Testing Sewer and Stormwater Infrastructure: Bacteria Source Investigations

Darcy Ebentier

Overview

1. **Background**
2. **How to Conduct a Source Investigation in Storm Drains and Sewers**
    1. Approach
    2. Strategies
    3. Key Tools and Processes
3. **Q&A**

Background

- **Regulatory drivers**
  - Fecal Indicator Bacteria (FIB) most common impairment and leading TMDL driver in rivers and streams of the US
- **FIB are not source specific**
  - Elevated levels make potential threat to human health unclear
- **Reduce uncertainties**
  - Sanitary surveys
  - Adopt new techniques

Urban storm drain in southern CA

Wrack and tuna crabs on the shoreline

Background

- **State of the science has evolved**
- **New tools in the tool box**
  - MST methods
  - Chemical tracers
  - California Source ID Manual

Assay	Sensitivity			Specificity		
	Human n^a	DNQ+	DNQ−	Non-human n^a	DNQ+	DNQ−
BacH	12	100%	75%	26	77%	85%
BacHum-UCD	72	97%	97%	156	37%	67%
BsteriF1	48	100%	96%	104	44%	61%
BtH	12	100%	92%	26	54%	96%
gyrB	12	92%	50%	26	58%	96%
HF183 endpoint	84	75%	NA	182	96%	NA
HF183 SYBR	48	100%	92%	104	78%	89%
HF183 Taqman	60	100%	95%	130	46%	92%
HumM2	72	93%	67%	156	75%	94%
Mnif	60	78%	60%	130	68%	76%

Source: Layton et al 2013

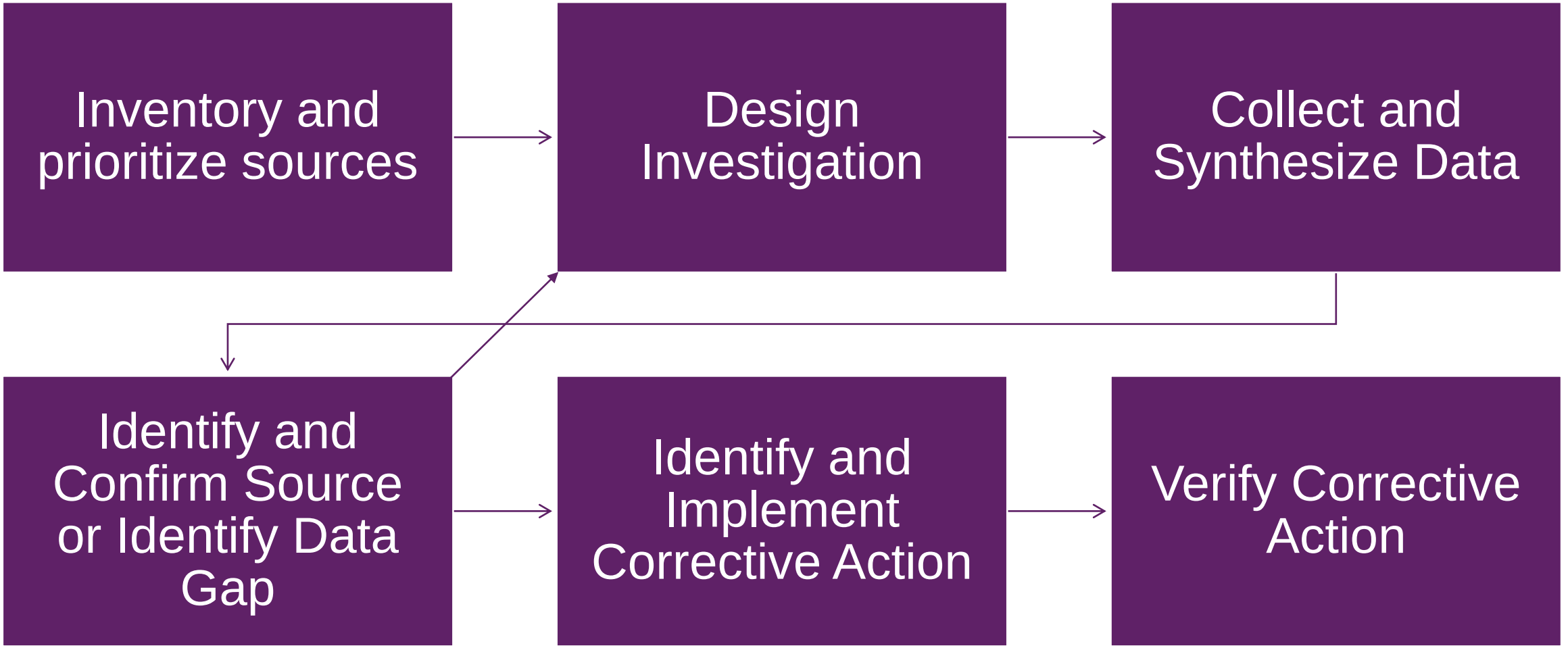
Researchers have developed more than a dozen human markers over the last decade, but one of these, HF183 Taqman®, performed best overall in method evaluation studies.[7] A slightly less sensitive marker, HumM2, also performed well. Both of these markers target *Bacteroides* bacteria in human fecal material. This group of bacteria consistently exhibits host-associated gene sequences. In evaluating human-associated markers, studies have evaluated method sensitivity (i.e., does the method detect human material when it is present in the sample?) and specificity (i.e., does it also detect other fecal sources?).

[7] Layton, B.A., Cao, Y., Ebentier, D.L., et al. 2013. Performance of human fecal anaerobe-associated PCR-based assays in a multi-laboratory method evaluation study. *Water Research* 47 (18), 6897–6908.

http://swrcb.ca.gov/water_issues/programs/beaches/cbi_projects/docs/sipp_manual.pdf

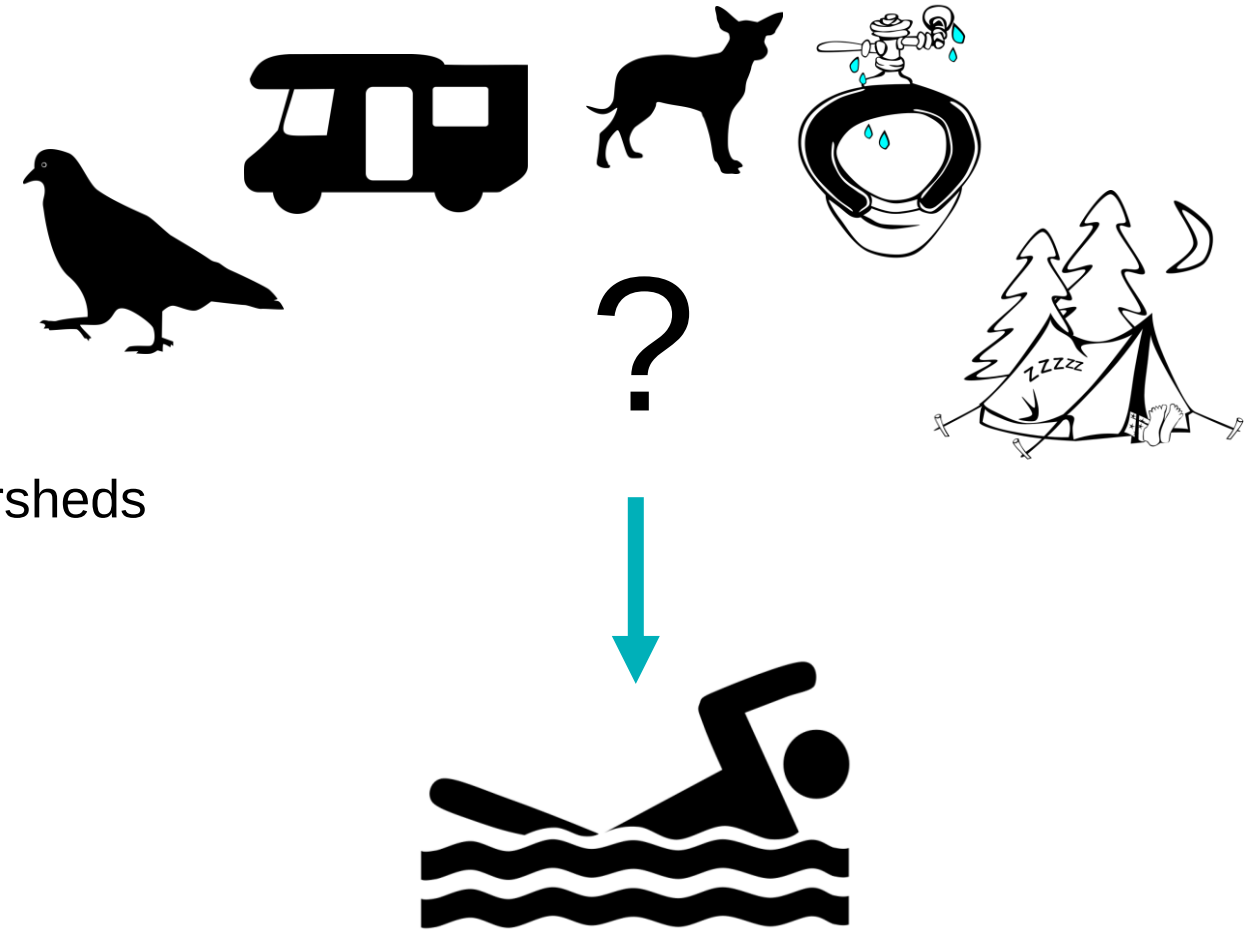
Photo source: Biorad

Approach


Inventory and prioritize sources
Design Investigation
Collect and Synthesize Data
Identify and Confirm Source or Identify Data Gap
Identify and Implement Corrective Action
Verify Corrective Action

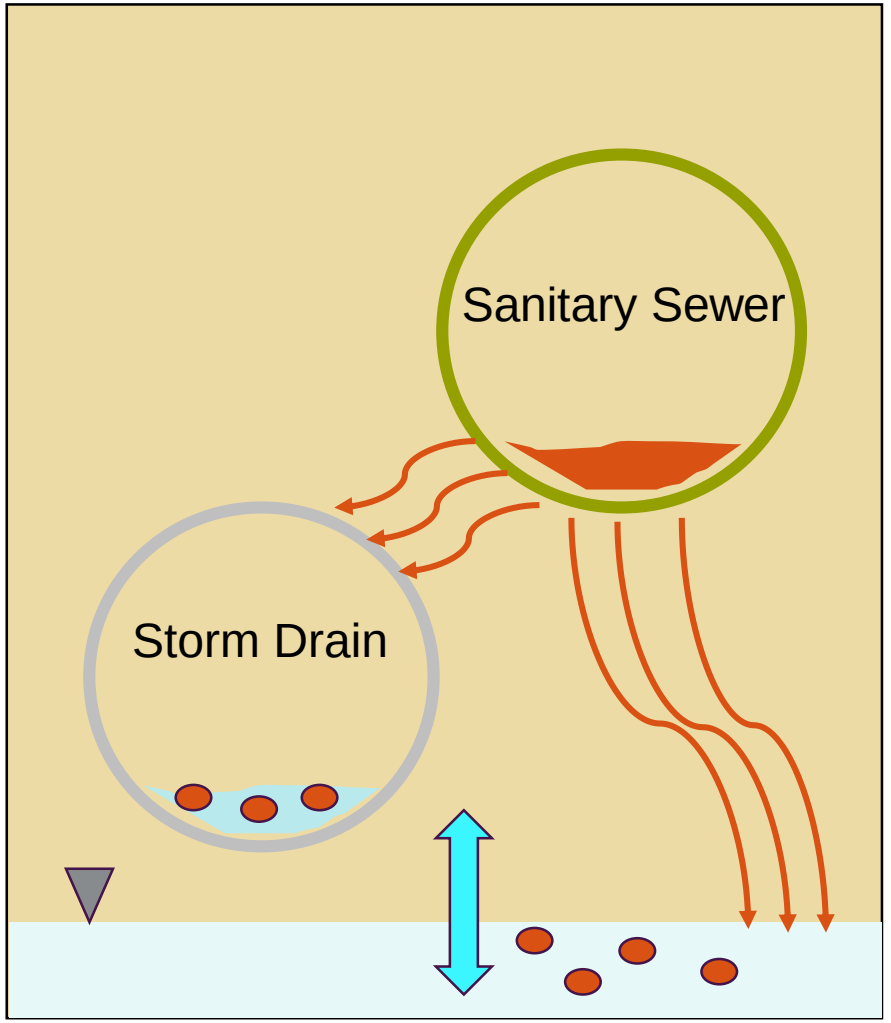
Inventory and Prioritize Sources

- **Must first understand the bacteria sources and pollution problem**
  - Sanitary survey and beyond
  - Identify priority locations
  - What's next?
- **Assumptions for today's discussion**
  - Storm drain outfalls
  - Prioritize human sources in urban watersheds



Design Data Collection

- **Identify critical spatial and temporal conditions**
- **Leaky sewer infrastructure is impacting the storm drain**
  - Critical conditions:
    - Spatial:
      - Areas where sewer runs directly over storm drain infrastructure
      - Areas where infrastructure is aged or susceptible to defects
    - Temporal:
      - Periods of increased groundwater height/flows/infiltration
  - “Bracketing” sources
  - Refine extent
    - Breaks investigation area into manageable pieces



Design Data Collection

- **Multiple monitoring events**
  - Determine persistence of signal, representative conditions
- **Combination of traditional and new methods**
  - Increases confidence in findings via multiple lines of evidence
    - Can also support differentiation of multiple sources
  - Permits leveraging existing staff and resources – cost effective

Tools and Processes

- **Toolbox approach**
- **Many tools and processes for testing storm drain and sewer infrastructure**
- **Considerations for use of methods**
  - Site-specific conditions

Urban stormwater at Tourmaline Beach in San Diego, CA

Tools and Processes

TOOL BOX

GIS analysis:

MS4 and sewer infrastructure, recycled water lines

Age, location, material type, invert depth

Visual/Sanitary Surveys:

Natural, animal, anthropogenic, and human bacteria sources

Traditional tools:

Tracer testing, CCTV, facility inspections, smoke testing

Water Quality Testing:

Visual obs, chemical constituents, field WQ, FIB, MST markers

Flow Monitoring:

Continuous flow monitoring

In situ Parameters

- **Color/Odor/Clarity**
- **Ammonia**
  - Elevated in sewage
  - Present in non-human waste, fertilizers
- **Conductivity**
  - Frequently elevated in groundwater
- **Temperature**
  - Elevated in sewage
- **Chlorine**
  - Present in potable water

Photo source: Chemetrics

Photo source: Hanna

In situ Parameters

Parameter	Critical Ranges		
	Municipal Sewage	**Recycled Water**	**Potable Water**
Color, Odor, Clarity	Gray/Brown, Sewage/Detergents Odor, Cloudy/Opaque	Colorless, Odorless, Clear	Colorless, Odorless, Clear
Ammonia	20-75 ppm[1]	5-10 ppm[2]	<1.5 ppm[3,4]
Conductivity	Source dependent	Source dependent	Source dependent, but typically <1000 us/cm
Temperature	Elevated temperatures may indicate discharge from sources such as showers, appliances, etc.	Ambient	Ambient
Chlorine	Source dependent	Source dependent	>0.5 ppm (free)[5]

Raw influent

Photo source Sandu, 2004

Flow Monitoring

- **Continuous flow monitoring**
  - Diurnal patterns
  - Increases in flow related to:
    - Over-irrigation
    - Illicit discharges
    - Use of cross-connected infrastructure

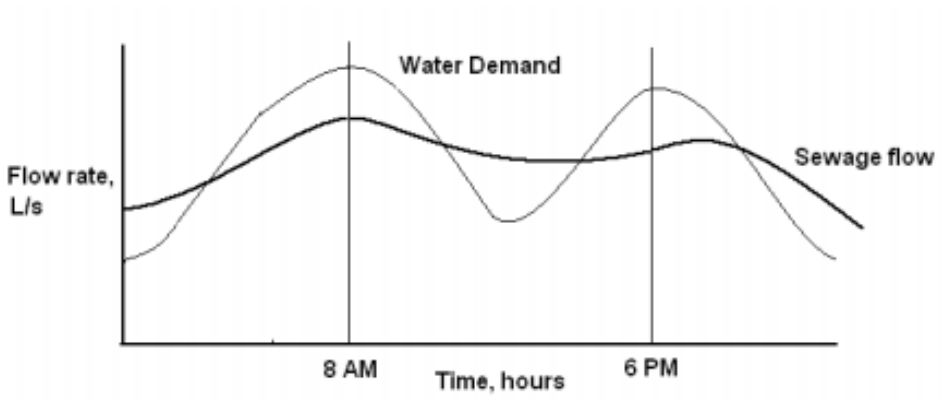
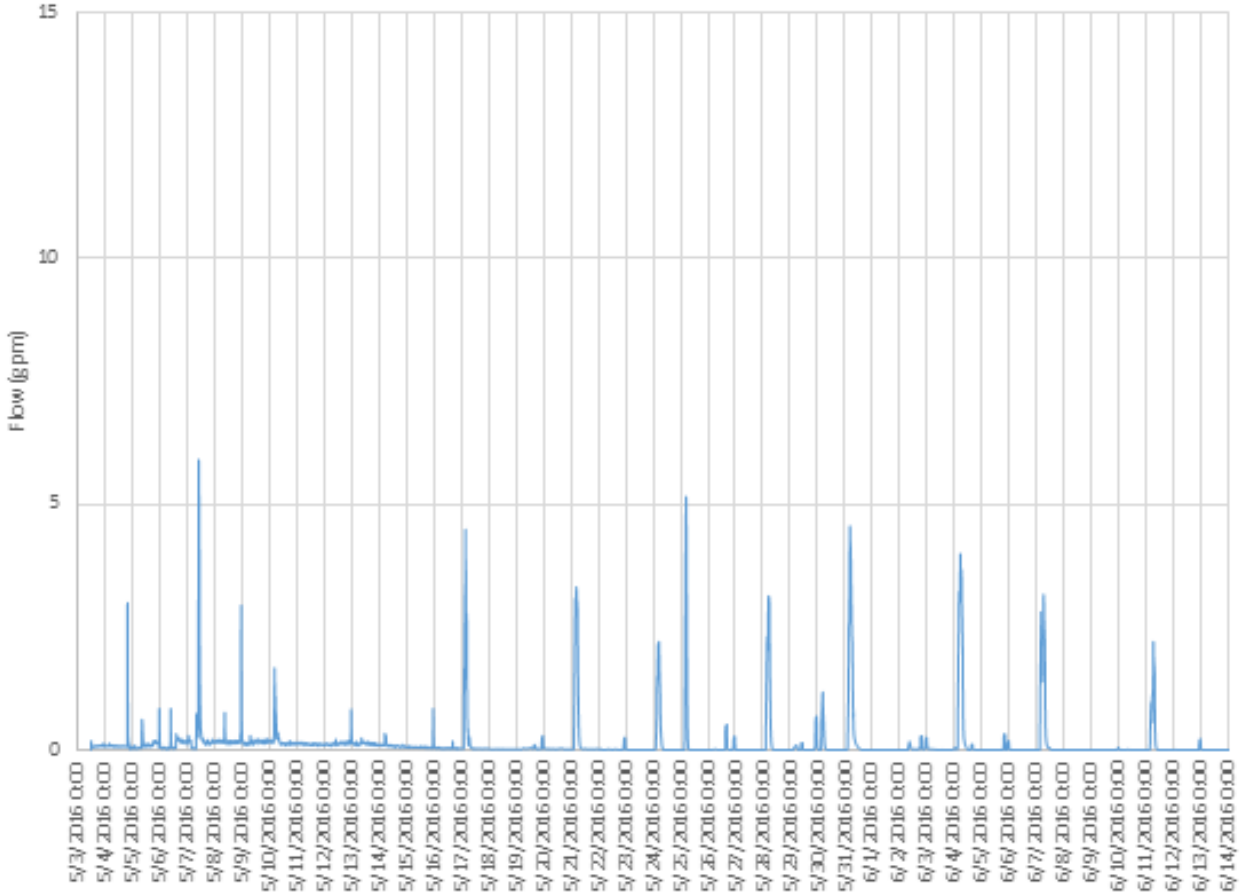


Figure 4.1 Typical hourly variations in sewage flow

Photo source: NPTEL IIT Kharagpur



Analytical Data

- **FIB**
  - Present in sewage, other fecal sources
  - Non-specific, can be elevated without fecal source present
- **HF183**
  - Indicates presence of human waste
  - DNA marker – can persist after treatment (recycled water false positive)
- **Chemical tracers (caffeine, nicotine, pharmaceuticals)**
  - Present in aggregate human waste
  - Expensive, variable persistence

Analytical Data

Parameter	Critical Ranges		
	Municipal Sewage	Recycled Water	Potable Water
FIB	10^{11}-10^{13} MPN/100mL total coliform[1]	Not present (Median total coliform ≤23 MPN/100mL)[2]	Not present (<5% of samples positive for total coliform)[3]
HF183	10^{5}-10^{7} copies/100mL[4]	0-10^{7} copies/100mL (source dependent)	Assumed Not Present

Analytical Data

- **Community Analysis (e.g. Phylochip)**
  - Can distinguish between multiple human sources
  - Data quality is a function of the calibration samples provided - $$$, site specific

Photo source: Phylochip

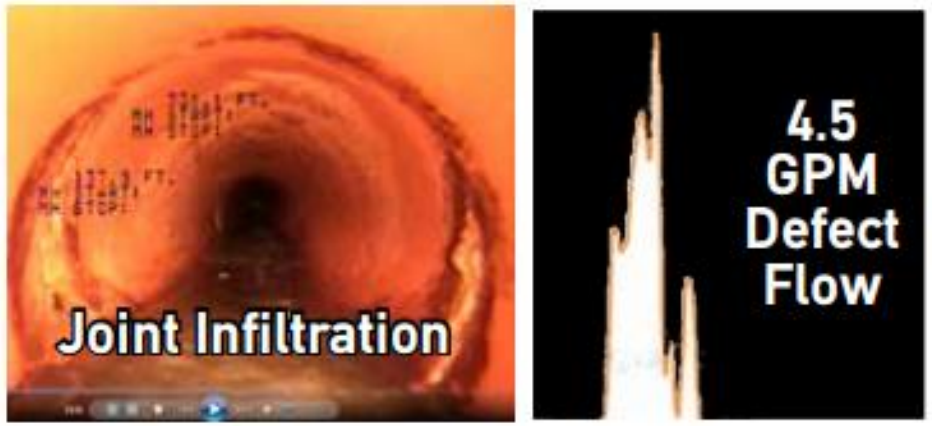
Traditional Tools to Identify Cross-Connection

- **CCTV**
  - Can be used in both storm drain and sewer
  - Can visualize source input (storm drain)
  - Can identify location and type of defect (sewer)
  - Does not assess water-tightness
  - Subject to operator interpretation
- **Smoke Testing**
  - Can be used to test multiple lines/laterals simultaneously
  - Requires extensive permissions/notifications
- **Tracer Testing**
  - Dye (e.g rhodamine, fluorescein)
    - Can be detected visually or with sensors
    - May bind to soils
  - Alternate Tracers (e.g. SF6, radon, isotope studies)
    - Improved detection of cross connections
    - Nonstandard – may be challenging to procure, use, and detect

Photo source: California Source ID Manual (2013).

New Tools to Identify Cross Connection

- **Sewer scanning technology (e.g Electroscan)**
  - Assesses water tightness
  - Pinpoints and quantifies leaks
  - Does not readily distinguish between infiltration and exfiltration
  - May not be representative of typical operating conditions



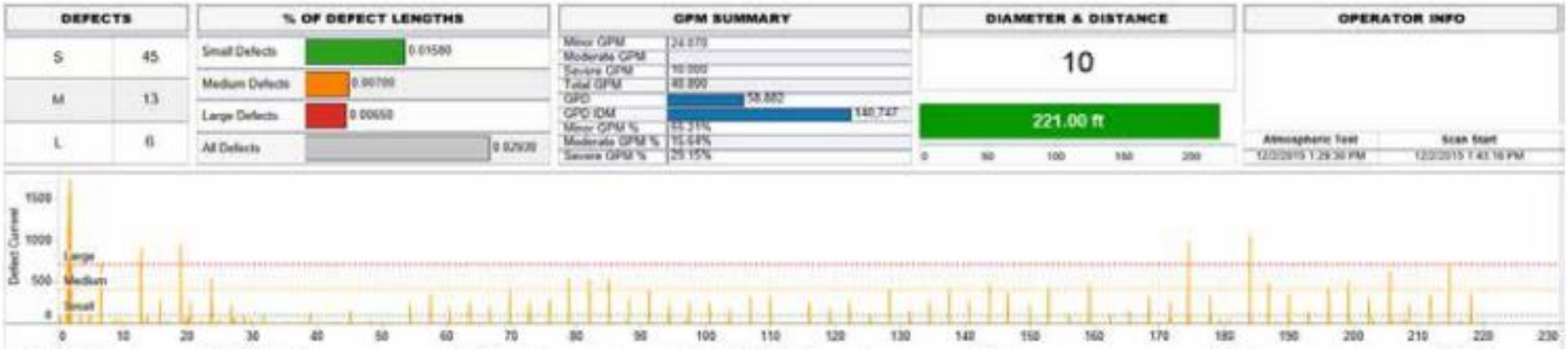


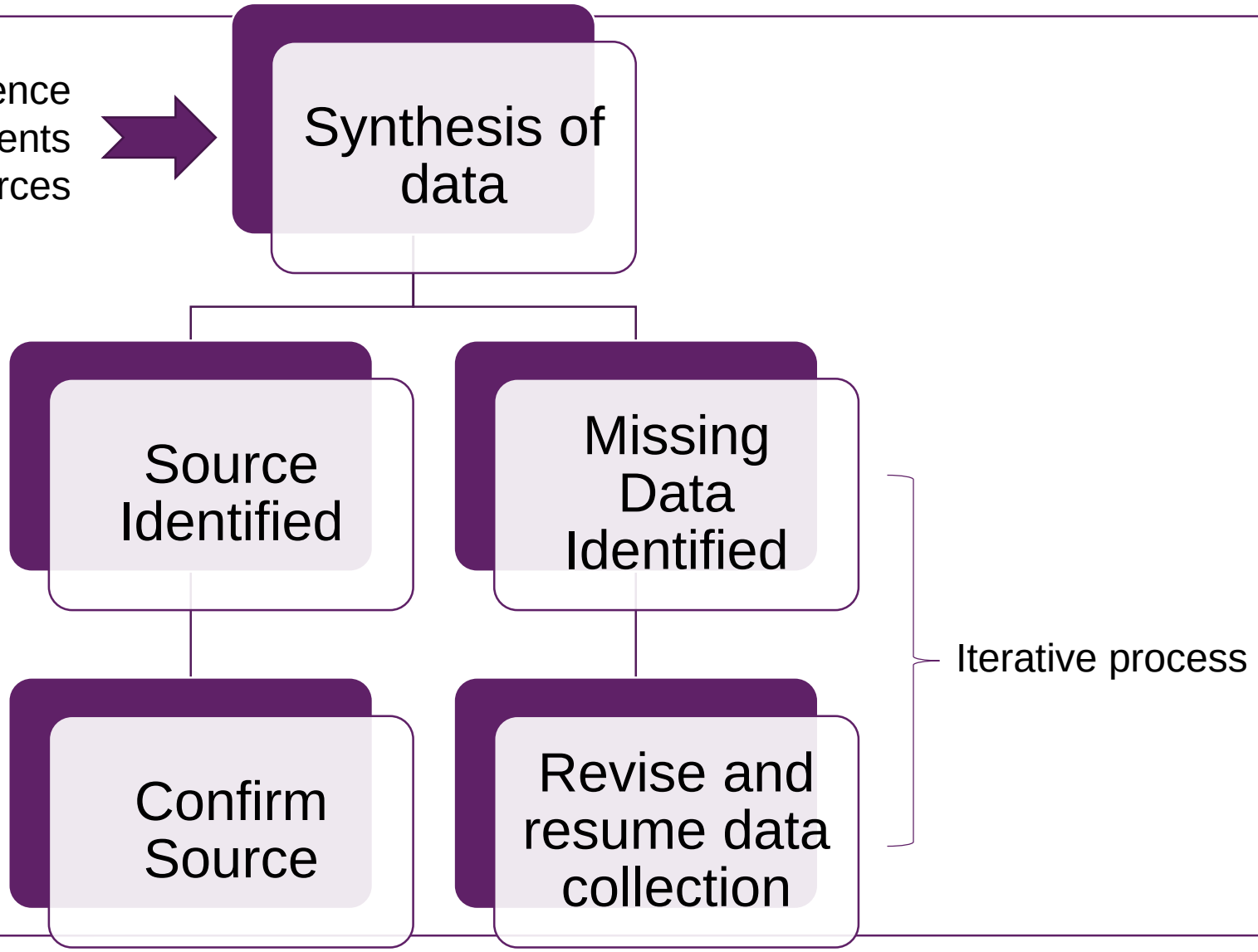
Photo source: Electroscan

Collect and Synthesize Data

- **Synthesize data – weight of evidence approach**
- **Assess data against potential sources identified**
  - Was there an increase in pollution as storm drain passed under infrastructure?
  - Was the increased pollution level observable in multiple lines of evidence?
  - Was the increase at multiple locations or just one?
  - Is there a priority area within the spatial extent?

Identify Source or Data Gap

Multiple lines of evidence
Spatial and temporal extents
Potential sources



Identify and Implement Corrective Actions

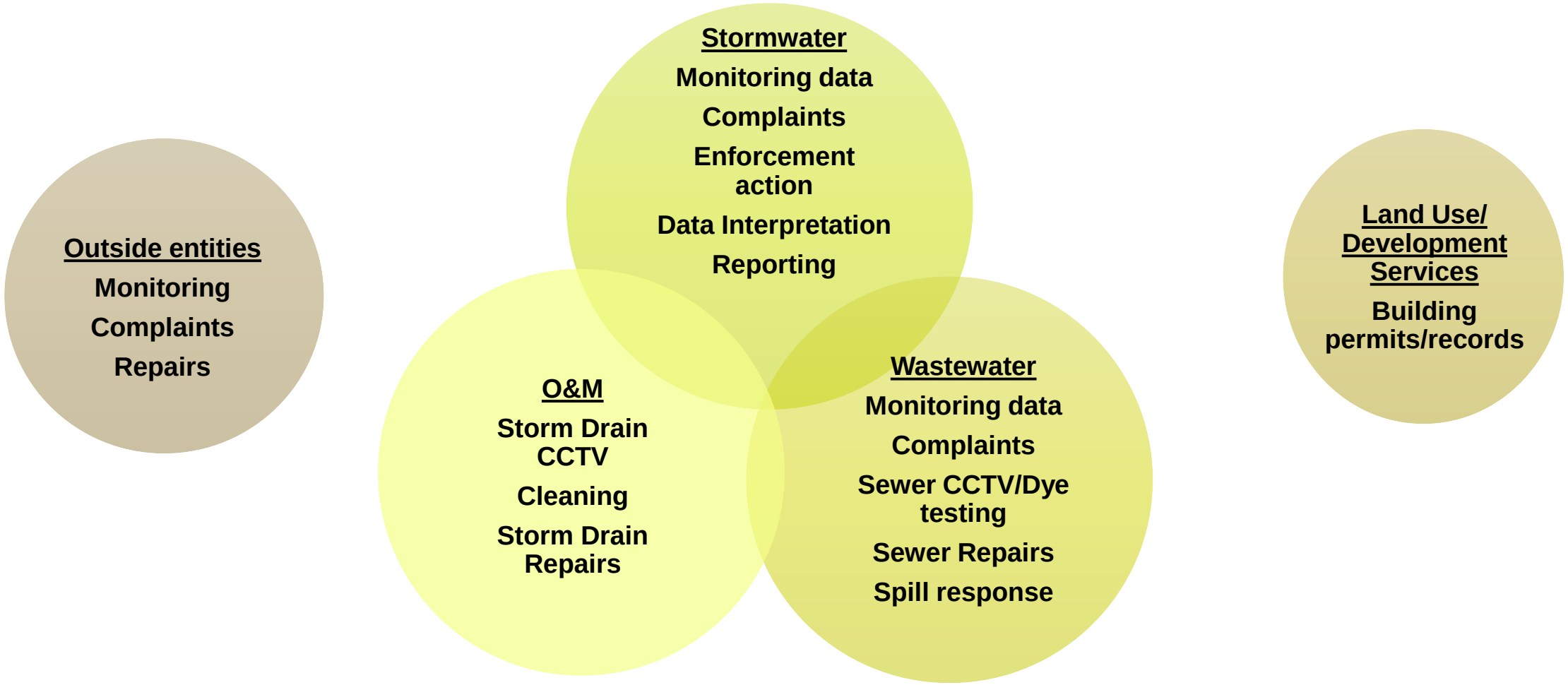
- **Examples of Corrective Actions**
  - Enforcement
    - NOVs
  - Maintenance/Repair
  - Programmatic BMPs
    - Lateral inspection programs
    - Service line warranties
- **Develop a process**
  - Speedy and effective corrective actions

Photo source: The California Source ID Manual, 2013.

Photo source: www.sandiego.gov

Identify and Implement a Corrective Action

Have a pre-defined process



Real Life Example

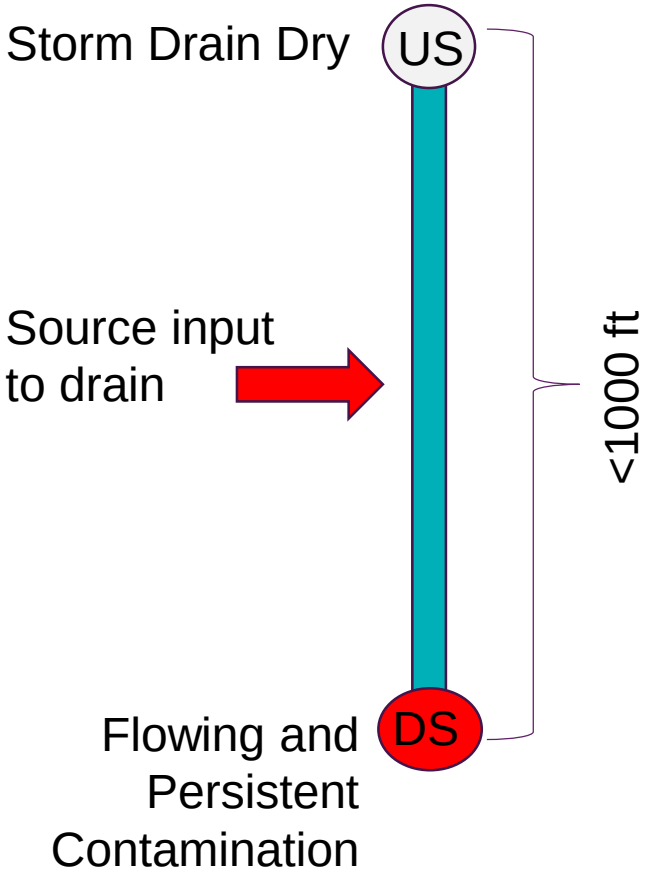
Storm drain based source investigation

Prior work showed presence of elevated FIB at storm drain outfall

Approach includes

- **Maps and field surveys**
- **Visual observations**
- **FIB**
- **MST markers**
- **Chemical markers**

Combined Approach

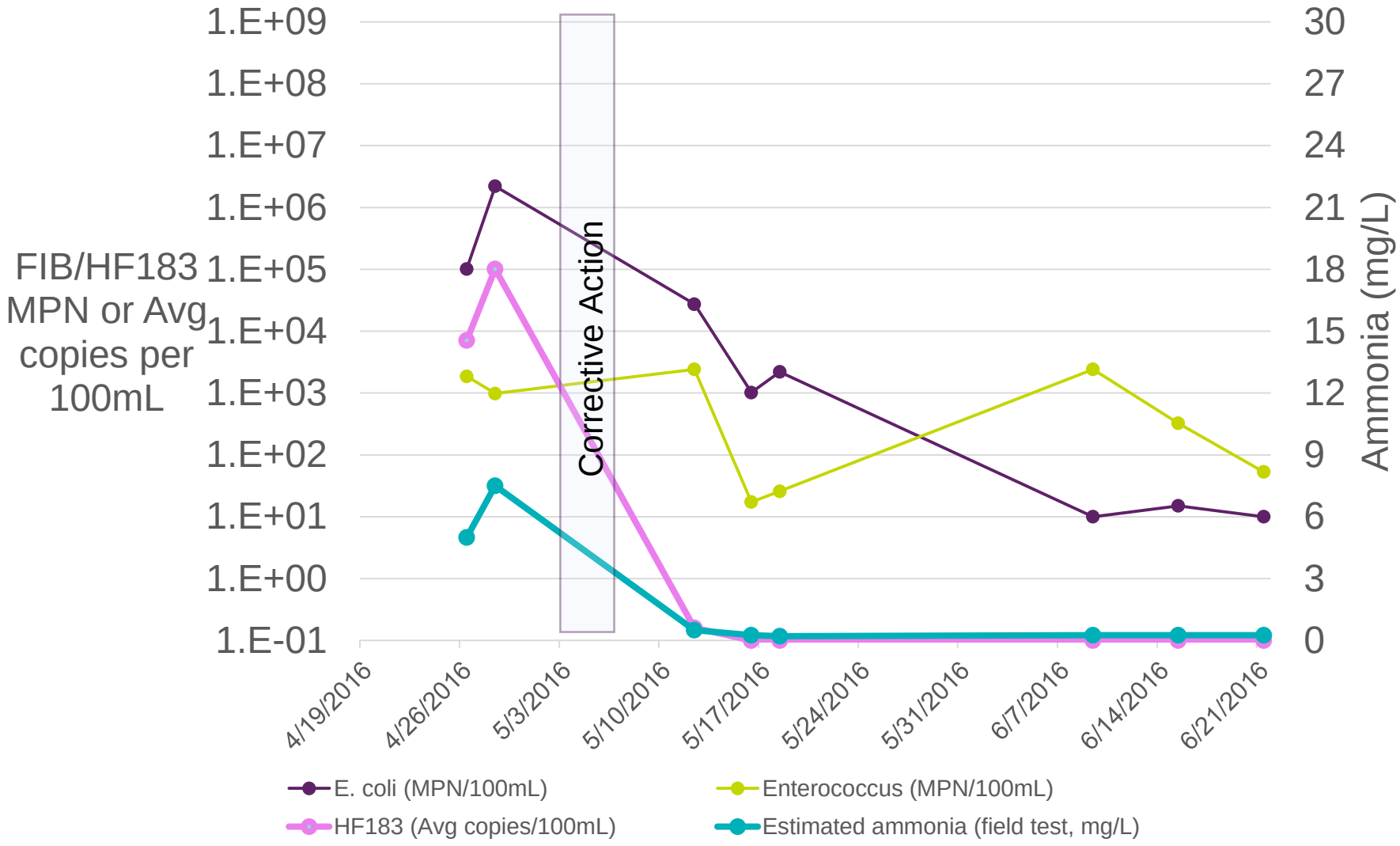


DS – Pre Corrective Action

Constituent	Range
HF183	10^3-10^5 copies/100mL
FIB	10^3-10^6 MPN/100mL
Ammonia	5-8 ppm

Combined Approach

- **Process in place for corrective actions resulted in repair within ~4 hours of source confirmation**



Takeaways

- **Approaches and key strategies**
  - Achieve meaningful results
  - Demonstrate control of highest risk sources
  - Improve protection of public health
- **Review of available tools**
  - Considerations for use

Urban stormwater at Tourmaline Beach in San Diego, CA

Thank you!

Darcy Ebentier

Senior 1 Scientist/Project Manager

Amec Foster Wheeler Environment & Infrastructure

A subsidiary of Wood PLC

San Diego Office

darcy.ebentier@woodplc.com