Utilizing DNA Markers and Pharmaceuticals to Identify Human Sources of Fecal Contamination in Stormwater Discharges

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Boston Water and Sewer Commission's Collection Systems

- 206 Storm Drain Outfalls/Sub-catchments
- 18 Interconnections
- 30 Combined Sewer Overflow Outfalls
- Appx. 80% of Boston is served by separated sewers and storm drains
- Appx. 20% served by combined sewe

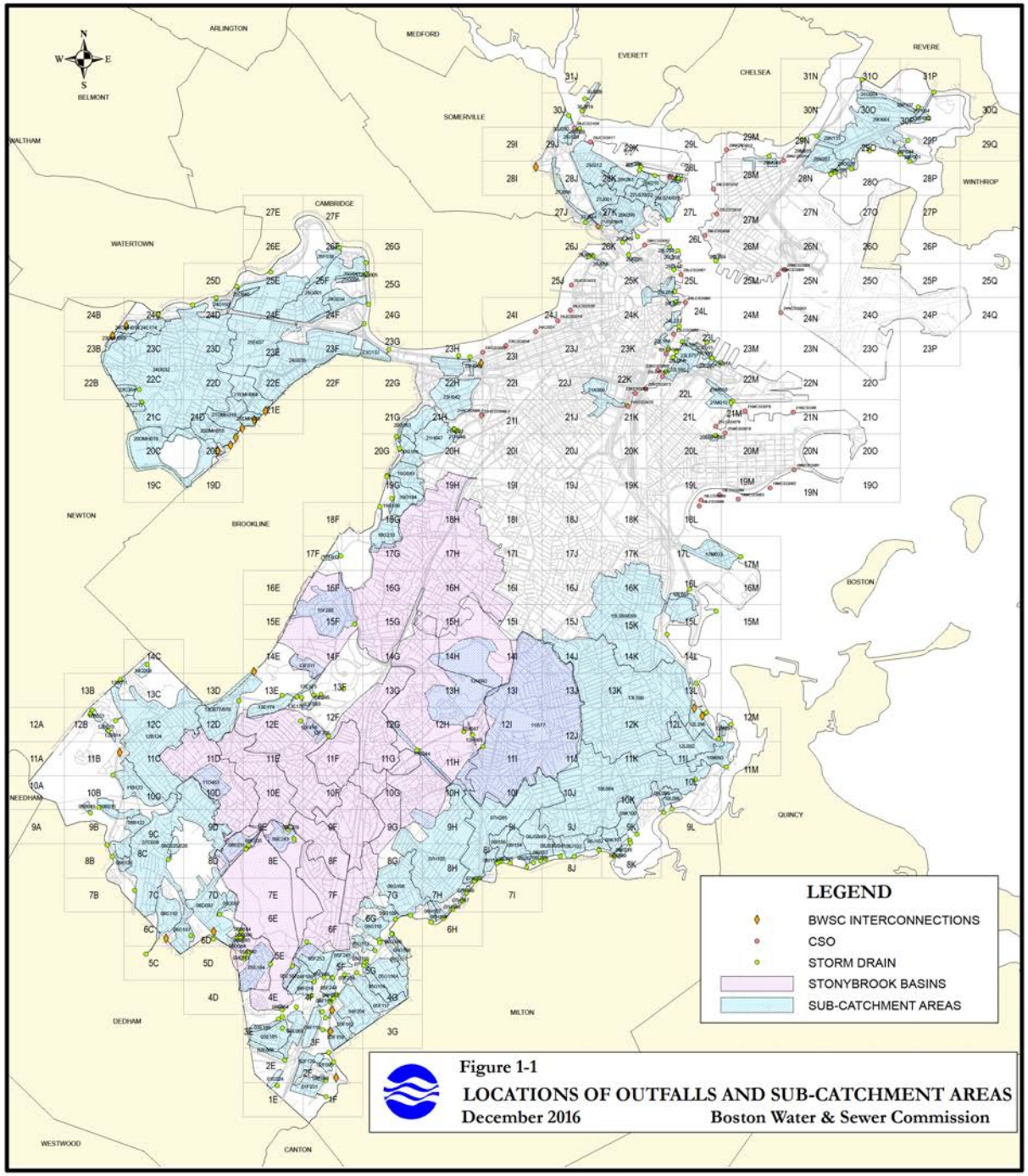


Figure 1-1

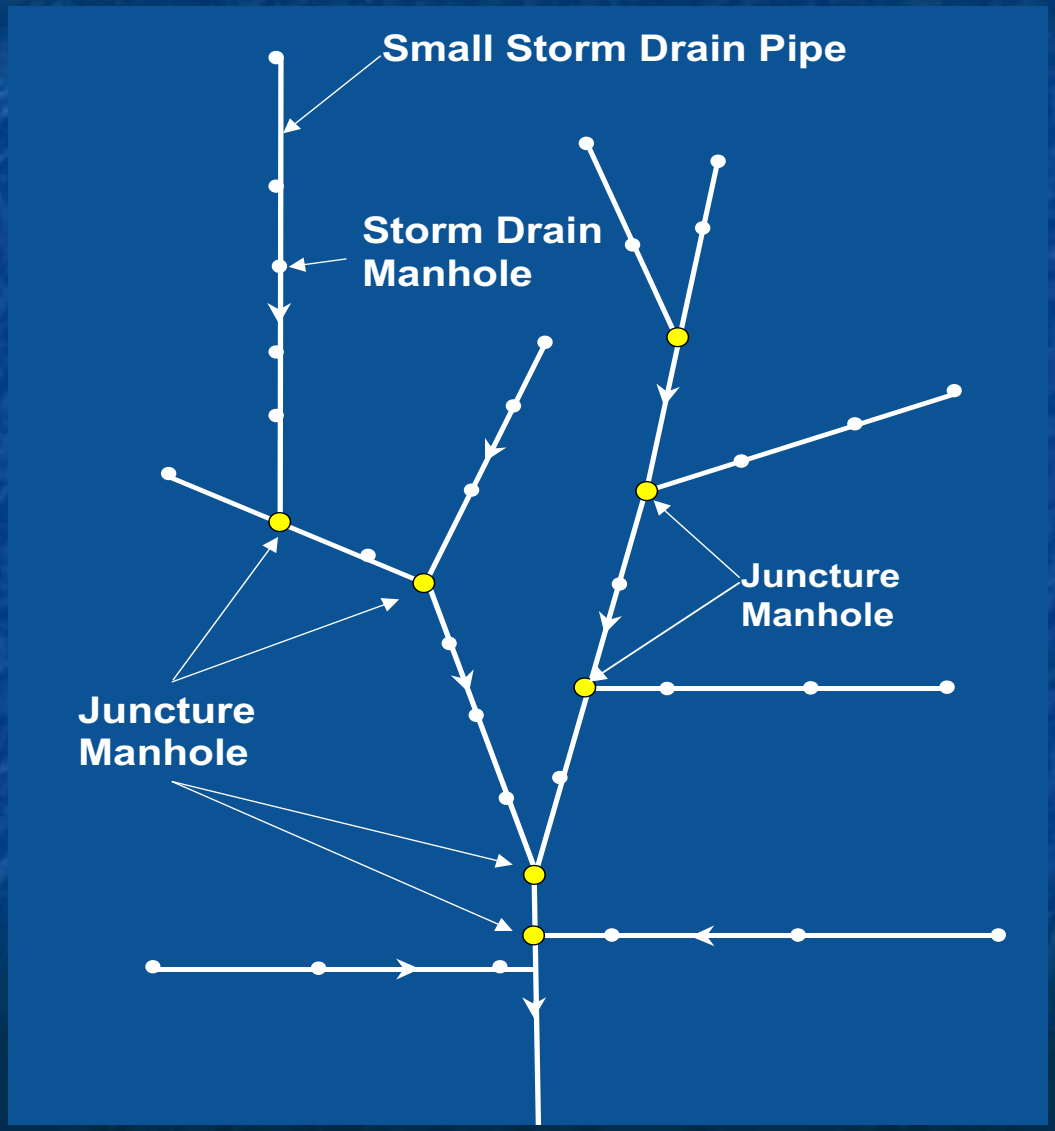
LOCATIONS OF OUTFALLS AND SUB-CATCHMENT AREAS

December 2016 Boston Water & Sewer Commission

BWSC's IDDE Program

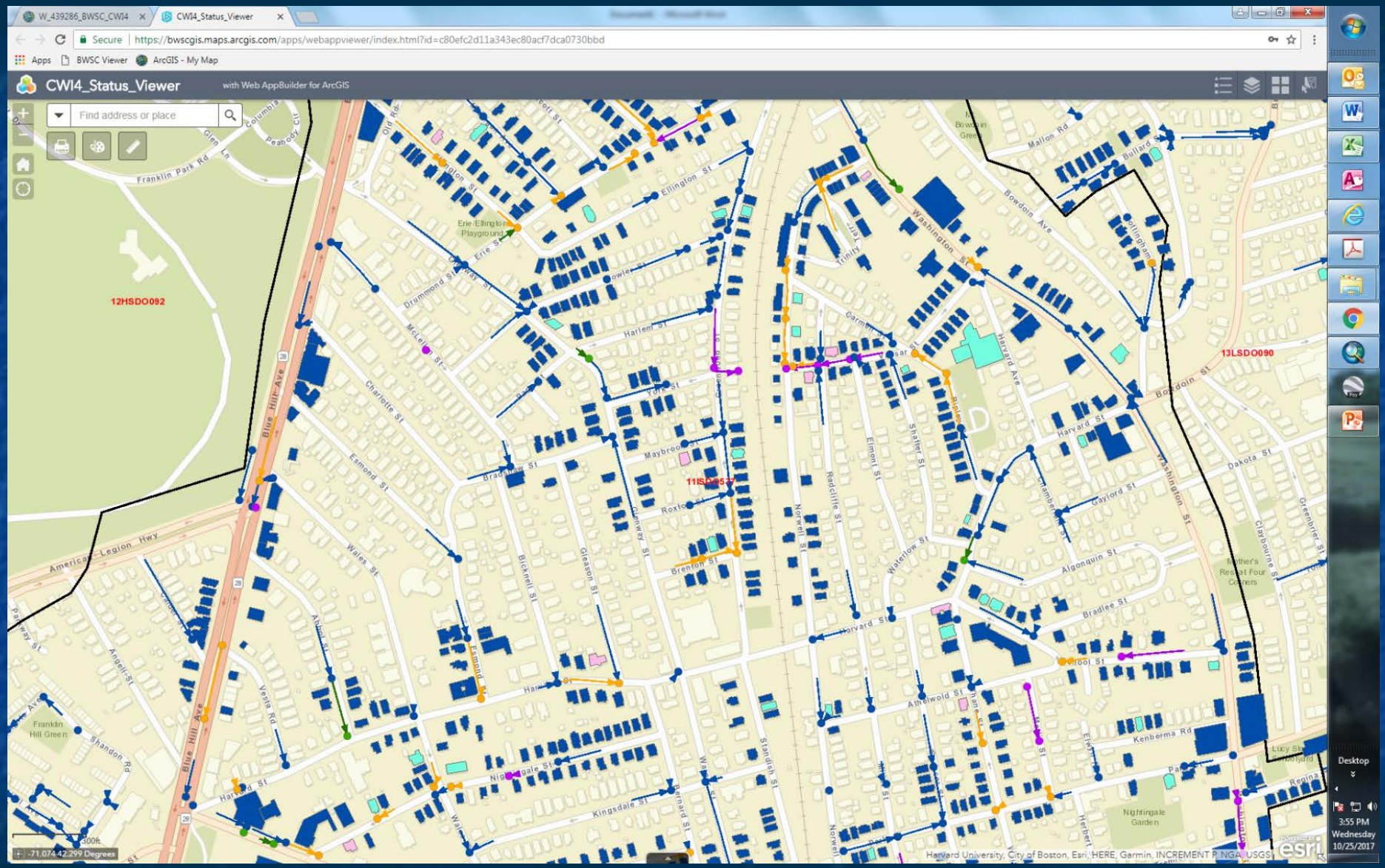
- BWSC has been doing IDDE since late 1980's
- Expanded 2000 with Stony Brook Investigation
- 4 more CWI Phases since 2000
- With each new phase
  - -Expanded areas under investigation
  - -Built on "lessons learned"
  - -Added new "Tools in the Tool Box"

IDDE Methodology



Field Test Kits

- Quick
- Easy to use
- Inexpensive
- <u>Immediate results</u>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Apps
BWSC Viewer
ArcGIS - My Map
CWI4_Status_Viewer
with Web AppBuilder for ArcGIS
Find address or place
12HSDO092
11ISDO527
13LSDO090
Franklin Park Rd
Blue Hill Ave
Washington St
Harvard St
Bowdoin St
Dakota St
Harlem St
Erie St
Ellington St
Mallon Rd
Bullard
Bowdoin Ave
Drummond St
McLellan St
Charlotte St
Esmond St
Bradlee St
Maybrook St
Roxton St
Brenton St
Gleason St
Bickness St
Wales St
America Legion Hwy
Vesta Rd
Angell St
Shandon Rd
Franklin Hill Green
Kingsdale St
Nightingale St
Bernard St
Standish St
Norwell St
Radcliffe St
Elmont St
Shatter St
Waterlow St
Algonquin St
Gaylord St
Almelwold St
Kenberma Rd
Clarkson St
Greenbrier St
Nightingale Garden
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Wednesday
10/25/2017

Illicits Found and Corrected 2000-2017

- 10,000 manholes investigated
- 21,500 dye tests performed
- 1,739 illicits corrected
  - -1,211 direct connect to drain
  - -230 internal (owner corrected)
  - -298 leaking laterals (most were owner corrected)
- 810,000 gpd sewage removed from drains

Consent Decree 2012

- Requires annual wet and dry weather screening of all storm drain/CSO outfalls and interconnects
- Prioritization of sub-catchments for IDDE investigation
- Deadlines for completion of IDDE investigation; ALL 254 sub-catchments must be completed by 2019
  - -35% inc. beaches were to be completed in 3 years (2015)
  - -35% completed by 2018
  - Remainder (30%) complete by 2019

Prioritization

- Ranked based primarily on outfall screening FIB results

Bacteria	Priority 2	Priority 3	Priority 4
E. coli (CFU/100mL)	>10,000	1,000 - 10,000	<1,000
Enterococci (CFU/100mL)	>5,000	500 - 5,000	<500

But What Were We Missing?

- As of 8/23/2015 investigations in 105 sub-catchments were considered complete (40%)
- But despite eliminating dozens of illicits, FIB in some sub-catchments remained high
- There were isolated locations (drains) within sub-catchments where there was contamination but no source had been found

Urban Runoff WQ Study Primary Objectives

- Objective 1: Determine whether elevated FIB concentrations at representative outfalls are due to human fecal contamination or non-human sources
- Objective 2: Evaluate the relative contribution of FIB and phosphorus to the MS4 from various sources, particularly during wet weather

	Parameters	Factor Tested	Purpose
H1	Human Fecal Bacterial DNA Markers	Sub-catchments with corrective actions completed vs incomplete	Evaluate if corrective actions performed through the current IDDE program are eliminating human fecal contamination, to confirm existing IDDE program effectiveness or improve the screening process.
H2	Human Fecal Bacterial DNA Markers	Wet vs dry weather in sub-catchments where corrective actions have been completed	Evaluate if aboveground human sources are contributing during wet weather, or if wet weather is flushing illicit discharges that do not reach the outfall during dry weather, to potentially improve the IDDE program.
H3	FIB, Nutrients, and Surfactants	Human waste present vs absent	Evaluate if conventional parameters are reliable indicators of human fecal contamination, to potentially improve the IDDE program.
H4	PPCPs	Human waste present vs absent	Evaluate if PPCPs could be used as a reliable additional line of evidence for human fecal contamination, to potentially improve the IDDE program.
H5	Non-Human Fecal Bacterial DNA Markers	Human vs dog and goose fecal sources	Evaluate if non-human fecal management actions may be effective in certain sub-catchments.
H6	Microbial Community DNA Analysis	Residential and open space vs urban sub-catchments	Evaluate if this analytical tool may be useful for identifying broader fecal and environmental sources.
H7	FIB and Phosphorous	Aboveground vs belowground sources	Evaluate if TMDL compliance measures may be more effective targeting aboveground sources of FIB and phosphorous. Also to develop data to support watershed model calibration.
H8	FIB and Phosphorous	Sediments	Evaluate if catch basin and storm drain cleaning may be effective in reducing FIB and phosphorous.
H9	FIB and Phosphorous	Illicit sewage discharges	Evaluate FIB and phosphorous contributions from known illicit discharges.
H10	FIB and Phosphorous	Season	Evaluate if seasonal management actions may be effective in reducing FIB and phosphorous. Also, to develop data to support watershed model calibration[7].

Objective 1

Objective 2

Group	Sampling Condition[1]	Dry Weather Outfall FIB Concentration[2]	Wet Weather Outfall FIB Concentration[2,3]	Status of IDDE Investigation	Status of Corrective Actions
1-1a	Dry	High	Not Sampled	Complete	Complete
1-1b	Wet	N/A (no flow)	High	Complete	Complete
1-1c	Wet	Low	High	Complete	Complete
1-2	Dry	High	Not Sampled	Complete	Not Complete
1-3	Dry	High	Not Sampled	Not Complete	Not Complete

1. Sub-catchments with a "Dry" sampling condition typically produce dry weather discharges while sub-catchments with a "Wet" sampling condition typically do not discharge during dry weather.
2. Based on bacteria screening levels in the Consent Decree, shown in Table 1. Exceedances of these criteria do not necessarily imply sewage contamination is present.
3. In accordance with the Consent Decree requirements, outfalls are sampled during wet weather only if there was no dry weather flow or concentrations of certain parameters in dry weather flows were below screening levels.

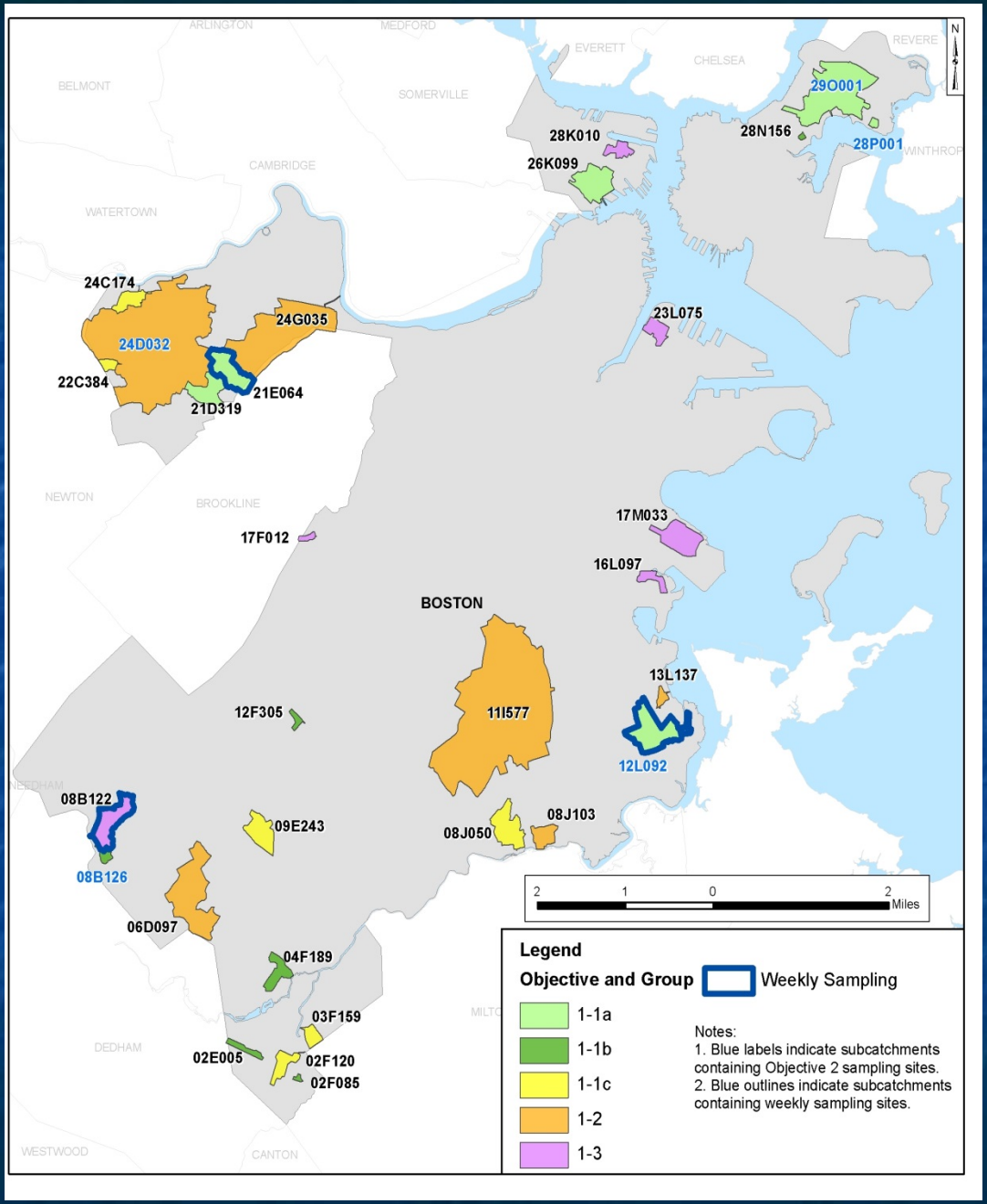
Group	Description	Sampling Condition
2-1	Stormwater surface runoff from representative land use types (e.g., residential, commercial, institutional, and mixed-use)[1]	Wet
2-2	Stormwater runoff in MS4 manholes[2]	Wet
2-3	Sediments in catch basins[3]	Dry
2-4	Illicit Discharges[4]	Dry

1. Collected prior to entering catch basins, composite sample of flow entering all accessible catch basins upstream of the manhole sampled in Group 2-2.
2. Collected downstream from locations sampled in Group 2-1.
3. Composite sample from catch basins sampled in Group 2-1.
4. Collected downstream from known illicit discharges.

Sample Parameters by Laboratory

Parameter	Analytical Labs
FIB (E. coli and Enterococcus) and DNA filtering	Northeast Environmental and Alpha Analytical
Phosphorous (total and dissolved) and TSS	Alpha Analytical
PPCPs[1] (Acetaminophen, Atenolol, Azithromycin, Caffeine, Carbamazepine, Cotinine, Primidone and Sucralose)	Weck Laboratories (California)
DNA markers (Human [HF183Taqman and HumM2][2], Dog, and Goose)	Source Molecular (Florida)
DNA Community Analysis	U. New Hampshire Hubbard Center for Genome Studies
Salinity, Conductivity, pH, and Temperature	Field Probe
Surfactants, Ammonia, and Total Residual Chlorine[3]	Field Kits

[1] PPCPs were selected based on guidance from EPA New England's draft source tracking protocol and the list of analytes recommended for analysis in the project RFP.
[2] Human fecal bacterial DNA markers selected based on the California Microbial Source Identification Manual
[3] A subset of samples was laboratory analyzed for surfactants, ammonia, and total residual chlorine at Alpha Analytical to validate the accuracy of field kit results. This analysis was performed for one (1) dry weather sampling event.


ARLINGTON
MEDFORD
EVERETT
CHELSEA
REVERE
BELMONT
SOMERVILLE
CAMBRIDGE
WATERTOWN
WINTHROP
NEWTON
BROOKLINE
BOSTON
NEEDHAM
DEDHAM
MILTON
WESTWOOD
CANTON
N
29O001
28N156
28P001
28K010
26K099
24C174
24G035
24D032
22C384
21E064
21D319
23L075
17M033
17F012
16L097
13L137
11I577
12F305
12L092
08B122
09E243
08J050
08J103
08B126
06D097
04F189
03F159
02E005
02F120
02F085
2 1 0 2
Miles
Legend
Objective and Group
Weekly Sampling
1-1a
1-1b
1-1c
1-2
1-3
Notes:
1. Blue labels indicate subcatchments containing Objective 2 sampling sites.
2. Blue outlines indicate subcatchments containing weekly sampling sites.

Sampling Program Summary

- 35 unique sampling locations
- 6 dry <u>and</u> 6 wet sampling events sampled
- 7/1/2016-7/31/2017 (Drought in 2016 required program extension)
- 378 samples collected in total
- Up to 25 different parameters analyzed resulting in 2,362 unique sample results

Preliminary Results

- The HM (HF183) was detected in all sub-catchments during dry weather regardless of IDDE program status.
- FIB were correlated with human marker results during dry weather, confirming the utility of FIB for dry weather outfall prioritization and screening.
- FIB were not effective in detecting human waste during wet weather, when a mixture of waste types and other FIB sources are conveyed.

Preliminary Results continued

- Acetaminophen, atenolol, and caffeine were correlated with the human marker in dry weather outfall flows.
- IDDE test kit parameters (ammonia, surfactants, and residual chlorine) in outfall flows were not correlated with human marker results, and were prone to false positive and false negative signals.* (based on OF screening data)
- Sewage (as indicated by the HM) was a significant source of TMDL pollutants (FIB and phosphorous) in discharges during dry weather, while non-sewage sources were more significant during wet weather.

Preliminary Recommendations -Outfall Screening

- Consider discontinuing use of test kits in outfall screening and for prioritizing sub-catchments for IDDE
- Consider discontinuing use of wet weather FIB sampling data for sub-catchment prioritization (not indicative of human waste).
- Use only dry weather FIB data for prioritizing sub-catchments for IDDE
- Consider collecting multiple FIB dry weather samples from each outfall and geometrically average results for prioritization

Preliminary Recommendations- Network IDDE Investigations

- Consider discontinuing use of field test kits in field investigations and use FIB instead*
  - -Requires delivery to lab within 6 hours
  - -Must be kept on ice
  - -Greater cost
  - -Results can take up to weeks to be provided
  - *Not recommended by BWSC
- Use CCTV in storm drains to ID illicits and leaks

Does not solve the Fundamental Problem:

We have numerous methods for detecting human contamination in storm drains.

HM and Pharmaceuticals are additional “Tools in the Tool Box”.

However, if we still can’t find the source of the contamination we can’t eliminate it.

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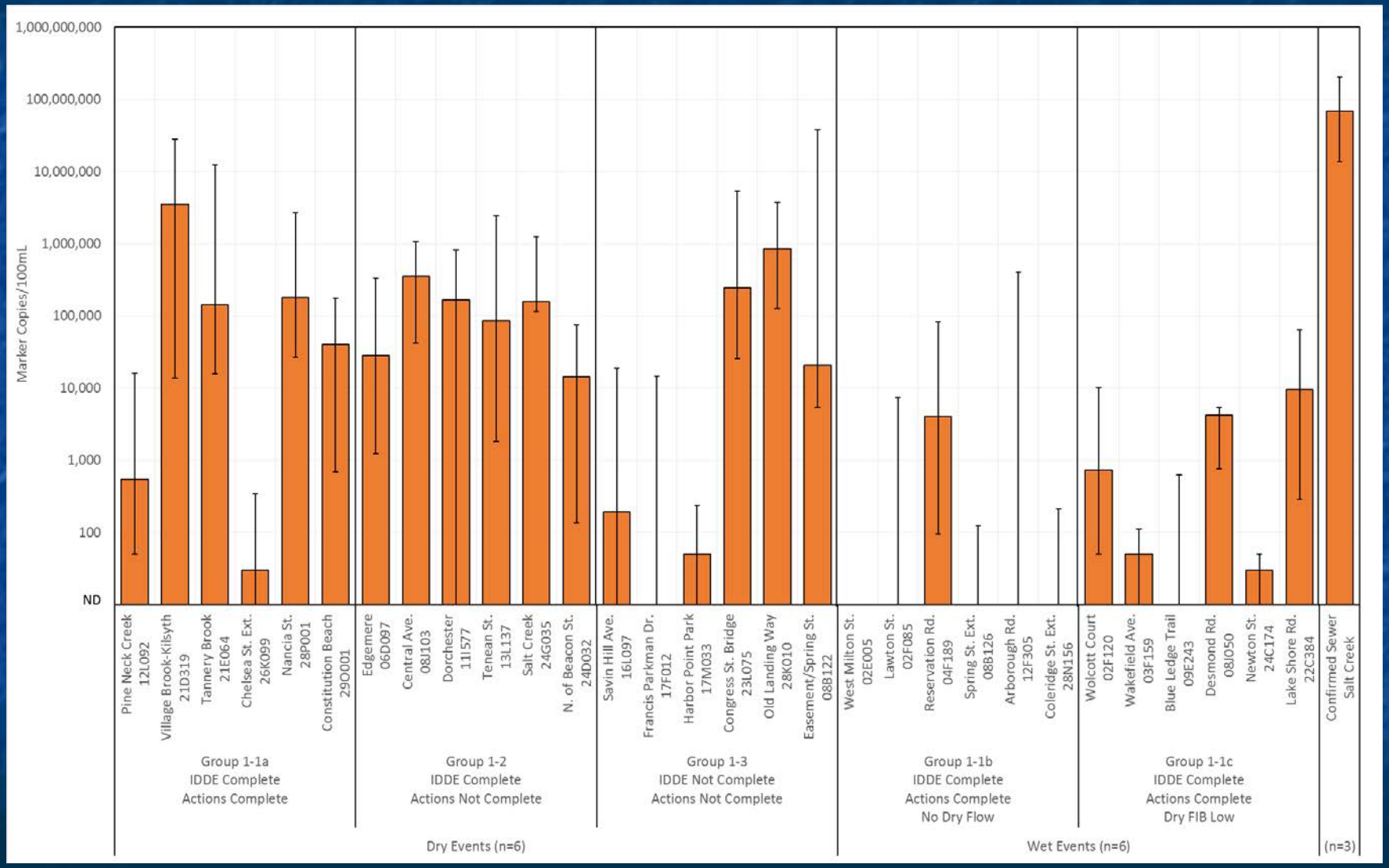
Geosyntec consultants

CDW CONSULTANTS, INC.
Civil and Environmental Engineers

Next Steps for BWSC

- Will continue using field test kits during outfall screening (required by Consent Decree)
- Will continue perform wet weather screening of outfalls (required by Consent Decree)
- Will continue using field test kits for network IDDE investigations- review existing data to determine validity of the ammonia vs. bacteria link
- Will consider sampling for FIBs during field investigation manhole inspections
- Will consider more piloting of HMs


Marker Copies/100mL
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
ND
Pine Neck Creek 12L092
Village Brook-Kilsyth 21D319
Tannery Brook 21E064
Chelsea St. Ext. 26K099
Nancia St. 28P001
Constitution Beach 29O001
Edgemere 06D097
Central Ave. 08J103
Dorchester 11I577
Tenean St. 13L137
Salt Creek 24G035
N. of Beacon St. 24D032
Savin Hill Ave. 16L097
Francis Parkman Dr. 17F012
Harbor Point Park 17M033
Congress St. Bridge 23L075
Old Landing Way 28K010
Easement/Spring St. 08B122
West Milton St. 02E005
Lawton St. 02F085
Reservation Rd. 04F189
Spring St. Ext. 08B126
Arborough Rd. 12F305
Coleridge St. Ext. 28N156
Wolcott Court 02F120
Wakefield Ave. 03F159
Blue Ledge Trail 09E243
Desmond Rd. 08J050
Newton St. 24C174
Lake Shore Rd. 22C384
Confirmed Sewer Salt Creek
Group 1-1a
IDDE Complete
Actions Complete
Group 1-2
IDDE Complete
Actions Not Complete
Group 1-3
IDDE Not Complete
Actions Not Complete
Group 1-1b
IDDE Complete
Actions Complete
No Dry Flow
Group 1-1c
IDDE Complete
Actions Complete
Dry FIB Low
Dry Events (n=6)
Wet Events (n=6)
(n=3)