Dye study of MWRA Squantum force main and Wollaston Beach storm drains in Quincy, Massachusetts

Massachusetts Water Resources Authority

Environmental Quality Department
Technical Report Series No. 95-11

Dye Study of MWRA Squantum Force Main and Wollaston Beach Storm Drains in Quincy, Massachusetts

Andrea Rex, Program Manager for Water Quality Monitoring
Kelly Coughlin, Biologist
Kevin McKenna, Staff Engineer

Sewerage Division
Massachusetts Water Resources Authority
100 First Avenue
Charlestown Navy Yard
Boston, Massachusetts 02129

July 1995

Citation:

Rex, A., K. Coughlin, and K McKenna. 1995. **Dye study of MWRA Squantum force main and Wollaston Beach storm drains in Quincy, Massachusetts.** MWRA Enviro. Quality Dept. Tech. Rpt. Series No. 95-11. Massachusetts Water Resources Authority, Boston, MA. 11 pp.

Summary

The Squantum Force Main carries wastewater under pressure from the Squantum Pump Station to the High Level Sewer in Quincy, running parallel to Wollaston Beach in Quincy. The force main is in proximity to storm drains that discharge into Quincy Bay at Wollaston Beach. The City of Quincy asked MWRA to perform a dye test to evaluate the possibility that sewage might be leaking from the Force Main and infiltrating into the Wollaston Beach storm drains. Rhodamine dye was introduced into the Force Main via the Squantum Pump Station. Samples were collected at seven storm drain outfalls and in storm drain manholes before the dye was introduced, and then three times after dye was introduced, throughout a complete tidal cycle. No dye was found in any of the storm drains, and samples collected at the High Level Sewer and at the Nut Island Treatment Plant were positive, confirming that the dye did travel through the Force Main. The results confirmed previous observations that the storm drains contain fecal coliform bacteria. The dye study did not indicate any leakage of sewage from the Force Main into the storm drains.

Introduction

Bacterial contamination of the water and resulting beach postings at Wollaston Beach in Quincy have been a concern for a number of years. Sewer and drain inspections and tests in the area draining to the beach since 1990 identified the storm drains that discharge to the beach area as sources of contamination. Inspections showed that some storm drain pipes and adjacent sewer pipes were found to be in poor structural condition, with potential for cross connections. Because the area is very low lying, tidally-influenced groundwater levels reach elevations which could permit infiltration into storm and sewer drains, and exfiltration from sewers into the storm drains.

In an effort to reduce contamination at Wollaston Beach, the City of Quincy Department of Public Works has worked to discover problems and repair pipes, manholes, and tidegates in areas of Quincy draining to six of the eight stormwater outfalls located along the beach. Unfortunately, despite these efforts, significant bacterial contamination in several of these six storm drains remains (Weston and Sampson 1995).

As part of the process of ruling out other potential sources of contamination to the storm drains, the City of Quincy requested that MWRA inspect and test the Squantum Force Main. This is a pressurized force main that carries wastewater from the Squantum Pump Station, located on Newland Street near the intersection of Huckins Avenue and East Squantum Street, to the High Level Sewer at Sea Street. The force main runs through the saltmarsh parallel to East Squantum Street. It then runs parallel to Quincy Shore Drive along Wollaston Beach to the

intersection of Shore Avenue. From this point it follows residential streets to join the High Level Sewer at Sea Street. The portion of the force main which parallels Wollaston Beach is in proximity to storm drains that discharge into Quincy Bay. (Figure 1). A portion of the Force Main, from the Squantum Pump Station to the intersection of East Squantum Street and Quincy Shore Drive, was recently rehabilitated.

The City of Quincy requested that MWRA perform a dye test of the Force Main to determine if sewage might be leaking from the Force Main into any of the beach storm drains. This report describes a dye test of the Force Main and the Wollaston Beach storm drains carried out by MWRA on June 1 and 2, 1995. Rhodamine dye was introduced into the Force Main, and the storm drains were tested for seepage of dye into the drains. If leakage was taking place from the Force Main to the storm drains, it was expected that high fecal coliform counts would be found in the storm drain together with rhodamine dye.

Methods

Weather conditions

Weather on June 1 and June 2, 1995 was hot and dry.

Sample locations

Eight storm drains discharge into Quincy Bay along Wollaston Beach in Quincy. The storm drains are numbered #1- #8 (Figure 1). Sampling locations were at the outfalls for seven drains (#1 was not included in the study because it has only one residence tributary to the drain, and is distant from the bathing area). Drains # 4, #5 and #8 had manholes seaward of the vicinity of the Force Main, and these manholes were also sampled. In addition to the storm drains, samples were collected in the pump station wet well, in the High Level Sewer downstream of the intersection with the Force Main, and in Nut Island influent. In addition to the dye measurements, fecal coliform measurements were done, focusing on storm drain #4 (Milton St.) because Quincy had made many structural improvements to the drainage area; and on storm drain #8 (The Strand), because this drainage area has known potential for cross-connections.

Sampling schedule

The travel time of sewage from the Squantum Pump Station wetwell to the High Level Sewer was calculated to be five pump cycles or approximately 14 hours. The sampling schedule was designed so that samples were collected over a period of 13

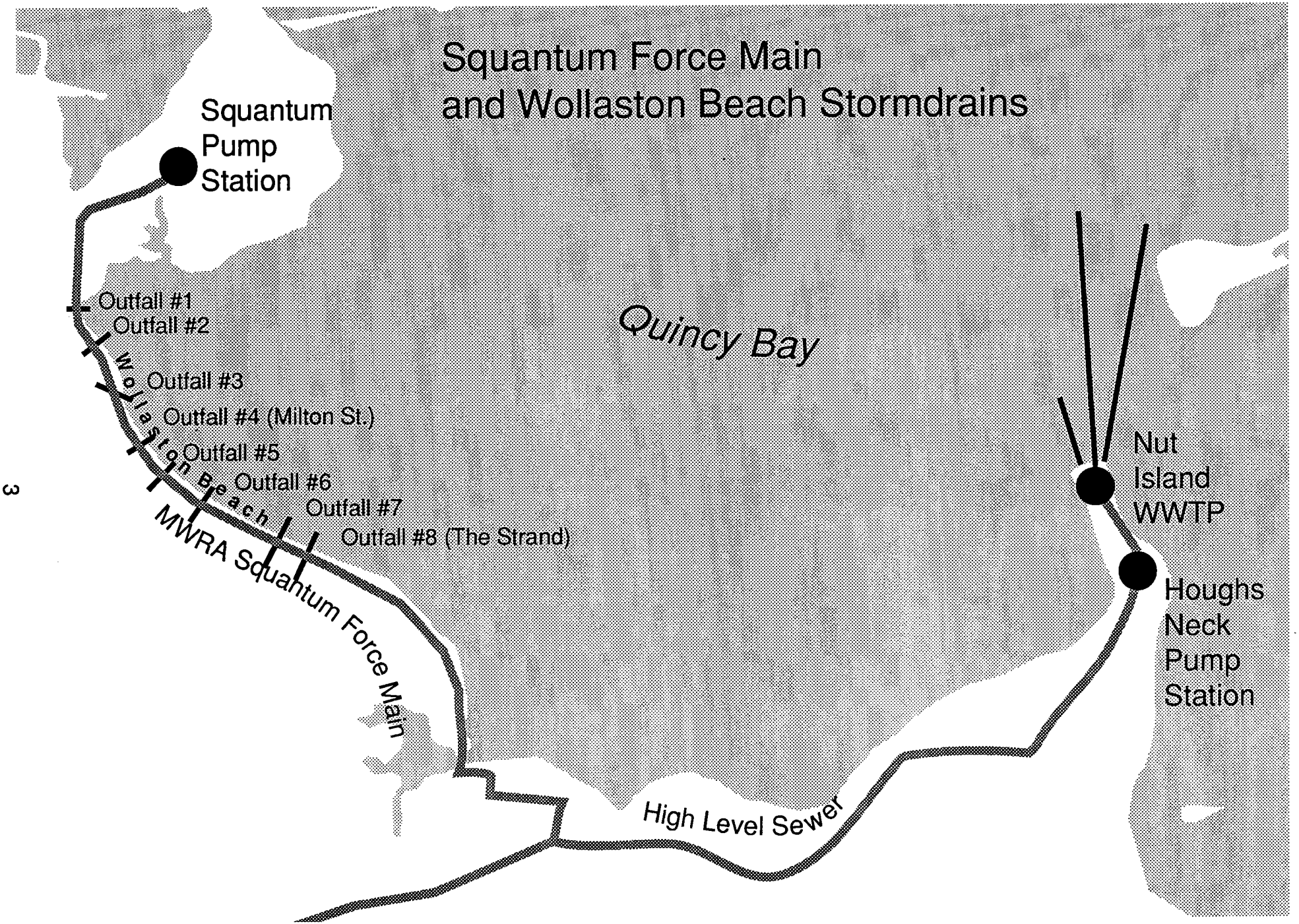

Figure 1. Location of local storm drain outfalls along Wollaston Beach, and MWRA's Squantum Force Main. The Force Main carries sewage under pressure from Squantum to the High Level Sewer. (Outfalls not drawn to scale.)

hours on day one, encompassing an entire tidal cycle. Each storm drain was sampled three times during day one on (June 1, 1995); first before dye was added in order to make background fluorescence measurements, and twice after the dye was added. Sampling was completed at 19:00. A last round of sampling at each outfall was done the next day (June 2, 1995), in order to detect any slow seeping of dye from the soil surrounding the Force Main that may have occurred.

Dye addition

We calculated that one gallon of 20% rhodamine added to the wet well would yield a concentration permitting detection after 100-fold to 1,000-fold dilution of the wastewater in the Force Main.[1]

Dye was added to the wet well at the Squantum Pump Station during two sequential pump cycles. Each pump cycle delivers approximately 160,000 gallons of sewage from the wet well to the Squantum Force Main. Approximately one gallon of dye was added to the wet well at 5:00 AM; the pumps activated at 7:40 am. A second

---

1 The average counts of fecal coliform in the storm drains from past studies were compared to average counts of fecal coliform in raw wastewater to estimate how much dilution of sewage would account for the observed bacteria counts, hypothesizing that the Squantum Force Main was the source of all the fecal coliform in the storm sewer.

Assumptions: Geometric mean fecal coliform count in Quincy's storm drains $\approx$ 50,000/100 ml (Weston and Sampson 1995), geometric mean of fecal coliform in raw wastewater $\approx$ 5,000,000/100 ml.

Therefore if all the fecal coliform in storm drains were derived from leaks from the Force Main, the storm drain count indicates an average dilution of 100-fold.

The laboratory detection limit for rhodamine = $3 \cdot 10^{-1}$ µg dye/L; thus the concentration in the Force Main should be at least $3 \cdot 10^{1}$ µg dye/L.

1g = 10^9 µg, 1 gal = 3.785 L;

Rhodamine dye = 20% rhodamine = $(2 \cdot 10^{-1}$ g/L) $(1 \cdot 10^9$ µg/g) = $2 \cdot 10^8$ µg dye/L;
($2 \cdot 10^8$ µg dye/L) (3.785 L/gal) = $7.6 \cdot 10^8$ µg dye/gal

Volume in pump station wet well $\approx 1.6 \cdot 10^5$ gallons

$7.6 \cdot 10^8$ µg dye/$1.6 \cdot 10^5$ gallons sewage
$\approx 4.7 \cdot 10^3$ µg dye/gallon sewage in wet well/3.8 L/gal
$\approx 1.25 \cdot 10^3$ µg dye/L sewage in wet well

After 1,000-fold dilution, the dye concentration would be 1.25 µg dye/L, a factor of four times the M. D. L.

The ratio of average fecal coliform counts in the wet well to the counts detected in the receiving water varied. We assumed that this ratio roughly reflected the likelihood of dye being detected in the receiving water if it had leaked from the Force Main together with the bacteria. The more similar the fecal coliform counts in the storm drains were to the counts in the Force Main, presumably the less dilution had occurred (if the Force Main were the source of the bacteria).

gallon of dye was added to the wet well at 9:00 AM; the pumps activated again at 11:30 AM.

Sample collection

Samples were collected from the wet well using a clean bucket, and from the manholes using an "alpha water bottle" (Wildco, Inc.); and transferred to sterile sample bottles. The sampler was rinsed in clean water between each sample. Samples from the storm drain outfalls were collected directly into sterile sample bottles either by wading to the outfall or from a small motor boat. All samples were immediately stored on ice, and delivered to the laboratory within 4 h of collection.

Analytical Methods

Rhodamine dye Samples were analyzed within 24 hours. The fluorometric method was used (Turner Model 450-000 Digital Fluorometer with excitation filter NB 540, emission filter SC 585). The dynamic range of the test was 0.5 - 50 µg/L for turbidities between 0 and 65 NTU. Fluorescence readings were compared to standard curves calculated for sewage or seawater as appropriate, and measurements were corrected for turbidity.

Fecal coliform Samples for fecal coliform analysis were refrigerated until processing. All samples were analyzed within 6 h of collection, except samples collected after 4 PM. Those samples were refrigerated and processed early the next morning. The membrane filtration method, using mFC agar with rosolic acid addition (Standard Methods, 9222 D) was used to enumerate fecal coliform.

Results and Discussion

Dye measurements.

All samples were analyzed for rhodamine dye concentration, shown in Table 1. "Background" dye measurements ranged from not detected (<0.300 µg/L), to 1.81 µg/L, with a standard error of $\pm$ 0.3 µg/L. In order for two samples to be considered significantly different, the difference between the fluorescence measurements would have to be > 0.6 µg/L. The higher background measurements are probably due to high turbidity from the stormwater, and algal fluorescence in the seawater. The standard curves for rhodamine dye measurements were calculated for wastewater or seawater. Some of the samples were probably a mixture of the seawater and wastewater, which would increase the measurement error.

Dye measurements from samples collected from the Squantum Pump Station wet well access shaft were much lower than predicted. It was impossible to actually sample from the wet well itself, and we assume that the low dye concentration

Table 1. Results of rhodamine dye and fecal coliform sampling from the Squantum Force Main/Wollaston Beach experiment, June 1-2, 1995.

LOCATION DESCRIPTION	TIME	FECAL COLIFORM /100 ML	RHODAMINE (+ 0.3µg/L)	STAGE OF TIDE	NOTE	LOCATION OF DYE
1-Jun-95						
Squantum pump station wet well	4:45	1,850,000	<0.300	low ebb	background	NA
Squantum pump station wet well	5:00	240000	11.4	low ebb	after dye added	Pump station
Outfall #2 Ocean St.	7:00	270	<0.300	low ebb	background	Dyed "slug" did not yet reach the vicinity of the storm drain being sampled.
Outfall #3 Appleton St.	7:30	2500	<0.300	low		
Outfall #4 Milton St. Manhole 1, nearer road	8:00	49000	<0.300	low		
Outfall #4 Milton St. Manhole 2, nearer water	8:10	90000	0.4*	low		
Outfall #4 Milton St.	8:20	74000	0.38*	low		
Outfall #5 Carle St. Manhole	8:30	2100	1.81*	low		
Outfall #5 Carle St.	8:45	68000	<0.300	low		
Outfall #6 Beach St.	9:00	30	<0.300	low		
Outfall #7 Sachem St.	9:30	1200	<0.300	low flood		
Outfall #8 "The Strand", Manhole	10:00	160000	<0.300	low flood		
Outfall #8 "The Strand"	10:15	240000	<0.300	low flood		
Squantum pump station wet well	8:50	7900000	9.70	low flood	after first dye addition	Pump station
Squantum pump station wet well	9:20	5100000	26.50	low flood	after second dye addition	Pump station
Outfall #2 Ocean St.	13:00	not analyzed	<0.300	high flood		Dye present in Force Main in vicinity of sampled storm drains.
Outfall #3 Appleton St.	13:30	not analyzed	<0.300	high		
Outfall #4 Milton St. Manhole 1, nearer road	14:00	29000	<0.300	high		
Outfall #4 Milton St. Manhole 2, nearer water	14:10	12000	<0.300	high		
Outfall #4 Milton St.	14:20	130	<0.300	high		
Outfall #5 Carle St. Manhole	14:30	not analyzed	<0.300	high		
Outfall #5 Carle St.	14:45	not analyzed	<0.300	high		
Outfall #6 Beach St.	15:00	not analyzed	<0.300	high		
Outfall #7 Sachem St.	15:30	not analyzed	<0.300	high ebb		
Outfall #8 "The Strand", Manhole	16:00	130000	<0.300	high ebb		
Outfall #8 "The Strand"	16:30	30	<0.300	high ebb		
High Level Sewer, Sea St	16:45	4700000	1.04*	high ebb		Dye not present

Table 1, continued. Results of rhodamine dye ...

LOCATION DESCRIPTION	TIME	FECAL COLIFORM /100 ML	RHODAMINE (+ 0.3µg/L)	STAGE OF TIDE	NOTE	LOCATION OF DYE
1-Jun-95						
Outfall #2 Ocean St.	16:00	not analyzed	<0.300	high ebb	after dye added	Dye present in Force Main in vicinity of sampled storm drains.
Outfall #3 Appleton St.	16:30	not analyzed	<0.300	high ebb		
Outfall #4 Milton St. Manhole 1, nearer road	17:00	64000	0.55*	high ebb		
Outfall #4 Milton St. Manhole 2, nearer water	17:10	42000	0.6*	high ebb		
Outfall #4 Milton St.	17:20	23700	0.47*	low ebb		
Outfall #5 Carle St. Manhole	17:30	not analyzed	<0.300	low ebb		
Outfall #5 Carle St.	17:45	not analyzed	<0.300	low ebb		
Outfall #6 Beach St.	18:00	not analyzed	<0.300	low ebb		
Outfall #7 Sachem St.	18:30	26000	<0.300	low ebb		
Outfall #8 "The Strand", Manhole	19:00	260000	<0.300	low ebb		
Outfall #8 "The Strand"	19:00	180000	<0.300	low ebb		
Nut Island influent channel, composite sample,	6/1-6/2	not analyzed	3.889			

Table 1, continued. Results of rhodamine dye ...

LOCATION DESCRIPTION	TIME	FECAL COLIFORM /100 ML	RHODAMINE (+ 0.3µg/L)	STAGE OF TIDE	NOTE	LOCATION OF DYE
2-Jun-95						
Outfall #2 Ocean St.	8:00	930	<0.300	low	after dye added	Dyed "slug" had passed beyond the locations of these storm drains. Testing for any delayed seepage into drains.
Outfall #3 Appleton St.	8:20	10100	<0.300	low		
Outfall #4 Milton St. Manhole 1, nearer road	8:40	180000	<0.300	low		
Outfall #4 Milton St. Manhole 2, nearer water	9:00	139000	0.41*	low		
Outfall #4 Milton St.	9:20	130000	<0.300	low		
Outfall #5 Carle St. Manhole	9:40	9800	1.89*	low		
Outfall #5 Carle St.	10:00	780	<0.300	low flood		
Outfall #6 Beach St.	10:20	70	<0.300	low flood		
Outfall #7 Sachem St.	10:40	9200	<0.300	low flood		
Outfall #8 "The Strand", Manhole	11:00	130000	<0.300	low flood		
Outfall #8 "The Strand"	11:20	480000	<0.300	low flood		
High Level Sewer, Sea St	9:40	not analyzed	25.8	low		

*This measurement is not significantly different from background; interference due to turbidity and algae present in natural waters

measured was due to poor mixing at the sampling site. We are confident that adequate dye was added, because the dye concentration measured in the High Level Sewer downstream of the Force Main, was 25.8 μg/L (High Level Sewer flow rate ≈ 100 MGD, Force Main flow rate ≈ 1 MGD, approximately 100-fold dilution). This concentration in the High Level Sewer is consistent with a concentration in the Force Main of approximately 2600 μg/L, on the same order as predicted.

The only locations showing measurements higher than background were the wet well after dye was added, the High Level Sewer, and the Nut Island Treatment Plant.

Fecal coliform counts

Fecal coliform counts were highly variable both in the wastewater samples and in the receiving water samples. Samples collected at the pump station wet well ranged from 240,000 colonies/100 ml to 7,900,000 colonies/100 ml. The geometric mean = 2,050,000 colonies/100 ml.

At the storm drains, fecal coliform measurements were focused on the Milton Street storm drain (outfall #4) and the "Strand" area (outfall #8), but all sites were sampled at least once. Table 2 shows that in the receiving water at the storm drain outfalls, the lowest counts were at outfalls #2 and #6, and the highest average counts were at outfalls #4 and #8. Bacteria counts varied greatly at #4 and #8 with tidal cycle: counts were three to four orders of magnitude higher at low tide than high tide.

At outfall #8, the average fecal coliform count was approximately 10-fold less than in the Force Main, and at outfall #4 the count was about 40-fold less than in the Force Main. We calculated that the dye was present in the Force Main at a level 1,000-fold higher than the detection limit. If a significant portion of the fecal coliform bacteria found at the storm drains had been derived from the Force Main, rhodamine dye would also have been detected.

Conclusions

- There was no evidence of leaking from the Squantum Force Main, or of infiltration of dye from the Force Main into any of the stormdrains at Wollaston Beach.

- Measured concentrations of fecal coliform were highest at outfalls #4 and # 8, and were in the range of 1% to 10% of average fecal coliform counts found in raw sewage. Fecal coliform counts were dramatically higher at low tide than high tide, consistent with discharge from the drains on the outgoing tide.

Table 2. Fecal coliform counts/100 ml at Wollaston Beach storm drain outfalls.

Location	High Tide	Low Tide*
Outfall #2 Ocean St.	nd	500
Outfall #3 Appleton St.	nd	5,000
Outfall #4 Milton St.	130	61,000
Outfall #5 Carle St.	nd	7,300
Outfall #6 Beach St.	nd	50
Outfall #7 Sachem St.	nd	6,600
Outfall #8 "The Strand"	30	275,000

*Geometric mean of two or three measurements

Acknowledgements

We appreciate the assistance of Anne Canaday, Joseph Del Greco, Tom Gibbons, Mariya Gofshteyn, Joseph Iannuzzo, Kenneth Keay, Yuban Malla, Richard Mandell, Jack Porcello, Rob Rabideau, and Lisa Wong.

References

Greenberg, A. E., L. S. Clesceri, and A. D. Eaton. 1992. Standard Methods for the Examination of Water and Wastewater. 18th Edition. American Public Health Association, Washington, D. C.

Weston and Sampson Engineers, Inc. March 1995. City of Quincy, MA. Wollaston Beach: Bathing Water Quality Improvement Program Summary Report on Actions to Date.

The Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Charlestown, MA 02129
(617) 242-6000