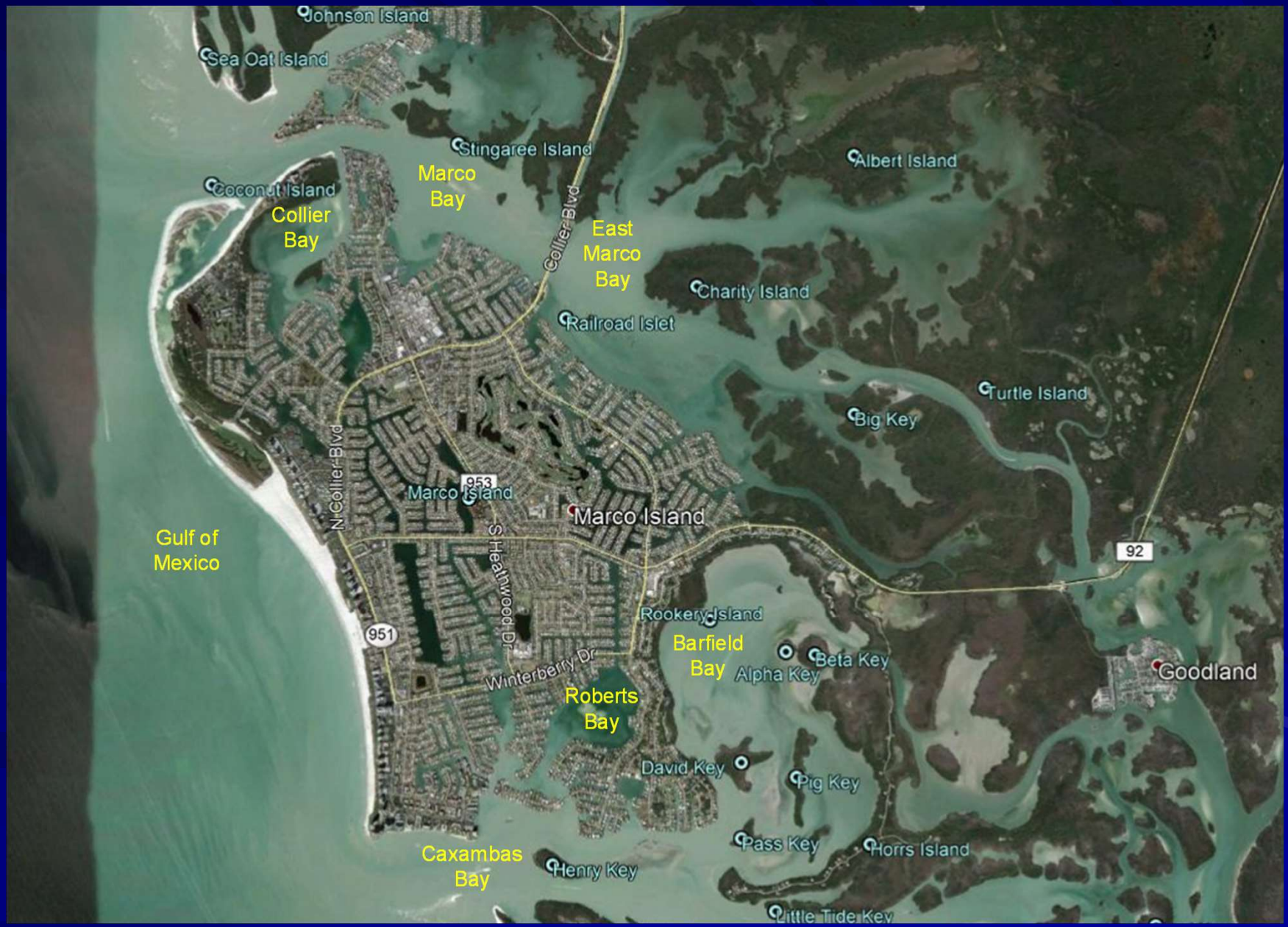
Marco Island Hydrologic/Nutrient Budgets and Water Quality Management Plan

Results and Recommendations

City Council Meeting
September 20, 2021

Harvey H. Harper, PhD, PE

Location Map for Marco Island



Observed Water Quality Issues

a. Photographs provided by residents

b. Photographs taken by ERD

Scope of Work

Objectives

- Develop hydrologic and nutrient budgets for Marco Island waterways
- Prioritize pollutant inputs, develop water quality management plans and conceptual retrofit projects

Work Efforts

- Collect/Review available information
- Compile and analyze historical water quality data
- Conduct 6-month field monitoring program
  - Surface water
  - Sediments
  - Runoff
  - Groundwater seepage
  - Precipitation
- Evaluate practices related to wastewater, reuse irrigation, stormwater, golf course, fertilizer
- Develop hydrologic and nutrient budgets
- Develop management recommendations
- Prepare Draft and Final Reports and give presentation to City Council

Numeric Nutrient Criteria (NNC) for Marco Island[1]

Parameter	Units	Criteria
Total N	µg/l	300
Total P	µg/l	46
Chlorophyll-a	µg/l	4.9
Enterococcus	Cfu/100 mL	35

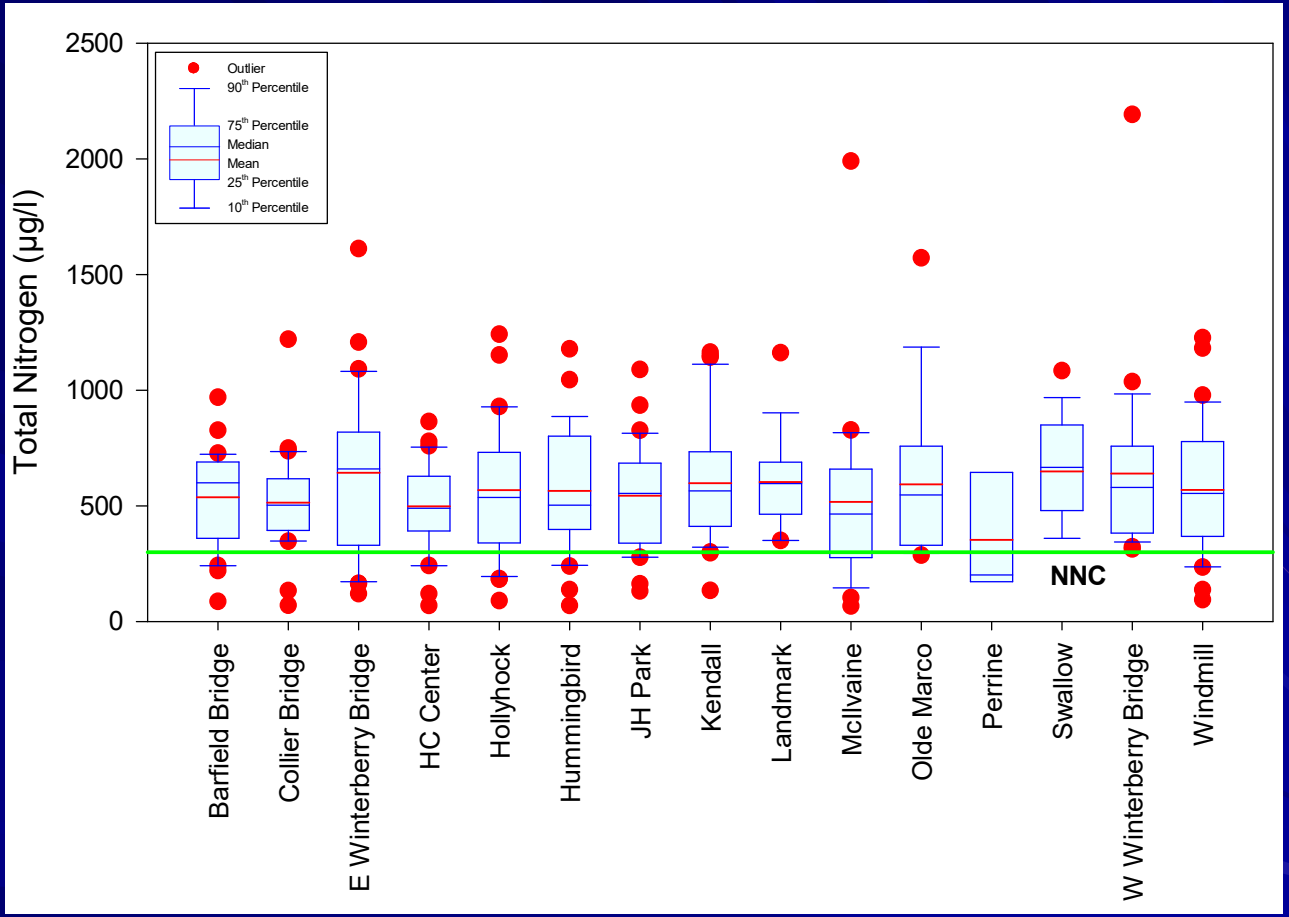
1. Chapter 62-302 Florida Administrative Code

- Nutrient criteria are developed by the Florida Department of Environmental Protection (FDEP) using the "reference site" method
  - Undisturbed areas used for reference sites
  - Criteria must be met on annual average basis (geometric mean)
- Waters which do not meet criteria are listed as "Impaired"
  - A water quality improvement document, referred to as a TMDL, must be developed

Impaired Waters Near Marco Island

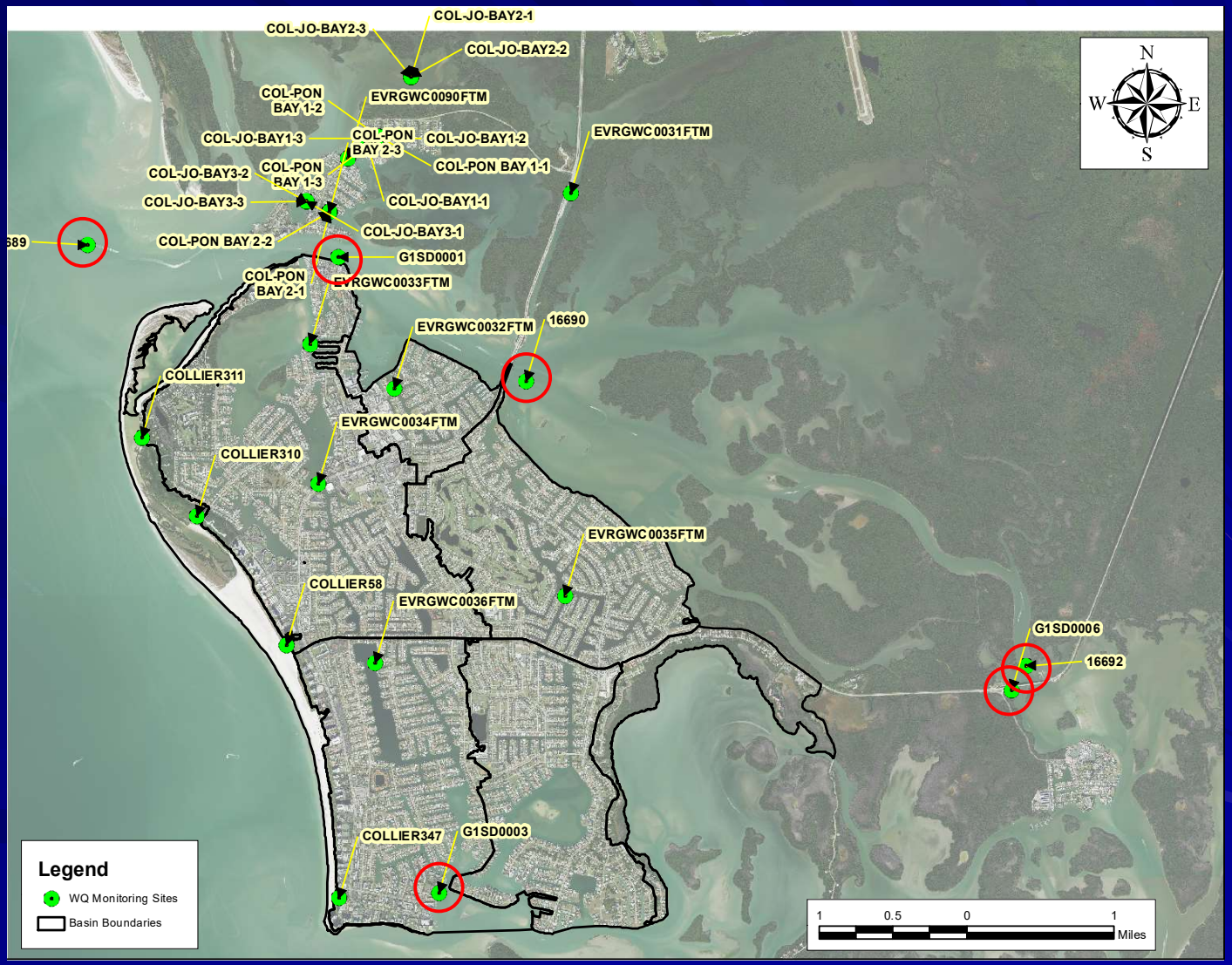
Total Nitrogen in Marco Island Waterways from 2015-2020

- City monitoring began in 2002 at quarterly to bi-monthly frequency
- Monthly monitoring initiated in 2015 at 15 sites
- Vast majority of concentrations exceed NNC



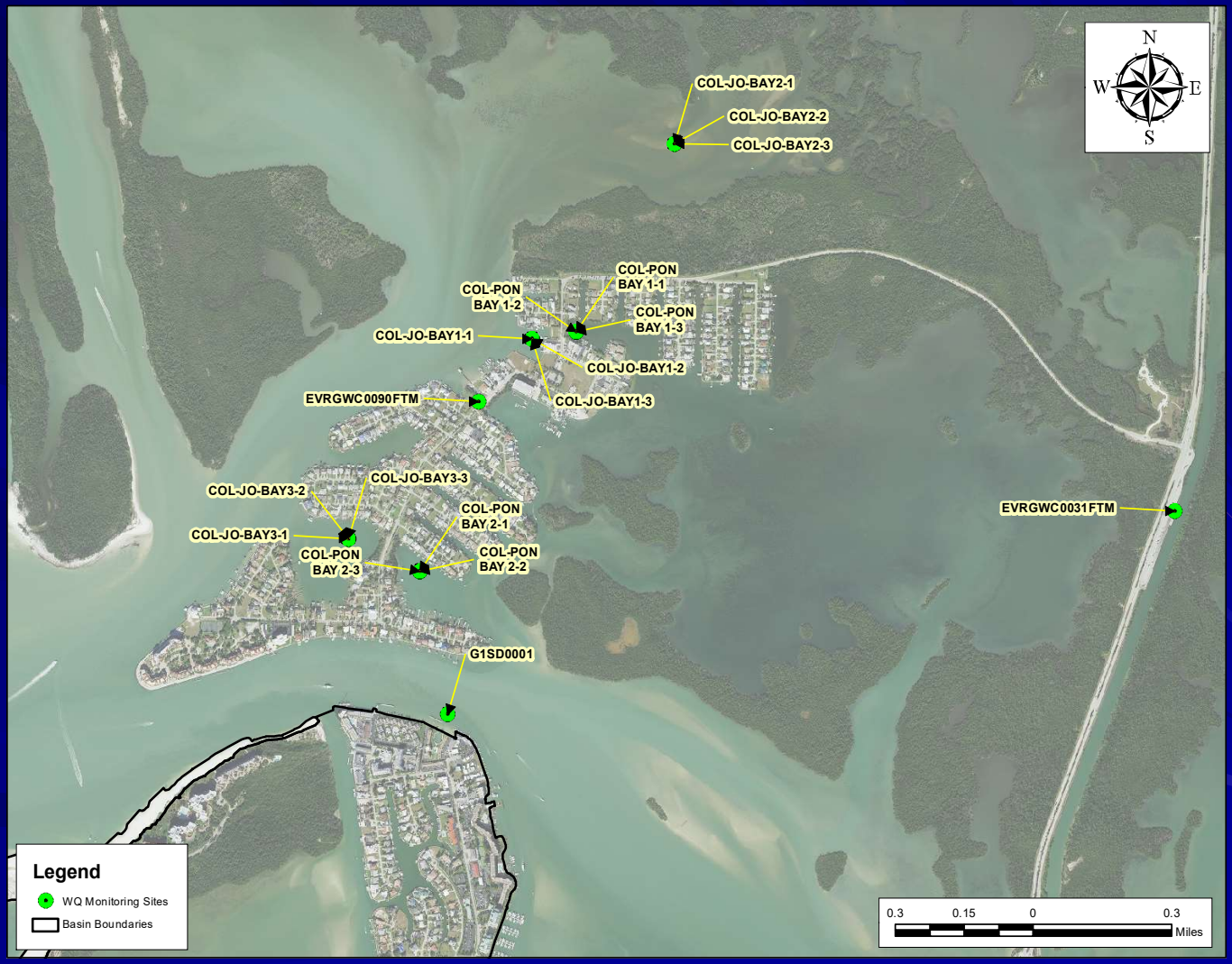
Historical Water Quality Monitoring Sites by Other Agencies

- Samples collected by SFWMD, Lakewatch, FDEP, and FDOH
- Monitoring initiated in 2001
- Monitoring ended in 2011
- Long term data are only available at 6 sites

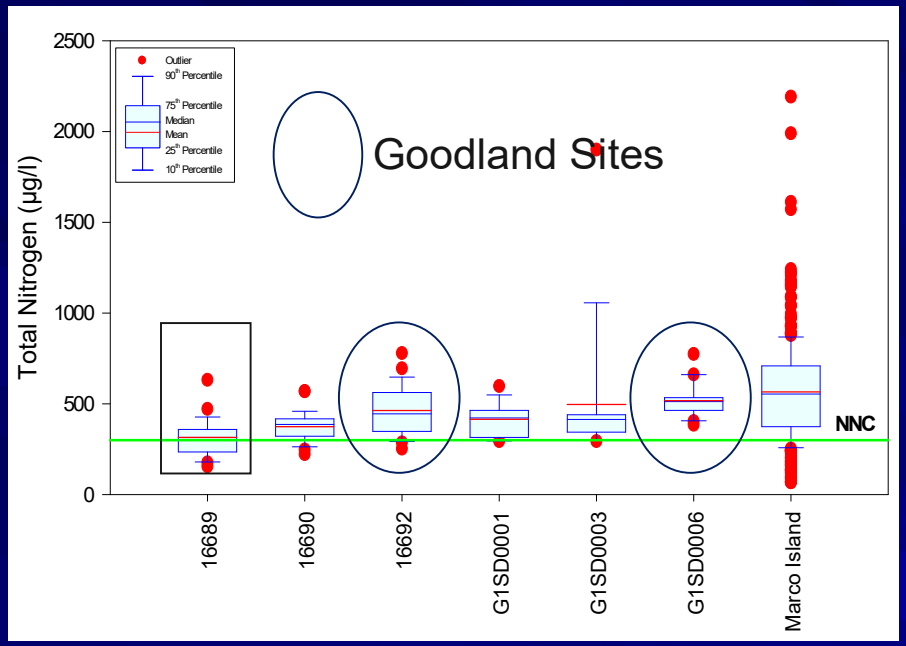


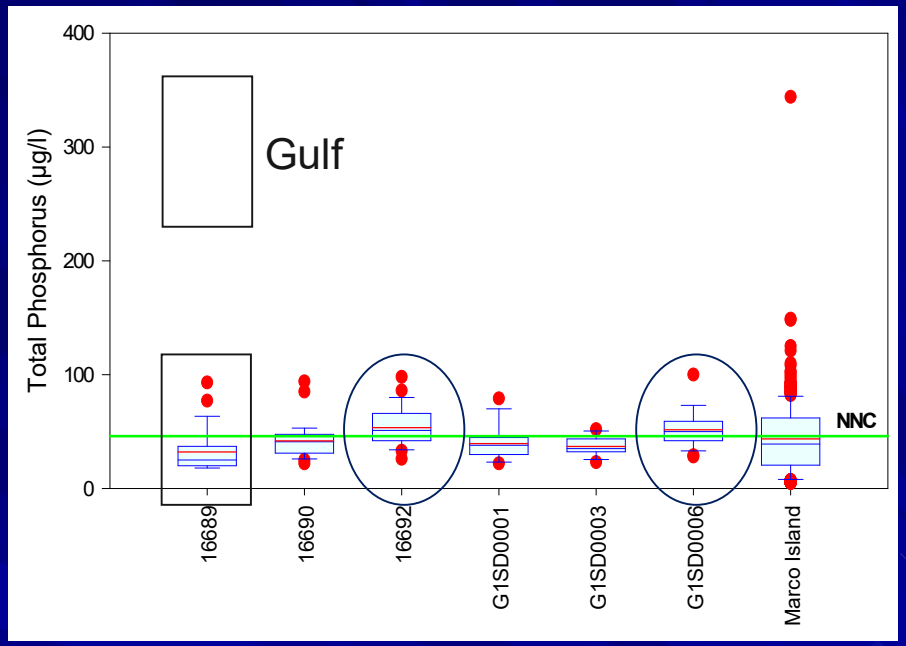
Off-Island Monitoring Sites Near Isles of Capri

- Monitoring initiated during 2001 at multiple sites
- Monitoring ended in 2011



Comparison of Total N and Total P at On- and Off-Island Waterways from 2015-2020





Nitrogen

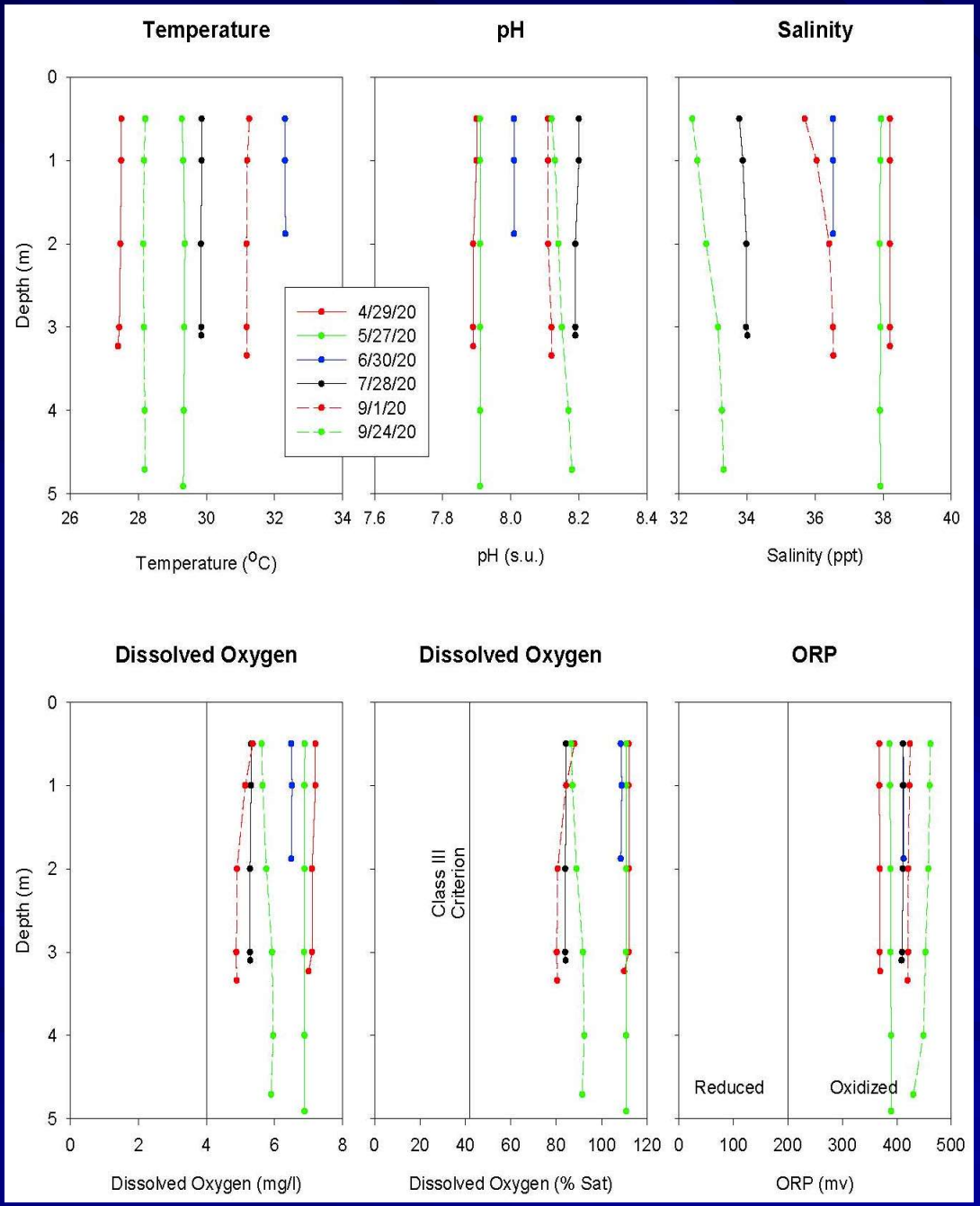
- Marco Bay enriched over Gulf
- Goodland enriched over Marco Bay
- Marco Island enriched over Goodland

Phosphorus

- Marco Bay and Marco Island are similar and enriched over Gulf
- Goodland enriched over Marco Bay and Marco Island

ERD Surface Water Monitoring Sites

- 17 Sites
- Monthly monitoring from April – September 2020
- Conducted vertical field profiles
- Collected samples under incoming and outgoing tide conditions



Vertical Field Profiles Collected in Marco Island at Site M-3

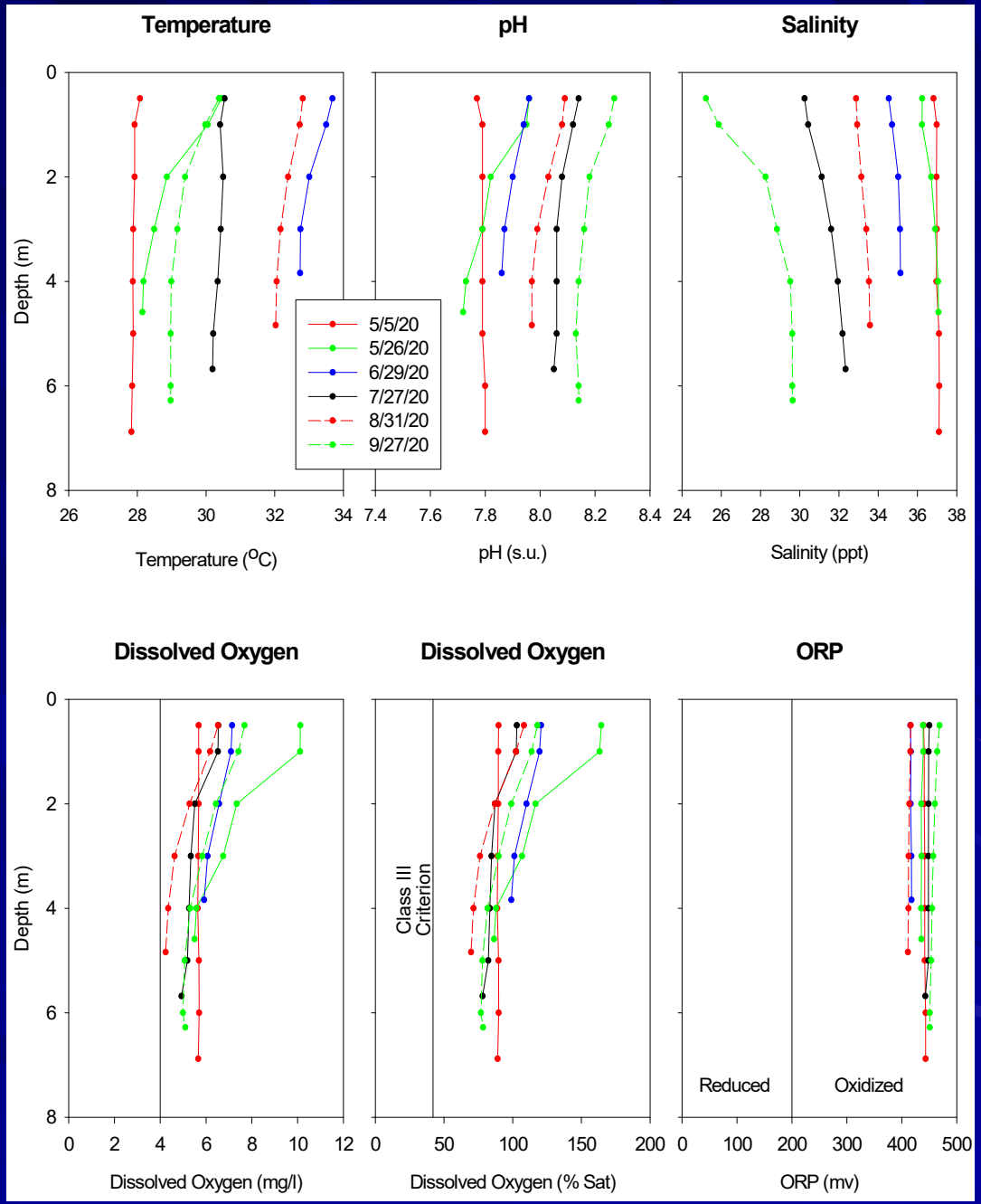
(Gulf)

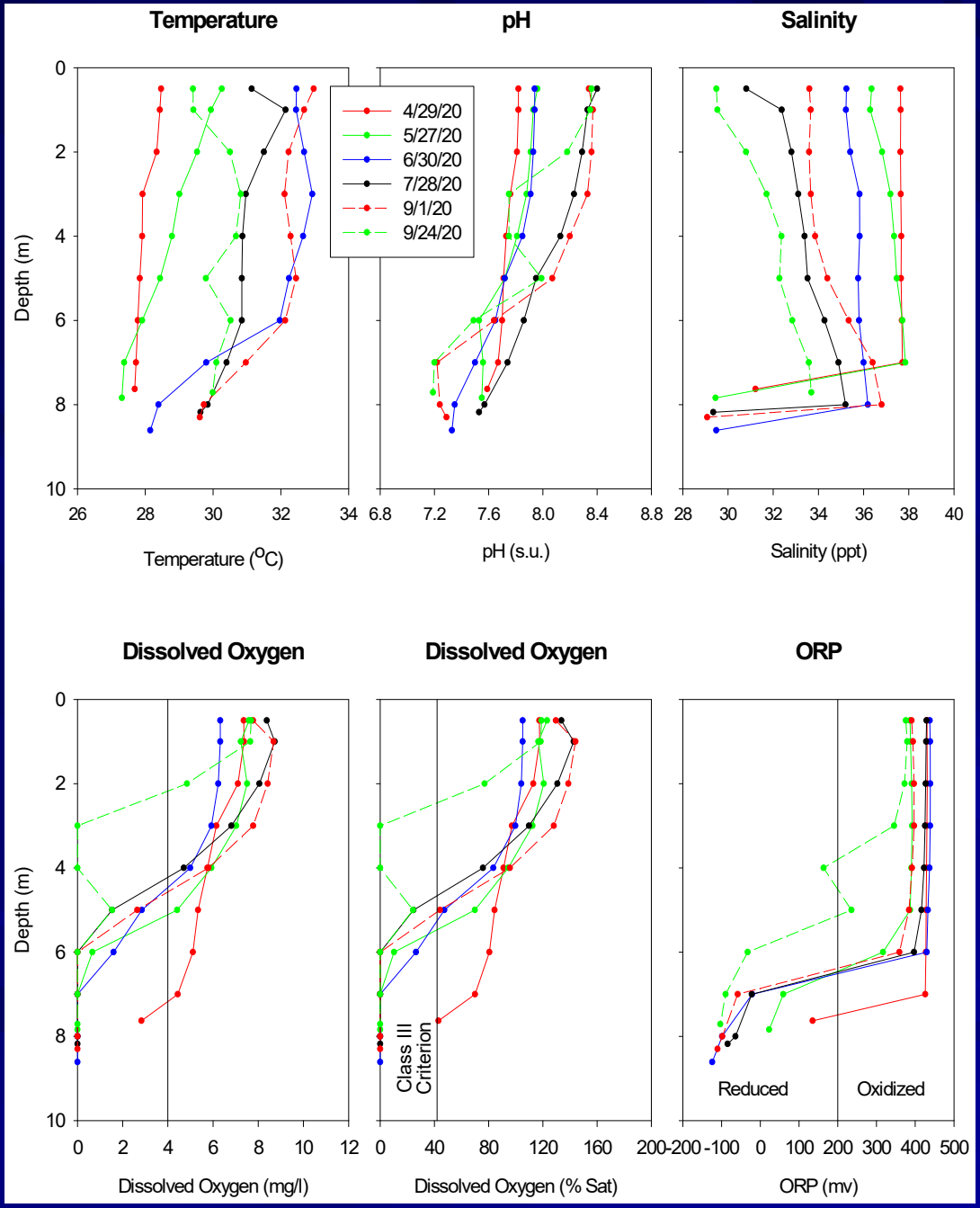
- Profiles typical of downstream areas with frequent water exchange

Vertical Field Profiles Collected in Marco Island at Site M-9

(Near golf course in middle of waterway)

- Profiles typical of middle portions of waterways





Vertical Field Profiles Collected in Marco Island at Site M-11

(Dead end canal)

- Profiles typical of upstream areas with poor water exchange

Locations of Sediment Core Monitoring Sites

Sediment Core Sample Photos

Site 4 – Waterway by Factory Bay

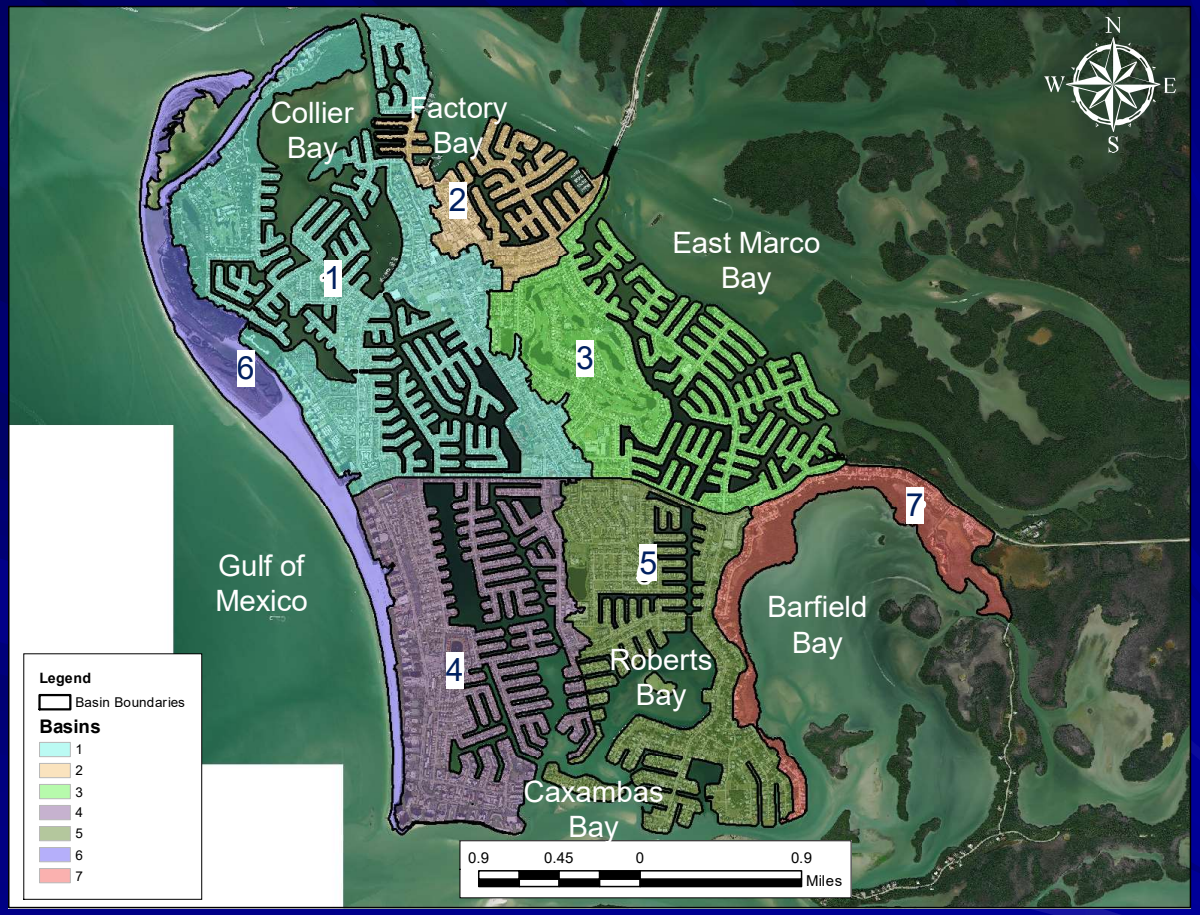
Site 9 – NW Waterway Middle

Site 14 – SW Waterway Dead End

Site 25 – Caxambas Bay

Marco Island Drainage Basin Areas

Sub-Basin	Area (acres)	Percent of Total (%)
1	1,487.05	27.7
2	306.51	5.7
3	935.45	17.4
4	955.10	17.8
5	834.67	15.6
6	497.82	9.3
7	350.08	6.5
Total:	5,366.68	100



- Soils are well drained
  - Virtually all rainfall infiltrates into soil
- Land use is primarily residential and commercial
- Internal waterways – 1,525 acres

City of Marco Island Stormsewer System

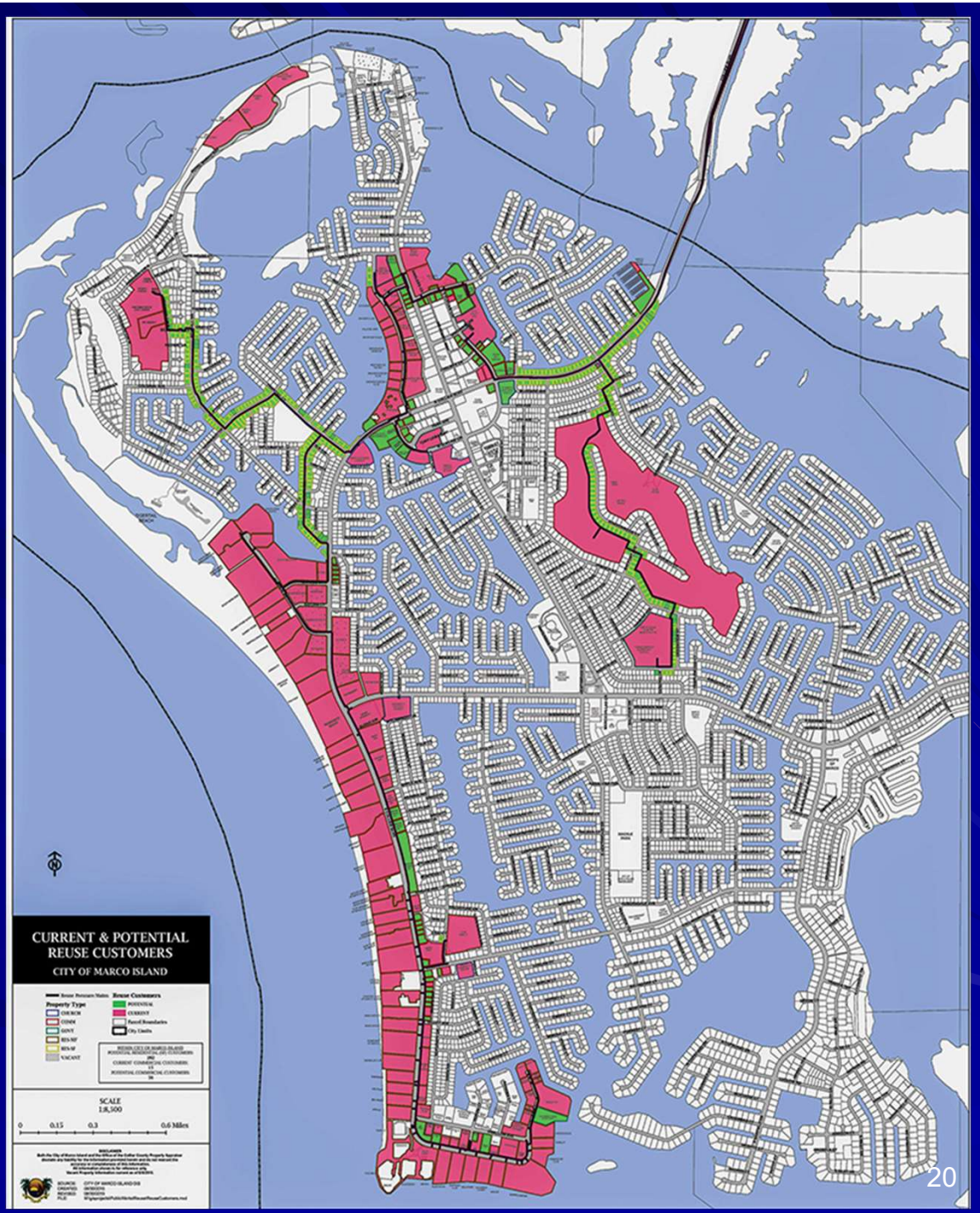
City of Marco Island
Wastewater Treatment Facility

- Almost all island areas have central sewer systems
  - About 20 septic tank systems will be phased out in 2024
- Sewer system has
  - 287 miles of sewage mains
  - 2,127 manholes
- Treated wastewater stored in 2- 500,000-gallon tanks
- Design capacity = 4.92 MGD
- Average from 2011-2020 = 2.20 MGD
  - Increasing at rate of 0.08 MGD/year

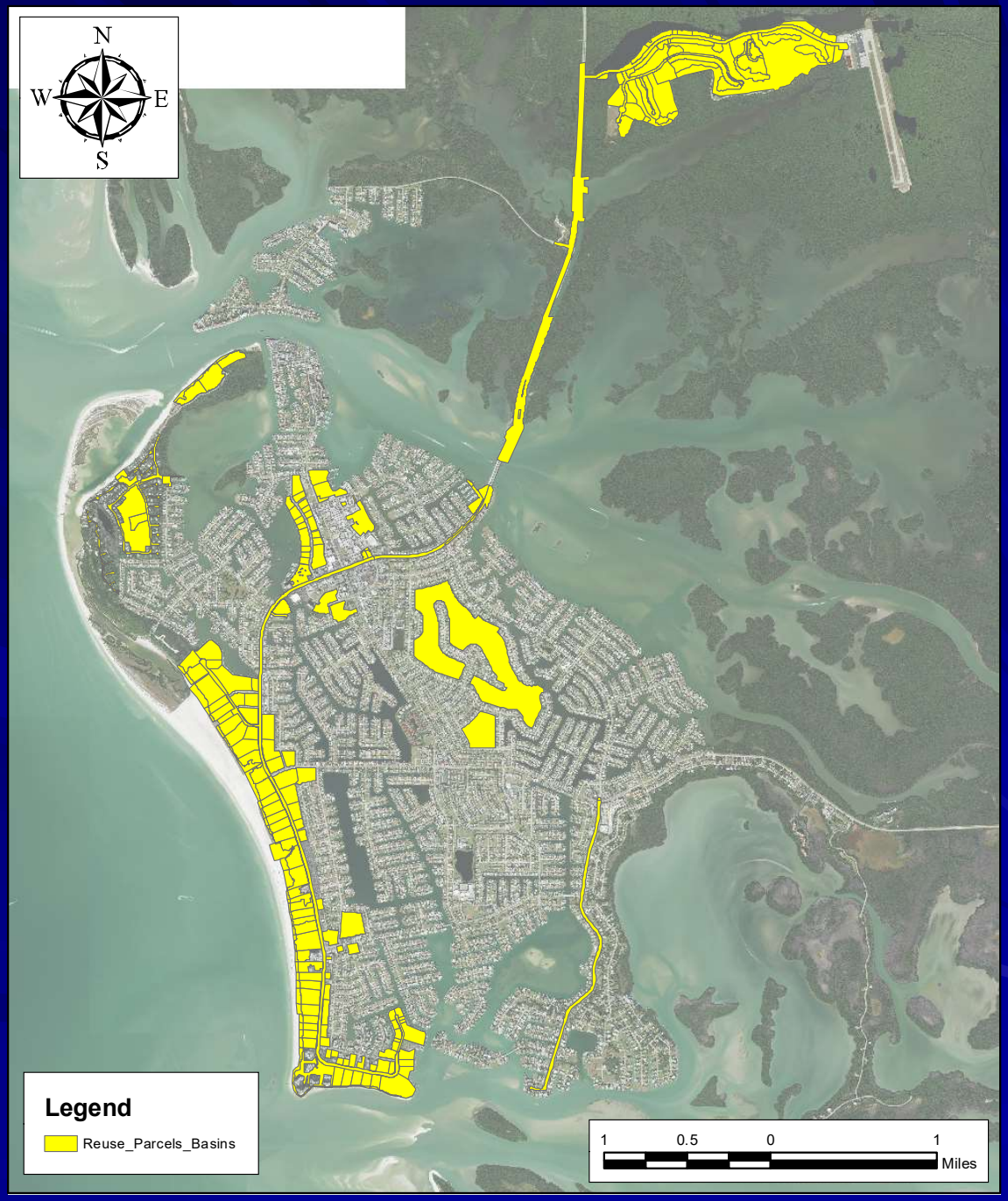
Marco Island Reclaimed Water Production Facility

Active and Potential Areas for Reuse Irrigation on Marco Island

(City Map)



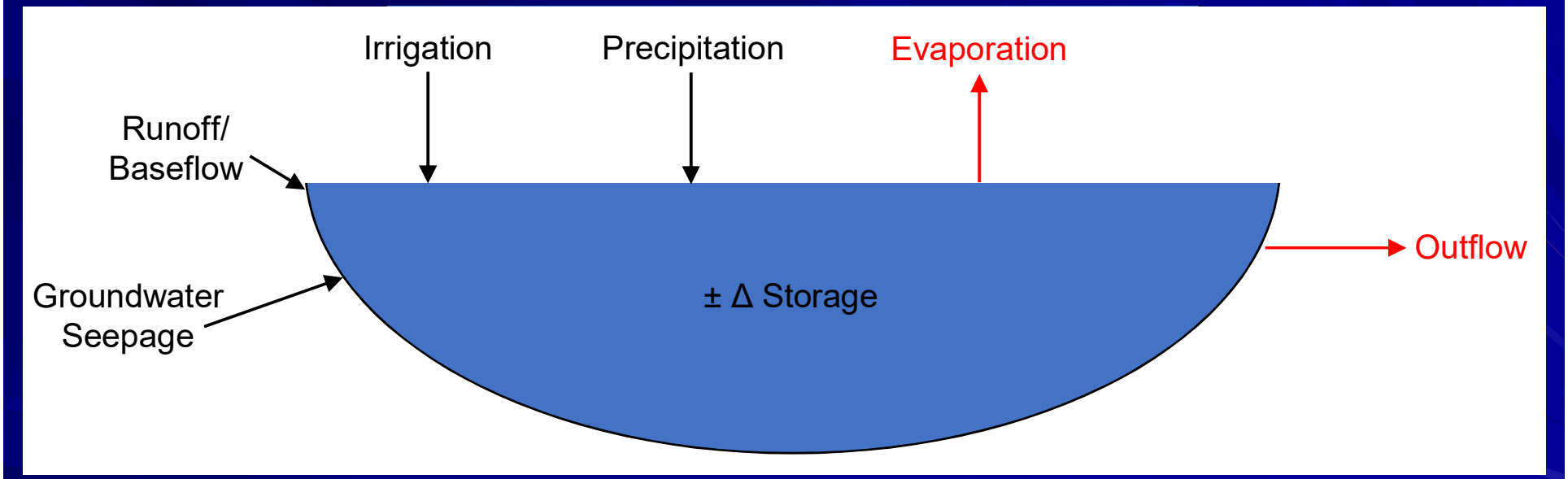
Revised Active Reuse Areas



Reuse Application Rates for Golf Course and Public Access Areas from 2015-2020

Reuse Area	Irrigated Areas (acres)	Average Application Rates	
		MGD	inch/week
Golf Courses	229.99	0.50	0.56
Other Public Access	398.96	1.34	0.88
Total:	628.95	1.84	

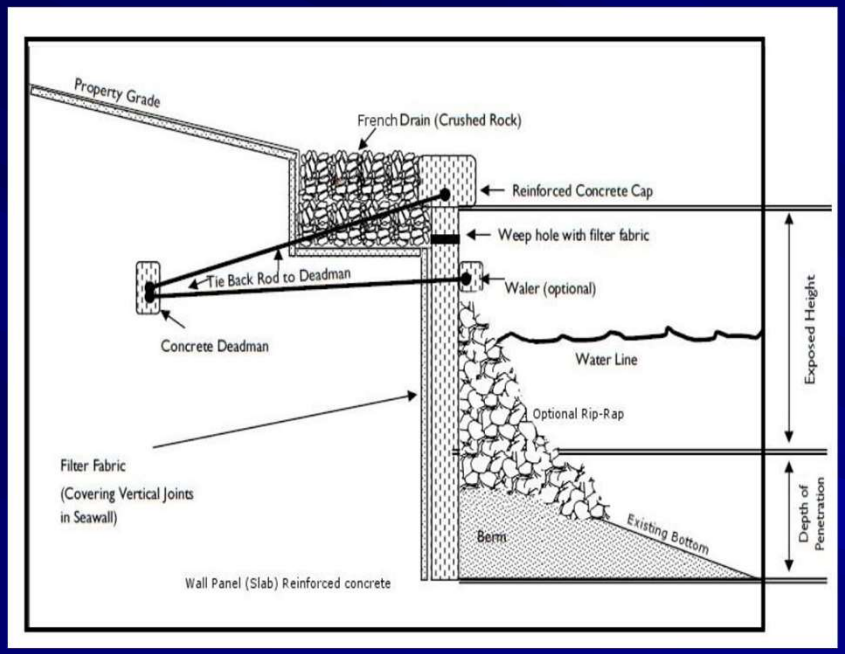
Evaluated Hydrologic Inputs and Losses to Marco Island Waterways



Estimation of Hydrologic Inputs/Losses to Waterways

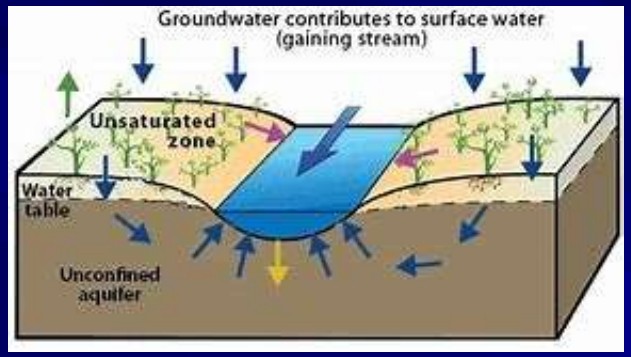
- Precipitation
  - Based on average monthly rainfall over previous 30-year period
- Runoff
  - Runoff inputs based on continuous modeling for each sub-basin area
  - Generated runoff adjusted for losses in ponds, stormwater systems, wetlands, and depressional areas
- Groundwater seepage
  - Based on direct field measurements
- Evaporation
  - Based on average monthly evaporation
- Irrigation
  - Based on City reports to FDEP

Typical Rear Yard French Drain

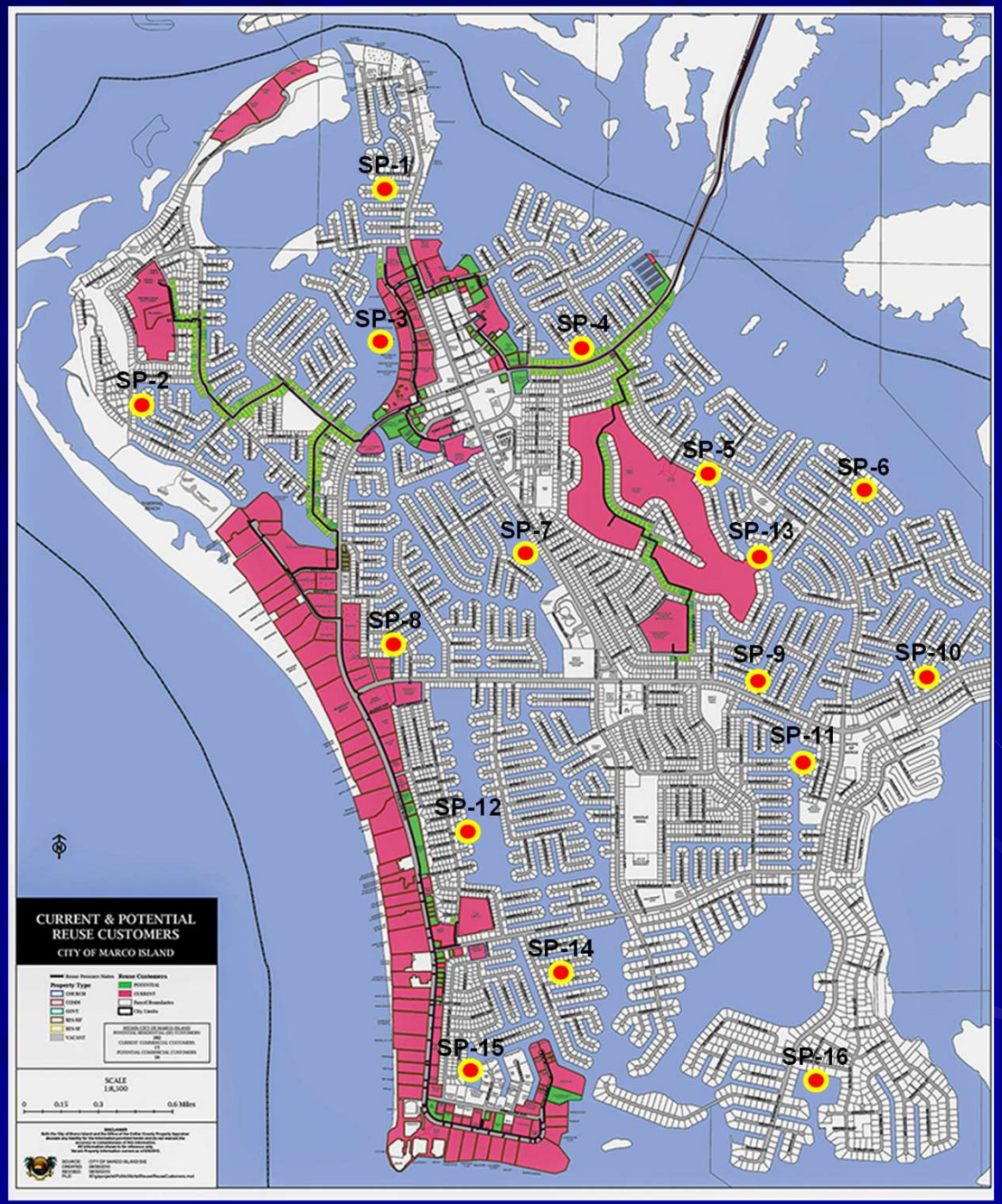


- Designed to reduce hydrostatic pressure behind the wall
- Essentially diverts all rear yard runoff into groundwater

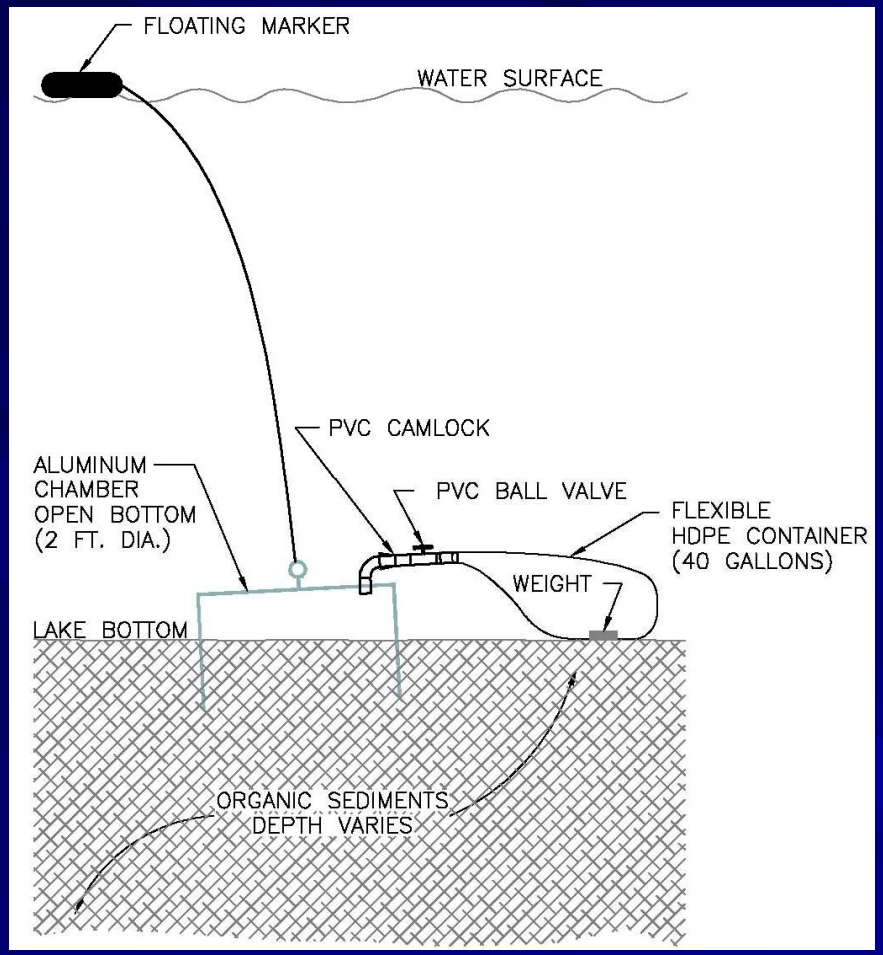
Seepage Monitoring Sites



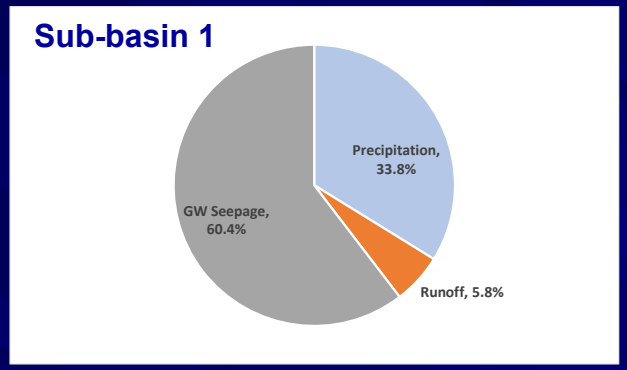
- Initially 16 sites
- Site 16 was missing and replaced 3 times so site was deleted

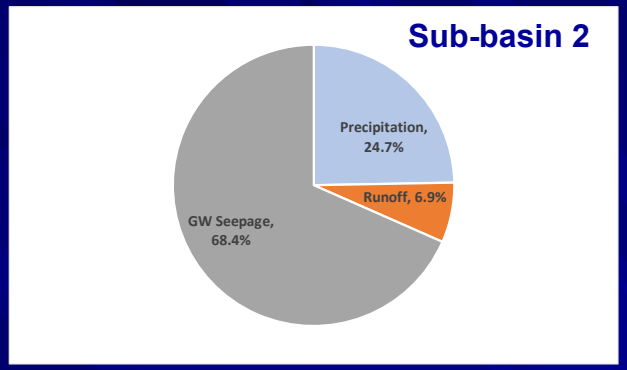


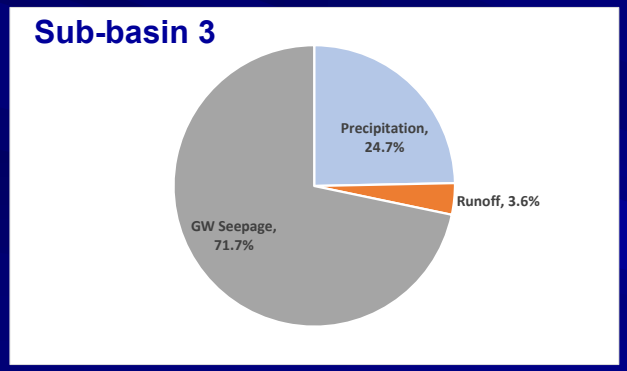
Typical Seepage Meter Installation

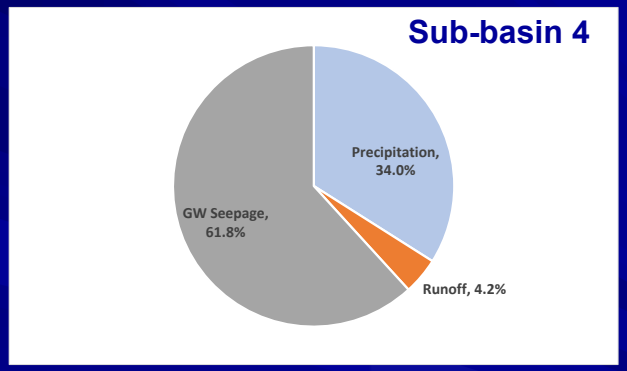


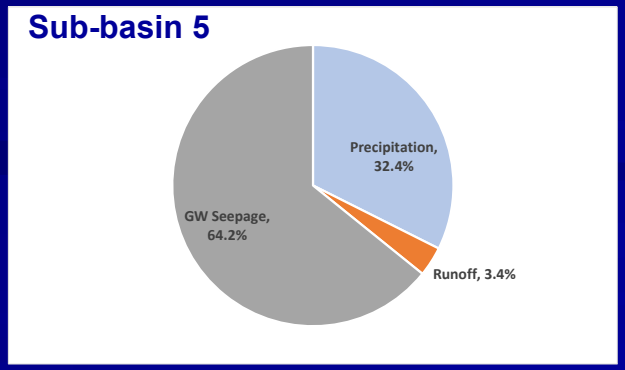
Annual Hydrologic Inputs to the Marco Island Waterways









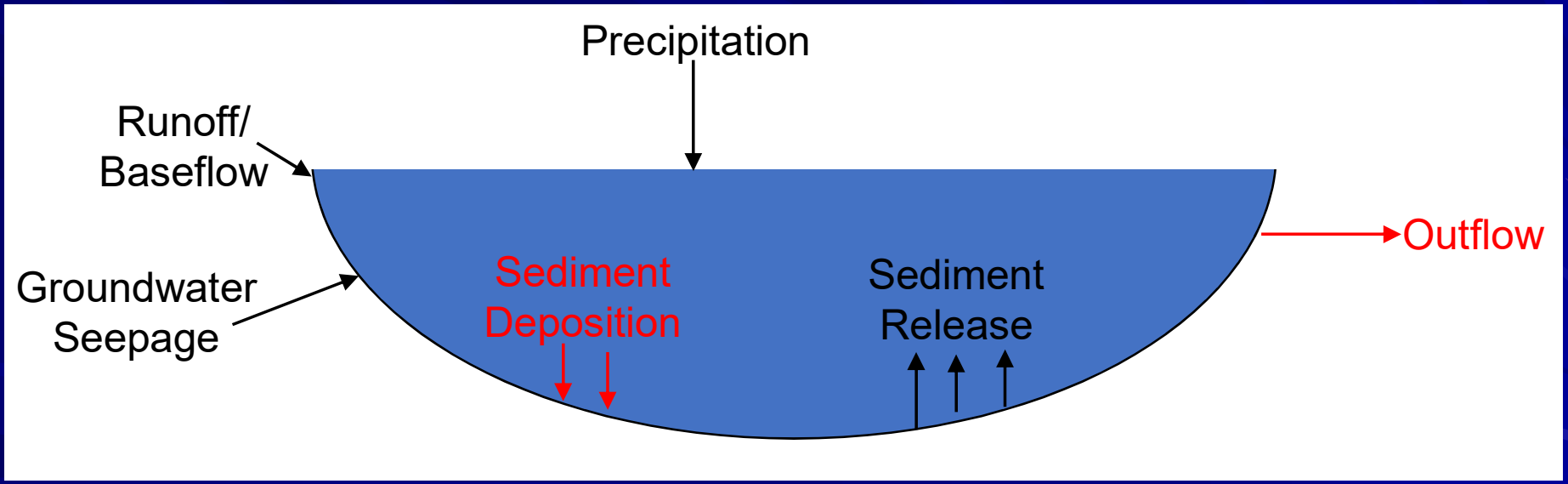


Waterway detention times:

5-11 months

Evaluated Nutrient Inputs and Losses for Marco Island Waterways

Nutrient Budget Components



Estimation of Nutrient Inputs/Losses to Waterways

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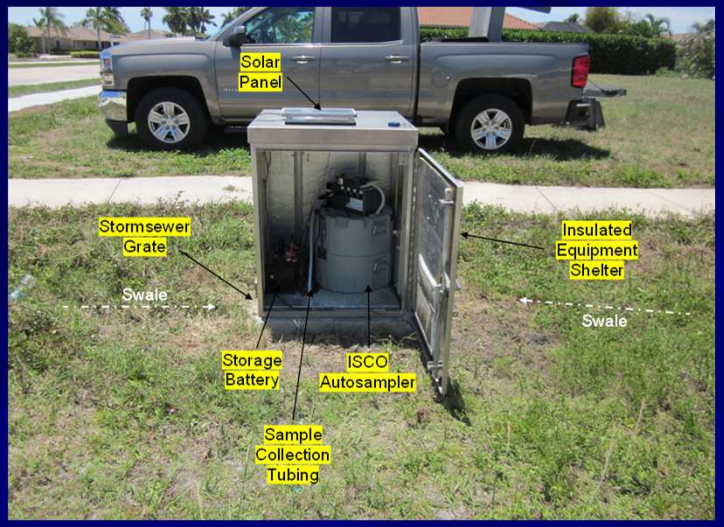
- Runoff
  - Runoff inputs based on continuous modeling for each sub-basin area
  - Generated runoff adjusted for losses in ponds, stormwater systems, wetlands, and depressional areas
- Groundwater seepage
  - Based on direct field measurements
- Evaporation
  - Based on average monthly evaporation
- Irrigation
  - Based on City reports to FDEP
- Collected 600 water samples, conducted 5,300 lab analyses, and 4,200 field measurements

Stormwater and Hydrologic Monitoring Sites

Site Descriptions

1. **MI-1 - residential with low maintenance**
2. **MI-2 – commercial corridor with reuse irrigation**
3. **MI-3 – commercial area w/ partial reuse irrigation**
4. **MI-4 – residential with high maintenance**
5. **MI-5 – Industrial area with partial reuse irrigation**
6. **H – Hydrologic monitoring site – rain gauge, bulk precipitation collector**

Rainfall, Stormwater and Reuse Monitoring Sites



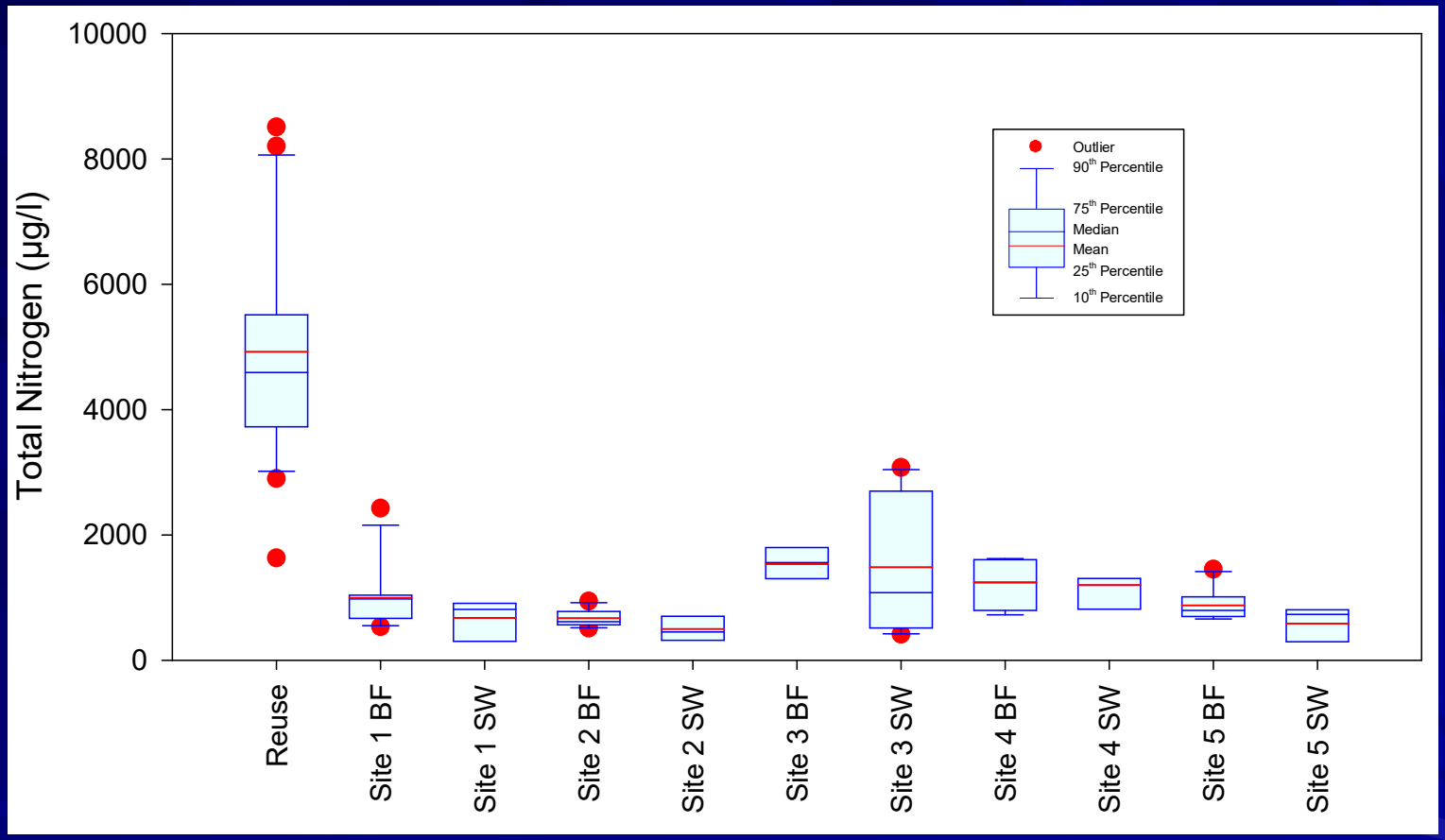
Typical Stormwater Monitoring Site

Reuse Monitoring Site

Rainfall and Evaporation Monitoring Site

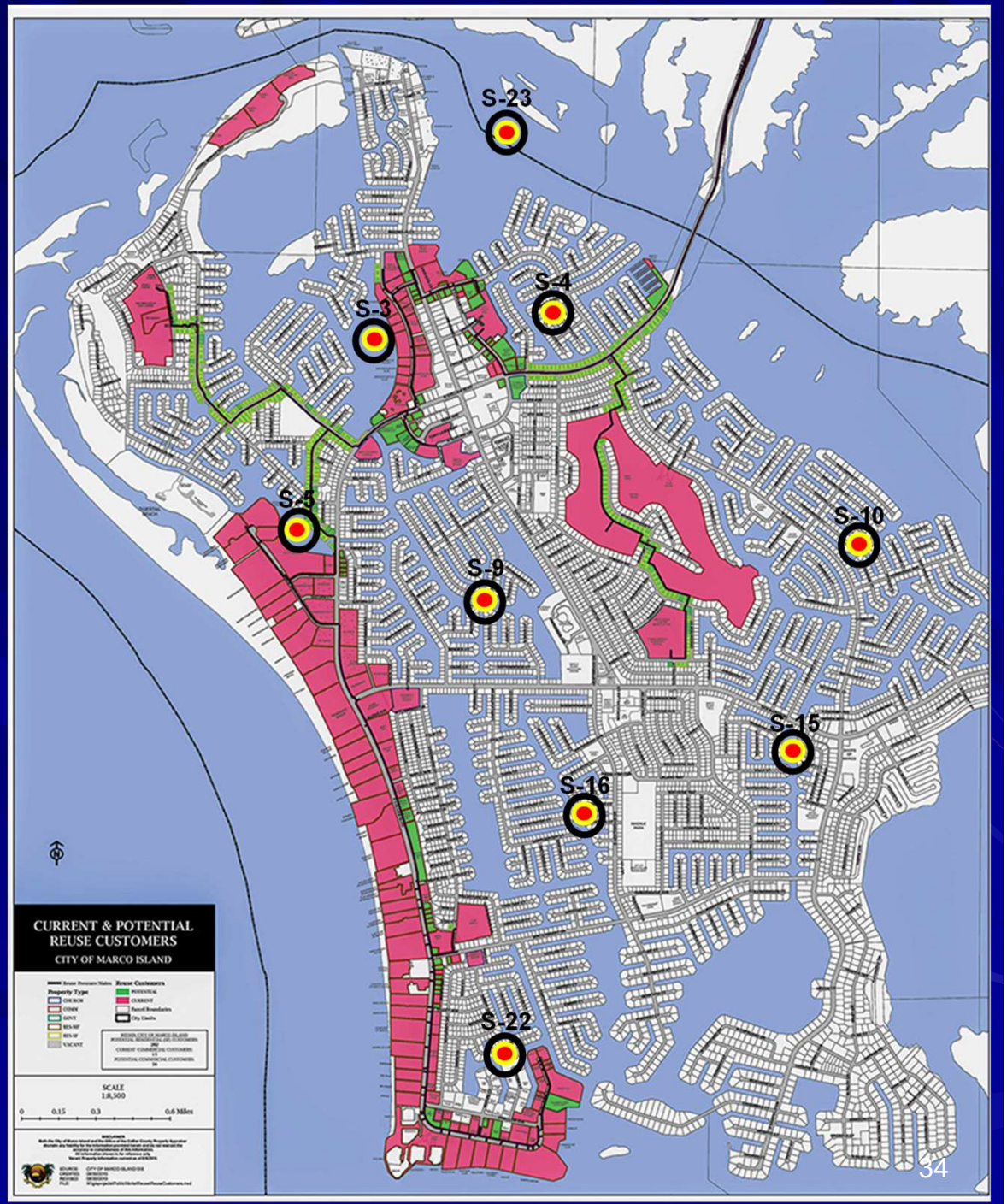
Golf Course Pond Monitoring Site

Total Nitrogen in Baseflow, Runoff, and Reuse Samples

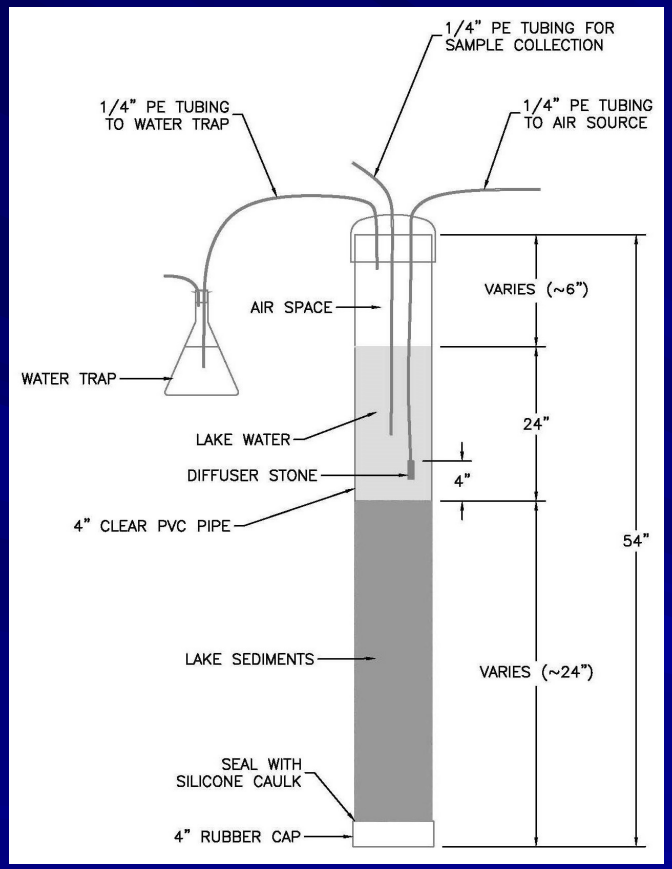


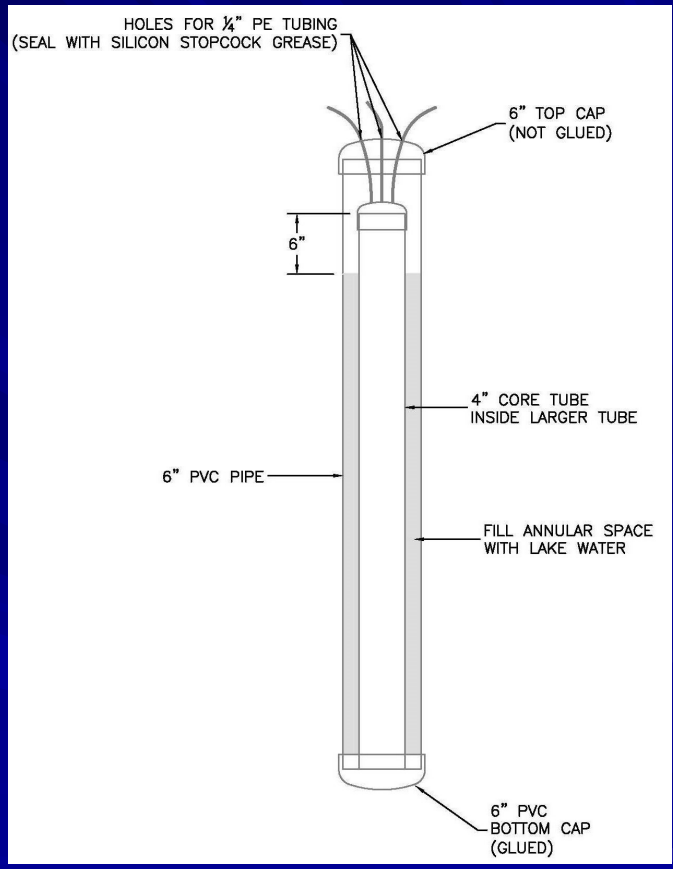
- Reuse concentrations are 5-15 times higher than runoff and baseflow

Large Core Sample Sites for Measurement of Internal Recycling in Marco Island Waterways



Schematic of Sediment Incubation Apparatus



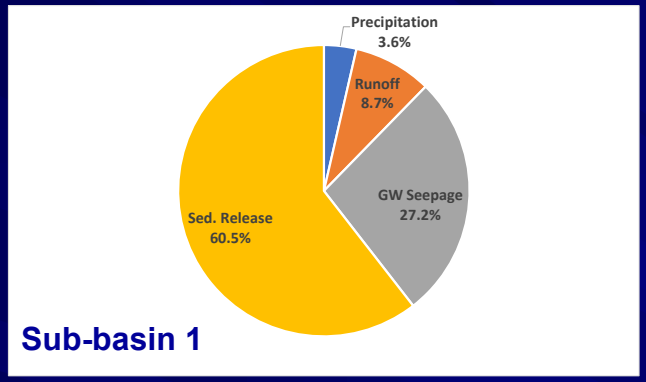


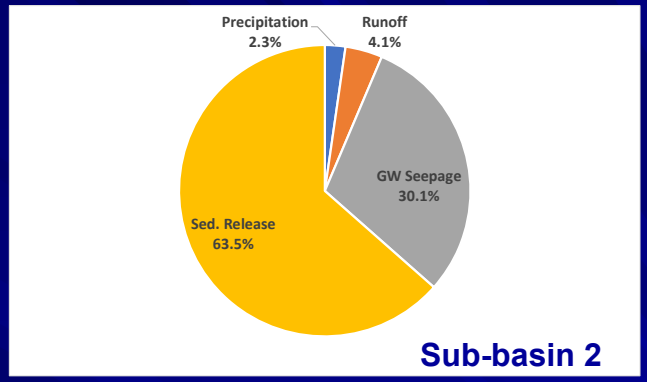
- ERD has conducted measurements of sediment benthic release rates in more than 50 Florida waterbodies

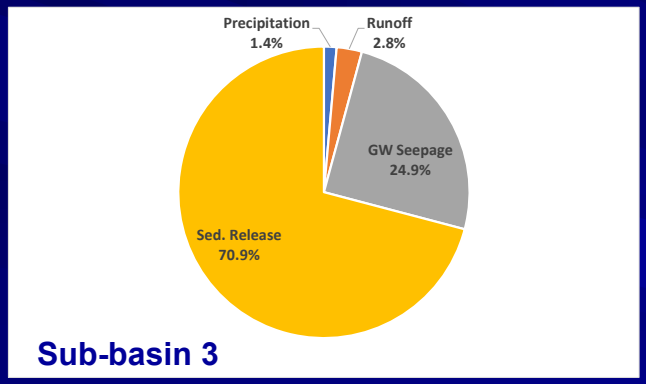
Sediment Nutrient Recycling

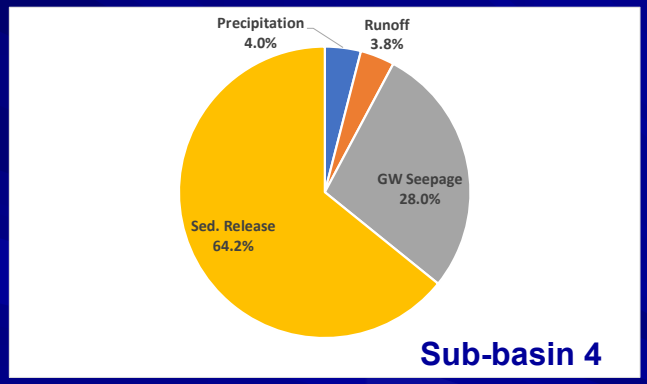
- Large diameter core samples collected at 9 sites
- Core samples incubated under aerobic and anoxic conditions
- Samples collected every 2 days and analyzed for phosphorus and nitrogen

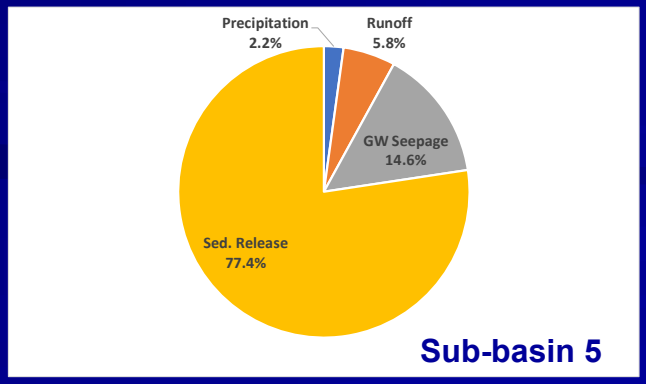
Comparison of Nitrogen Sources for the Five Marco Island Sub-basin Waterways











Isotope Analyses

Sample Type	Samples Submitted for Isotope Analyses
Bulk Precipitation	23
Runoff	97
Reuse Irrigation	27
Reuse Pond	14
Groundwater Seepage	74
Total:	235

- Groundwater
  - N in seepage contributed by both fertilizer and reuse
- Stormwater
  - Runoff impacted primarily by fertilizers
  - Baseflow impacted primarily by reuse irrigation

Comparison of Total Nitrogen Concentrations in Seepage Sources

Sub-Basin	Geometric Mean Total Nitrogen Concentrations (μg/l)			
	Precipitation	Runoff	Reuse	Seepage
1	273	606	8,630	1,160
2	273	467	8,630	1,272
3	273	1,128	8,630	1,633
4	273	1,098	8,630	1,063
5	273	521	8,630	905

Management Philosophy

- Marco Island waterways are N-limited and N loadings must be controlled to maintain or improve water quality
- Current N loadings to waterways are excessive and enhancing an existing water quality impairment
- Management of N loadings should emphasize significant inputs

Combined N Loadings to the Waterways

Source	Total N Load (kg/yr)	Percent of Total Loading (%)
Groundwater Seepage	20,507	24
Internal Recycling	57,958	68

- Smaller inputs should be managed as opportunities arise
  - Ex. Incorporate water quality into drainage improvement projects

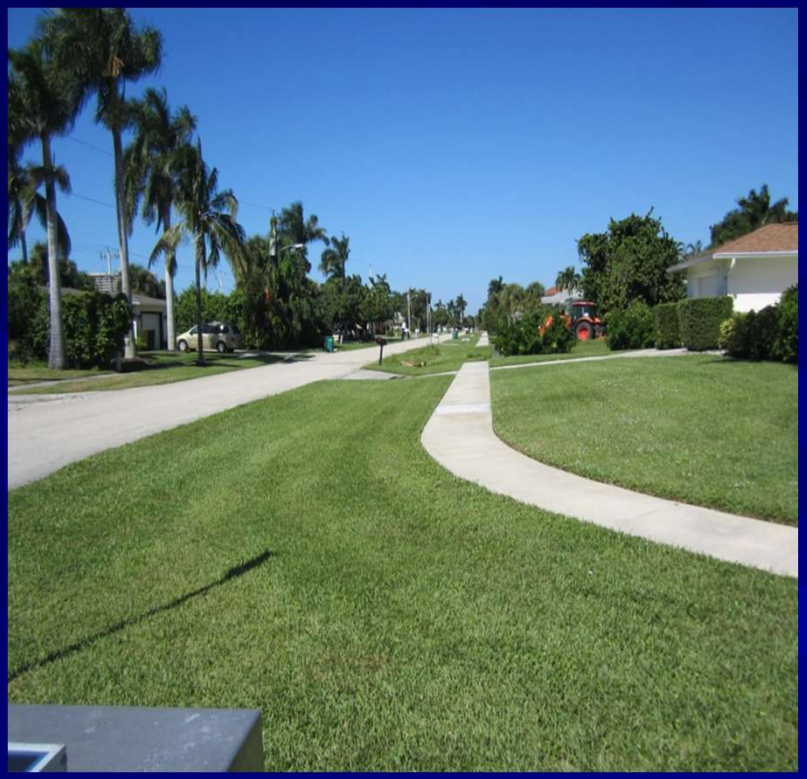
1. Sediment Nutrient Release

- Control of sediment nutrient release in marine areas is typically conducted by sediment removal or dredging
- Dredging is conducted when:
  - Negatively impact water quality
  - Impact navigation or recreational activities
- Multiple methods of sediment removal
  - Drawdown and mechanical removal
  - Mechanical dredging
  - Hydraulic dredging
    - Hydraulic dredge with rotating cutterhead sucks up sediments and generates a water-sediment slurry
    - Slurry is pumped to a dewatering area
    - Expensive - $2500 – 5000/kg TP

1. Sediment Nutrient Release – cont.
Hydraulic Dredging Costs

Parameter	Units	Value
Sediment Volume	yd^3	3,690,500
Assumed Dredging Cost	$/$yd^3$	40
Dredging Cost	$	147,620,000
Assumed Land Costs (824 acres)	$	41,200,000
Engineering/Design	$	1,000,000
Total Cost:	$	189,820,000

2. Stormwater
Marco Island Grassed Swale Systems

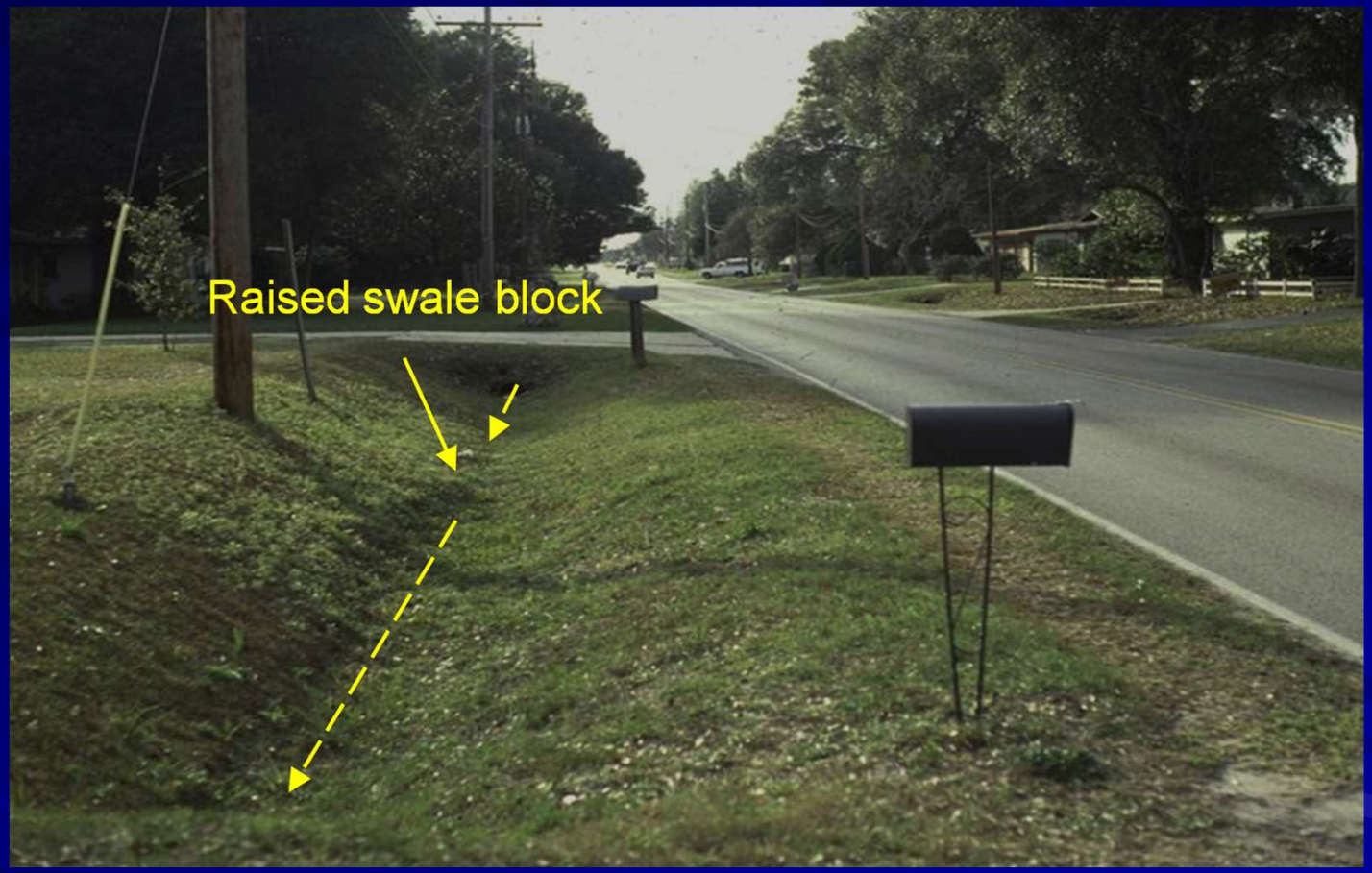


Swale system between storm events

Swale system during storm events

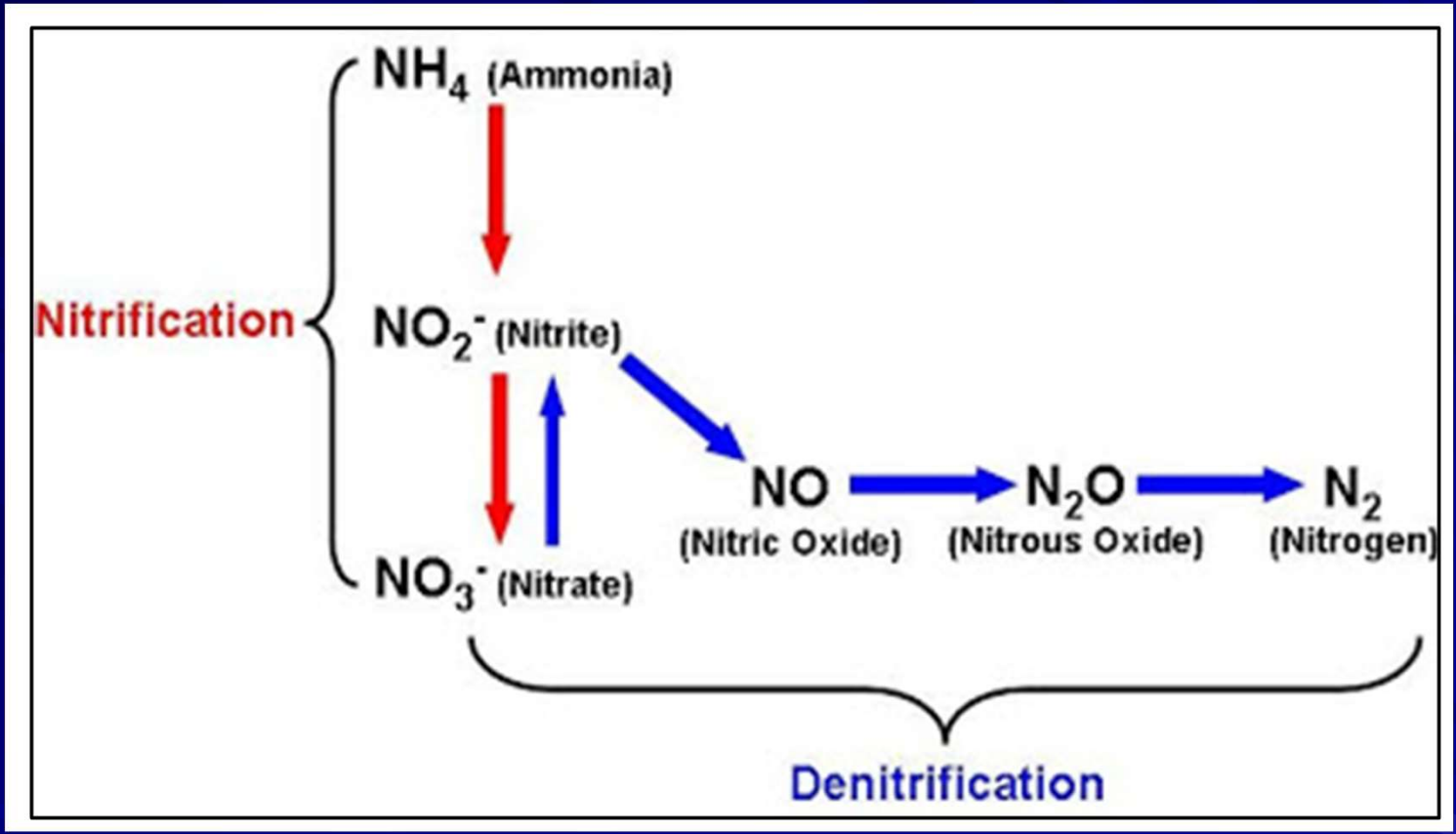
- More than 90% of the generated annual runoff infiltrates into landscaped areas and in the swale system and becomes groundwater seepage
- Direct runoff to waterways is not a significant problem

2. Stormwater – cont.
Typical Swale Block



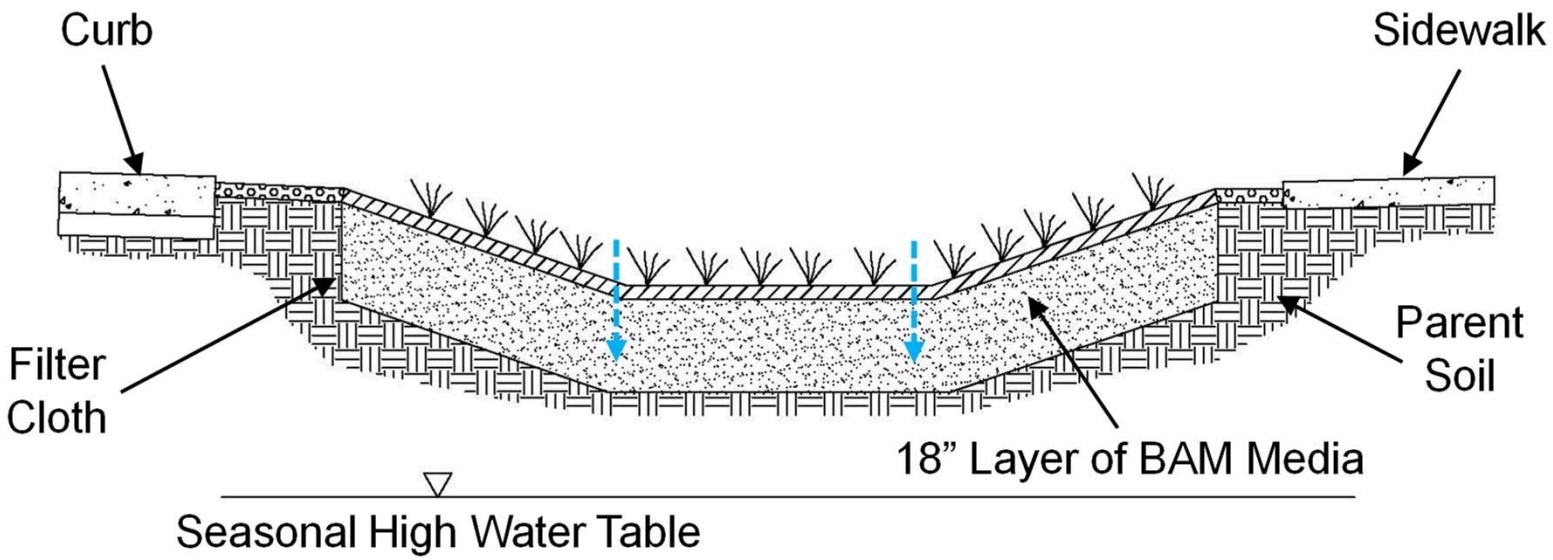
- Increases the volume of runoff which infiltrates into groundwater
- Soil infiltration and uptake reduces concentrations

2. Stormwater – cont.
Denitrification Process



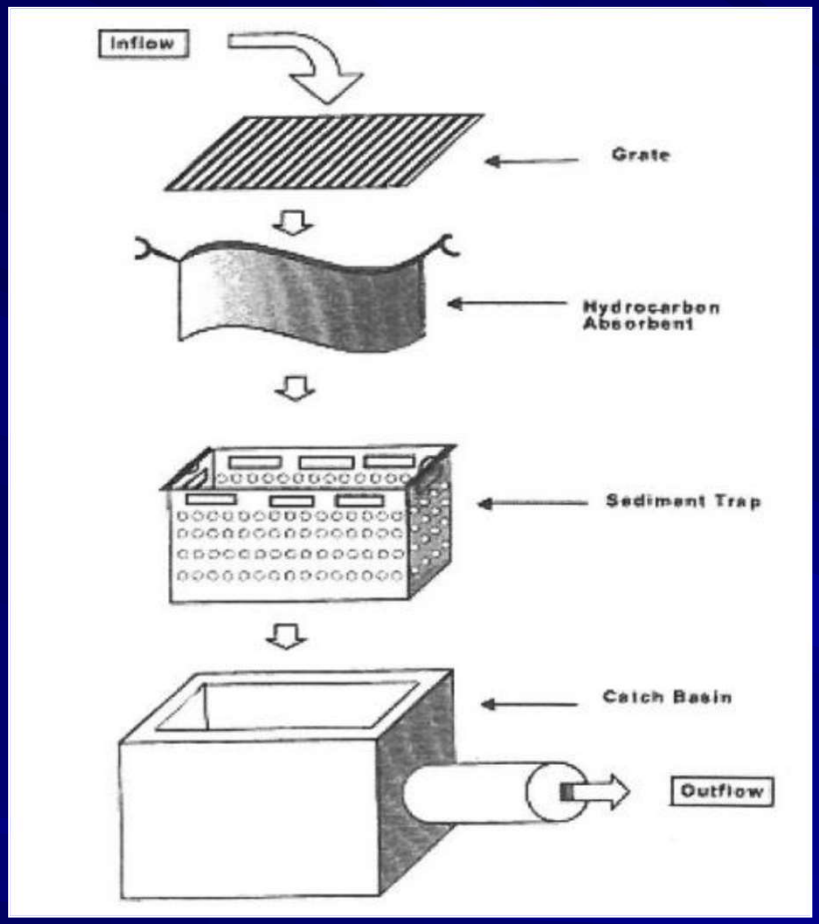
- Specialized media have been developed to encourage these conditions
- BAM – Biologically Activated Media

2. Stormwater – cont.
Denitrification Bed Incorporated into Swales



- Incorporate during maintenance or regrading activities

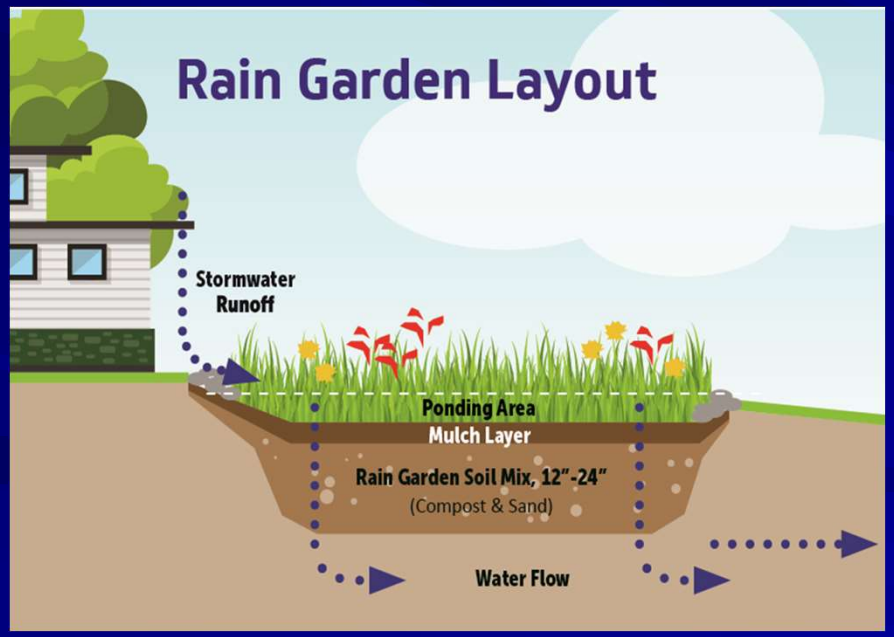
2. Stormwater – cont.
Inlet Filter System Installed at Marco Island



- Collects both solids and litter
- Recommend that practice continue

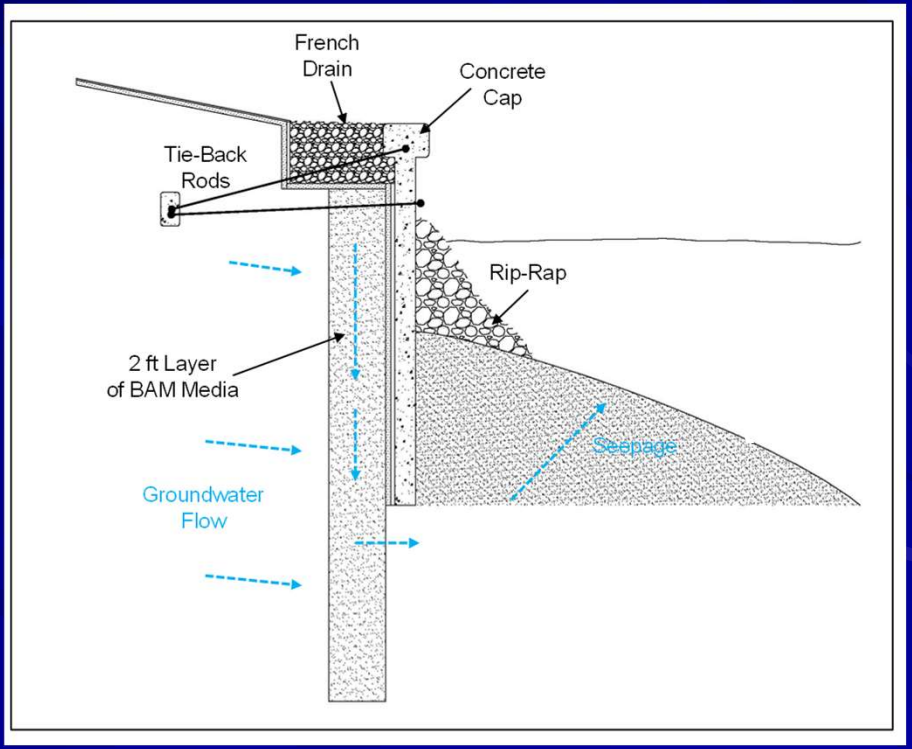
2. Stormwater – cont.
Stormwater Regulations

- City defers to the South Florida Water Management District (SFWMD) for stormwater design and treatment criteria
- SFWMD only requires treatment for commercial development and exempts residential
- Recommend that City implement treatment criteria for single family
- Treatment can easily be incorporated into landscaping



3. Seepage

- Seepage is the second most significant source of N to waterways
- Two methods of reducing loadings
- Reduce N sources to groundwater
- Reduce N seepage concentrations
  - Groundwater passes beneath seawalls and through the bottom of the waterways
  - A denitrification wall can be added next to the seawalls to remove N in seepage flows
  - For a 100 ft seawall, the media volume would be 90 yd^3
  - At a media cost \$300/yd^3 media cost would be \$27,000/lot
  - Recommend that media installed with new seawalls and renovations



4. Reuse Irrigation

- Reuse irrigation contains elevated concentrations of both N and P
- Contributes 12% (1.44 MGD or 526 million gallons) of the annual seepage volume and much higher portion of mass loading
- Irrigation is intended to supplement plant requirements not provided by rainfall
  - Vary throughout the year
- Reuse is applied at a relatively constant rate
  - Average annual reuse application is 1.84 MGD
  - Average of 1.44 MGD (78%) enters groundwater with little change in concentration
- Recommendations
  - City investigate alternate disposal methods for reuse in excess of requirements
    - Limit supply during rainy periods
    - Deep aquifer injection well already exists
  - Educational program should be conducted to inform users about water quality impacts from excess irrigation
    - Areas receiving reuse should reduce fertilizer applications

Percentage of Annual St. Augustine Grass Fertilization Requirements Supplied by Marco Island Reuse Irrigation

Nutrient	Annual Nutrient Requirement (%) Supplied From Reuse Irrigation By Application Rate (inches/week)			
	0.5	0.75	1	1.25
Nitrogen	24	35	47	59
Phosphorus	280	420	569	713

4. Reuse Irrigation – cont.
Reuse Overspray

Median irrigation with reuse water

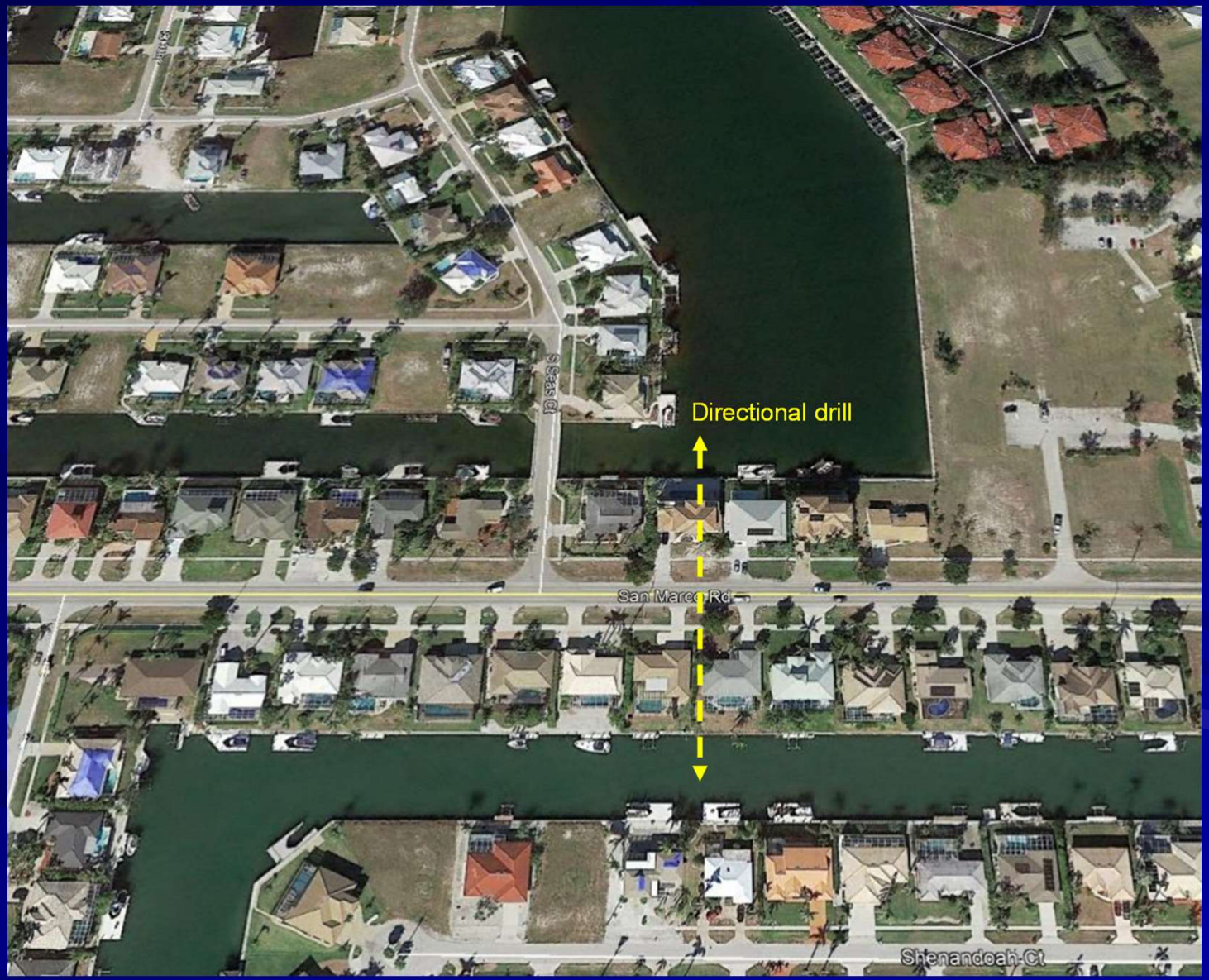
Overspray of reuse irrigation along Collier Blvd.

- Overspray of 7.5% generates a N load equivalent to the annual runoff loading
- Recommend routine inspection and repair of system to keep spray off impervious surfaces

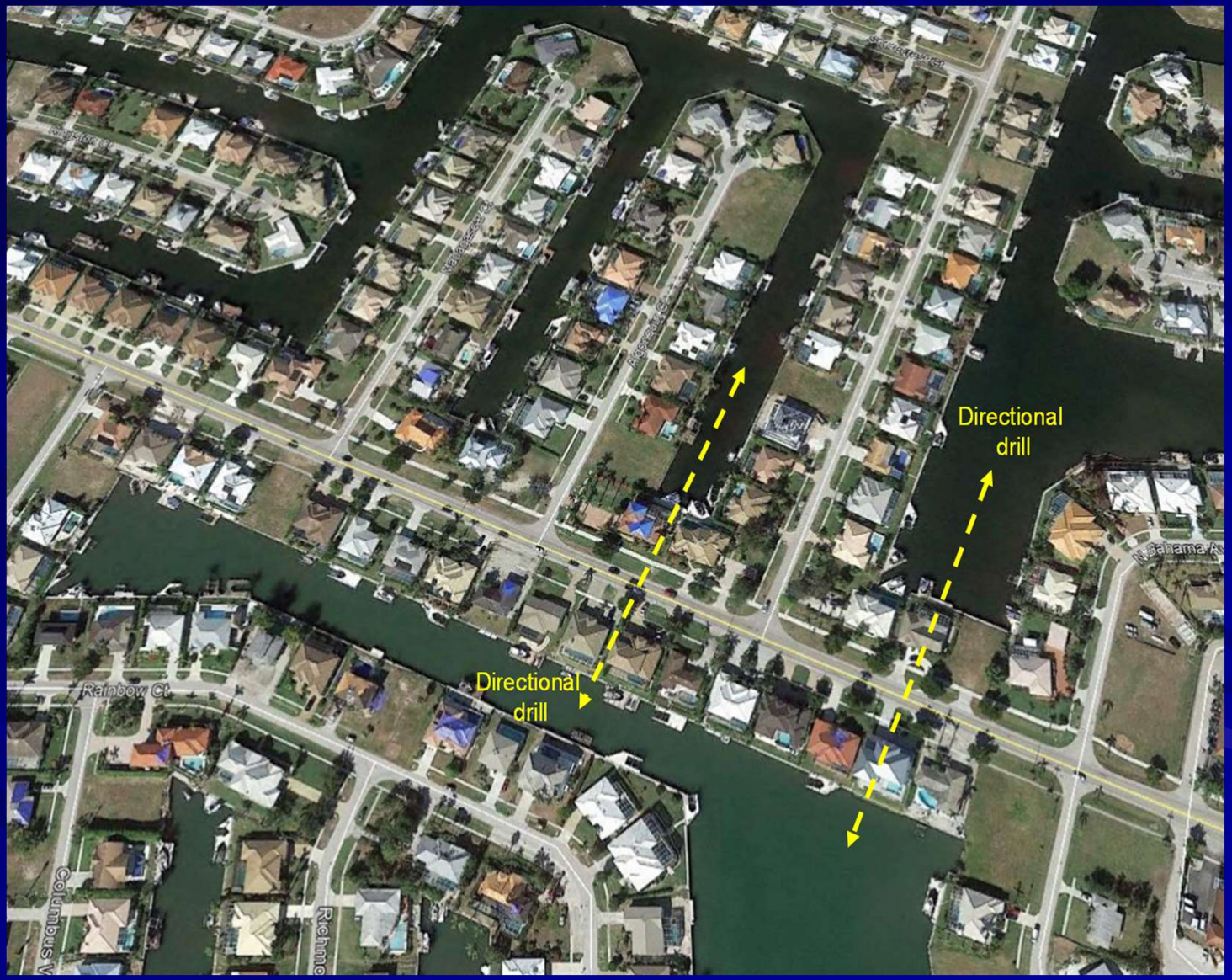
5. Improved Recirculation
Proposed Locations for Hydraulic Connections

- Upstream portions of waterways have little or no circulation and degraded water quality
- Existing culverts exist (~24-inch), but locations and conditions are not known
- Recommend locating and cleaning existing culverts
- A hydraulic study is recommended to evaluate best culvert locations and water exchange

5. Improved Recirculation
Proposed Location for Site 3 Interconnection



5. Improved Recirculation
Proposed Location for Sites 4 and 5 Interconnection



5. Improved Recirculation – cont.
Estimated Cost

Pipe Size (inches)	Installation Cost ($/inch diameter/ft)	Pipe Length (ft)	Estimated Cost ($)
24	45	350	378,000
36	45	350	567,000
48	45	350	756,000
54	45	350	850,500
60	45	350	945,000

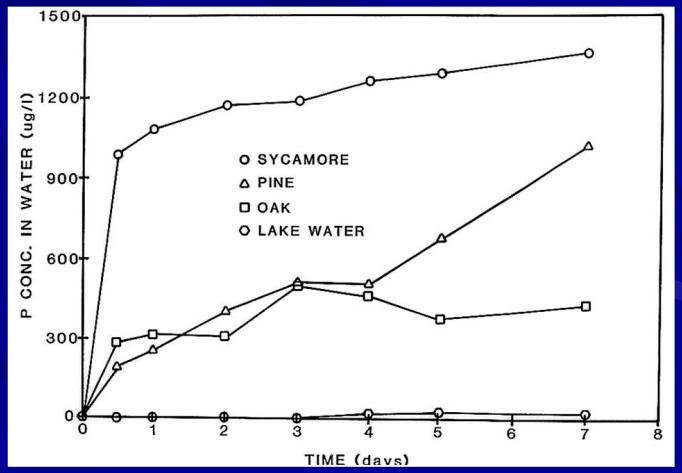
Proposed Site 1 Location

6. Fertilizer and Landscape Activities

- Improper landscape maintenance activities have a potential for significant impacts to adjacent waterbodies:
  - Blowing grass clippings, leaves and other vegetation onto roadways
  - Improper application of fertilizers/pesticides

- Instances of improper landscaping activities were observed by ERD during this project

- Discharge of grass clippings and other landscaping wastes onto roadway surfaces or into stormsewers is a senseless and irresponsible practice



After entering water, leaves exhibit a rapid nutrient release

Marco Island Fertilizer Ordinance

- In March 2016 Marco Island has adopted a Fertilizer Ordinance that restricts the amount and timing of fertilizer applications
  - Prohibits application of P unless a soil test identifies a deficiency
  - Summer season ban (June-Sept), except for commercial applicators
- Prohibitions on discharge of grass clippings, vegetation debris, and fertilizers onto impervious surfaces
- Fertilizer free zones
  - Fertilizer shall not be applied within 10 ft of waters or storm drains
  - Fertilizer shields required when next to impervious surfaces
- Education and outreach
  - The City will provide educational materials and 2 educational sessions per year
  - Retailers must post notice of Ordinance in conspicuous place
- Enforcement provisions
  - First violation = NTE $150, then increasing to NTE $300
- Does not require consideration of nutrients in reclaimed water
  - Recommend modifying Ordinance

7. Source Control

- Source reduction programs have the potential to provide effective reductions in runoff concentrations
- The two most common source reduction methods are
  - Street sweeping
  - Public education

7. Source Control – cont.
a. Street Sweeping

- Most applicable for paved streets having curbs and gutters, but can be used on any impervious surface
- Particularly applicable to urban built-out areas where space for conventional stormwater treatment is unavailable or too expensive
- Best types of street sweepers:
  - Vacuum (plus mechanical)
    - Provides air vacuum over entire path with mechanical broom assist
    - Some particles do not receive sufficient agitation to become air-entrained
  - Regenerative Air
    - Air is forced down onto the pavement, suspending particles, which are then picked up by the vacuum

7. Source Control – cont.

Estimated TSS Reduction from Street Sweeping (%)

(Residential Area)

Sweeper Type	Frequency of Sweeping			
	Monthly	Twice Monthly	Weekly	Twice Weekly
New Type Vacuum	51	63	79	87
Air Regenerative	43	53	65	71
Mechanical Brush Type	17	23	29	33

- More frequent street sweeping during periods of leaf fall
- City has budgeted for a street sweeper in 2021-22 budget
- ERD recommends that street sweeping be enhanced in Marco Island watersheds

7. Source Control – cont.
b. Public Education

- Many homeowners are unaware of the relationship between their day-to-day activities and water pollution
- Educational programs can be effective in reducing Pointless Personal Pollution
    1. Relationship between land use, runoff, and pollutants
    2. Typical stormwater treatment systems
    3. How to reduce stormwater runoff volume
    4. Impacts of waterfowl and pets on runoff and surface water quality
    5. Stormwater program goals and regulations
    6. Responsible use of fertilizer, pesticides, and herbicides
    7. Elimination of illicit connections to stormwater system
    8. Controlling erosion and turbidity
    9. Proper operation and maintenance of stormwater systems
- Educational materials can be distributed in utility bills or mass mailouts
- Conduct educational seminars around the community

8. Stormwater Utility

- Currently, Marco Island does not have a Stormwater Utility to fund water quality projects
- A Stormwater Utility collects fees for planning, construction, operation and maintenance of stormwater management systems
- Funding requirements are going to increase in the future, and a dedicated source should be implemented
- Recommend that City implement a Stormwater Utility

9. Regulatory Issues

- Marco Island waterways have been designated as “Impaired” which requires that a TMDL be developed
  - Current priority is listed as “moderate”
  - 5-10 years away
  - With this process FDEP directs restoration
  - FDEP process primarily involves stormwater treatment
- The City should file for a 4e designation
  - Requires City to develop a nutrient loading evaluation with water quality improvements
  - City directs program
  - Must show measured water quality improvements through routine monitoring

10. Water Quality Monitoring

- The City should continue the current monthly monitoring program to provide documentation on water quality improvements
- Improvements are recommended to enhance the existing program
  - Include vertical profiles
  - Improvements to testing methods and QC
- Contract with a qualified water quality consultant to conduct annual reviews of data and trends and provide guidance on implementation of water quality improvement projects

Good News!

- Groundwater seepage contributes about 15 - 30% of the nitrogen loadings to waterways
- Study indicated that fertilizer and reuse irrigation are primary sources of elevated nitrogen
- Fertilizer impacts can be reduced by
  - Educational programs
  - Requirement to consider reuse irrigation in annual N application
    - Result in 33-50% reduction
- Reuse irrigation impacts can be reduced by
  - Educational programs
  - Applying reuse at rates necessary to match evapotranspiration
  - Use alternative disposal options for remainder
    - Deep aquifer well already exists
    - Develop other off-island customers
- A significant impact to existing loadings can be achieved at low cost

Recommended Management Options

Issue	Recommendation	Cost ($)
Internal Sediment Nutrient Recycling	Sediment removal is prohibitively expensive; most feasible option is to reduce the rate of nutrient release by improving water quality by managing other sources to maintain aerobic conditions in waterways	189,820,000
Stormwater Management	a. Install shallow swale blocks in swales to increase retention of runoff	$300/swale block
	b. Install denitrification beds beneath existing swales during maintenance or regrading projects.	8,400/100 ft for media
	c. Continue current inlet filter system to assist in removing solids and debris from waterways	Included in current program
	d. Consider stormwater management requirements for single-family homes such as rain gardens	Low
Seepage Management	Install denitrification beds adjacent to seawalls during repair or replacement; add to new seawalls during construction	27,000 per 100 ft of seawall
Reuse Irrigation	a. Evaluate alternative methods for reuse disposal which do not increase loadings to groundwater or surface water	Unknown
	b. Conduct routine inspection and repair of the reuse irrigation system to prevent areas of overspray	
	c. Provide an educational program to inform residents about nutrients contained in reuse irrigation and potential water quality impacts	

Recommended Management Options (Continued)

Issue	Recommendation	Cost ($)
Golf Course	a. Evaluate potential reduction in irrigation rates	Unknown/ Low
	b. Reduce fertilizer applications to account for nutrients in irrigation	
Recirculation	a. Locate and clean existing interconnecting culverts, if present	Unknown/ High
	b. Conduct a hydraulic study to identify optimum areas for interconnecting culverts to increase recirculation	
	c. Install additional culverts, as necessary	
Street Sweeping	City to purchase regenerative air sweeper in 2022; increase sweeping to all City streets.	Low
Fertilizer Ordinance	a. Assist retailers with educational signage regarding summer season ban	Low
	b. Increase enforcement and revoke license from repeat offenders	
	c. Modify ordinance to require consideration of nutrients in reuse	
Public Education	a. Conduct public education program to inform residents of link between personal activities and water pollution	Low
	b. Conduct a dedicated educational program regarding responsible fertilizer use.	

Recommended Management Options
(Continued)

Issue	Recommendation	Cost ($)
Stormwater Utility	Adopt a Stormwater Utility to provide a dedicated funding source for water quality improvement projects	Unknown/ Low
Regulatory Issues	The City should submit documentation for a 4e designation which would allow the City to control the process rather than FDEP	Low
Water Quality Monitoring	a. The City should continue the current monthly monitoring program to provide documentation on water quality improvements; improvements are recommended to enhance the existing program	Low
	b. Contract with a qualified water quality consultant to conduct annual reviews of data and trends and provide guidance on implementation of water quality improvement projects	

Acknowledgements

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Water and Sewer

Questions?