# A decision-support tool to assist implementation of fecal coliform basin management action plans (BMAPs)

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# Acknowledgments

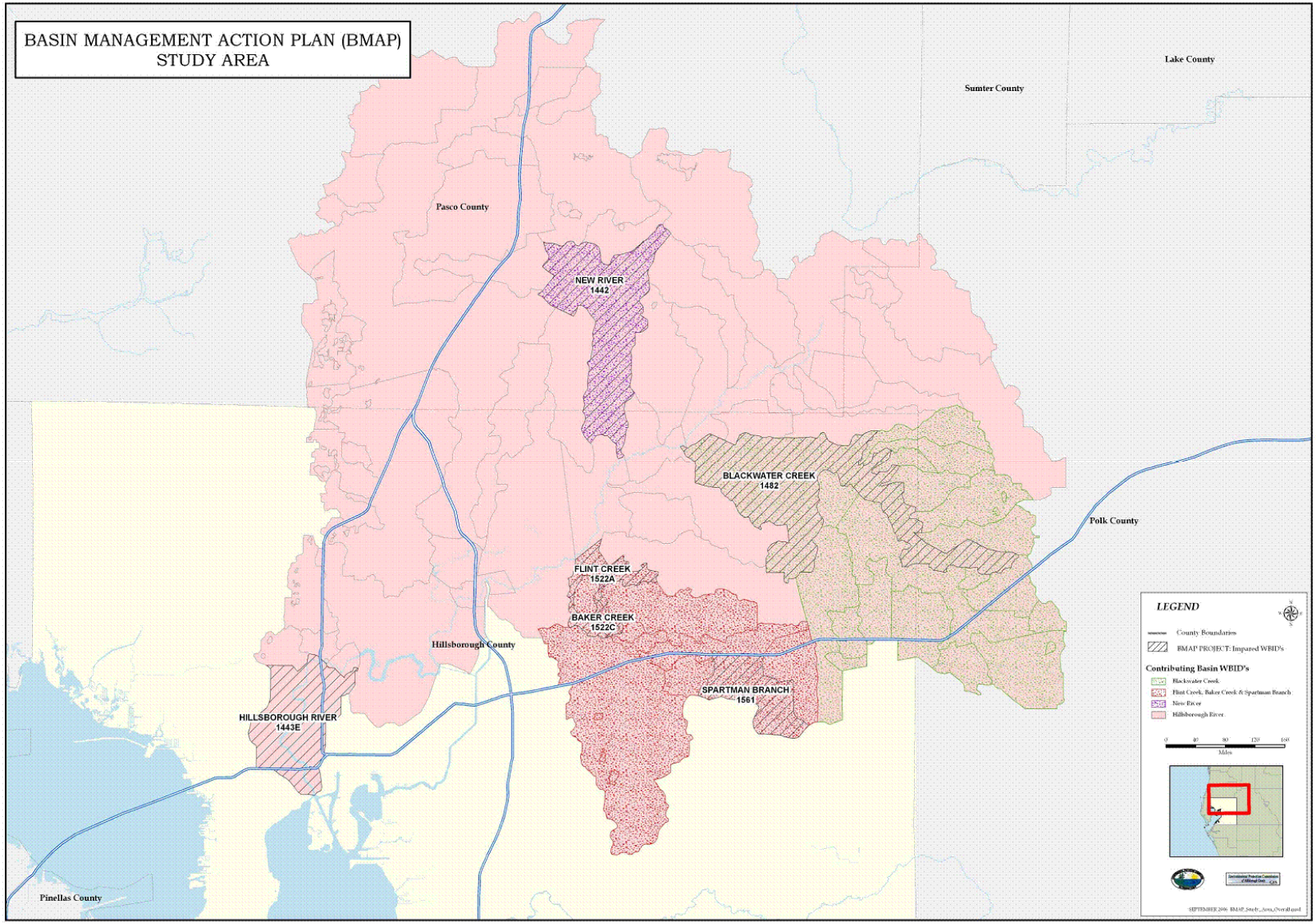

- Project funding provided by FDEP, through its TMDL and Watershed Management programs
- Ambient monitoring data provided by the Environmental Protection Commission of Hillsborough County (EPC)
- MST data provided by the University of South Florida

# What's a BMAP ?
# (and more fun with acronyms...)

- BMAP – basin management action plan; used by Florida DEP to achieve the water quality requirements of a TMDL
- TMDL – total maximum daily load (of a pollutant); the maximum load a WBID can receive while continuing to meet water quality criteria
- WBID – water body ID; identifies the impaired water body (or other hydrologic unit) for which a TMDL and BMAP are developed

# Project Location

## (In the Hillsborough River portion of the Tampa Bay watershed)



# Why is a decision-support tool needed to help with fecal coliform BMAPs ?

- The State of Florida currently has water quality criteria for fecal coliforms (e.g., no more than 10% of samples should exceed 400 CFU/100 mL), and is developing TMDLs and BMAPs for WBIDs that aren't meeting those criteria
- Coliform bacteria have been used as indicators of potential fecal contamination of water since the late 1800s. (Originally for detecting contamination of water by untreated or minimally-treated sewage.)
- In tropical and sub-tropical areas, fecal coliforms and other bacterial indicators can grow in soils and on vegetation, producing "false-positive" monitoring results
- They can also produce "false-negative" results – e.g., pathogenic viruses and protozoa (*Giardia* or *Cryptosporidium*) can survive longer than fecal coliforms in surface waters

# How does this tool help ?

- Provides a framework for interpreting and responding to concentrations of fecal coliforms and other indicators observed in ambient monitoring programs
- Helps managers prioritize WBIDs and areas within WBIDs for investigation and follow-up action
- Based on approaches currently used by the World Health Organization (WHO 2003) and recommended by the National Research Council (NRC 2004)
- Also based on an existing local approach, used in Tampa Bay to provide annual tracking of water quality conditions and achievement of water quality goals

# Issues with existing bacterial indicators

- Recent studies have confirmed relationships between enterococci concentrations and human health risk in marine waters (WHO 2003, NRC 2004)
- In fresh waters, correlations between indicator (e.g., fecal coliforms, enterococci, *E. coli*) concentrations and health risk are present but highly variable
- In tropical and sub-tropical regions, the indicators have a number of potential environmental sources
- A recent Tampa Bay study (Rose et al. 2001) recommended continued use of fecal coliforms and enterococci as indicators in this region, with caution

# Recommendations from national / international groups ?

- WHO (2000, 2003) recommends use of “Annapolis protocol”, which combines bacterial indicator counts with on-site assessment of potential pathogen sources
- NRC (2004) recommends Annapolis protocol and a “phased monitoring approach” to help identify and address pathogen sources

# “Annapolis protocol” (WHO 2003) conceptual overview

Bacterial Indicator Concentrations
(based on monitoring data)

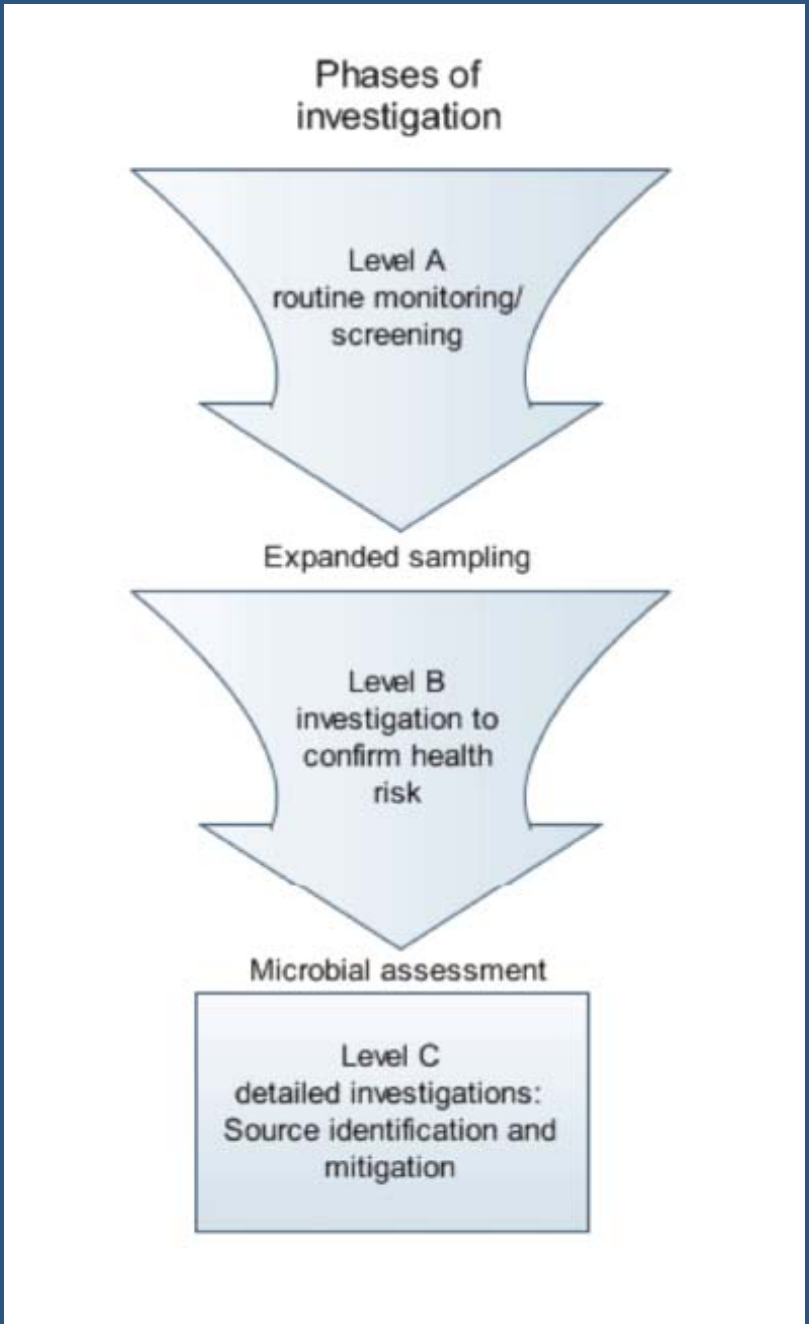
Lower ⟷ Higher

Estimated Health Risk Posed by Sources
(based on contaminant source survey)

Lower ↕ Higher

| | | | |
|---|---|---|---|
| **Good** | Investigate further | Investigate further | Investigate further |
| Investigate further | **Fair** | Investigate further | Investigate further |
| Investigate further | Investigate further | **Poor** | Investigate further |
| Investigate further | Investigate further | Investigate further | **Very Poor** |

Phased monitoring approach, recommended by NRC (2004)



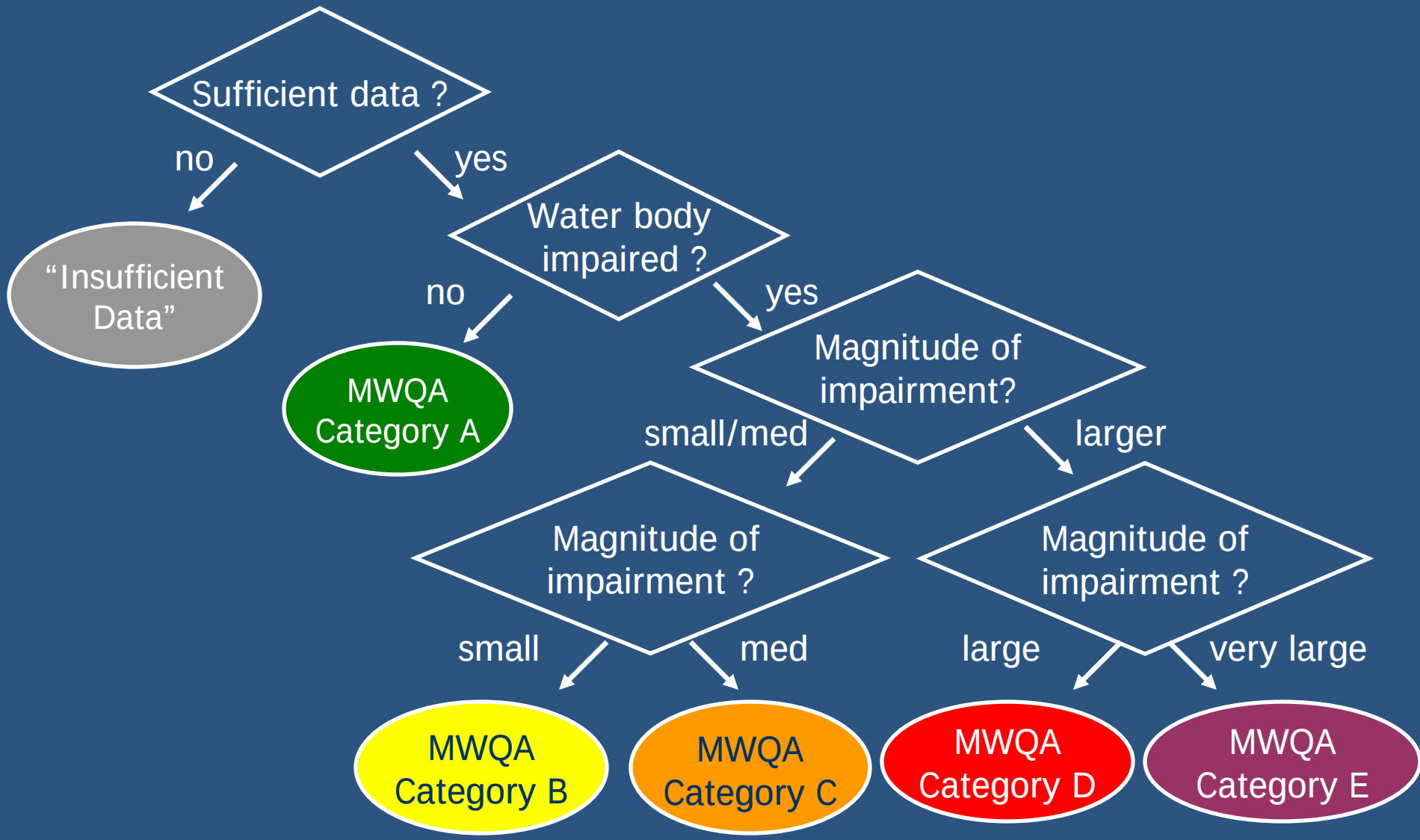
# How to incorporate these ideas into fecal coliform TMDLs and BMAPs ?

- Use monitoring data (e.g., fecal coliform concentrations) as a screening tool, to identify and prioritize sites for management attention
- Use information from “contaminant source surveys” (CSS) to supplement the bacterial data
- Use “Annapolis protocol” approach to combine the information and guide management responses

# Step 1

- Characterize microbial water quality conditions within each WBID, based on fecal coliform concentrations observed in the available monitoring data

# Decision Tree to Define Microbial Water Quality Assessment (MWQA) Categories Using Fecal Coliform Data)



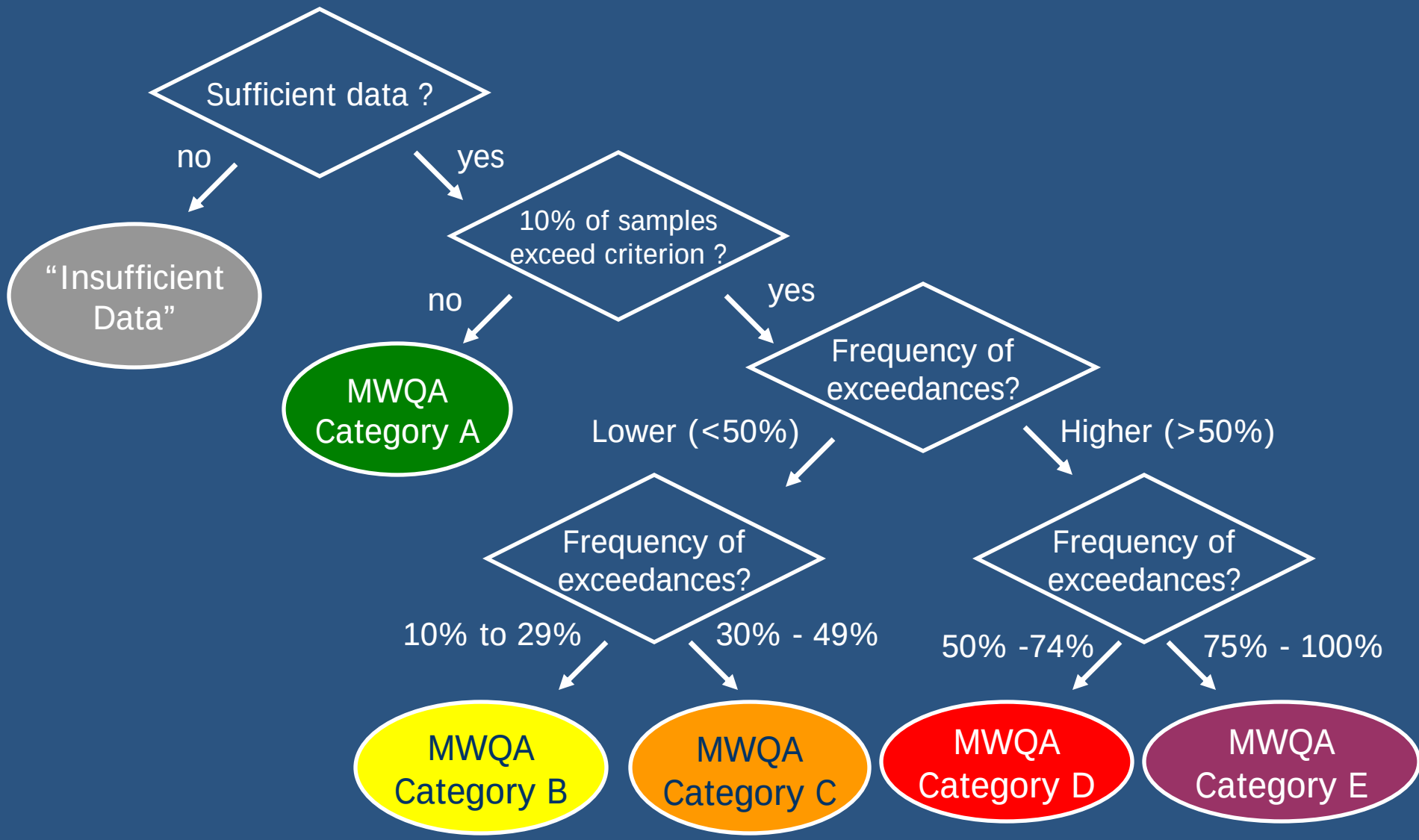
# How to Make the Decision Tree Quantitative ?

- Incorporate potential human health risk
- Incorporate information on frequency of exceedances of State water quality criterion (400 CFU/100 mL)
- Incorporate binomial test used by Florida DEP to determine statistical significance of criterion exceedances

**Table 6. Proposed microbial water quality assessment (MWQA) categories, based on the percentage of samples exceeding the State's 400 CFU/100 mL fecal coliform criterion. "Break points" separating the MWQA categories are at exceedance frequencies of 10%, 30%, 50% and 75%.**

| MWQA Category | Break Point (percentage of samples exceeding the 400 CFU/100 mL fecal coliform criterion) | Range of exceedance frequencies (percentage of samples exceeding the 400 CFU/100 mL fecal coliform criterion) included in category |
|---|---|---|
| A | ≤ 10% | 0% to 10% |
| B | > 10% | >10% to 30% |
| C | > 30% | >30% to 50% |
| D | > 50% | >50% to 75% |
| E | > 75% | >75% to 100% |

# Decision Tree to Define Microbial Water Quality Assessment (MWQA) Categories Based on Exceedances of 400 CFU/100 mL Fecal Coliform Criterion



# Step 2

- Add information from contaminant source surveys (CSS) and, when available, MST
- Classify sites based on the likelihood of fecal contamination that would pose human health risks, using CSS assessment categories and MST data

# CSS assessment categories (likelihood of fecal contamination posing human health risks)

- **Very Low**: No visual evidence of potential sources of human pathogens; natural environment; no or minimal anthropogenic land uses; wildlife present (any density)
- **Low:** Low density agricultural and residential sources, including pets, livestock (without direct access to surface waters), or poultry operations; residences on septic systems
- **Moderate**: Urban stormwater sources (including pet waste) present; well-functioning wastewater infrastructure (both sewer and septic); episodic/low volume sanitary sewer overflows (SSOs) reaching surface waters; moderate-density livestock with little direct access to surface waters; Class A residual and/or septage spreading areas may be present
- **High**: Major stormwater outfalls present; history of failing wastewater infrastructure (central sewer or onsite systems); episodic or chronic/high volume SSOs reaching surface waters; concentrated livestock without direct access to surface waters; residual/septage spreading (Class B)
- **Very High**: Current failing wastewater infrastructure; chronic/high volume SSOs reaching surface waters; concentrated livestock with direct access to surface waters; evidence of direct sewage inputs (e.g., confirmed illicit discharges)

# Classification matrix ("Annapolis protocol") approach

| | | MWQA group (based on binomial assessment of frequency of 400 CFU/100 mL fecal coliform exceedances) | | | | | Exceptional Circumstances (e.g., sewer line break)[c] |
|---|---|---|---|---|---|---|---|
| | | A (≤ 10%) | B (>10% - 30%) | C (>30% - 50%) | D (>50% - 75%) | E (>75%) | |
| Contaminant source survey (CSS) assessment category (likelihood of fecal contamination posing human health risks) | 1. Very Low | A1 | B1 | C1[a] | D1[a] | E1[a] | Immediate Action |
| | 2. Low | A2[b] | B2 | C2 | D2[a] | E2[a] | |
| | 3. Moderate | A3[b] | B3 | C3 | D3 | E3 | |
| | 4. High | A4[b] | B4[b] | C4 | D4 | E4 | |
| | 5. Very High | A5[b] | B5[b] | C5[b] | D5 | E5 | |
| | Exceptional Circumstances (e.g., sewer line break)[c] | Immediate Action | | | | | |

**Notes:**

a) These outcomes imply that the CSS may be providing an overly optimistic rating of water quality, or the fecal coliform sources in the area may be relatively low-risk or primarily environmental (e.g., wildlife, sediments, soils, vegetation), and the cause(s) of the discrepancy should be verified.

b) These outcomes imply that the fecal coliform indicator may be providing an overly optimistic MWQA rating, or the CSS may be providing an overly negative assessment, and the cause(s) of the discrepancy should be verified.

c) As explained by WHO (2003), exceptional circumstances involve acute situations known to be associated with higher public health risks, such as sewer line breaks and other SSOs that contaminate surface waters, which require immediate remedial action.

# Phased CSS Investigation Levels

**Phase 1 CSS** – basic (screening-level) analyses applied automatically to MWQA Group B

- Analysis of available water quality data and land use information to identify potential sources;
- followed by boots-on-the-ground survey to verify and characterize existing sources

# Phase 2 CSS
## (applied automatically to MWQA Group C, and to Group A or B if needed or desired)

All elements of Phase 1, plus:

- Analysis of regulatory data (e.g., DMRs, compliance/ enforcement data, SSOs, septic system repairs);
- More detailed evaluation of land use intensity and condition of wastewater treatment systems
- If necessary, expanded spatial and temporal monitoring of indicator bacteria (and/or other water quality constituents) to identify gradients in contamination and trace those gradients to individual sources (e.g., McDonald et al. 2006)

# Phase 3 CSS

## (applied automatically to MWQA Groups D and E, and to Groups A, B or C if needed or desired)

- Includes all elements of Phases 1 and 2, plus appropriate microbial source tracking (MST) tools, as necessary, to identify and characterize sources.
- A number of MST tools of varying cost and complexity, and their applications in identifying sources of fecal contamination, have been summarized by NRC (2004), EPA (2005).
- A review of the need for validation of MST methods and strategies to accomplish this goal is presented in Stoeckel and Harwood (2007).

# Reporting outcomes to the public and elected officials (using the color-coded classification matrix)

Allows water quality conditions to be tracked over time and across monitoring locations

| | Monitoring Location | | | |
|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 |
| 2004 | D4 | A1 | B1 | C3 |
| 2005 | C4 | B1 | B1 | C3 |
| 2006 | D4 | B1 | C1 | B3 |
| 2007 | C3 | A1 | B1 | B2 |
| 2008 | C3 | A1 | A1 | B2 |

# Using the classification matrix to prioritize WBIDs (and sites within WBIDS) for management action

| | | | | Human Fecal MST Markers | | Ruminant Fecal MST Marker | |
|---|---|---|---|---|---|---|---|
| Sub-Basin | WBID | Monitoring Location | Classi-fication Matrix Outcome | No. Sampling Dates | % Dates Marker(s) Detected | No. Sampling Dates | % Dates Marker Detected |
| Lower Hillsborough River | 1443E | DHR4A | D5 | 5 | 100 % | 5 | 20 % |
| | | HR3 | D4 | 5 | 80 % | 5 | 20 % |
| | | DHR5 | D4 | 2 | 50 % | 2 | 0 % |
| | | DHR8 | D3 | 4 | 50 % | 4 | 0 % |
| | | HR2 | C4 | 3 | 67 % | 3 | 0 % |
| | | HR4 | C4 | 3 | 67 % | 3 | 0 % |
| | | DHR7 | C3 | 5 | 60 % | 5 | 60 % |
| | | DHR6 | C3 | 3 | 33 % | 3 | 0 % |
| | | HR1 REF | B3 | 3 | 100 % | 8 | 0 % |
| | | HR5 | B3 | 5 | 60 % | 5 | 0 % |
| | | DHR10 | A4 | 1 | 100 % | 1 | 0 % |
| | | | | | | | |
| Blackwater Creek | 1482 | BW3 | D4 | 4 | 75 % | 1 | 0 % |
| | | BW2 | D4 | 3 | 67 % | 3 | 100 % |
| | | DBW4 | A3 | 1 | 100 % | 1 | 0 % |
| | | BW5A | A3 | 2 | 50 % | 2 | 0 % |
| | | BW1 REF | A2 | 7 | 43 % | 6 | 17 % |
| | | | | | | | |
| Baker Creek | 1552C | BK2 | D3 | 6 | 67 % | 6 | 67 % |
| | | BK1 | C3 | 7 | 57 % | 7 | 29 % |
| | | BK3 | C2 | 2 | 50 % | 2 | 0 % |
| | | BK4 | A4 | 1 | 100 % | 1 | 0 % |
| | | BK5 | A3 | 2 | 100 % | 2 | 0 % |
| | | | | | | | |
| Flint Creek | 1552A | FL2 | C2 | 6 | 50 % | 6 | 0 % |
| | | FL1 | C2 | 5 | 20 % | 5 | 0 % |
| | | FL3 | A3 | 6 | 33 % | 6 | 0 % |
| | | | | | | | |
| New River | 1442 | NR2 | C3 | 7 | 29 % | 7 | 29 % |
| | | NR1 | C2 | 2 | 0 % | 2 | 50 % |
| | | NR3 | C2 | 2 | 0 % | 2 | 50 % |
| | | | | | | | |
| Spartman Branch | 1561 | SB2 | D3 | 5 | 20 % | 6 | 0 % |
| | | SB1 | D3 | 6 | 17 % | 6 | 0 % |
| | | DSB3 | C2 | 2 | 0 % | 2 | 50 % |
| | | SB3 | B2 | 4 | 25 % | 4 | 0 % |

# Using the matrix approach for county-wide site prioritization

(MWQA scores based on fecal coliform data from EPC of Hillsborough County monitoring stations; 2001-2007 data)

| Location | Sta. No. | No. Samples ($N$) | No. >400 CFU/ 100 mL ($x$) | % >400 CFU/ 100 mL ($\hat{P}$) | MWQA category | Geometric mean fecal coli. (CFU/ 100 mL) | Geometric mean enterococci (CFU/ 100 mL) |
|---|---|---|---|---|---|---|---|
| L. Thonotosassa at Flint Creek | 118 | 82 | 2 | 2% | A | 46.8 | 68.5 |
| L. Thonotosassa middle | 135 | 82 | 2 | 2% | A | 32.9 | 41.7 |
| Hillsborough River at Fowler Ave | 106 | 84 | 4 | 5% | A | 46.6 | 96.4 |
| Little Manatee River at US 41 | 112 | 84 | 4 | 5% | A | 34.6 | 55.1 |
| TBC at MLK Blvd | 147 | 84 | 5 | 6% | A | 31.9 | 31.0 |
| Palm River at US 41 | 109 | 84 | 6 | 7% | A | 39.1 | 36.4 |
| Palm River at SR 60 | 110 | 84 | 6 | 7% | A | 25.4 | 21.8 |
| TBC at Fowler Ave | 146 | 82 | 6 | 7% | A | 40.5 | 51.0 |
| Alafia River South Prong ab confluence | 116 | 84 | 8 | 10% | A | 80.6 | 207.3 |
| Alafia River North Prong ab confluence | 115 | 84 | 9 | 11% | A | 100.4 | 267.3 |
| Hillsborough River at US 301 | 108 | 83 | 9 | 11% | A | 101.7 | 159.4 |
| Channel A at Hillsborough Ave | 102 | 84 | 12 | 14% | A | 63.2 | 63.1 |
| Alafia River at US 301 | 153 | 83 | 12 | 14% | A | 152.7 | 209.7 |
| Alafia River South Prong at Bethlehem Rd | 139 | 83 | 13 | 16% | B | 138.8 | 215.7 |
| Alafia River at Bell Shoals Rd | 114 | 84 | 15 | 18% | B | 136.4 | 240.7 |
| Trout Creek at CR 581 | 145 | 65 | 12 | 18% | B | 152.9 | 281.8 |
| Cypress Creek at CR 581 | 120 | 72 | 14 | 19% | B | 132.9 | 261.9 |
| Little Manatee River at US 301 | 113 | 84 | 17 | 20% | B | 250.8 | 664.0 |
| Sweetwater Creek at Anderson Rd | 142 | 84 | 17 | 20% | B | 152.2 | 764.8 |
| Blackwater Creek at SR 39 | 143 | 82 | 17 | 21% | B | 156.9 | 284.2 |
| Little Manatee River at CR 674 | 129 | 84 | 20 | 24% | B | 218.5 | 704.0 |
| Flint Creek at US 301 | 148 | 84 | 21 | 25% | B | 191.2 | 359.8 |
| Turkey Creek at Durant Rd | 151 | 82 | 21 | 26% | B | 142.0 | 322.6 |
| Rocky Creek at Hillsborough Ave | 103 | 84 | 22 | 26% | B | 242.6 | 285.2 |
| Hillsborough River at Rowlett Pk | 105 | 84 | 22 | 26% | B | 208.7 | 127.7 |
| Rocky Creek at Waters Ave | 141 | 84 | 22 | 26% | B | 205.8 | 343.4 |
| Double Branch Creek at Hillsborough Ave | 101 | 84 | 23 | 27% | B | 185.1 | 222.6 |
| Hillsborough River at Sligh Ave | 152 | 84 | 23 | 27% | B | 239.8 | 182.8 |
| English Creek at SR 60 | 154 | 83 | 25 | 30% | B | 266.6 | 487.7 |
| Little Manatee River at CR 579 | 140 | 84 | 26 | 31% | B | 283.6 | 664.9 |
| Hillsborough River at Columbus Ave | 137 | 84 | 28 | 33% | B | 195.5 | 153.7 |
| Baker Creek at Thonotosassa Rd | 107 | 84 | 29 | 35% | B | 216.5 | 508.7 |
| Bullfrog Creek at US 41 | 144 | 84 | 31 | 37% | B | 233.7 | 254.7 |
| Mill Creek at I-4 | 149 | 81 | 30 | 37% | B | 258.0 | 578.7 |
| Delaney Creek at US 41 | 133 | 84 | 35 | 42% | C | 376.7 | 596.8 |
| Delaney Creek at 36th Ave | 138 | 84 | 45 | 54% | C | 443.3 | 642.2 |
| Sweetwater Creek at Hillsborough Ave | 104 | 84 | 58 | 69% | D | 786.4 | 849.9 |
| Bullfrog Creek at Symmes Rd | 132 | 78 | 65 | 83% | E | 1,134.8 | 2,658.9 |
| Turkey Creek at SR 60 | 111 | 77 | 65 | 84% | E | 1,212.0 | 1,426.0 |

# This is a work-in-progress; some remaining issues are:

- How to deal with tidal / estuarine sites ?
  - *fecal coliform die-off in estuarine waters may affect site ratings in tidal streams and rivers*
  - *a different set of MWQA categories may be needed*

- How to deal with Class I and Class II waters ?
  - *different MWQA categories probably necessary*
  - *additional indicators (e.g., Crypto, Giardia) may also be needed*

# Thanks !

# Questions ?

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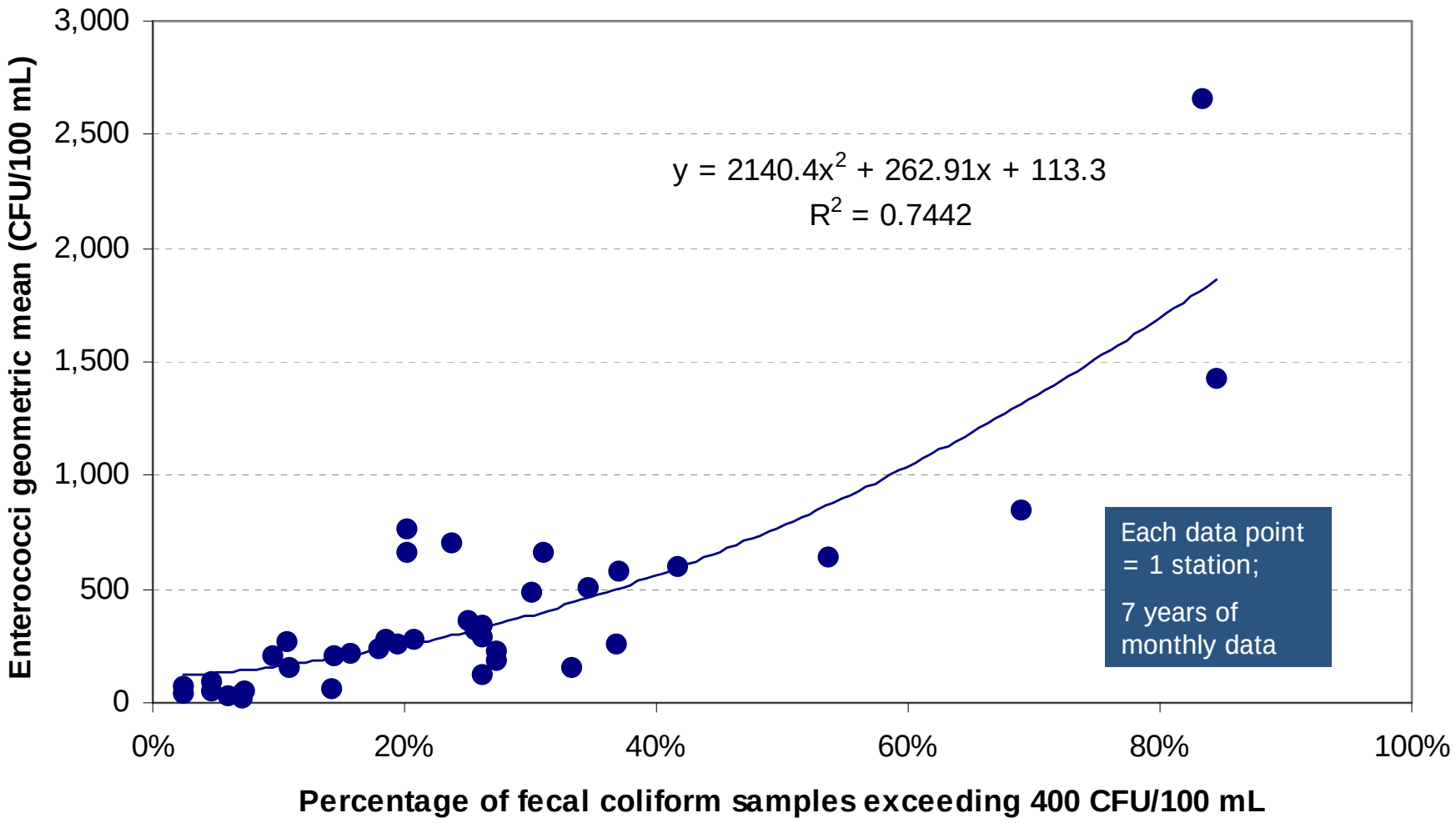
# Some additional reading…


- National Research Council (NRC). 2004. Indicators for waterborne pathogens. National Academy Press, Washington, DC
- Rose, J.B., and others. 2001. Healthy beaches Tampa Bay: Microbiological monitoring of water quality conditions and public health impacts. Tampa Bay Estuary Program Technical Report #03-01. TBEP. St. Petersburg, FL
- U.S. Environmental Protection Agency (U.S. EPA). 2007. Report of the experts scientific workshop on critical research needs for the development of new or revised recreational water criteria. EPA 823-R-07-006. Washington, DC
- World Health Organization (WHO). 2003. Guidelines for Safe Recreational Water Environments. Volume 1. Coastal and Fresh Waters. WHO, Geneva, Switzerland

# Geometric mean enterococci counts vs. exceedances of 400 CFU criterion (EPC data)



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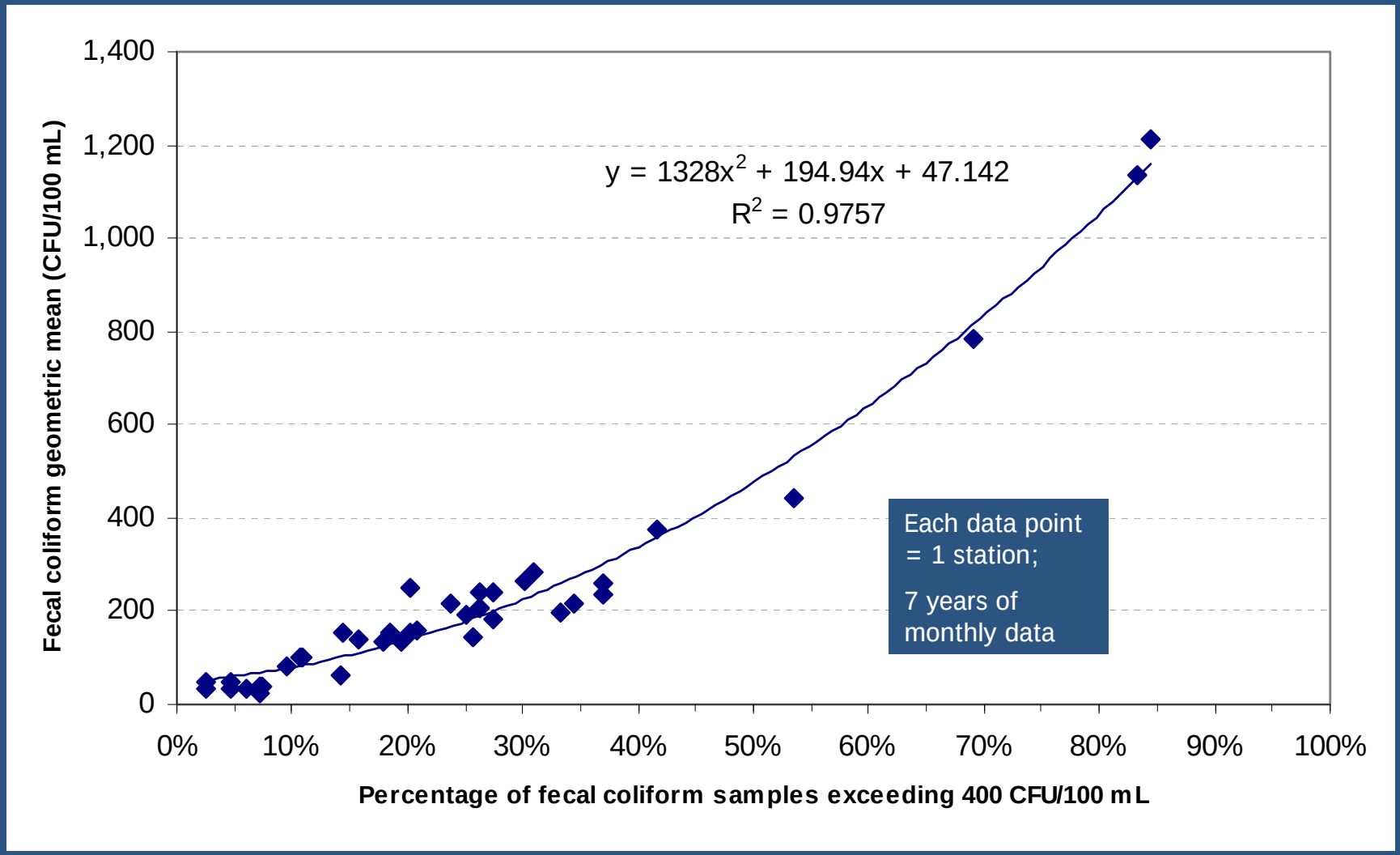
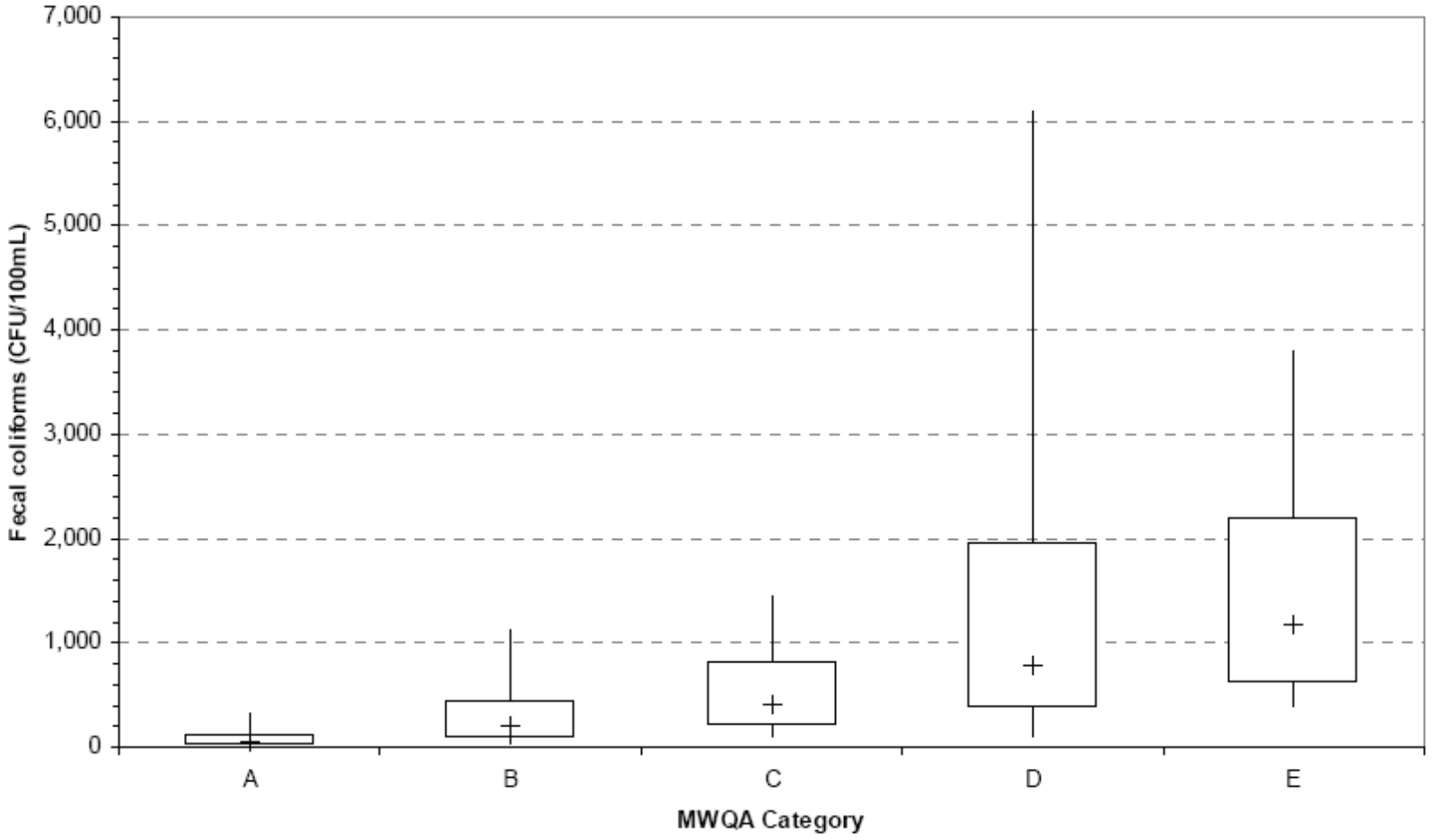
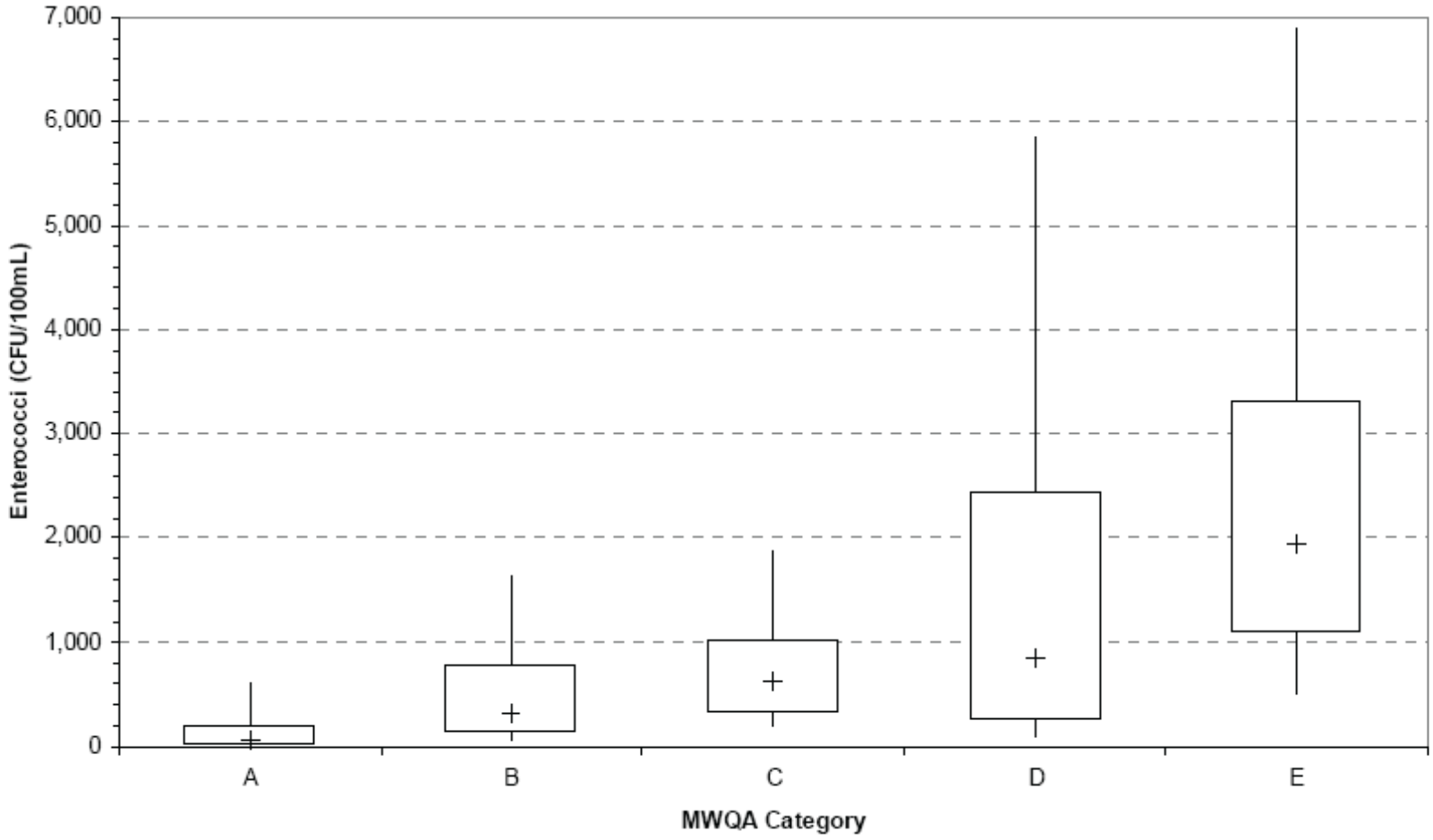


# fecal coliform concentrations in MWQA categories A through E
(EPC data, 2001 - 2007)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