
95	25.3	25.6	25.8	25.9	26.0	25.9	25.8	25.6	25.4	25.2	24.9	24.6	24.3	24.0	23.6	23.3	23.0	22.6	22.3	21.9
98	23.8	23.8	23.8	23.7	23.7	23.6	23.5	23.4	23.3	23.2	23.1	23.0	22.9	22.8	22.6	22.5	22.4	22.2	22.1	21.9

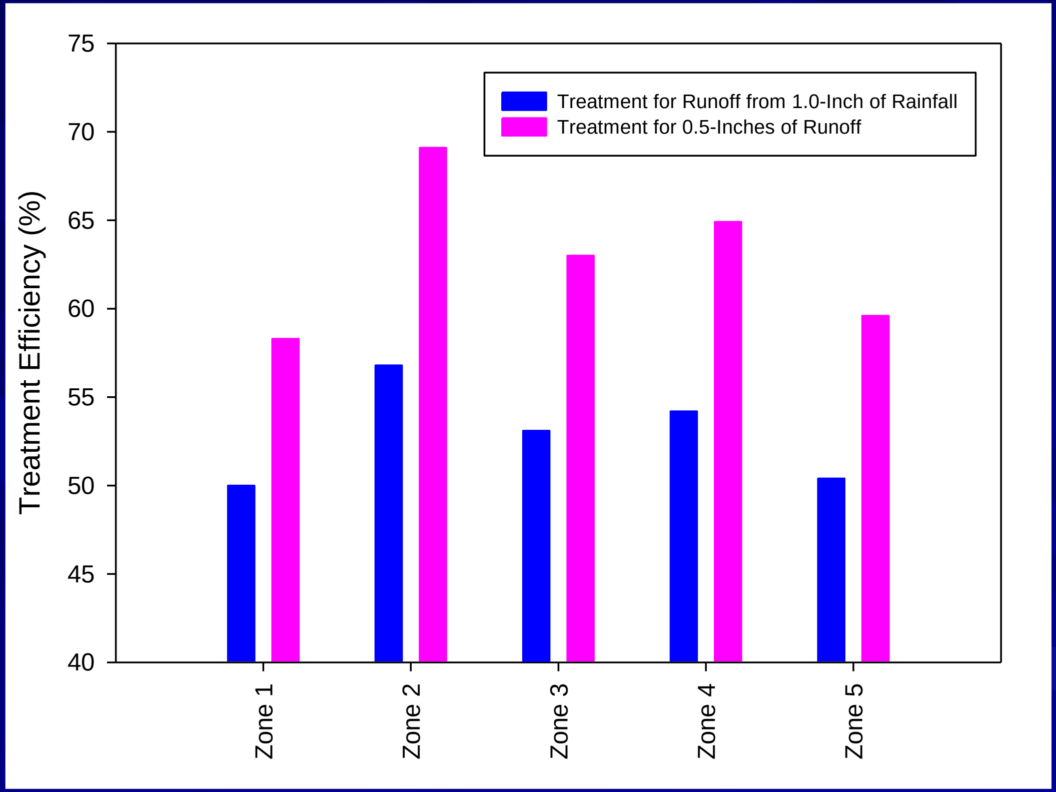
Mean Annual Mass Removal Efficiencies for 0.50-inches of Retention for Zone 1

NDCIA	Percent DCIA																			
CN	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	91.8	91.5	88.3	84.0	79.5	75.0	70.7	66.6	62.9	59.6	56.5	53.6	51.1	48.7	46.6	44.6	42.8	41.1	39.6	38.1
35	88.2	89.1	86.6	82.8	78.6	74.3	70.1	66.2	62.6	59.3	56.3	53.5	51.0	48.7	46.5	44.6	42.8	41.1	39.6	38.1
40	84.0	86.3	84.4	81.2	77.4	73.4	69.4	65.7	62.2	59.0	56.0	53.3	50.8	48.5	46.4	44.5	42.7	41.1	39.6	38.1
45	79.6	82.9	81.9	79.3	75.9	72.2	68.5	65.0	61.7	58.6	55.7	53.0	50.6	48.4	46.3	44.4	42.7	41.0	39.5	38.1
50	74.8	79.1	79.0	77.0	74.1	70.8	67.4	64.1	61.0	58.0	55.3	52.7	50.4	48.2	46.2	44.3	42.6	41.0	39.5	38.1
55	70.1	74.9	75.6	74.2	71.9	69.1	66.1	63.0	60.1	57.3	54.7	52.3	50.0	47.9	46.0	44.2	42.5	40.9	39.5	38.1
60	65.5	70.4	71.7	71.1	69.4	67.0	64.4	61.7	59.1	56.5	54.1	51.8	49.6	47.6	45.8	44.0	42.4	40.9	39.5	38.1
65	61.0	65.8	67.5	67.6	66.4	64.7	62.5	60.2	57.8	55.5	53.3	51.1	49.1	47.2	45.5	43.8	42.3	40.8	39.4	38.1
70	56.7	61.1	63.1	63.6	63.1	61.9	60.2	58.3	56.3	54.3	52.3	50.3	48.5	46.8	45.1	43.5	42.1	40.7	39.4	38.1
75	52.7	56.6	58.6	59.3	59.3	58.6	57.5	56.0	54.4	52.7	51.0	49.3	47.7	46.1	44.6	43.2	41.8	40.5	39.3	38.1
80	49.1	52.2	54.1	55.0	55.2	54.9	54.2	53.2	52.1	50.8	49.4	48.0	46.6	45.3	44.0	42.7	41.5	40.3	39.2	38.1
85	46.1	48.3	49.7	50.5	50.8	50.8	50.5	49.9	49.2	48.3	47.3	46.3	45.2	44.2	43.1	42.1	41.0	40.0	39.1	38.1
90	43.5	44.8	45.6	46.1	46.4	46.5	46.4	46.1	45.7	45.2	44.6	44.0	43.3	42.6	41.9	41.1	40.4	39.6	38.9	38.1
95	41.1	41.5	41.8	41.9	42.0	42.1	42.0	41.9	41.8	41.6	41.3	41.1	40.8	40.4	40.1	39.7	39.3	38.9	38.5	38.1
98	39.8	39.8	39.8	39.8	39.8	39.7	39.7	39.6	39.5	39.4	39.3	39.2	39.1	39.0	38.9	38.7	38.6	38.4	38.3	38.1

Source: Harper and Baker (2007) - Appendix D

Regional Variability in Treatment Efficiency of Dry Retention

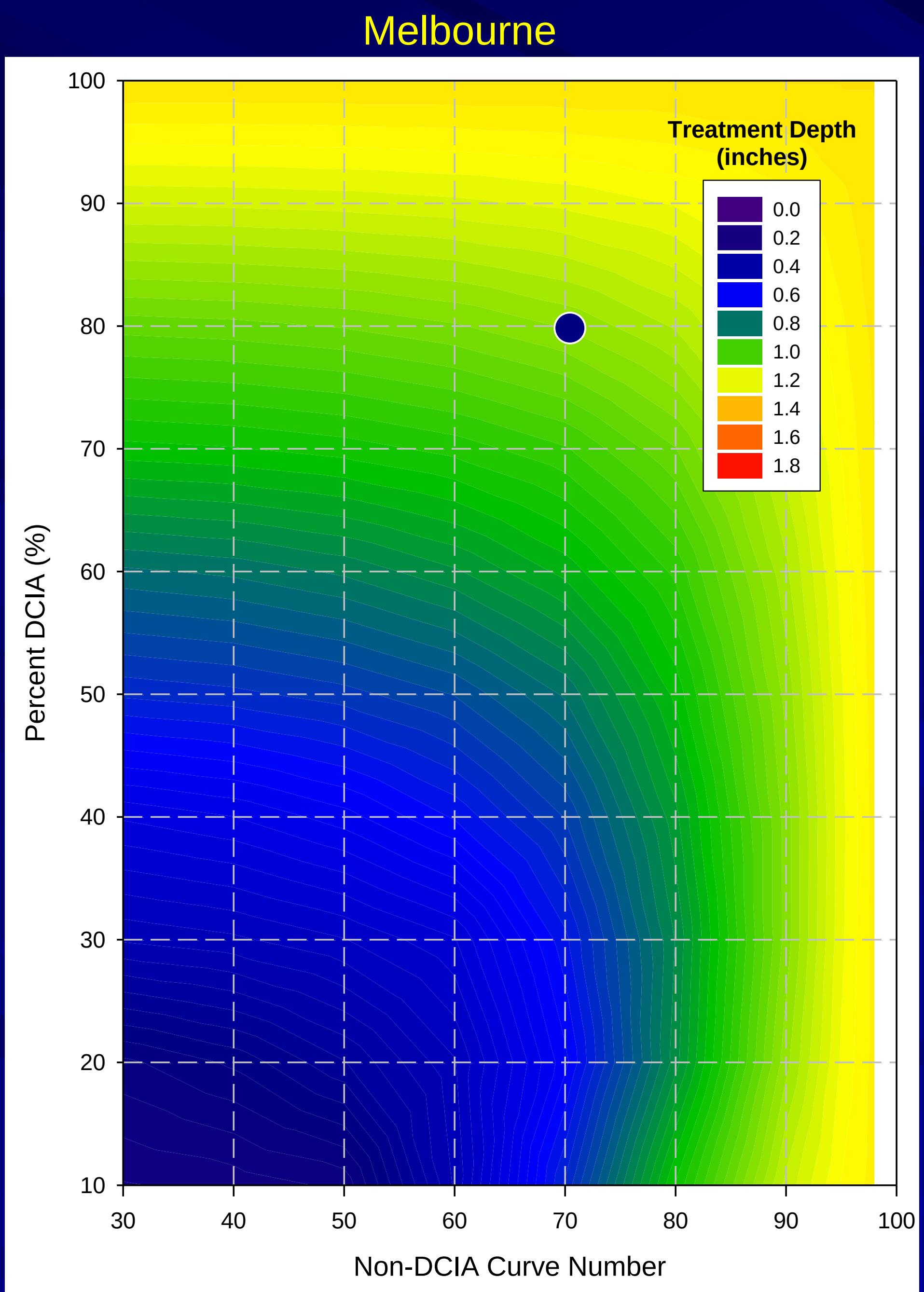
Treatment of 0.5 inch Runoff vs. Treatment of 1 inch of Runoff
(40% DCIA and non-DCIA CN of 70)

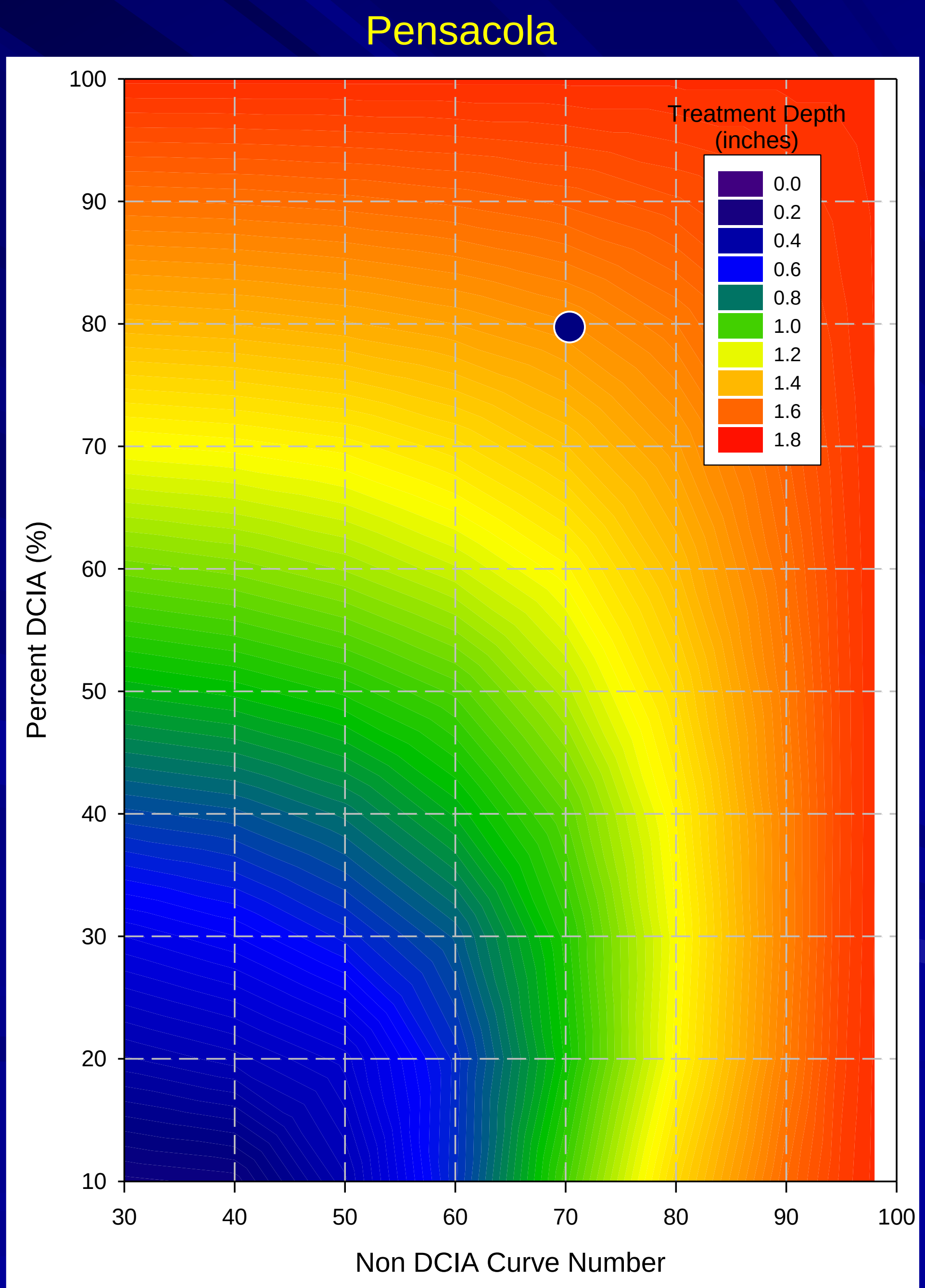


Design criteria based on treatment of 0.5 inch of runoff provide better annual mass removal than treatment of 1 inch of rainfall

Conclusion: Current dry retention designs fail to meet the 80% design standard

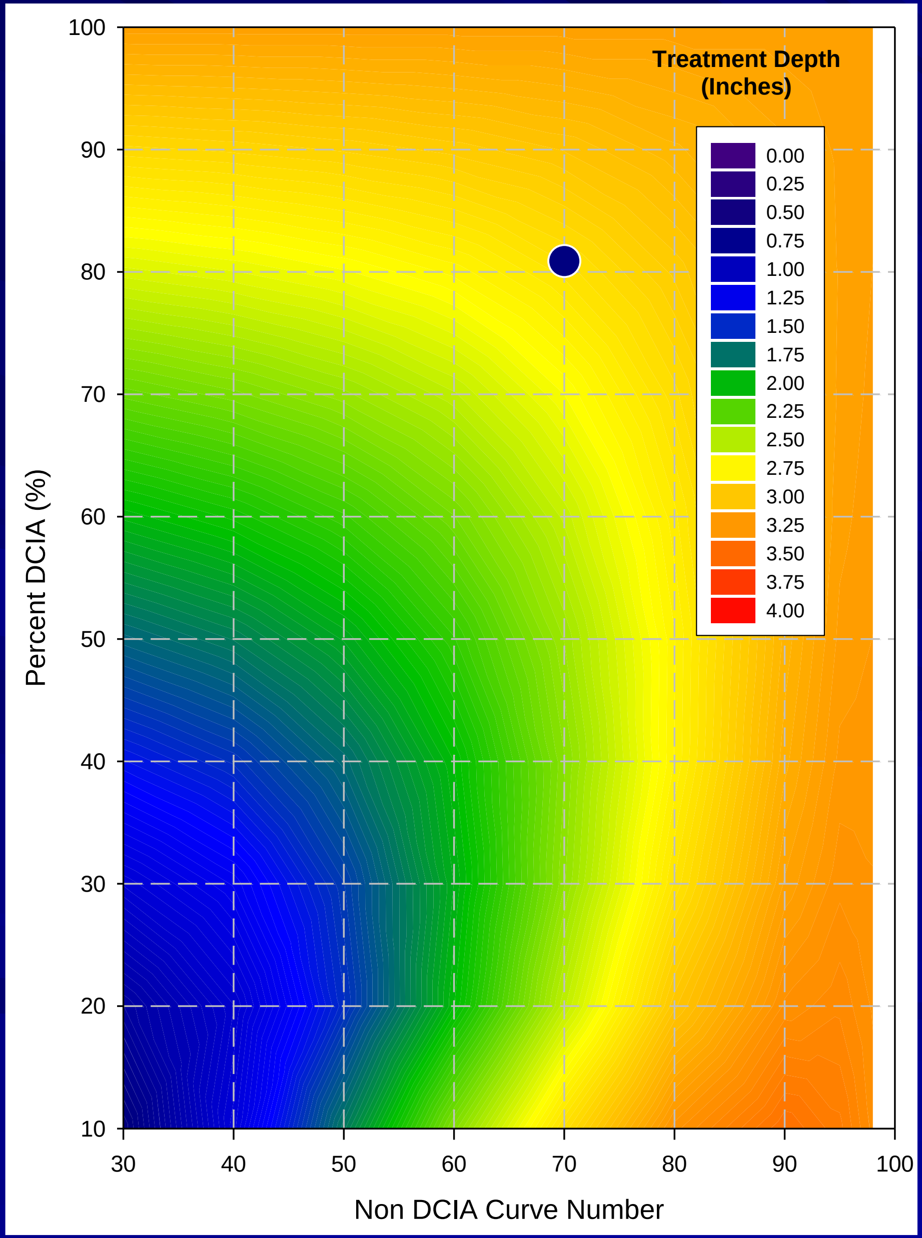
Retention Depth Required for 80% Removal





Retention Depth Required to Achieve 95% Mass Removal

State-Wide Average



BMPTRAINS Retention Efficiency Calculations

- Calculation of runoff in the BMPTRAINS model uses the tabular retention efficiency relationships developed by Harper and Baker (2007) – App. D

Mean Annual Mass Removal Efficiencies for 0.25-inches of Retention for Zone 1

NDCIA	Percent DCIA																			
CN	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	86.2	81.3	73.3	65.5	58.7	53.0	48.3	44.2	40.8	37.9	35.3	33.1	31.1	29.4	27.8	26.4	25.1	24.0	22.9	21.9
35	81.6	78.7	71.7	64.5	58.0	52.5	47.9	44.0	40.6	37.7	35.2	33.0	31.0	29.3	27.8	26.4	25.1	23.9	22.9	21.9
40	76.4	75.5	69.6	63.1	57.1	51.9	47.4	43.6	40.3	37.5	35.0	32.9	30.9	29.2	27.7	26.3	25.1	23.9	22.9	21.9
45	70.7	71.7	67.2	61.4	55.9	51.0	46.8	43.1	40.0	37.2	34.8	32.7	30.8	29.1	27.6	26.3	25.0	23.9	22.9	21.9
50	64.7	67.5	64.2	59.4	54.5	50.0	46.0	42.6	39.5	36.9	34.6	32.5	30.7	29.0	27.5	26.2	25.0	23.9	22.9	21.9
55	58.6	62.8	60.9	57.0	52.7	48.7	45.1	41.8	39.0	36.5	34.2	32.3	30.5	28.9	27.4	26.1	24.9	23.9	22.9	21.9
60	52.8	57.8	57.1	54.2	50.7	47.1	43.9	40.9	38.3	35.9	33.8	31.9	30.2	28.7	27.3	26.0	24.9	23.8	22.8	21.9
65	47.3	52.6	53.0	51.1	48.3	45.3	42.5	39.8	37.4	35.3	33.3	31.5	29.9	28.4	27.1	25.9	24.8	23.8	22.8	21.9
70	42.2	47.3	48.6	47.6	45.6	43.2	40.8	38.5	36.4	34.4	32.6	31.0	29.5	28.1	26.9	25.7	24.7	23.7	22.8	21.9
75	37.8	42.2	43.9	43.7	42.4	40.7	38.8	36.9	35.1	33.4	31.8	30.4	29.0	27.8	26.6	25.5	24.5	23.6	22.7	21.9
80	34.0	37.5	39.1	39.4	38.8	37.7	36.4	34.9	33.5	32.1	30.8	29.5	28.3	27.2	26.2	25.2	24.3	23.5	22.7	21.9
85	30.8	33.1	34.3	34.8	34.7	34.2	33.4	32.5	31.4	30.4	29.4	28.4	27.4	26.5	25.7	24.8	24.1	23.3	22.6	21.9
90	27.9	29.2	29.9	30.3	30.3	30.2	29.8	29.3	28.8	28.2	27.5	26.8	26.2	25.5	24.9	24.2	23.6	23.0	22.5	21.9
95	25.3	25.6	25.8	25.9	26.0	25.9	25.8	25.6	25.4	25.2	24.9	24.6	24.3	24.0	23.6	23.3	23.0	22.6	22.3	21.9
98	23.8	23.8	23.8	23.7	23.7	23.6	23.5	23.4	23.3	23.2	23.1	23.0	22.9	22.8	22.6	22.5	22.4	22.2	22.1	21.9

- Required input data include:
  - Rainfall meteorological zone based on rainfall zone map
  - Annual rainfall depth from isopleth maps
  - Project DCIA
  - Non-DCIA curve number
  - Retention provided or desired performance efficiency
- BMPTRAINS conducts iterations within and between tables

Example Calculation

Calculate required removal efficiencies to achieve no net increase in post development loadings

A summary of pre- and post-loadings and required removal efficiencies for hypothetical projects in different meteorological zones is given in the following table:

Project Location	Total Nitrogen			Total Phosphorus		
	Pre-Load (kg/yr)	Post-Load (kg/yr)	Required Removal (%)	Pre-Load (kg/yr)	Post-Load (kg/yr)	Required Removal (%)
Pensacola (Zone 1)	140	381	63.2	6.64	60.2	89.0
Orlando (Zone 2)	76.2	242	68.5	3.62	38.2	90.5
Key West (Zone 3)	69.2	179	61.4	3.29	28.3	88.4

Calculate Treatment Requirements for No Net Increase

Dry Retention: For dry retention, the removal efficiencies for TN and TP are identical since the removal efficiency is based on the portion of the annual runoff volume which is infiltrated. The required removal is the larger of the calculated removal efficiencies for TN and TP.

A. Pensacola Project: For the Pensacola area, the annual load reduction is 63.2% for total nitrogen and 89.0% for total phosphorus. The design criteria is based on the largest required removal which is 89.0%. The required retention depth to achieve an annual removal efficiency of 89.0% in the Pensacola area is determined from Appendix D (Zone 1) based on DCIA percentage and the non-DCIA CN value. For this project:

DCIA Percentage = 18.75% of developed area   Non-DCIA CN = 81.4

From Appendix D (Zone 1), the required removal efficiency of 89.0% is achieved with a dry retention depth between 2.25 and 2.50 inches.

For a dry retention depth of 2.25 inches, the treatment efficiency is obtained by iterating between DCIA percentages of 10 and 20, and for non-DCIA CN values between 80 and 90. The efficiency for the project conditions is 87.8%.

For a dry retention depth of 2.50 inches, the treatment efficiency is obtained by iterating between DCIA percentages of 10 and 20, and for non-DCIA CN values between 80 and 90. The efficiency for the project conditions is 89.6%.

By iterating between 2.25 inches (87.8%) and 2.50 inches (89.6%), the dry retention depth required to achieve 89.0% removal is 2.42 inches.

BMPTRAINS Model performs iterations and calculates the treatment efficiency

Summary

- Efficiencies of retention systems vary throughout the State due to variability in meteorological characteristics

- BMPTRAINS Model calculates efficiencies of dry detention systems based on location, hydrologic, and meteorological characteristics of the project site

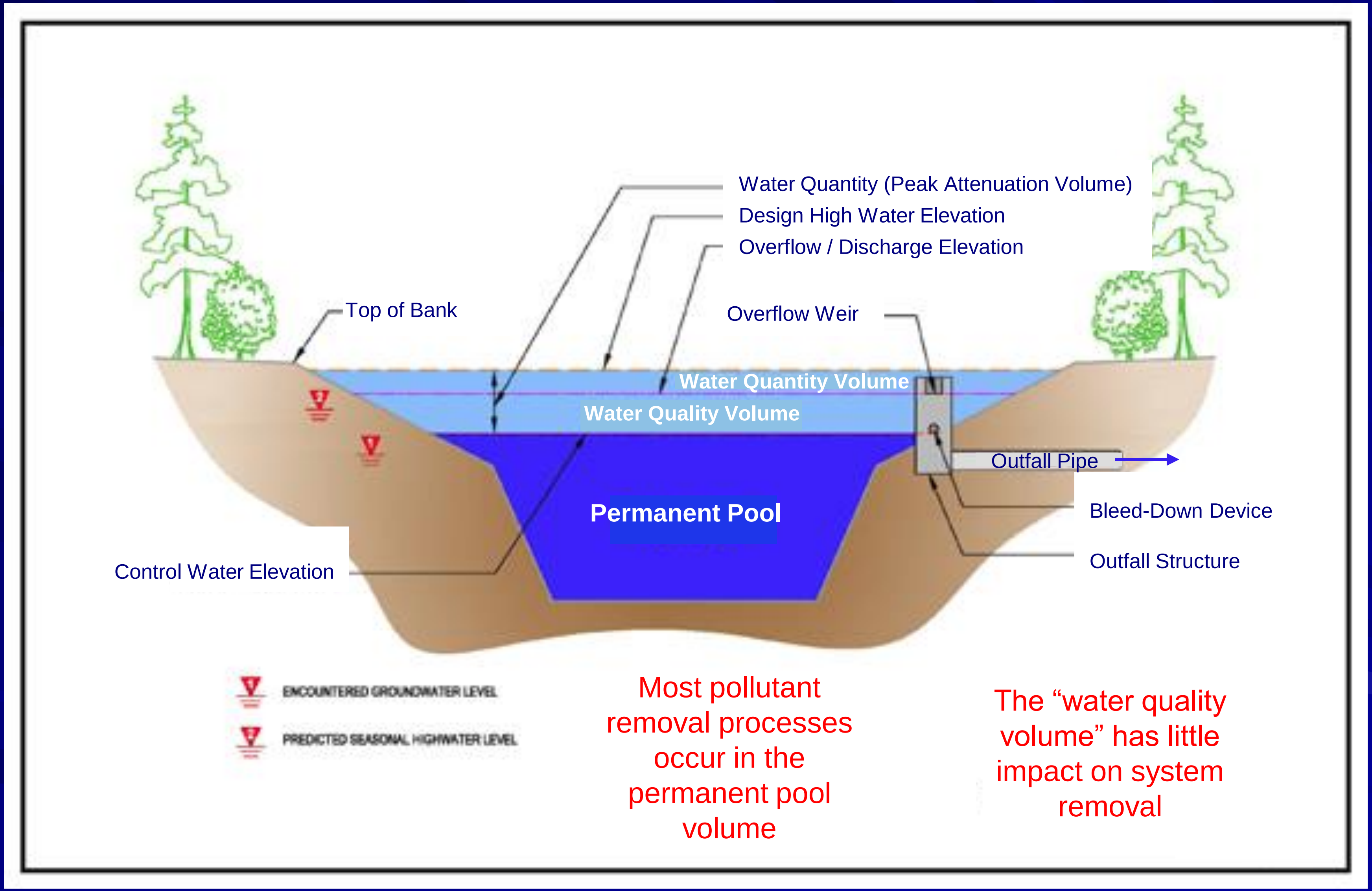
BMPTRAINS MODEL:
WET DETENTION

BY: HARVEY H. HARPER, PHD, P.E.

Definitions

- Retention - A group of stormwater practices where the treatment volume is evacuated by either percolation into groundwater or evaporation
  - No surface discharge for treatment volume
  - Substantial reduction in runoff volume
- Detention - A group of stormwater practices where the treatment volume is detained for a period of time before release
  - Continuous discharge of treatment volume over a period of days
  - No significant reduction in runoff volume

Typical Wet Detention Pond



Wet Detention Ponds

Wet detention ponds are essentially man-made lakes

Wet Detention Ponds Can Be Constructed as Amenities

Wet Detention Lakes Can Be Integral to the Overall Development Plan

Pollutant Removal Processes

- Physical Processes
  - Gravity settling – primary physical process
    - Efficiency dependent on pond geometry, volume, residence time, particle size
  - Adsorption onto solid surfaces
- Biological processes
  - Uptake by algae and aquatic plants
  - Metabolized by microorganisms
- Natural chemical processes (precipitation, natural flocculation, etc.)
- Most removal occurs during quiescent period between storms
- Permanent pool crucial
  - Reduces energy and promotes settling
  - Provides habitat for plants and microorganisms

Wet Detention

Performance efficiency is a function of detention time:

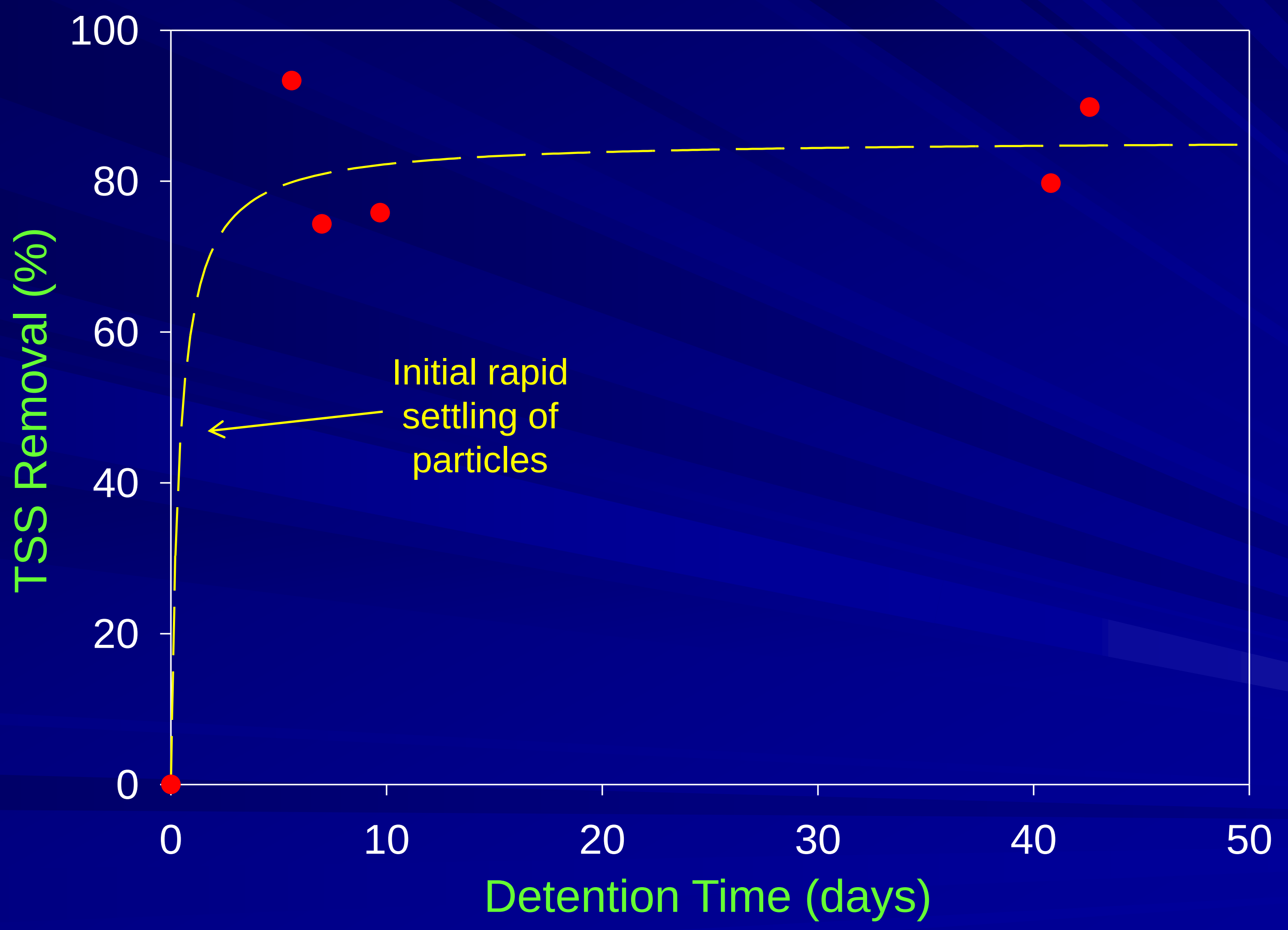
$$\text{Detention Time, } t_d \text{ (days)} = \frac{PPV}{RO} \times \frac{365 \text{ days}}{\text{year}}$$

where:

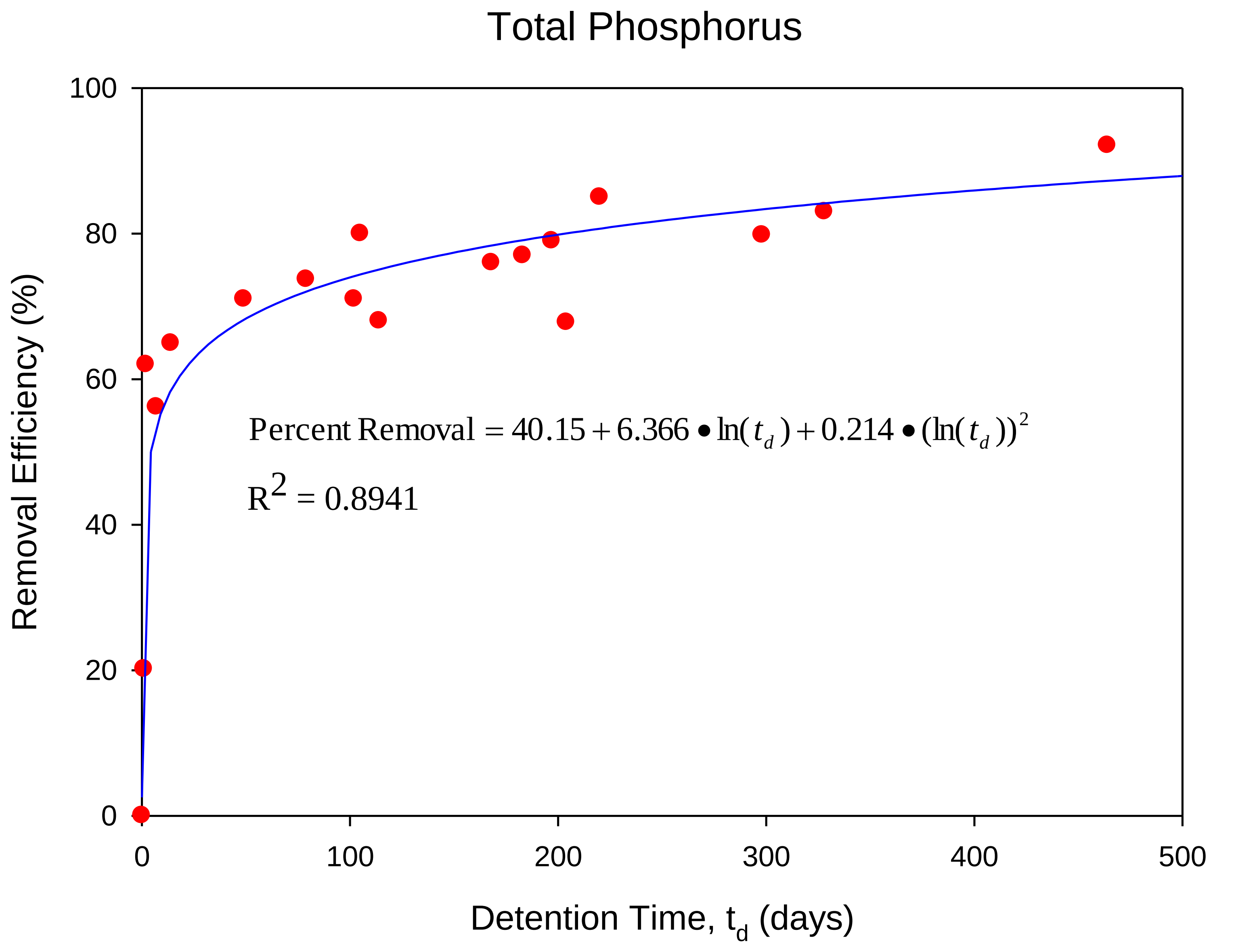
PPV = permanent pool volume below control elevation (ac-ft)

RO = annual runoff inputs (ac-ft/yr)

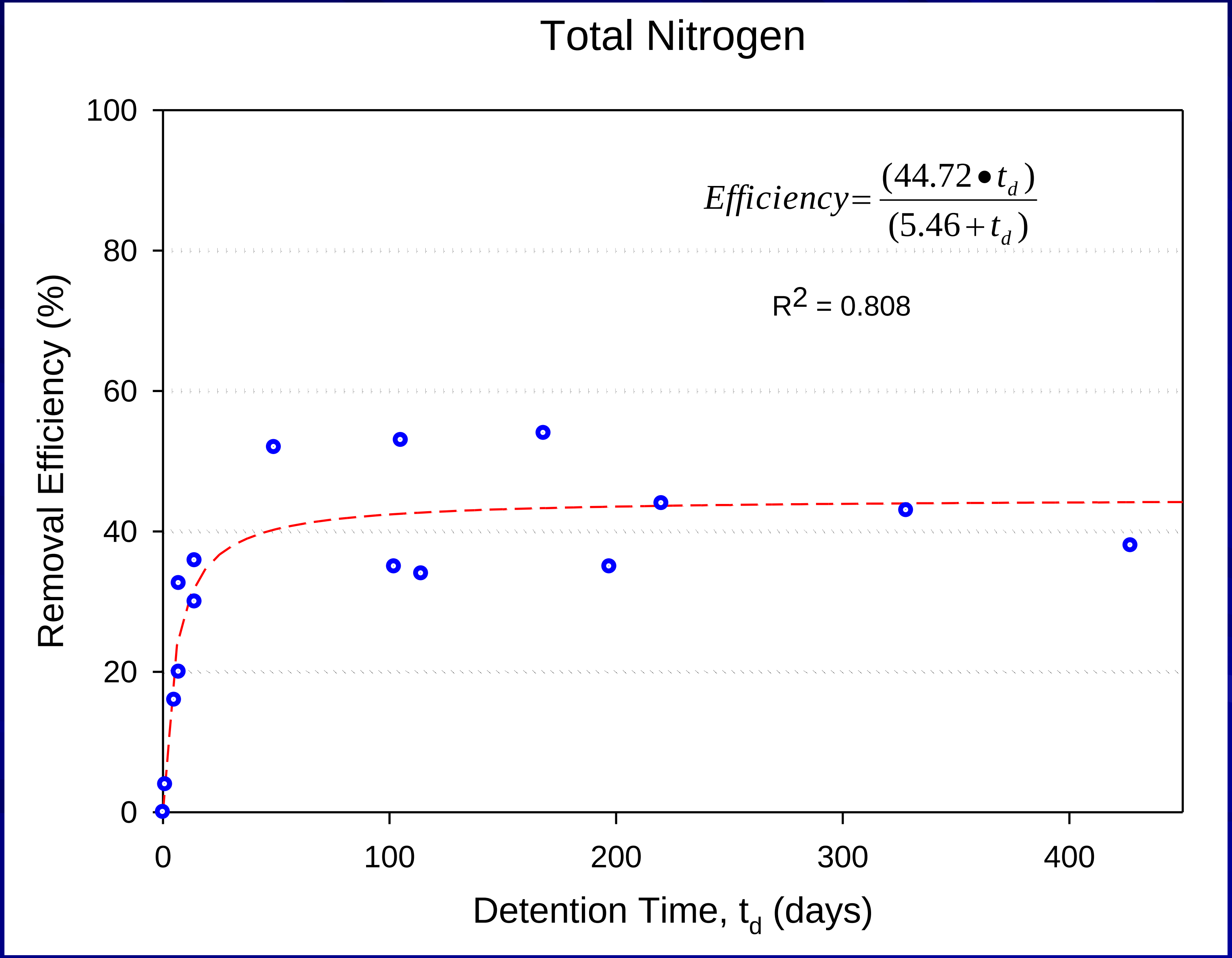
TSS Removal as a Function of Detention Time



Phosphorus Removal in Wet Ponds as a Function of Detention Time



Nitrogen Removal in Wet Ponds as a Function of Detention Time



Wet Detention Example Calculations

Calculate the wet detention efficiencies for similar developments in Pensacola, Orlando, and Key West

1. Land Use: 90 acres of single-family residential
   5 acres of stormwater management systems
   5 acres of preserved wetlands

2. Ground Cover/Soil Types

   A. Residential areas will be covered with lawns in good condition
   B. Soil types in HSG D

3. Impervious/DCIA Areas

   A. Impervious area =22.50 acres
   DCIA Area = 22.50 acres x 0.75 = 16.88 acres
   DCIA Percentage = (16.88 ac/90.0 ac) x 100 = 18.7% of developed area

4. Composite non-DCIA curve number: Non-DCIA CN Value = 81.4

5. Wet Detention Pond Design Criteria:

   A. Pond designed for a detention time of 200 days

Example Calculations – cont.

5. Project Hydrologic and Mass Loading Characteristics:

Location	Annual C Value	Runoff (ac-ft/yr)	TN Loading (kg/yr)	TP Loading (kg/yr)
Pensacola	0.304	149.3	344	55.4
Orlando	0.253	94.8	219	35.2
Key West	0.266	79.8	184	29.6

6. Calculate Permanent Pool Volume (PPV):

For the Pensacola site, the PPV requirement is:

$$\frac{149.3 \text{ ac-ft}}{\text{yr}} \times 200 \text{ days} \times \frac{1 \text{ year}}{365 \text{ days}} = \underline{81.8 \text{ ac-ft}}$$

For the Orlando site, the PPV requirement is:

$$\frac{94.8 \text{ ac-ft}}{\text{yr}} \times 200 \text{ days} \times \frac{1 \text{ year}}{365 \text{ days}} = \underline{51.9 \text{ ac-ft}}$$

For the Key West site, the PPV requirement is:

$$\frac{79.8 \text{ ac-ft}}{\text{yr}} \times 200 \text{ days} \times \frac{1 \text{ year}}{365 \text{ days}} = \underline{43.7 \text{ ac-ft}}$$

Example Calculations – cont.

7. Calculate pond efficiency:

Anticipated TN removal for a 200 day detention time =

$$\text{Eff} = \frac{(43.75 \times t_d)}{(4.38 + t_d)} = \frac{44.72 \times 200}{5.46 + 200} = 42.6\%$$

Anticipated TP removal for a 200 day detention time =

$$\text{Eff} = 40.13 + 6.372 \ln (t_d) + 0.213 (\ln t_d)^2 = 40.13 + 6.372 \ln (200) + 0.213 (\ln 200)^2 = 79.9\%$$

Modeled Impacts of Additional PPV

Detention Time (days)[1]	TP Mass Removal (%)	Mean TP Conc. (mg/l)	TP Discharge (kg/yr)
8	68.6	0.094	56.4
11	69.9	0.089	53.9
17	71.3	0.085	51.2
26	72.7	0.080	48.4
39	74.3	0.075	45.4
58	75.9	0.069	42.1
87	77.7	0.063	38.7
130	79.6	0.057	35.0
195	81.6	0.050	31.1
293	83.8	0.042	26.9
440	86.1	0.035	22.3

1. Each detention time increased by 50%

Impacts

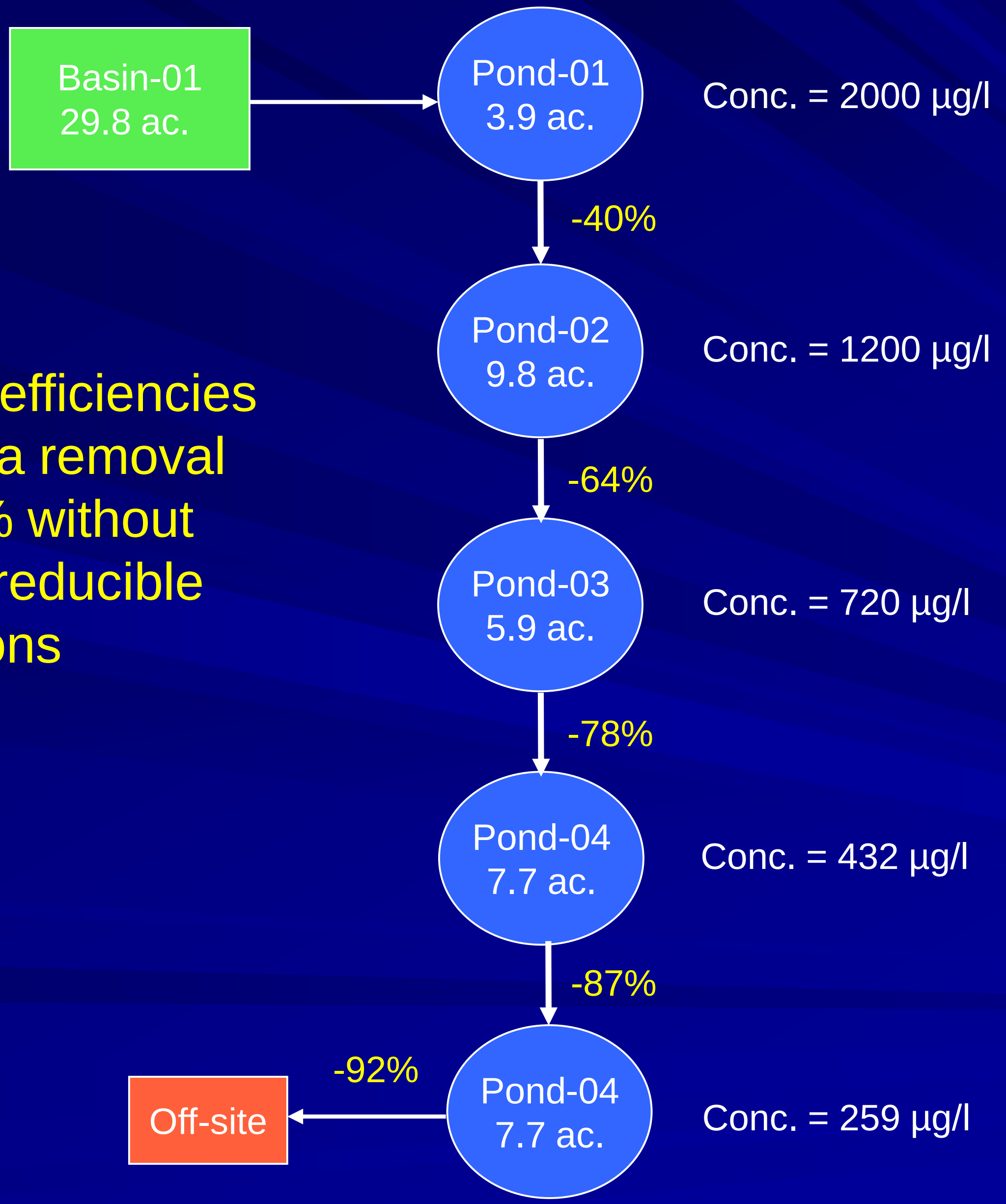
1. Increased mass removal
2. Reduced discharge concentrations
3. Reduced mass discharge
4. Increased dilution for slug inputs

Concept of Irreducible Concentration

- Irreducible concentrations reflect the limitations of removal pathways for a particular pollutant in a treatment system
  - In wet ponds, the most significant processes are:
    - Sedimentation
    - Biological uptake
- When the irreducible concentration is reached, no additional removal is possible regardless of additional treatment volume or time
- Concept is widely used in modeling wastewater treatment wetlands

Parameter	Units	Total N	Total P
Assumed Minimum Irreducible Concentration	µg/l	400	10

Example Removal Patterns for a Multi-Pond System



Theoretical removal efficiencies for a pollutant with a removal efficiency of ~40% without consideration of irreducible concentrations

Example Calculations for Wet Detention Ponds in Series

Pond	Det. Time (days)	Cumulative Pond Detention time (days)				
		Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1	315	315				
2	252	567	252			
3	151	718	403	151		
4	123	841	526	274	123	
5	87	928	613	361	210	87

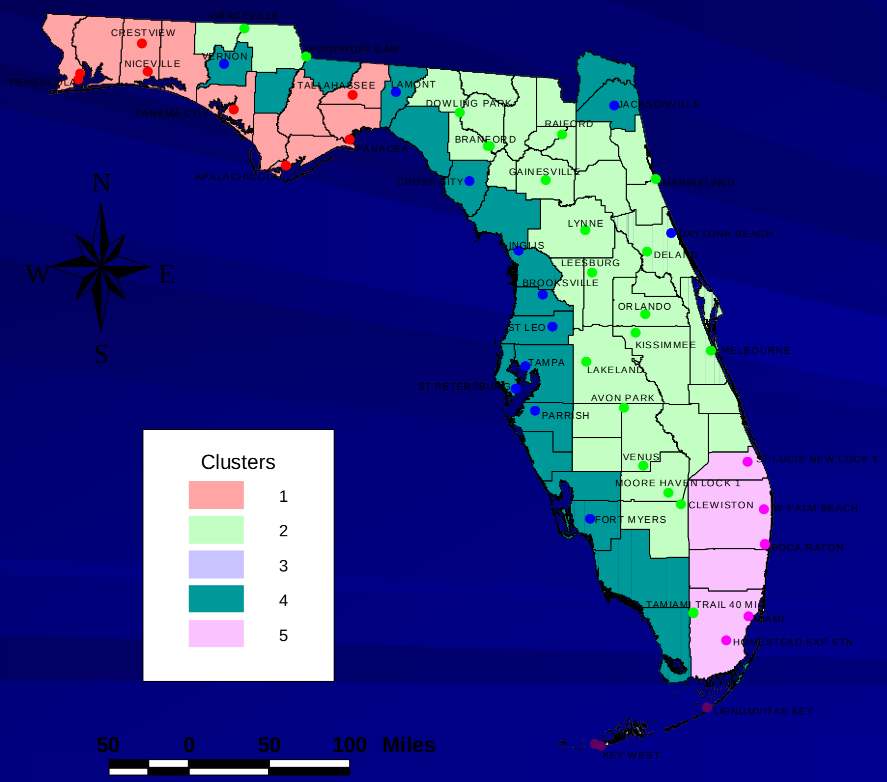
Pond	TP Load (kg/yr)	Incremental TP Removal (kg/yr)				
		Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1	13.57	11.5				
2	16.17	0.7	13.4			
3	21.15	0.4	0.8	16.7		
4	24.42	0.3	0.5	1.1	18.9	
5	19.46	0.2	0.2	0.4	0.8	14.6
Totals:	94.76					

Pond	Det. Time (days)	Cumulative TP Removal (%)				
		Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1	315	85				
2	252	89	83			
3	151	91	87	79		
4	123	93	89	84	77	
5	87	93	90	86	82	75

Pond	TP Load (kg/yr)	Cumulative TP Remaining (kg/yr)					Pond Load (kg/yr)
		Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	
1	13.57	2.1					2.1
2	16.17	1.3	2.8				4.1
3	21.15	0.9	2.0	4.4			7.3
4	24.42	0.6	1.5	3.3	5.5		10.9
5	19.46	0.5	1.2	2.9	4.7	4.9	14.2

Detention times are cumulative from one pond to another

Comparison of 14 Day Wet Season Detention Time with Mean Annual



Meteorological Zone	Equivalent Annual Detention Time (days)
1- Panhandle	17.1
2- Central	19.9
3- Keys	21.8
4- West Coastal	20.2
5- Southeast	21.0

Summary

- Wet detention ponds are man-made lakes designed to treat runoff
- Wet detention ponds provide significant removal efficiencies for nutrients
  - Total N: 35 – 45%
  - Total P: 65 – 80%
- The efficiency of wet detention is a function of detention time
- Wet detention ponds should be designed to maintain aerobic conditions throughout the water column
- Wet detention ponds exhibit irreducible concentrations below which no further reduction is possible
- BMPTRAINS model conducts all calculations for pond design and evaluation

BMPTRAINS MODEL:
ALUM STORMWATER TREATMENT

BY: HARVEY H. HARPER, PHD, P.E.

Characteristics of Alum

-Clear, light green to yellow solution, depending on Fe content

-Liquid is 48.5% solid aluminum sulfate by wt.

-Specific gravity = 1.34

-11.1 lbs/gallon

-Freezing point = 5° F

-Delivered in tanker loads of 4500 gallons each

Alum is made by dissolving aluminum ore (bauxite) in sulfuric acid

History of Alum Usage

Drinking water – Roman Times

Wastewater – 1800s

Lake surface – 1970

Stormwater – 1986

Alum is used to make many common items, such as:

- pickles
- baseballs
- antacids
- deodorants
- vaccines

Significant Alum Removal Processes

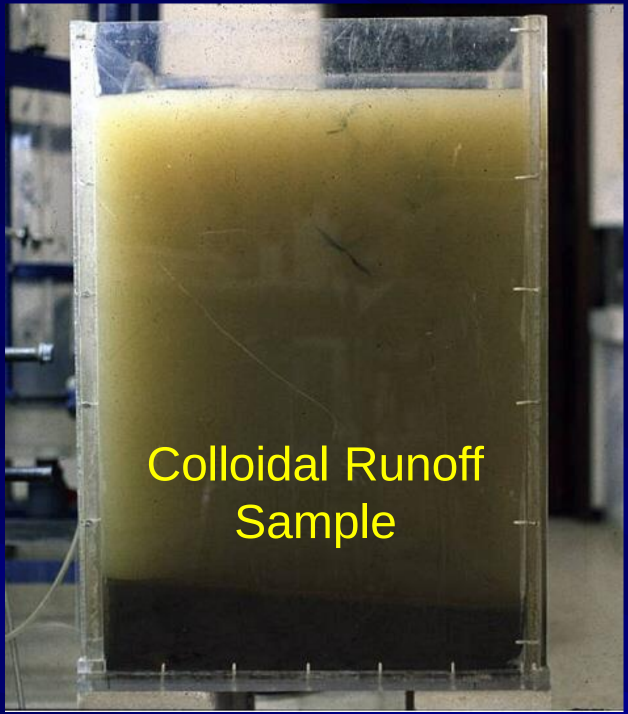
1. Removal of suspended solids, algae, phosphorus, heavy metals and bacteria:

$$Al^{+3} + 6H_2O \rightarrow Al(OH)_{3(ppt)} + 3H_3O^+$$

2. Removal of dissolved phosphorus:

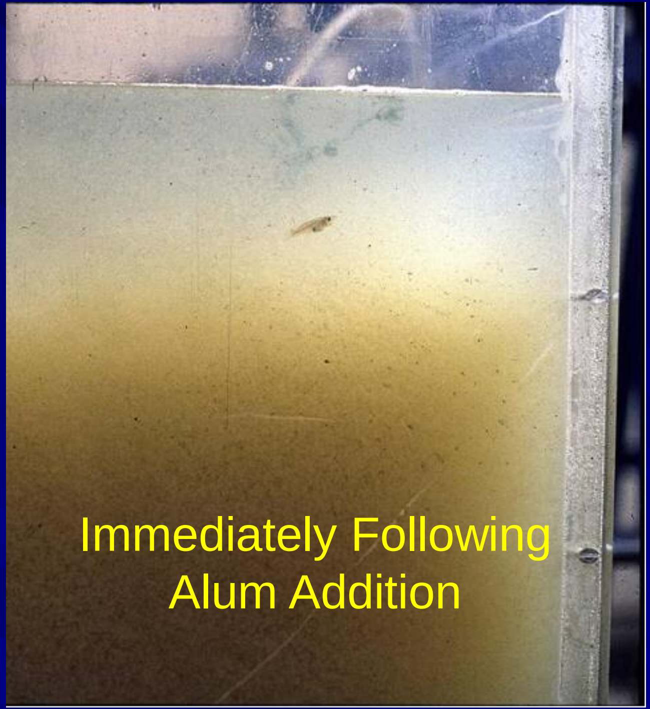
$$Al^{+3} + H_nPO_4^{n-3} \rightarrow AlPO_{4(ppt)} + nH^+$$

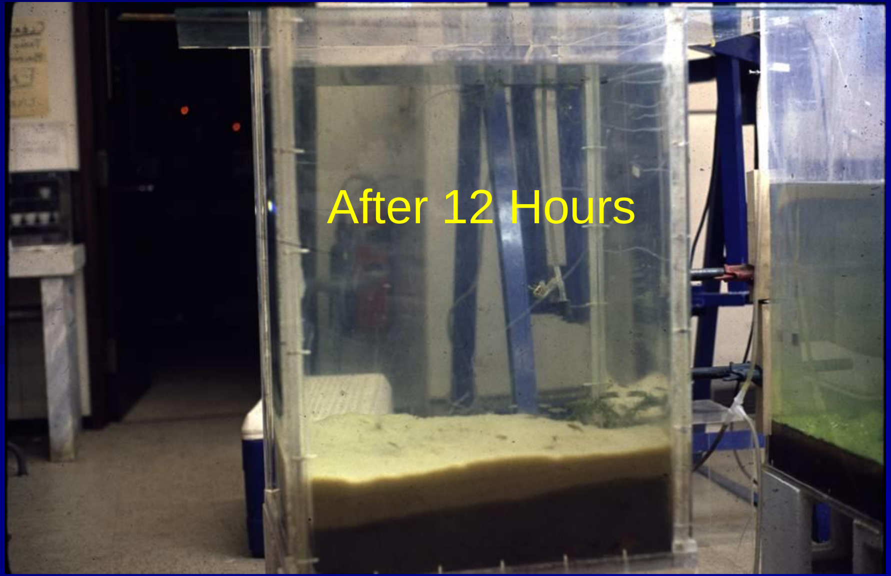
Initial Experiments (1980)



Initial testing evaluated salts of:
- Aluminum
- Iron
- Calcium

Alum was most effective





Alum Reacts Quickly to Remove Both Particulate and Dissolved Pollutants

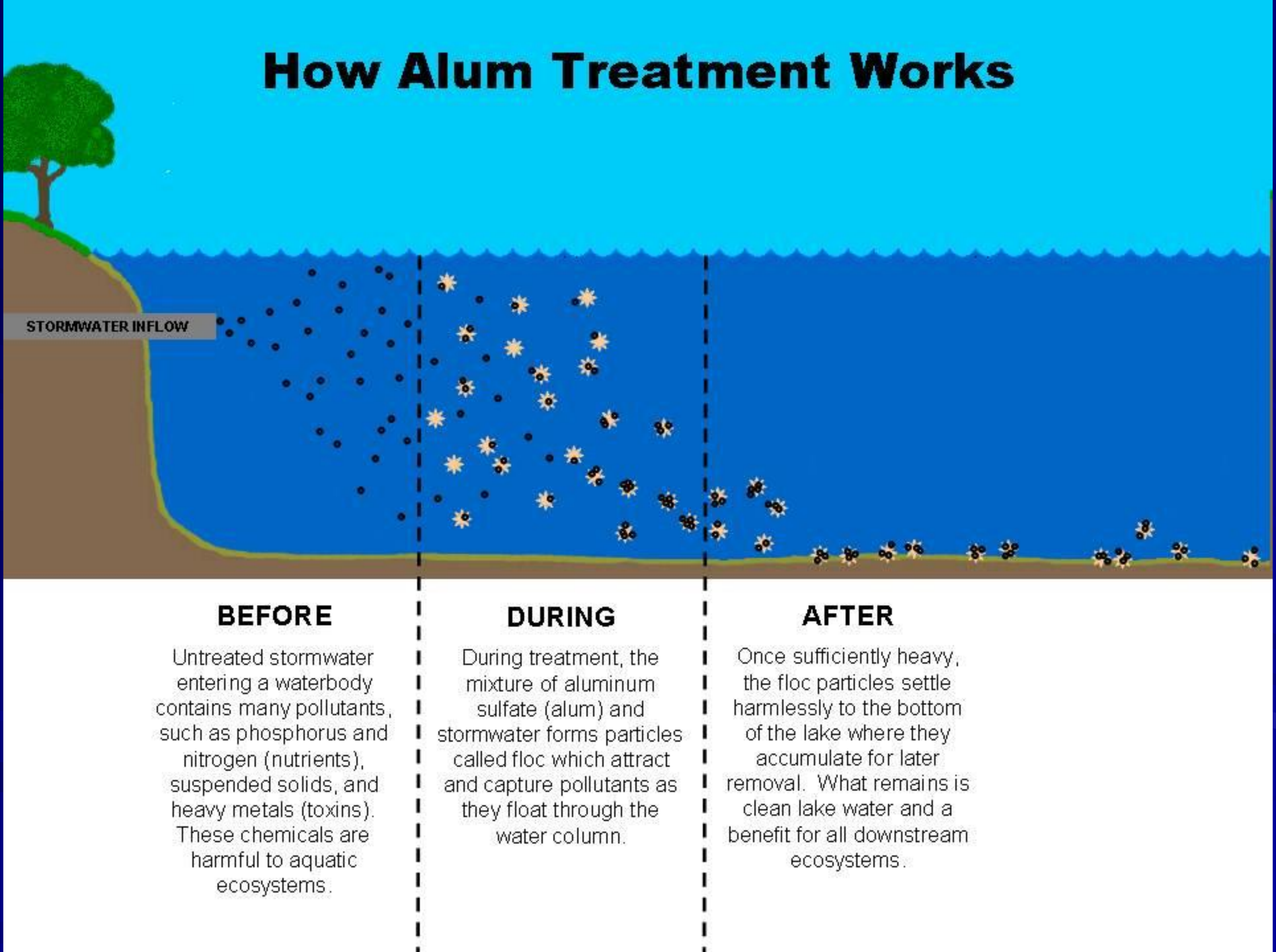
Alum Coagulation

Advantages

- Rapid, efficient removal of solids, phosphorus, and bacteria
- Inexpensive – approximately $0.45/gallon
- Low contaminant levels
- Relatively easy to handle and feed
- Does not deteriorate under long-term storage
- Floc is inert and is immune to normal fluctuations in pH and redox
- Floc binds heavy metals in sediments, reducing sediment toxicity

Disadvantage

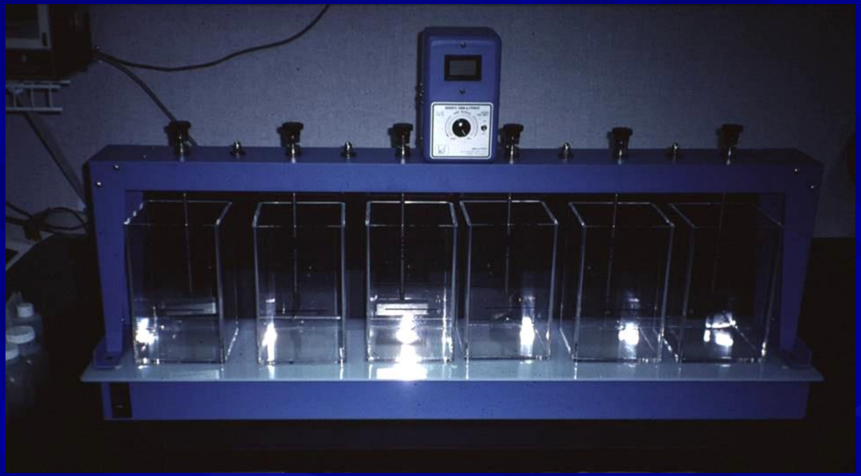
- May result in lowered pH and elevated levels of Al^{+3} if improperly applied


How Alum Treatment Works
STORMWATER INFLOW
BEFORE
Untreated stormwater entering a waterbody contains many pollutants, such as phosphorus and nitrogen (nutrients), suspended solids, and heavy metals (toxins). These chemicals are harmful to aquatic ecosystems.
DURING
During treatment, the mixture of aluminum sulfate (alum) and stormwater forms particles called floc which attract and capture pollutants as they float through the water column.
AFTER
Once sufficiently heavy, the floc particles settle harmlessly to the bottom of the lake where they accumulate for later removal. What remains is clean lake water and a benefit for all downstream ecosystems.

Procedures For
Evaluation Of Alum Treatment Feasibility

1. Collect representative samples of inflow to be treated
   - Include stormwater as well as dry weather baseflow, if present
   - Samples should reflect anticipated range of water quality characteristics

2. Perform jar testing to evaluate:
   - pH response to alum addition
   - floc formation rates and settling characteristics
   - removal efficiencies for constituents of interest



3. Perform hydrologic modeling to:
   - evaluate range of flows to be treated
   - estimate annual volume to be treated
   - establish design parameters for process equipment

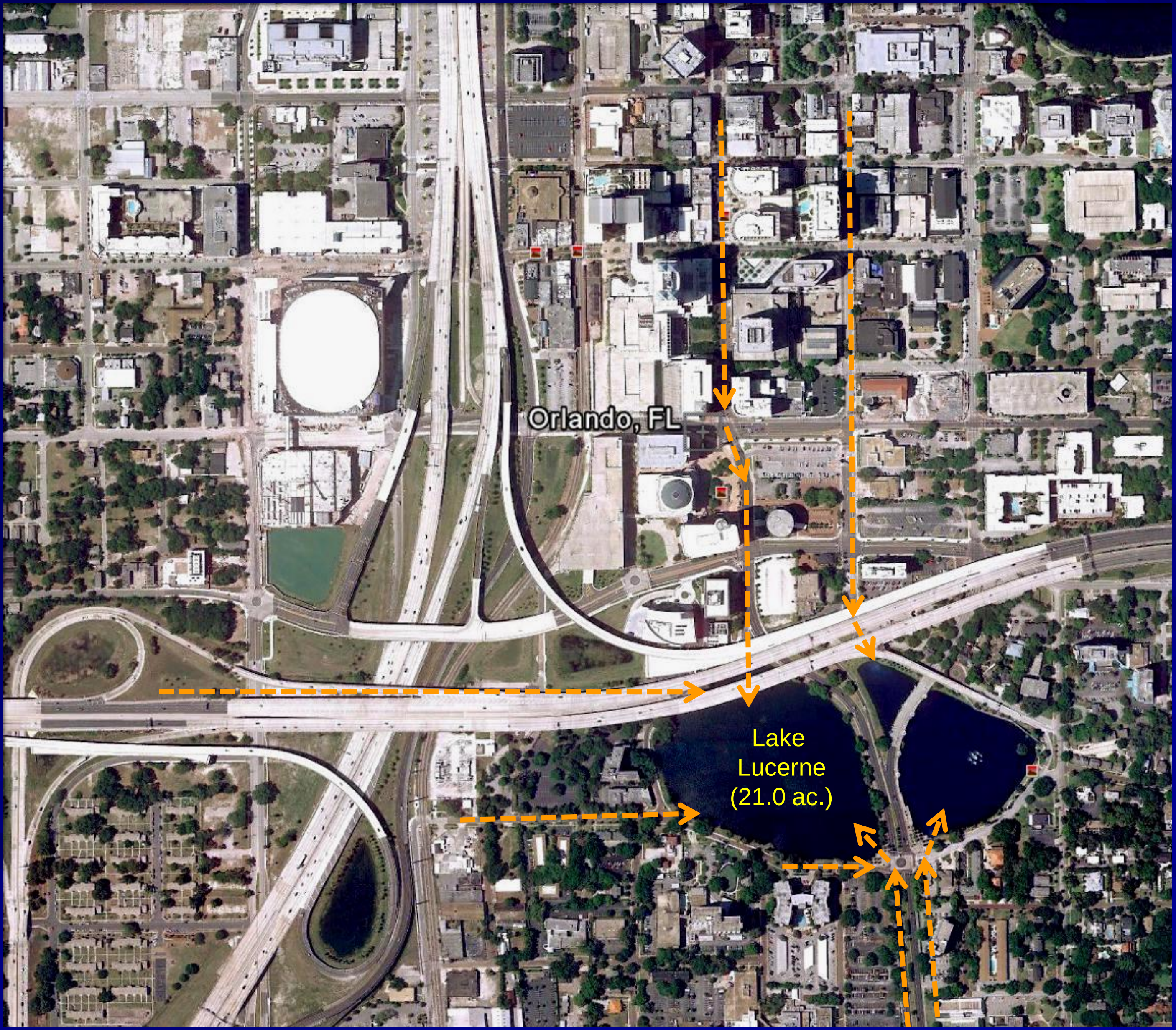
4. Evaluate floc collection and disposal options
   - floc collection may or not be required depending on the receiving water
   - floc may be collected in a dedicated settling pond
   - collection and disposal to sanitary sewer
   - direct inflow into receiving water

Typical Percent Removal Efficiencies for Alum Treated Stormwater Runoff

Parameter	Settled Without Alum (24 hrs)	Alum Dose (mg Al/liter)		
		5	7.5	10
Ammonia	~ 0	~ 0	~ 0	~ 0
NOx	~ 0	~ 0	~ 0	~ 0
Diss. Organic N	20	51	62	65
Particulate N	57	88	94	96
Total N	15	~ 20	~ 30	~ 40
Diss. Ortho-P	17	96	98	98
Particulate P	61	82	94	95
Total P	45	86	94	96
Turbidity	82	98	99	99
TSS	70	95	97	98
BOD	20	61	63	64
Fecal Coliform	61	96	99	99

- Removal efficiencies for waters with elevated color will be lower

Lake Lucerne
– Orlando Southern Gateway



- Surface area = 29 acres (11.7 ha)

- Lake divided into eastern and western lobes by 6 lane road

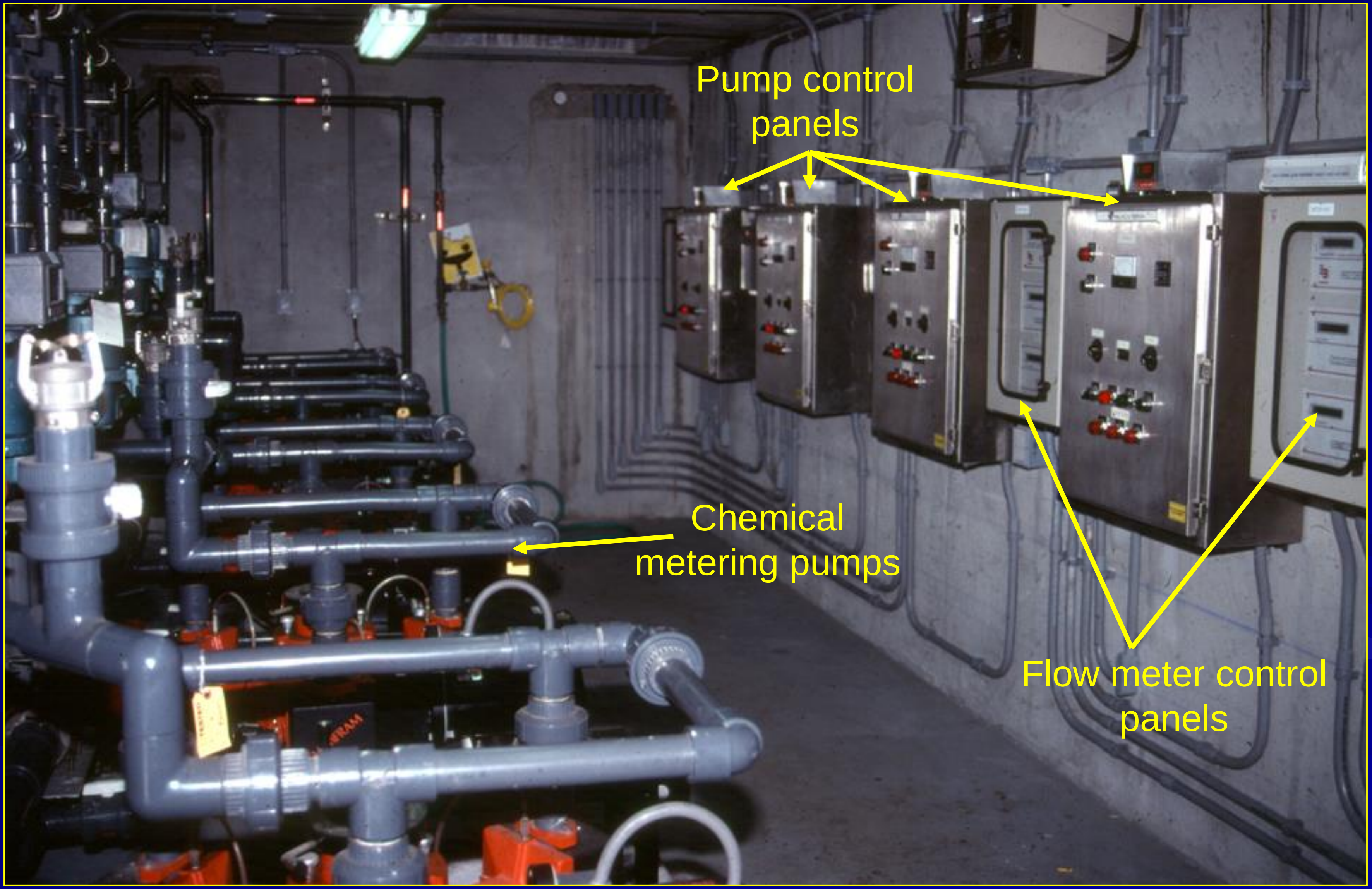
- 267 acre watershed

- Six primary inflows contribute 95% of annual runoff

- Mean depth = 10 ft (3 m)

- Pre-modification TP conc. > 100 µg/l

Mechanical components for the Lake Lucerne alum treatment system are housed in an underground vault beneath an elevated expressway



Alum Treatment Design Guidelines

- Guidelines are provided in Section 19 of the Draft Statewide Stormwater Rule (March 2010)
- Issues that must be addressed in an application:
  - Range of flow rates to be treated by system
  - Recommended optimum coagulant dose
  - Chemical pumping rates
  - Provisions to ensure adequate turbulence for chemical mixing and a minimum 60 second mixing time
  - Sizes and types of chemical metering pumps - must include flow totalizer for alum injected
  - Requirements for additional chemicals to buffer for pH neutralization, if any
  - Post-treatment water quality characteristics
  - Percentage of annual runoff flow treated by chemical system

Alum Treatment Design Guidelines

- Issues that must be addressed in an application – con't.
  - Method of flow measurement – must include flow totalizer
  - Floc formation and settling characteristics
  - Floc accumulation rates
  - Recommended design settling time
  - Annual chemical costs
  - Chemical storage requirements
  - Proposed maintenance procedures
- Floc collection required when using as stormwater treatment for new development
- Floc can discharge into receiving water for retrofit projects if receiving water is impaired or eutrophic and floc will benefit internal recycling

Treatment Efficiencies for Typical Stormwater Management Systems

Type of System	Estimated Removal Efficiencies (%)		
	Total N	Total P	TSS
Dry Retention	Varies with hydrologic characteristics and treatment volume Generally 50-75% for typical design criteria		
Dry Detention	Highly variable – depends on pond bottom/GWT relationship		
Wet Detention	30	65	85
Gross Pollutant Separators	0 -10	0 - 15	10 - 80
Alum Treatment	50	90	90

Pollutant Removal Costs for Typical Stormwater Management Systems

Type of System	Mass Removal Costs ($/kg)		
	Total N	Total P	TSS
Dry Retention	800 – 3,000	2,000 – 5,000	20 - 50
Dry Detention	Highly variable		
Wet Detention	150 - 300	350 – 750	2 - 3
Gross Pollutant Separators	15,000 – 25,000	10,000 – 20,000	10 - 100
Alum Treatment	15 - 75	75 - 250	1 - 4

Summary

- Alum treatment is a highly effective stormwater treatment technology
- Alum treatment can provide significant removal efficiencies for nutrients
  - Total N: 35 – 45%
  - Total P: 80 – 95%
- Lowest pollutant removal costs of all common BMPs
- Requires dedicated maintenance personnel