Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO 07-79

FECAL COLIFORM DENSITIES IN THE CHICAGO WATERWAY SYSTEM DURING DRY AND WET WEATHER 2004–2006

December 2007

Metropolitan Water Reclamation District of Greater Chicago
100 East Erie Street Chicago, IL 60611-2803 (312) 751-5600

FECAL COLIFORM DENSITIES IN THE CHICAGO WATERWAY SYSTEM DURING DRY AND WET WEATHER 2004–2006

by

Samuel G. Dennison
Biologist IV

Geeta K. Rijal
Microbiologist IV

Thomas C. Granato
Assistant Director of Research and Development

Research and Development Department
Louis Kollias, Director

December 2007

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

ACKNOWLEDGEMENT

Thanks are extended to the Industrial Waste Division for collecting water samples for this study and to the Analytical Microbiology and Biomonitoring Section of the Environmental Monitoring and Research Division for analyzing the samples for fecal coliform bacteria.

Thanks to Mr. Michael Sopcak, Biologist III, for the preparation of many of the figures.

Special thanks to Ms. Joan Scrima, Principal Office Support Specialist, for her assistance in formatting and organizing this report.

DISCLAIMER

Mention of proprietary equipment, computer software, or chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

In 2004 the Metropolitan Water Reclamation District of Greater Chicago (District) undertook a three-year study to predict the die-off of fecal coliform (FC) in the receiving streams downstream of the North Side and Calumet Water Reclamation Plants (WRPs). These streams included the North Shore Channel and the North Branch of the Chicago River (North area), and the Little Calumet River and Calumet-Sag Channel (South area), respectively. Currently the effluents of these WRPs are not disinfected. Fecal coliform densities upstream and downstream of the North Side and the Calumet WRPs were measured during dry and wet weather including light rain conditions in which no pumping station discharge occurred and heavy rain conditions in which pumping station discharge did occur.

The purpose of this study was to assess from the collected data whether disinfection of the effluents from these WRPs would significantly reduce the FC load in the receiving streams and result in compliance with the proposed Illinois Environmental Protection Agency (IEPA) effluent standard of no more than 400 cfu/100 mL for discharges to the Chicago Waterway System from March 1 through November 30 (IEPA, 2007).

Fecal coliform densities downstream of these WRPs were shown to die off at an exponential rate, and FC densities at specific locations downstream of these WRPs were predicted using exponential equations calculated from the FC data collected. Predicted dry weather FC values were subtracted from the predicted wet weather FC values to estimate FC densities that might occur in the waterways during wet weather if disinfection eliminated the FC burden in the WRP outfalls.

Based on the analysis of data collected in this study, we have concluded the following:

1. Fecal coliform densities in the North Shore Channel upstream of the North Side WRP at Oakton Street were greater than 400 cfu/100 mL 88 percent of the time during heavy rainfalls, 86 percent of the time during light rainfall periods, and 45 percent of the time during dry weather periods. Fecal coliform densities were as high as 9,800 cfu/100 mL, 42,000 cfu/100 mL, and 470,000 cfu/100 mL during dry weather, light rain, and heavy rain periods, respectively.

2. Fecal coliform densities in the North Branch of the Chicago River at Albany Avenue, a downstream tributary to the North Side WRP effluent outfall, were greater than 400 cfu/100 mL 97 percent of the time during heavy rainfall periods, 93 percent of the time during light rainfall periods, and 77 percent of the time during dry weather periods. Fecal coliform densities were as high as 3,500 cfu/100 mL, 100,000 cfu/100 mL, and 360,000 cfu/100 mL during dry weather, light rain, and heavy rain periods, respectively.

3. Fecal coliform densities in the Little Calumet River upstream of the Calumet WRP at Indiana Avenue were greater than 400 cfu/100 mL 53 percent of the time during heavy rainfall periods, 15 percent of the time during light rainfall

periods, and 8 percent of the time during dry weather periods. Fecal coliform densities were as high as 490 cfu/100 mL, 7,200 cfu/100 mL, and 13,000 cfu/100 mL during dry weather, light rain, and heavy rain periods, respectively.

4. Fecal coliform densities in the Little Calumet River at Ashland Avenue, a downstream tributary to the Calumet WRP effluent outfall were greater than 400 cfu/100 mL 95 percent of the time during heavy rainfall periods, 90 percent of the time during light rainfall periods, and 60 percent of the time during dry weather periods. Fecal coliform densities were as high as 3,600 cfu/100 mL, 33,000 cfu/100 mL, and 76,000 cfu/100 mL during dry weather, light rain, and heavy rain periods, respectively.

5. Climatological data collected during the three-year study period indicate that rainfall occurs on approximately 145 days, about 40 percent, each year. The elevated FC densities that occurred during wet weather periods often persisted for 48 hours or longer suggesting that dry weather conditions, when effluent disinfection would be most effective, occur in the waterways less than 50 percent of the time. During these dry weather times upstream and tributary flows are often contributing FC densities greater than 400 cfu/100 mL.

6. Analysis of the collected data indicated that FC densities less than the proposed IEPA effluent standard were predicted to occur 16 miles and 8 miles downstream of the North Side and Calumet WRPs, respectively, during dry weather under current conditions with no effluent disinfection. It is not clear the extent to which this would be improved were the effluents from these WRPs to be disinfected given the FC densities that were determined to exist upstream of the WRPs and in significant downstream tributaries.

7. Fecal coliform densities less than the proposed IEPA effluent standard were predicted to occur at North area stations 22 and 108 miles downstream of the North Side WRP during light rain and heavy rain, respectively. The analysis predicted that disinfection of the North Side WRP effluent would only marginally improve the microbiological water quality downstream of the North Side WRP in that the proposed IEPA effluent standard could be met at a point 10 miles downstream of the WRP during light rain and the standard could not be met during heavy rain.

8. Fecal coliform densities less than the proposed IEPA effluent standard were predicted to occur at South area stations 11 and 70 miles downstream of the Calumet WRP during light rain and heavy rain, respectively. The analysis predicted that disinfection of the Calumet WRP effluent would only marginally improve the microbiological water quality downstream of the Calumet WRP in that the proposed IEPA effluent standard could be met at 8 miles downstream of the WRP during light rain and the standard could not be met during heavy rain.

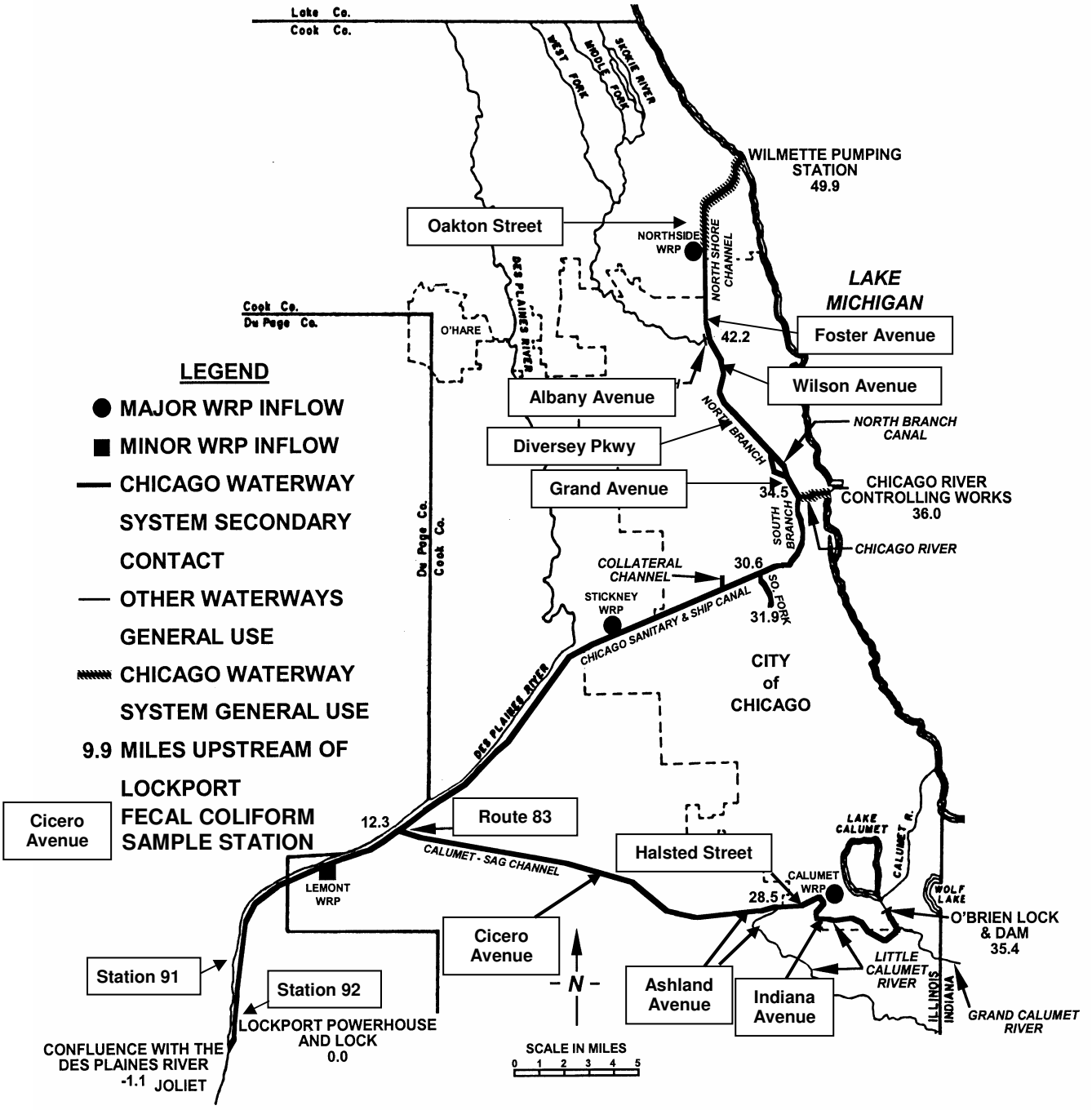
This study indicates that disinfection of the North Side and Calumet WRP effluents during wet weather would not improve the microbiological water quality downstream of these WRPs in terms of compliance with the proposed IEPA effluent standard.

Since measurable rainfall occurred approximately 40 percent of the year, including the period March–November when the proposed IEPA effluent standard would be in effect, disinfection of WRP effluents would be ineffective for a substantial portion of the year, when wet weather is occurring.

INTRODUCTION

This study was initiated in 2004 to determine the densities and die-off of FC bacteria in District waterways relative to issues raised by the Chicago Area Waterways Use Attainability Analysis (CDM, 2004). An interim report was completed for that year (Dennison and Zmuda, 2005). The original plan was for this to be a two-year study; however, since 2005 was a very dry year with only one documented heavy rain event, the study was continued through 2006. Fecal coliform density was measured at each of 12 locations in two segments of the Chicago Waterway System, including the North area waterways (North Shore Channel and North Branch Chicago River) and South area waterways (Little Calumet River and Calumet-Sag Channel). Sample stations are shown in Figure 1.

FIGURE 1: CHICAGO WATERWAY SYSTEM SAMPLE STATIONS FOR FECAL COLIFORM DENSITY STUDY



MATERIALS AND METHODS

Water samples were collected twice a month between April and December 2004 through 2006. The Industrial Waste Division (IWD) collected water samples for FC at the North area stations on the first Tuesday and second Monday of each month and at the South area stations on the third Tuesday and fourth Monday of each month. IWD also collected water samples for FC density each day, for a maximum of three days, following any rain event sufficient to cause an overflow at the North Side Pumping Station (for North area stations) or at the 122nd Street, 125th Street, or 95th Street Pumping Stations (for South area stations). No samples were collected on weekends or holidays. Fecal coliform density data from routine bridge run samples collected during January through March 2005 and 2006 at the North and South area stations were also included as dry weather data in this study. Rain gauge data were obtained from the Maintenance and Operations Department.

Water samples were collected as grab samples from mid-channel at a 1m depth and were analyzed for FC density by the Analytical Microbiology Section of the Environmental Monitoring and Research Division using the FC density membrane filter procedure (SM 9222 D, SM 18th ed., [APHA, 1992]).

Equations for FC die-off curves, and corresponding R^2 values, were formulated using the exponential curve fitting function of the computer program Microsoft Excel®. Statistical analysis was performed using GraphPad Prism® version 4.03 for Windows (GraphPad Software, San Diego, California, USA www.graphpad.com). All decisions of statistical significance were made using the 0.05 level of probability.

RESULTS AND DISCUSSION

Rainfall recorded at rain gauge stations in the North and South areas during 2004, 2005, and 2006 are summarized in Table 1. In general, measurable rainfall occurred approximately 40 percent of the year; specifically 39.2 percent for the entire year and 39.7 percent for the March–November period.

Results of FC densities are shown for each station in the North area in Figures 2–7 and in the South area in Figures 8–13. Fecal coliform density data are expressed as colony forming units (cfu) per 100 mL. Certain patterns are able to be seen from the graphs in these figures. For example, the station located upstream of the North Side WRP at Oakton Street (Figure 2) generally had FC values distributed at higher densities than at the station located upstream of the Calumet WRP at Indiana Avenue (Figure 8) with the majority of FC concentrations being much greater than the proposed IEPA effluent standard for the North Side WRP of 400 cfu/100 mL. Fecal coliform densities at Albany Avenue on the North Branch of the Chicago River, which is a downstream tributary to the outfall from the North Side WRP, were usually far above 400 cfu/100 mL (Figure 4) as were FC densities at Ashland Avenue on the Little Calumet River, which is a downstream tributary to the outfall from the Calumet WRP (Figure 10). Also, the FC values at Route 83 were generally lower than at the other South area stations downstream of the Calumet WRP.

Trends in Fecal Coliform Densities with Rainfall

In order to determine trends in FC densities associated with rainfall and rates of FC density die-off during dry and wet weather, grouping of FC values within three intensities of rainfall were decided upon. These groups were named: heavy rain, light rain, and dry weather (no rain). A "heavy rain" was defined as rainfall that exceeded the capacity of the Deep Tunnel and resulted in a discharge of combined sewer overflow (CSO) from a major District pumping station to a receiving stream. In the North area, such a CSO discharge entered the North Branch of the Chicago River from the North Branch Pumping Station and in the South area the CSO entered the Calumet-Sag Channel from the 125th Street Pumping Station. A "light rain" sample was defined as having been collected on any day when measurable rainfall occurred on that day, or one or two days prior, in either the North or South area. A "dry weather" sample was defined as having been collected on any day on which no measurable rainfall occurred, including none two days prior and one day after, the day on which a routine FC sample was collected. As shown in Table 2, in the North area, heavy rains averaged 0.5 inches, with a maximum of 2.2 inches. Light rains averaged 0.1 inches, with a maximum of 0.4 inches. In the South area, heavy rains averaged 0.7 inches, with a maximum of 3.1 inches. Light rains averaged 0.3 inches, with a maximum of 0.8 inches.

Individual dry weather and wet weather (heavy and light rain) rainfall and FC density measurements for these groupings are given in Appendix Table AI-1 for the North area stations and Appendix Table AI-2 for the South area stations. Summaries of the FC density values for each rainfall group are listed in Table 3.

TABLE 1: RAINFALL RECORDED AT NORTH AND SOUTH AREA RAIN GAUGE STATIONS DURING 2004, 2005, AND 2006

Rain Gauge Stations	Year	Rain Measurement Period	No. of Days Gauges in Operation	No. of Days Rainfall Occurred	Percent of Days Rainfall Occurred
North Side WRP or North Branch Pumping Station	2004	Entire Year	364	141	38.7
		March-November	274	111	40.5
	2005	Entire Year	365	135	37.0
		March-November	275	92	33.5
	2006	Entire Year	364	162	44.5
		March-November	274	126	46.0
Total for	**2004-2006**	**Entire Year**	**1,093**	**438**	**40.1**
		March-November	**823**	**329**	**40.0**
Calumet WRP or Melvina Pumping Station	2004	Entire Year	364	139	38.2
		March-November	274	115	42.0
	2005	Entire Year	365	124	34.0
		March-November	275	84	30.5
	2006	Entire Year	364	157	43.1
		March-November	274	126	46.0
Total for	**2004-2006**	**Entire Year**	**1,093**	**420**	**38.4**
		March-November	**823**	**325**	**39.5**

FIGURE 2: FECAL COLIFORM BACTERIA AT OAKTON STREET ON THE NORTH SHORE CHANNEL DURING THE YEARS 2004, 2005, AND 2006

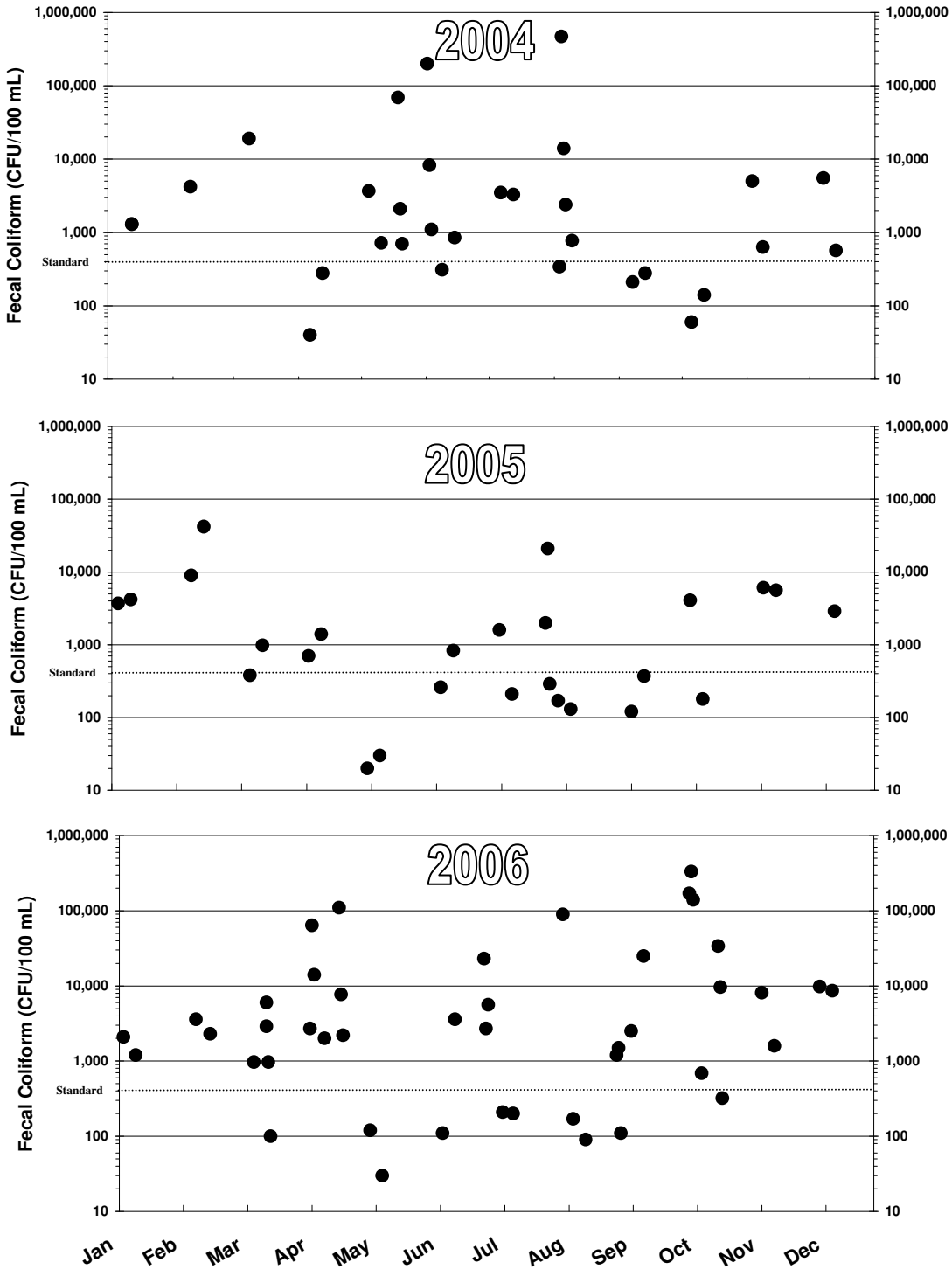


FIGURE 3: FECAL COLIFORM BACTERIA AT FOSTER AVENUE ON THE NORTH SHORE CHANNEL DURING THE YEARS 2004, 2005, AND 2006

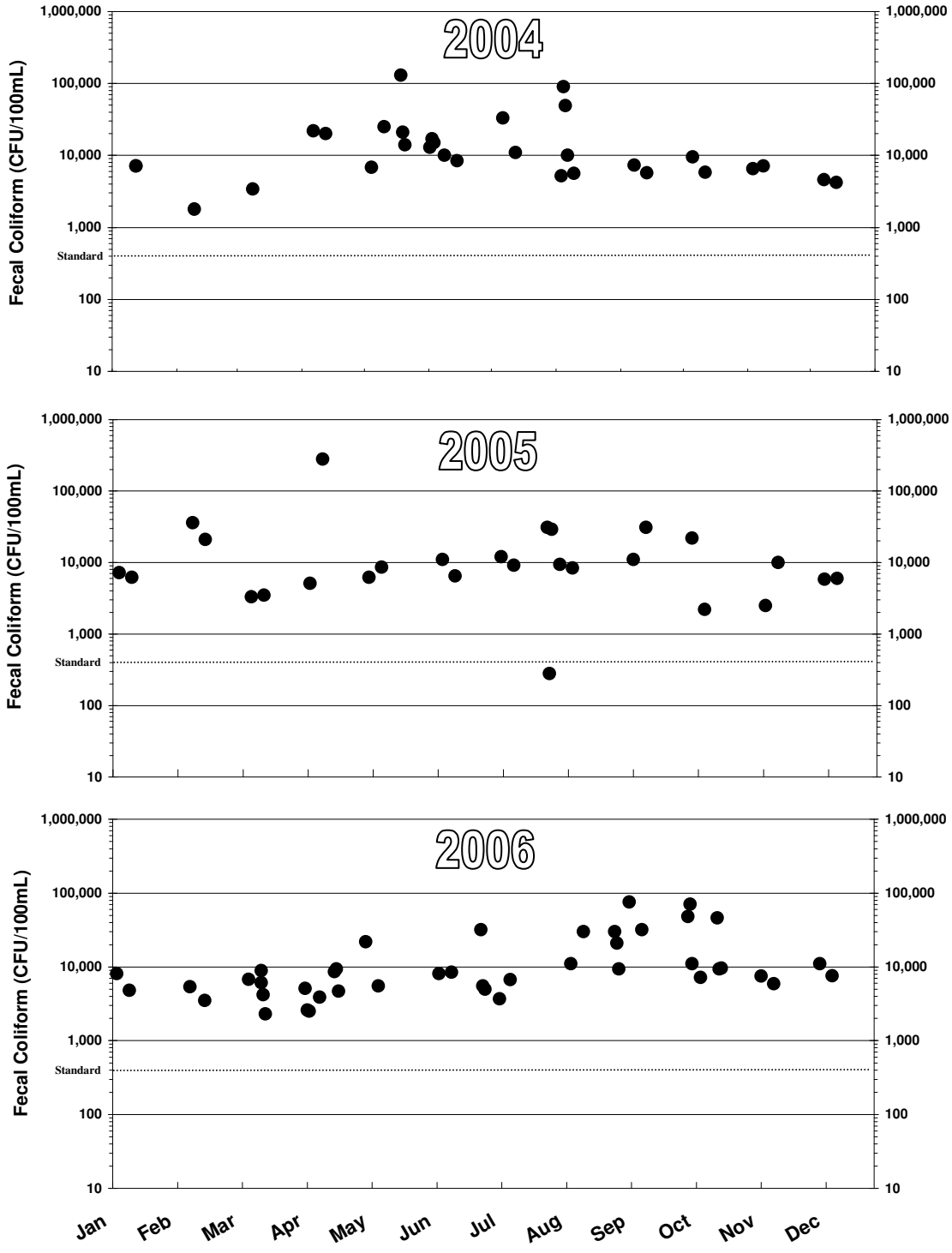


FIGURE 4: FECAL COLIFORM BACTERIA AT ALBANY AVENUE ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

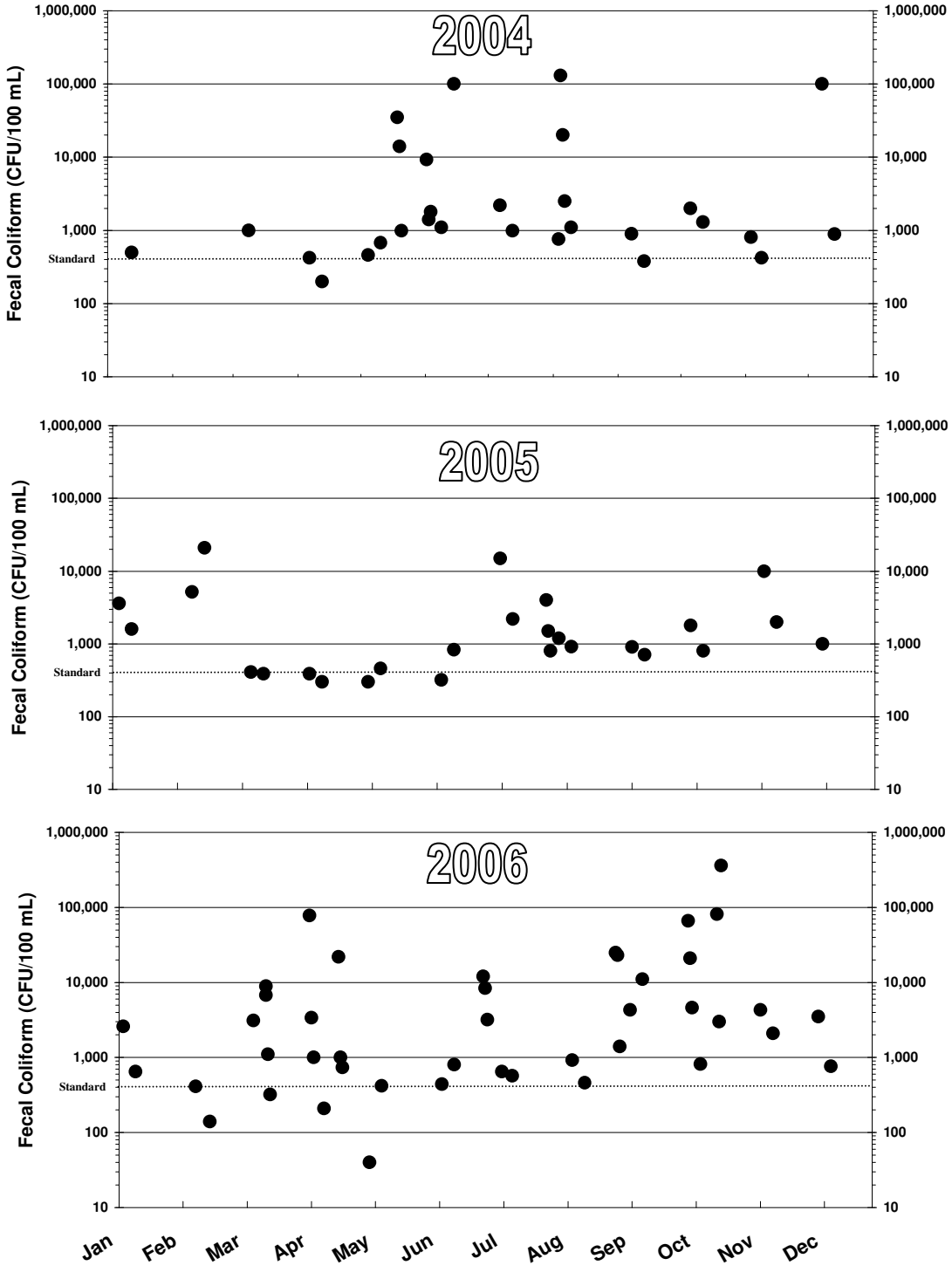


FIGURE 5: FECAL COLIFORM BACTERIA AT WILSON AVENUE ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

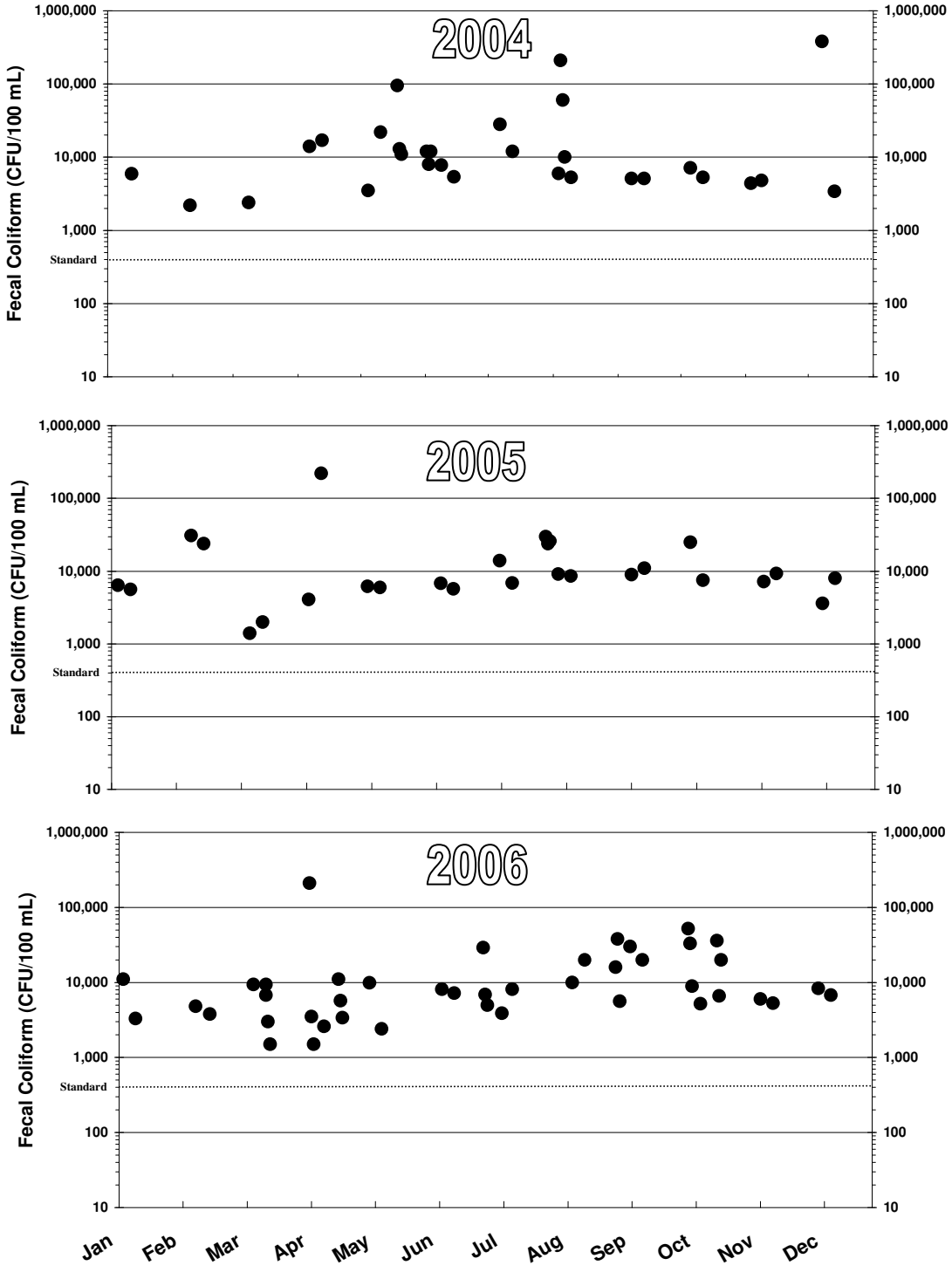


FIGURE 6: FECAL COLIFORM BACTERIA AT DIVERSEY PARKWAY ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

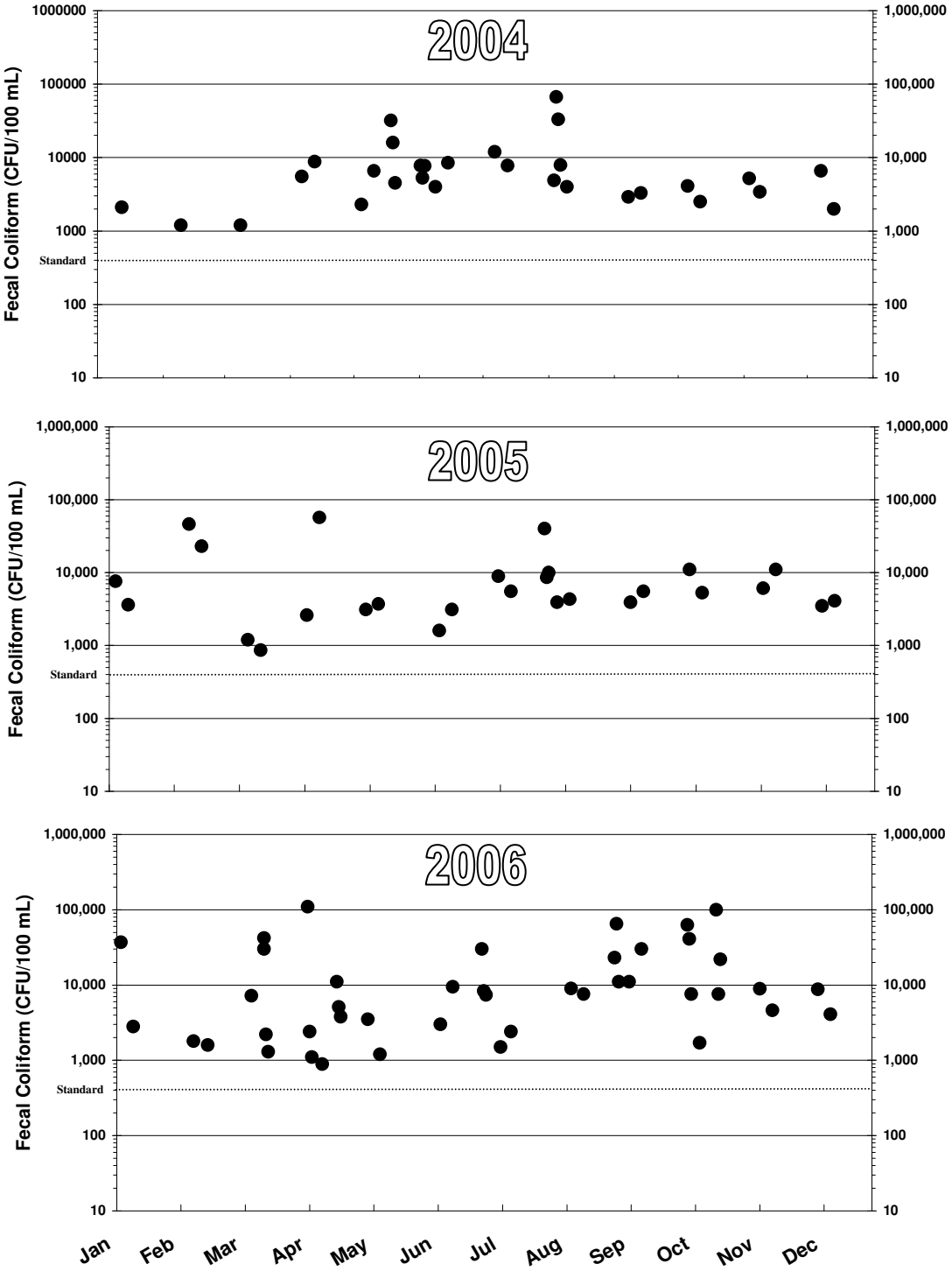


FIGURE 7: FECAL COLIFORM BACTERIA AT GRAND AVENUE ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

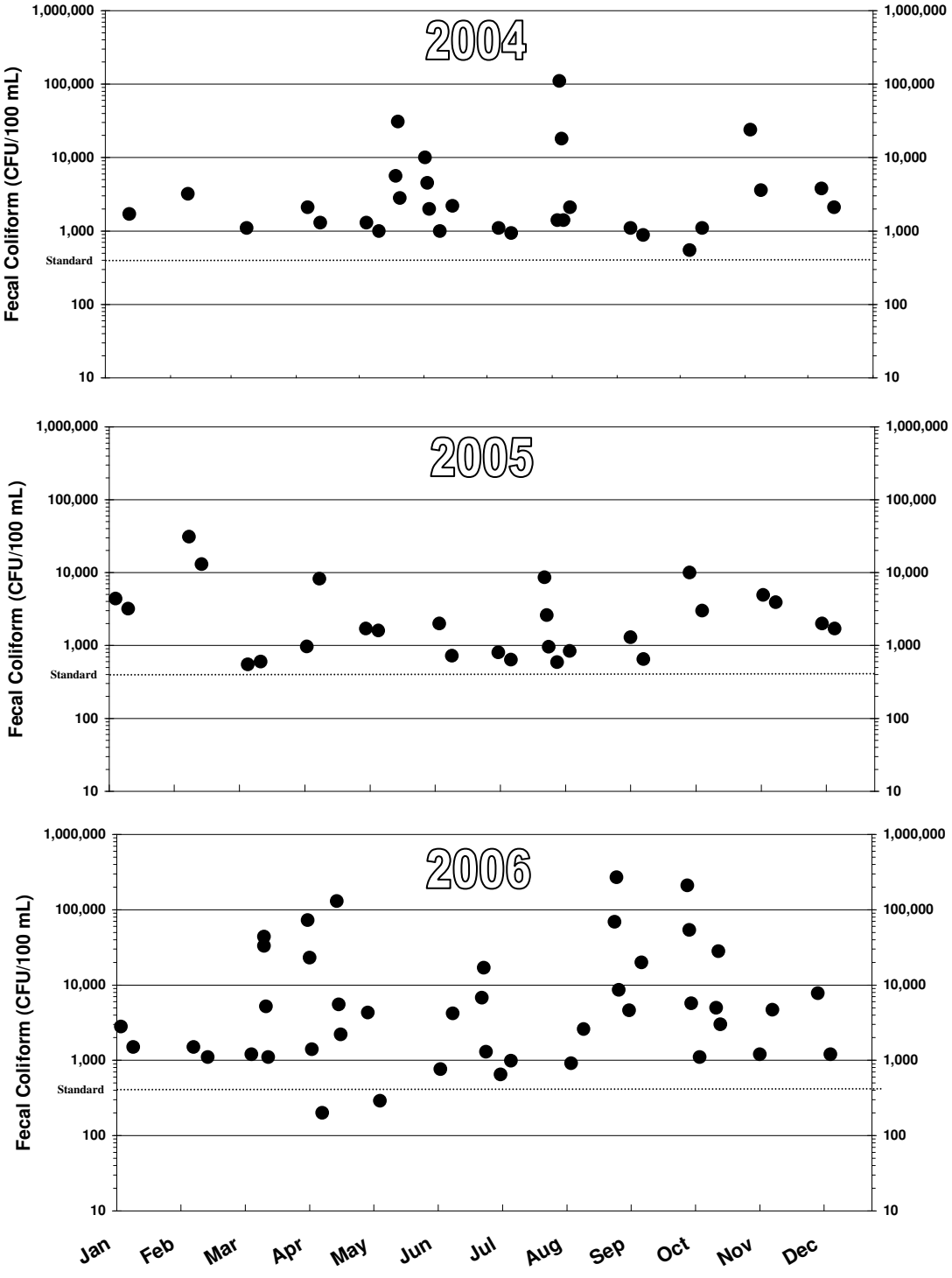


FIGURE 8: FECAL COLIFORM BACTERIA AT INDIANA AVENUE ON THE LITTLE CALUMET RIVER DURING THE YEARS 2004, 2005, AND 2006

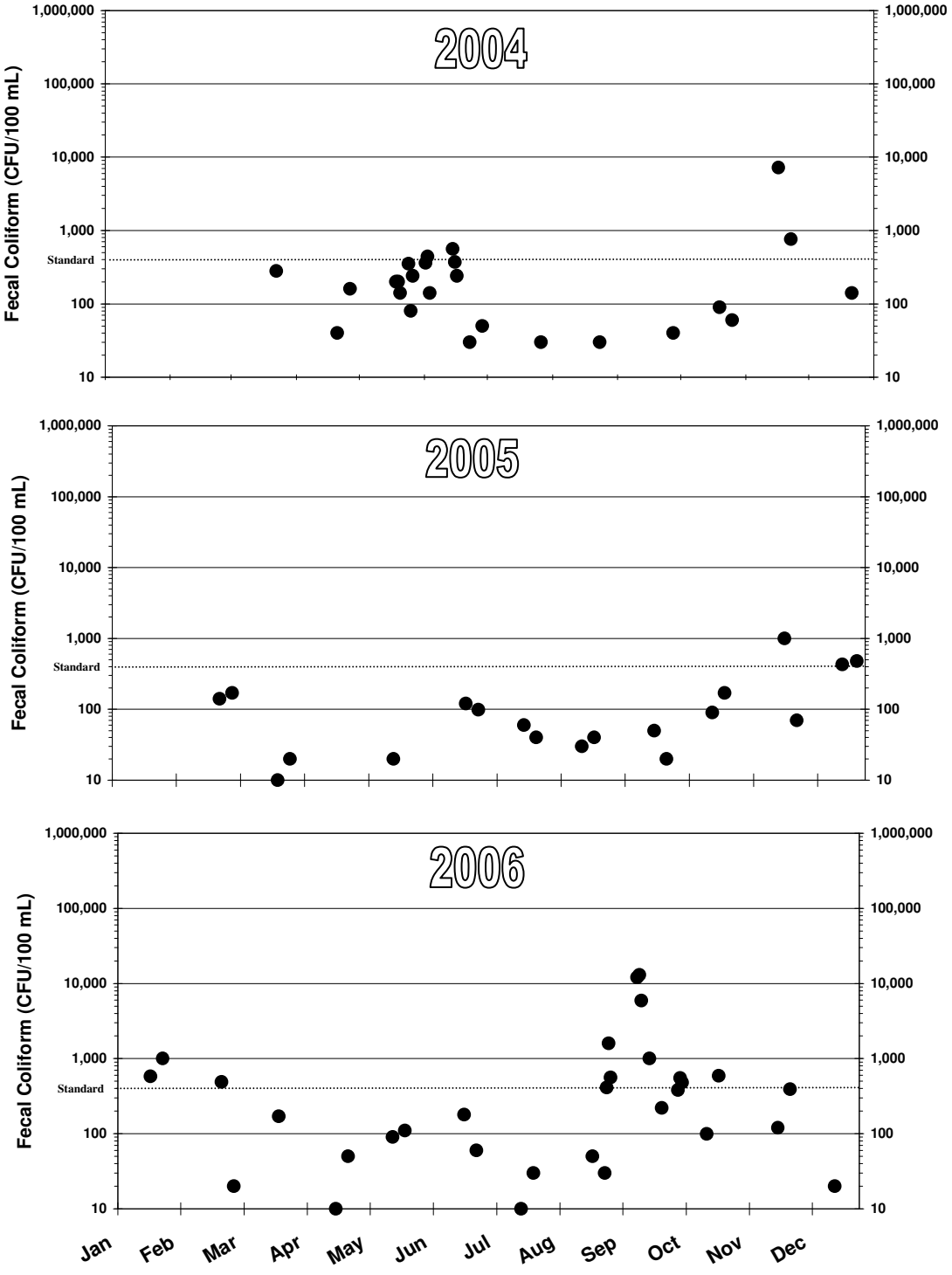


FIGURE 9: FECAL COLIFORM BACTERIA AT HALSTED STREET ON THE LITTLE CALUMET RIVER DURING THE YEARS 2004, 2005, AND 2006

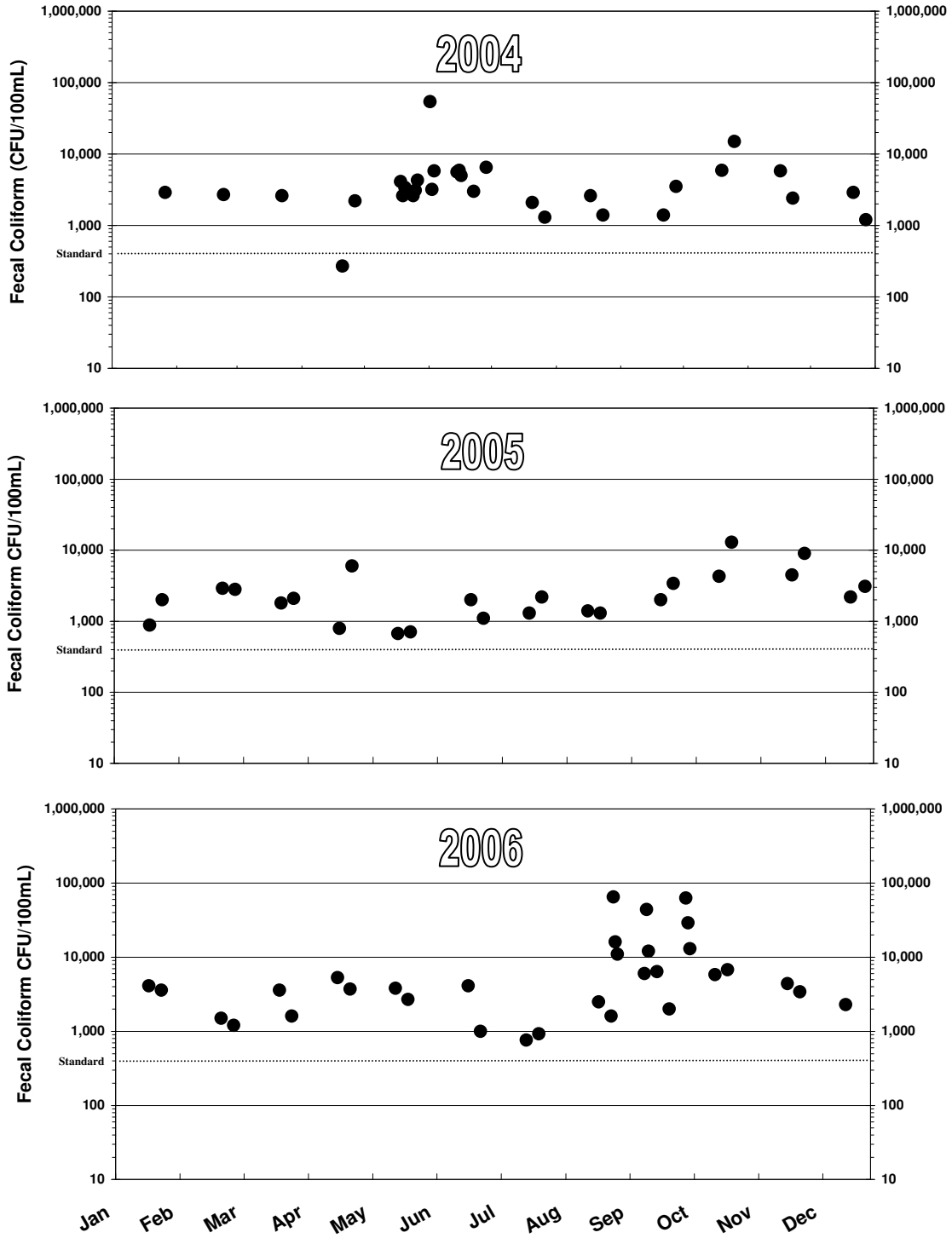


FIGURE 10: FECAL COLIFORM BACTERIA AT ASHLAND AVENUE ON THE LITTLE CALUMET RIVER DURING THE YEARS 2004, 2005, AND 2006

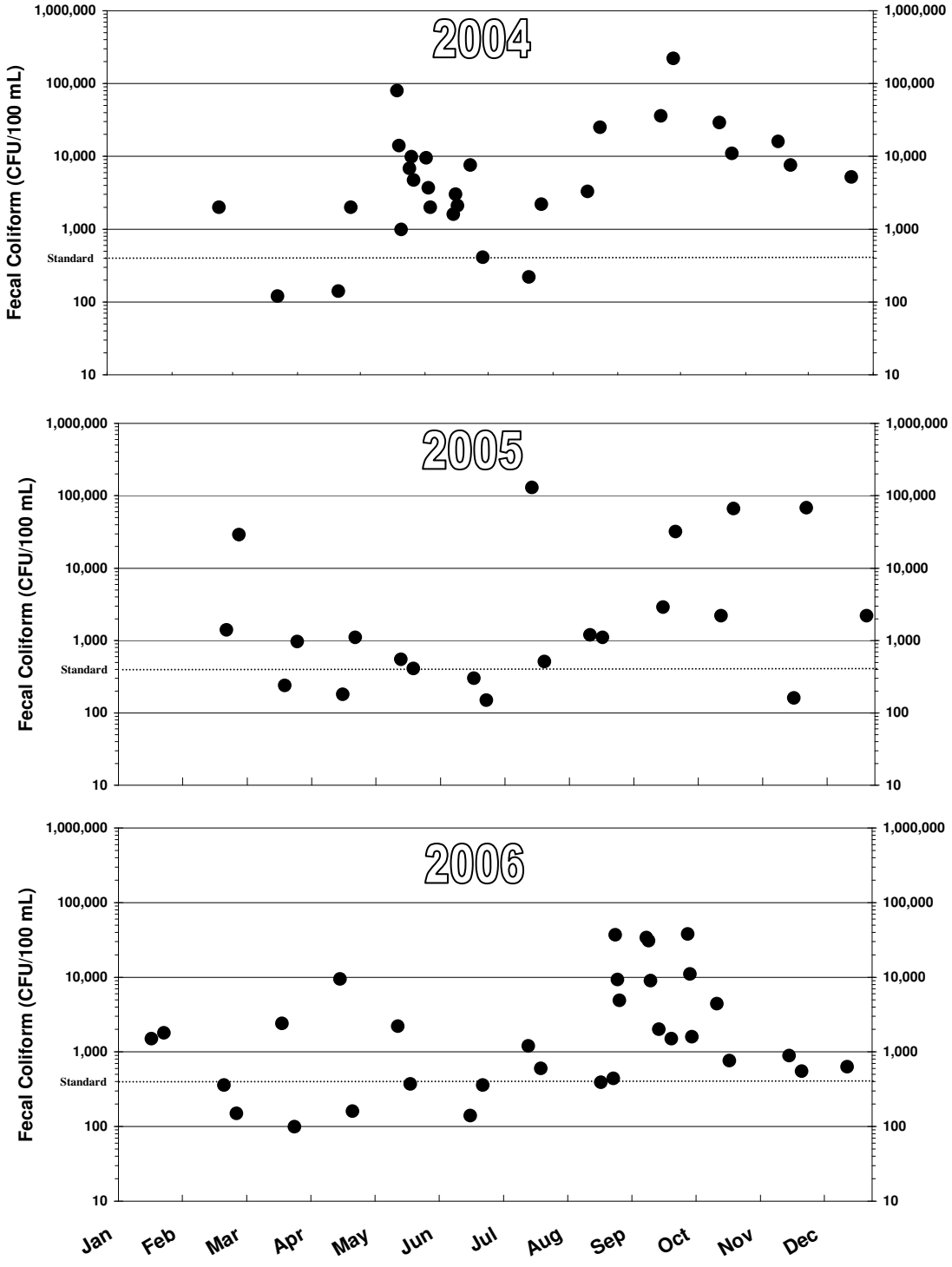


FIGURE 11: FECAL COLIFORM BACTERIA AT ASHLAND AVENUE ON THE CALUMET-SAG CHANNEL DURING THE YEARS 2004, 2005, AND 2006

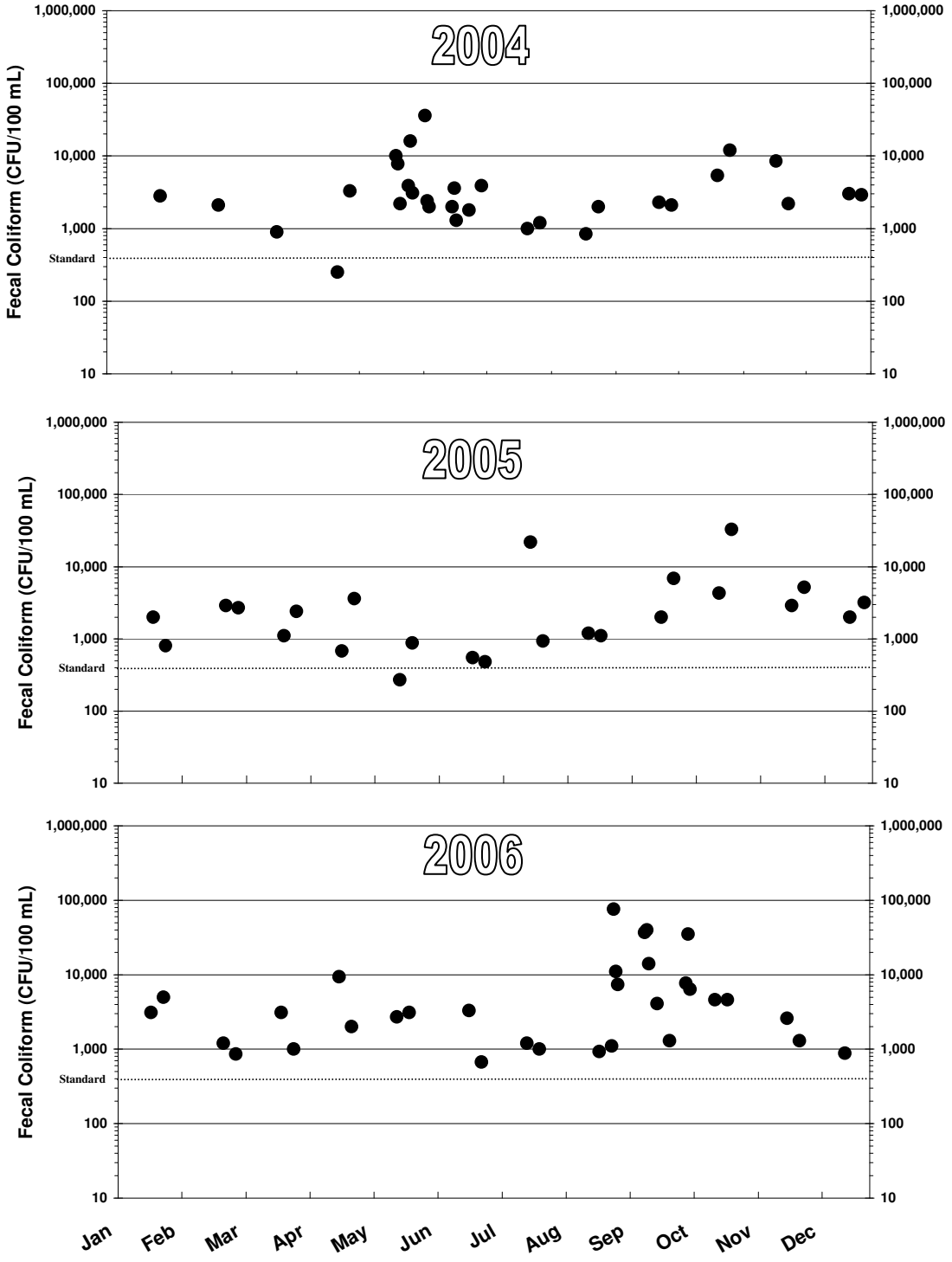


FIGURE 12: FECAL COLIFORM BACTERIA AT CICERO AVENUE ON THE CALUMET-SAG CHANNEL DURING THE YEARS 2004, 2005, AND 2006

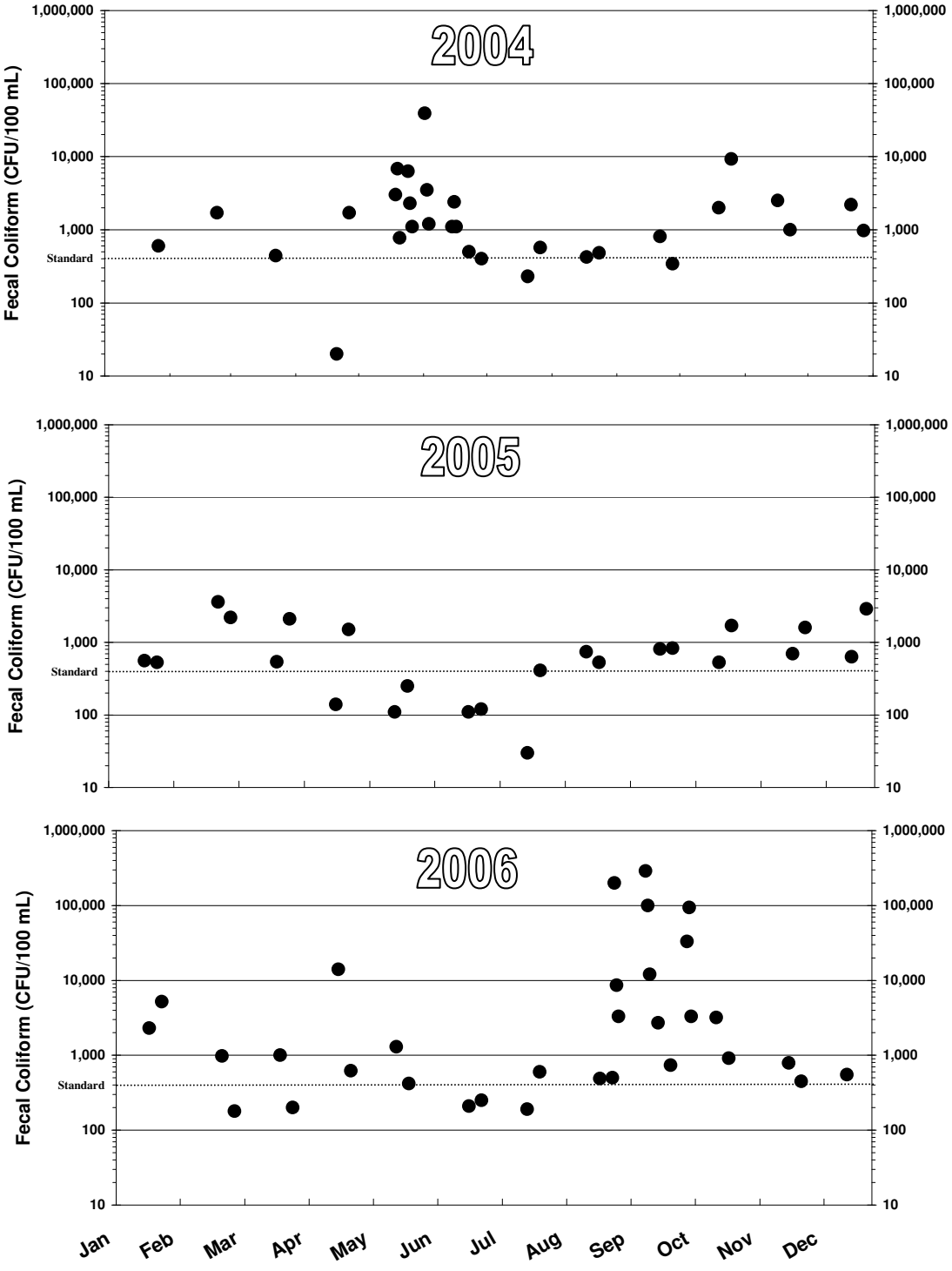


FIGURE 13: FECAL COLIFORM BACTERIA AT ROUTE 83 ON THE CALUMET-SAG CHANNEL DURING THE YEARS 2004, 2005, AND 2006

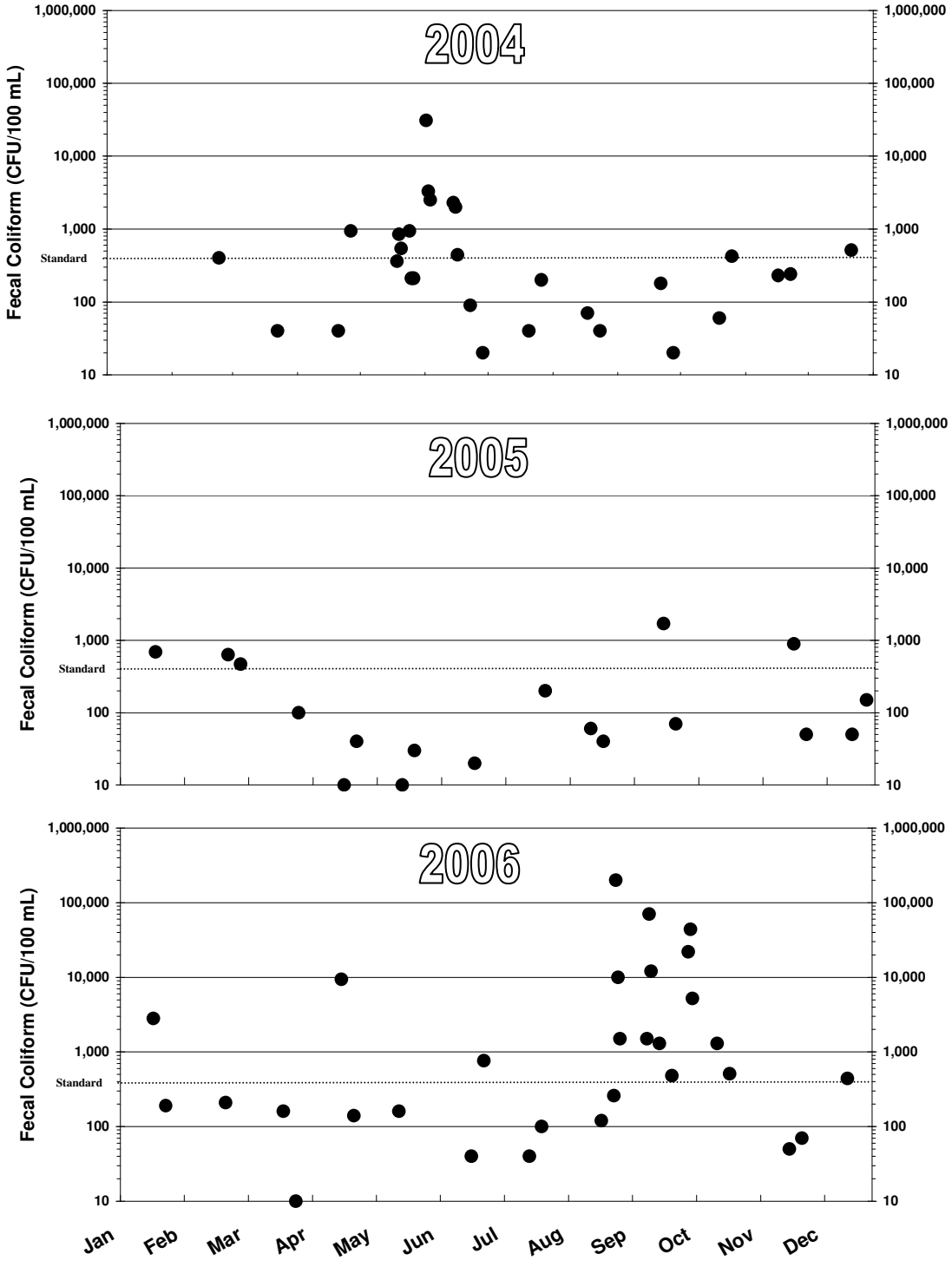


TABLE 2: RAINFALL MEASURED AT FOUR GAUGE LOCATIONS DURING HEAVY AND LIGHT RAINS FROM 2004 THROUGH 2006

Rain Intensity[a] and Gauge Location	Rain (inches)			
	Average	Minimum	Maximum	Number of Rain Gauge Measurements >0 Inches
Heavy Rain – North Area				
North Side WRP	0.51	0.01	1.69	27
North Branch Pumping Station	0.52	0.01	2.16	26
Light Rain – North Area				
North Side WRP	0.14	0.02	0.42	13
North Branch Pumping Station	0.12	0.01	0.40	14
Heavy Rain – South Area				
Calumet WRP	0.68	0.03	1.99	13
Melvina Pumping Station	0.67	0.01	3.09	14
Light Rain – South Area				
Calumet WRP	0.27	0.03	0.66	21
Melvina Pumping Station	0.27	0.01	0.80	20

[a]"Heavy rain" was defined as rainfall that exceeded the capacity of the Deep Tunnel and resulted in a discharge of combined sewer overflow (CSO) from a major District pumping station to a receiving stream. In the North area, such a CSO discharge entered the North Branch of the Chicago River from the North Side Pumping Station and in the South area the CSO entered the Calumet-Sag Channel from the 125th Street Pumping Station. A "light rain" was defined as any measurable rainfall that occurred on the same day, or on one or two days prior, to a routine fecal coliform sample from a monitoring station in either the North or South area. "Dry weather" was defined as any day on which no measurable rainfall occurred, including none two days prior and one day after, and on which a routine fecal coliform sample was collected.

TABLE 3: FECAL COLIFORM DENSITY IN CFU/100 mL (NUMBER OF SAMPLES, MINIMUM, GEOMETRIC MEAN, AND MAXIMUM) IN CHICAGO WATERWAY SYSTEM DURING DRY AND WET WEATHER 2004–2006

Sample Station and Year	Dry Weather				Wet Weather – Light Rain No Pumping Station CSO				Wet Weather – Heavy Rain Pumping Station CSO			
	N	Min	Geomean	Max	N	Min	Geomean	Max	N	Min	Geomean	Max
North Shore Channel												
Oakton Street (0.6)[a]												
2004	8	40	315	3,700	2	720	782	850	9	700	11,267	470,000
2005	6	20	207	4,200	7	1,600	5,187	42,000	3	290	2,301	21,000
2006	8	30	478	9,800	5	120	663	2,500	22	100	6,332	330,000
2004-2006 Combined	22	20	327	9,800	14	120	1,899	42,000	34	100	6,745	470,000
Foster Avenue (3.1)[b]												
2004	8	4,200	8,511	22,000	2	8,400	14,491	25,000	9	10,000	26,083	130,000
2005	6	5,100	9,119	31,000	7	2,500	9,293	22,000	3	280	6,314	31,000
2006	8	3,500	7,553	30,000	5	3,700	12,779	76,000	22	2,300	9,720	71,000
2004-2006 Combined	22	3,500	8,304	31,000	14	2,500	11,095	76,000	34	280	12,151	130,000
North Branch Chicago River												
Albany Avenue (3.3)[c]												
2004	8	200	671	2,000	2	680	8,246	100,000	9	990	7,487	130,000
2005	6	300	618	1,600	6	1,800	5,868	21,000	3	800	1,687	4,000
2006	8	140	519	3,500	5	40	979	4,300	22	320	7,401	360,000
2004-2006 Combined	22	140	598	3,500	13	40	3,106	100,000	34	320	6,516	360,000
Wilson Avenue (4.0)[b]												
2004	8	3,400	6,370	17,000	2	5,400	10,900	22,000	9	8,000	23,233	210,000
2005	6	4,100	6,625	11,000	7	6,400	11,631	25,000	3	24,000	26,552	30,000
2006	8	2,400	5,659	20,000	5	3,900	10,367	30,000	22	1,500	10,236	210,000
2004-2006 Combined	22	2,400	6,167	20,000	14	3,900	11,060	30,000	34	1,500	13,832	210,000

TABLE 3 (Continued): FECAL COLIFORM DENSITY IN CFU/100 mL (NUMBER OF SAMPLES, MINIMUM, GEOMETRIC MEAN, AND MAXIMUM) IN CHICAGO WATERWAY SYSTEM DURING DRY AND WET WEATHER 2004–2006

Sample Station and Year	Dry Weather				Wet Weather – Light Rain No Pumping Station CSO				Wet Weather – Heavy Rain Pumping Station CSO			
	N	Min	Geomean	Max	N	Min	Geomean	Max	N	Min	Geomean	Max
North Branch Chicago River												
Diversey Parkway (6.6)[b]												
2004	8	2,000	3,643	8,800	2	6,600	7,490	8,500	9	4,500	13,276	67,000
2005	6	2,600	3,634	5,500	7	4,100	8,980	23,000	3	8,600	15,096	40,000
2006	8	890	3,105	9,000	5	1,500	6,877	37,000	22	1,100	12,783	110,000
2004-2006 Combined	22	890	3,435	9,000	14	1,500	7,955	37,000	34	1,100	13,103	110,000
Grand Avenue ((10.7)[b]												
2004	8	550	1,554	3,600	2	1,000	1,483	2,200	9	1,400	7,910	110,000
2005	6	650	1,387	3,200	7	800	3,945	13,000	3	960	2,779	8,600
2006	8	200	1,037	7,800	5	650	2,124	4,600	22	1,100	14,129	270,000
2004-2006 Combined	22	200	1,301	7,800	14	650	2,750	13,000	34	960	10,498	270,000
Little Calumet River												
Indiana Avenue (1.4)[a]												
2004	2	40	75	140	6	30	142	7,200	9	140	264	560
2005	5	20	43	120	8	20	71	170	0			
2006	6	20	124	490	6	10	166	1,000	9	380	1,479	13,000
2004-2006 Combined	13	20	76	490	20	10	113	7,200	18	140	625	13,000
Halsted Street (1.0)[b]	15	670	1,979	6,000	24	270	2,934	13,000	18	2,600	10,955	65,000
2004	2	2,900	3,186	3,500	6	270	2,722	6,500	8	2,600	5,672	54,000
2005	7	670	1,517	6,000	9	1,300	3,217	13,000	0			
2006	6	1,200	2,302	3,600	6	760	3,178	6,800	9	6,000	21,188	65,000
2004-2006 Combined	15	670	1,979	6,000	21	270	3,057	13,000	17	2,600	11,396	65,000

TABLE 3 (Continued): FECAL COLIFORM DENSITY IN CFU/100 mL (NUMBER OF SAMPLES, MINIMUM, GEOMETRIC MEAN, AND MAXIMUM) IN CHICAGO WATERWAY SYSTEM DURING DRY AND WET WEATHER 2004–2006

Sample Station and Year	Dry Weather				Wet Weather – Light Rain No Pumping Station CSO				Wet Weather – Heavy Rain Pumping Station CSO			
	N	Min	Geomean	Max	N	Min	Geomean	Max	N	Min	Geomean	Max
Ashland Avenue (1.3)[c]												
2004	2	5,200	33,823	220,000	6	140	2,622	16,000	8	990	5,145	80,000
2005	7	150	538	1,200	8	510	13,527	130,000	0			
2006	6	150	466	2,400	6	140	972	2,200	9	1,600	13,013	38,000
2004-2006 Combined	15	150	882	220,000	20	140	3,753	130,000	17	990	8,409	80,000
Calumet-Sag Channel												
Ashland Avenue (2.1)[b]												
2004	2	2,100	2,510	3,000	6	250	3,007	16,000	8	1,300	4,393	36,000
2005	7	270	940	3,600	9	800	4,066	33,000	0			
2006	6	860	1,513	3,100	6	1,200	2,530	4,600	9	6,400	18,218	76,000
2004-2006 Combined	15	270	1,296	3,600	21	250	3,257	33,000	17	1,300	9,329	76,000
Cicero Avenue (6.2)[b]												
2004	2	340	865	2,200	6	20	542	2,500	8	770	3,013	39,000
2005	7	110	364	2,100	9	30	769	3,600	0			
2006	6	180	504	1,000	6	190	675	2,700	9	3,300	30,090	290,000
2004-2006 Combined	15	110	465	2,200	21	20	670	3,600	17	770	10,188	290,000
Route 83 (16.9)[b]												
2004	2	20	101	510	6	20	95	230	8	360	1,569	31,000
2005	7	9	28	100	8	9	114	1,700	0			
2006	6	9	53	210	6	40	208	1,300	9	1,500	13,872	200,000
2004-2006 Combined	15	9	43	510	20	9	129	1,700	17	360	4,974	200,000

[a]Upstream WRP effluent outfall.
[b]Downstream WRP effluent outfall.
[c]Tributary downstream WRP effluent outfall.

For the 12 sampling stations during 2004–2006, dry weather FC density ranged from 9 to 220,000 cfu/100 mL. During wet weather, light rain FC density ranged from 9 to 130,000 cfu/100 mL. During wet weather, heavy rain FC density ranged from 100 to 470,000 cfu/100 mL. Geometric mean dry weather FC density ranged from 28 to 33,823 cfu/100 mL. During wet weather, light rain geometric mean FC density ranged from 71 to 14,491 cfu/100 mL. During wet weather, heavy rain geometric mean FC density ranged from 264 to 30,090 cfu/100 mL.

North Area. Downstream from the North Side WRP effluent outfall, dry weather, the three-year combined geometric mean for FC density during dry weather decreased from 8,304 cfu/100 mL at Foster Avenue on the North Shore Channel to 1,301 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River. During wet weather, light rain, the geometric mean FC density decreased from 11,095 cfu/100 mL at Foster Avenue on the North Shore Channel to 2,750 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River. During wet weather, heavy rain, the geometric mean FC density decreased from 12,151 cfu/100 mL at Foster Avenue on the North Shore Channel to 10,498 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River.

Minimum, median, and maximum FC density values for dry and wet weather are shown in Figure 14 for the North area stations. The differences in FC density among rainfall groups at each station are easier to follow as the FC density moves downstream in these figures. Dry weather FC density was generally lowest at the Oakton Street Station, 0.6 miles upstream of the North Side WRP effluent outfall and in the tributary (North Branch of the Chicago River) which enters the North Shore Channel 3.3 miles downstream of the WRP effluent outfall. However, 45 percent of the dry weather FC density measurements at the upstream Oakton Street Station were above the 400 cfu/100 mL FC density proposed IEPA effluent standard and 77 percent of the dry weather FC density measurements at the tributary Albany Avenue Station were above the proposed 400 cfu/100 mL standard. The maximum FC density (470,000 cfu/100 mL) during heavy rain wet weather was higher at the upstream station than at any of the stations downstream from the North Side WRP effluent outfall. Heavy rain FC density showed little decline as distance from the North Side WRP increased down the North area waterway, though a reduction was apparent during dry weather and light rain.

South Area. Downstream from the Calumet WRP effluent outfall, the combined geometric mean FC density during dry weather decreased from 1,979 cfu/100 mL at Halsted Street on the Little Calumet River to 43 cfu/100 mL at Route 83 on the Calumet-Sag Channel. During wet weather, light rain, the geometric mean FC density decreased from 3,057 cfu/100 mL at Halsted Street on the Little Calumet River to 129 cfu/100 mL at Route 83 on the Calumet-Sag Channel. During wet weather, heavy rain, the geometric mean FC density decreased from 11,396 cfu/100 mL at Halsted Street on the Little Calumet River to 4,974 cfu/100 mL at Route 83 on the Calumet-Sag Channel.

Minimum, median, and maximum FC density values for dry and wet weather are shown in Figure 15 for the South area stations. More than 75 percent of the FC density measurements were below the 400 cfu/100 mL proposed IEPA effluent standard during dry weather and light

FIGURE 14: FECAL COLIFORM DENSITIES AT NORTH AREA WATERWAY STATIONS DURING DRY AND WET WEATHER FROM 2004 THROUGH 2006

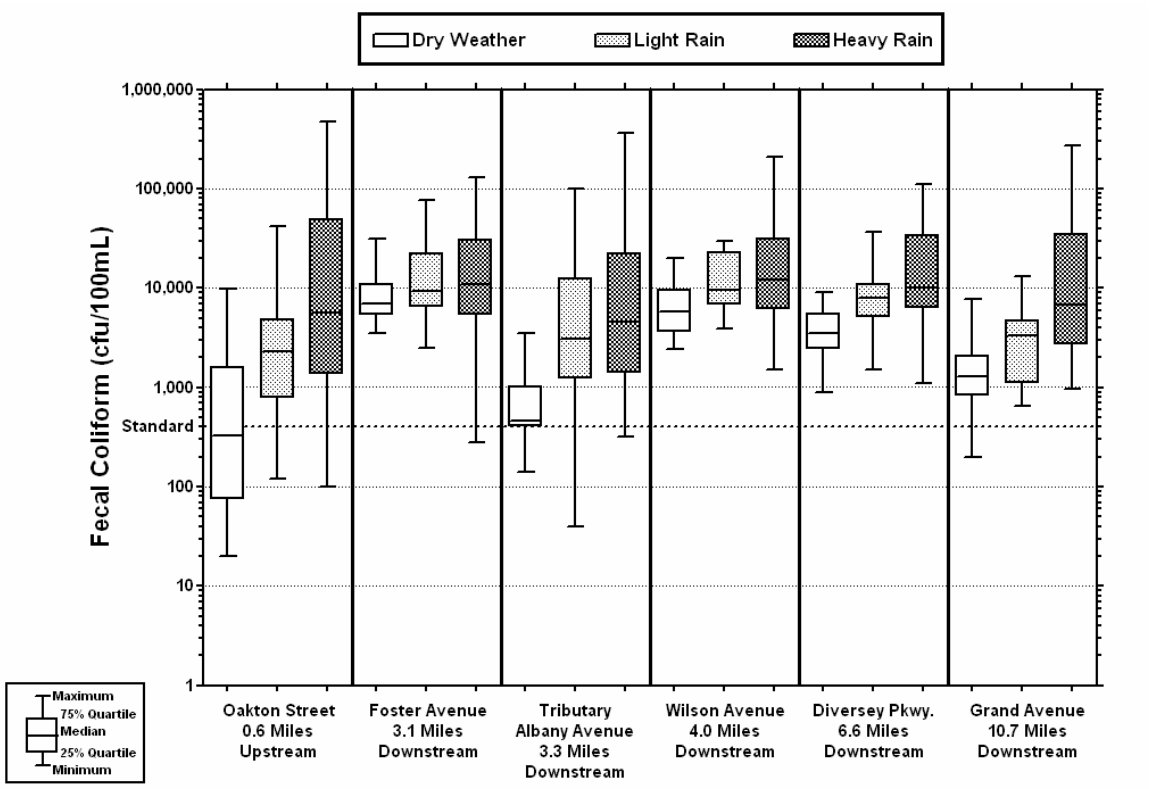
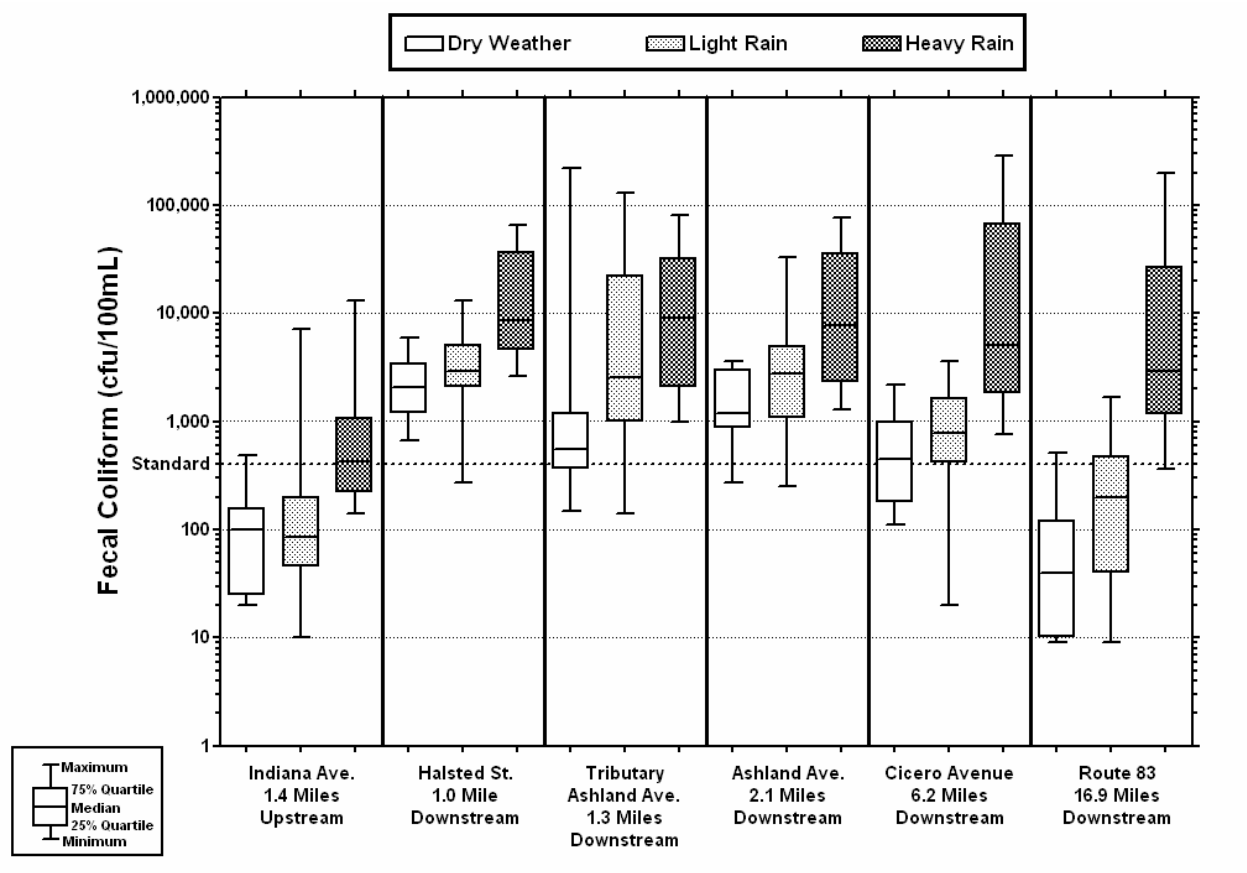


FIGURE 15: FECAL COLIFORM DENSITIES AT SOUTH AREA WATERWAY STATIONS DURING DRY AND WET WEATHER FROM 2004 THROUGH 2006



rain at the Indiana Avenue Station, 1.4 miles upstream of the Calumet WRP effluent outfall, while during heavy rains more than 75 percent of the FC density measurements at the upstream station exceeded the proposed IEPA effluent standard.

At the Ashland Avenue Tributary Station, located in the wadeable portion of the Little Calumet River which enters the deep-draft portion of the Little Calumet River 1.3 miles downstream of the Calumet WRP effluent outfall, 60 percent of the dry weather FC density, and almost all of the wet weather FC density, exceeded the proposed IEPA effluent standard. The highest dry weather FC density (220,000 cfu/100 mL) for the South area waterway occurred at this station. This highest dry weather FC density result appears to be an anomaly, but it has not been excluded in the analysis of the data set. At the Route 83 Station, 16.9 miles downstream of the Calumet WRP, 93 percent of the FC density measurements were below the proposed IEPA effluent FC density standard during dry weather, and 70 percent of the FC density measurements were in compliance with the standard during light rain. Heavy rain FC density showed little decline as distance from the Calumet WRP increased down the South area waterway, though reduction in FC density was apparent during dry weather and light rain.

Results of statistical analysis of the trend (linear regression of FC density measurements transformed to base 10 logarithms) in FC density downstream of the WRP outfalls are shown in Figure 16 for the FC density at the North area waterway mainstream stations (i.e., the upstream and tributary stations were not included), and in Figure 17 for the FC density at the South area mainstream stations. In both the North area and South area waterways, heavy rain FC density showed no significant reduction (rate of die-off) among the stations, i.e., the slope of the FC density trend line was not significantly different from zero ($p>0.05$). Also, in both the North area and South area waterways, the reduction (rate of die-off) was significant ($p<0.05$) as distance increased from the WRPs for both the dry weather and light rain FC density, and in both areas, the light rain FC density was significantly higher than the dry weather FC density ($p<0.05$).

Trend of Fecal Coliform Density During Three-Day Period After Rainfall

In order to investigate what conditions were causing the heavy rain wet weather FC density to remain high, without reduction, as distance increased downstream from the WRPs, geometric mean FC density was plotted for each of three days during both heavy and light rains, and compared with dry weather FC density, at waterway stations in the North and South areas.

North Area. In the North area (Figure 18) during heavy rains, FC density on the first and second days of measurements were extremely high and did not show a pattern of reduction with downstream distance from the WRPs. This was likely due to effects of FC density from the North Branch Pumping Station discharges, as well as FC input from other CSOs and storm water inflows that would have been greatest on days during or immediately following the storms. Light rain FC density was also highest on the first two days following the rain event, but the pattern of FC density reduction was more apparent with distance downstream from the North Side WRP.

FIGURE 16: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG10 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE NORTH SIDE WRP DURING WET AND DRY WEATHER 2004–2006

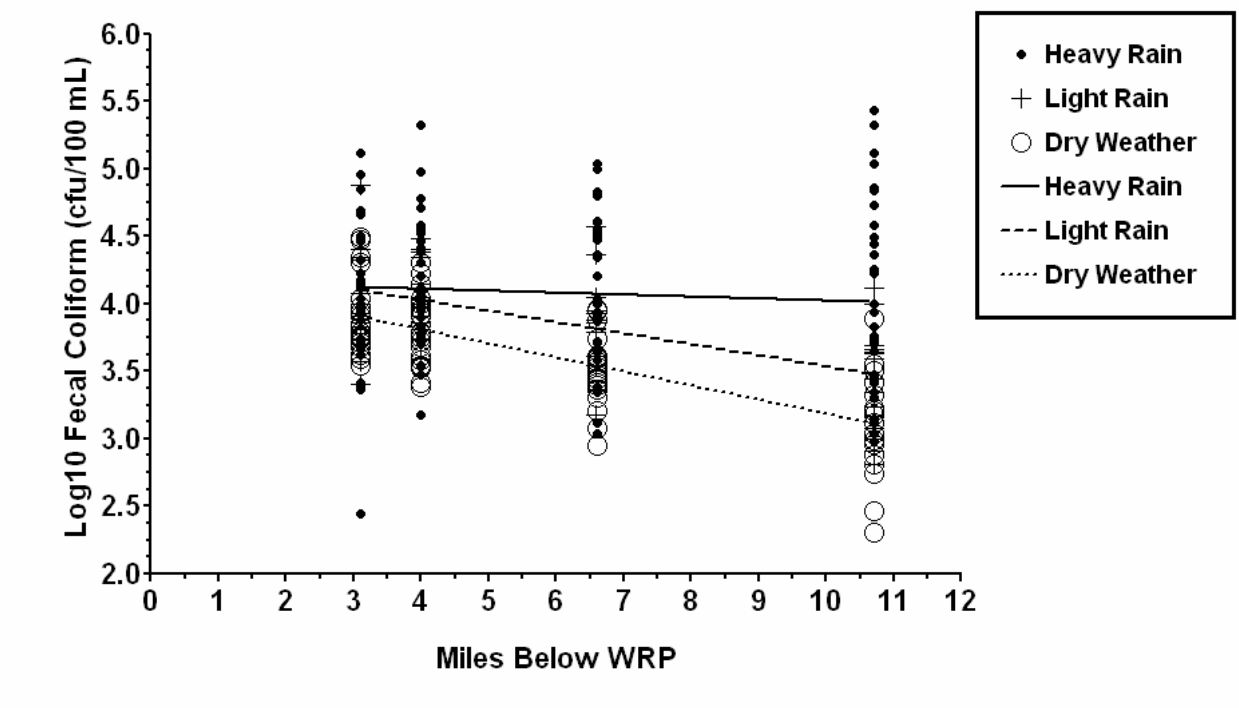


FIGURE 17: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG10 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE CALUMET WRP DURING WET AND DRY WEATHER 2004–2006

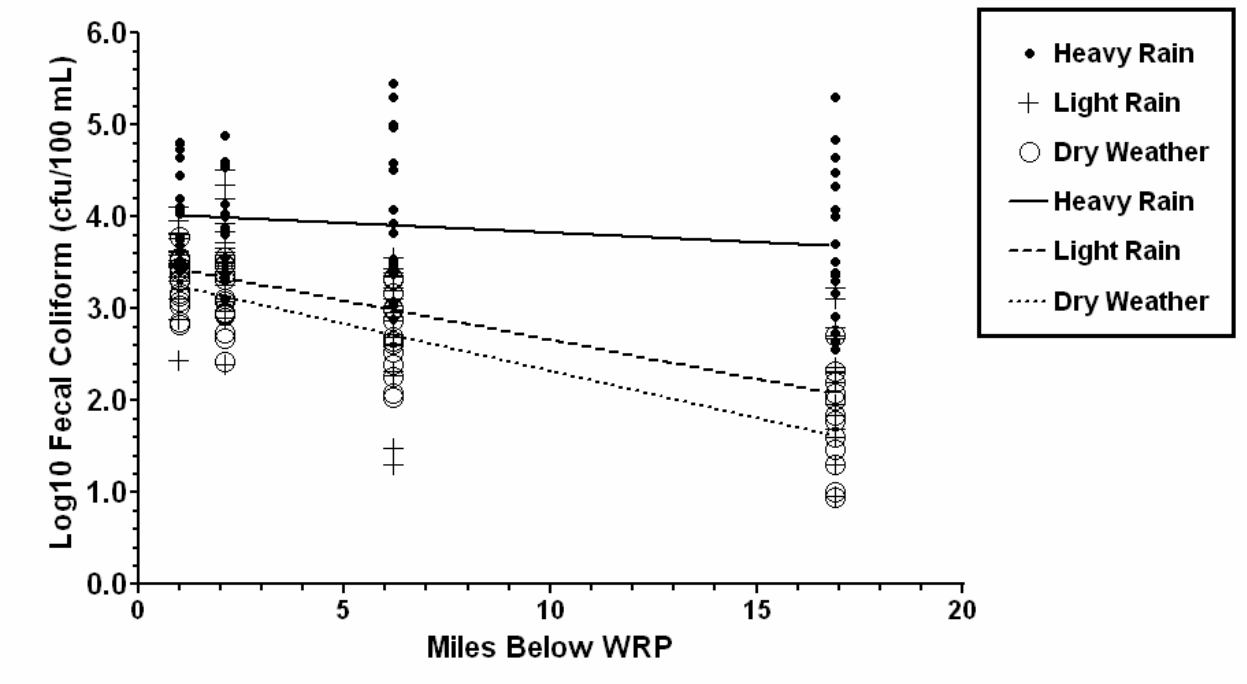
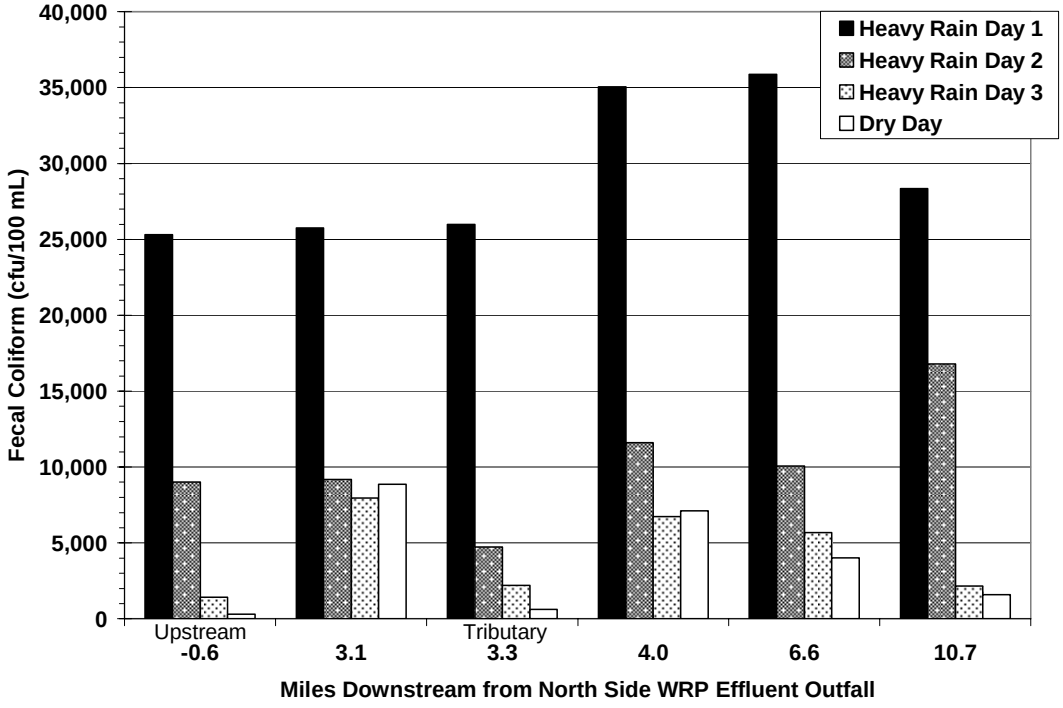
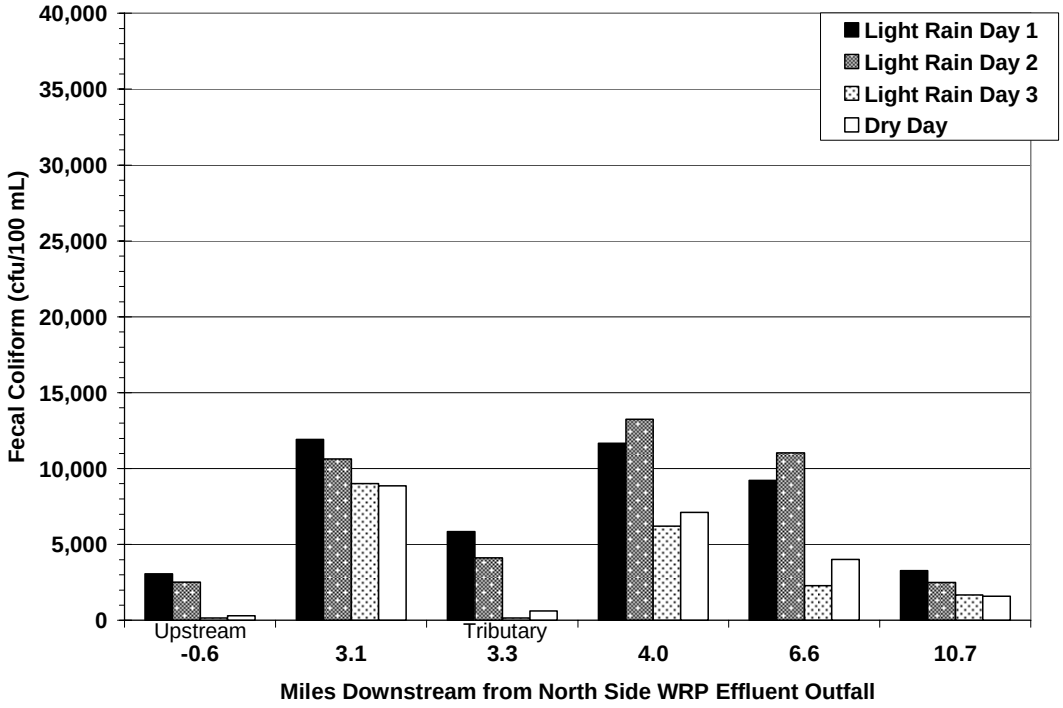


FIGURE 18: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT NORTH AREA STATIONS EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES





South Area. In the South area (Figure 19), FC density on the first and second days of measurements after heavy rains were extremely high and also did not show a pattern of reduction with downstream distance from the WRPs. This was likely due to effects of FC density from the 125th Street Pumping Station discharges, as well as FC density input from other CSOs and storm water inflows that would have been greatest on days during or immediately following the storms. Light rain FC density varied as to which of the three days following a rain event would be highest, the pattern of FC density reduction being more apparent with distance below the Calumet WRP.

Trend of Fecal Coliform Across Stations, Upstream to Downstream

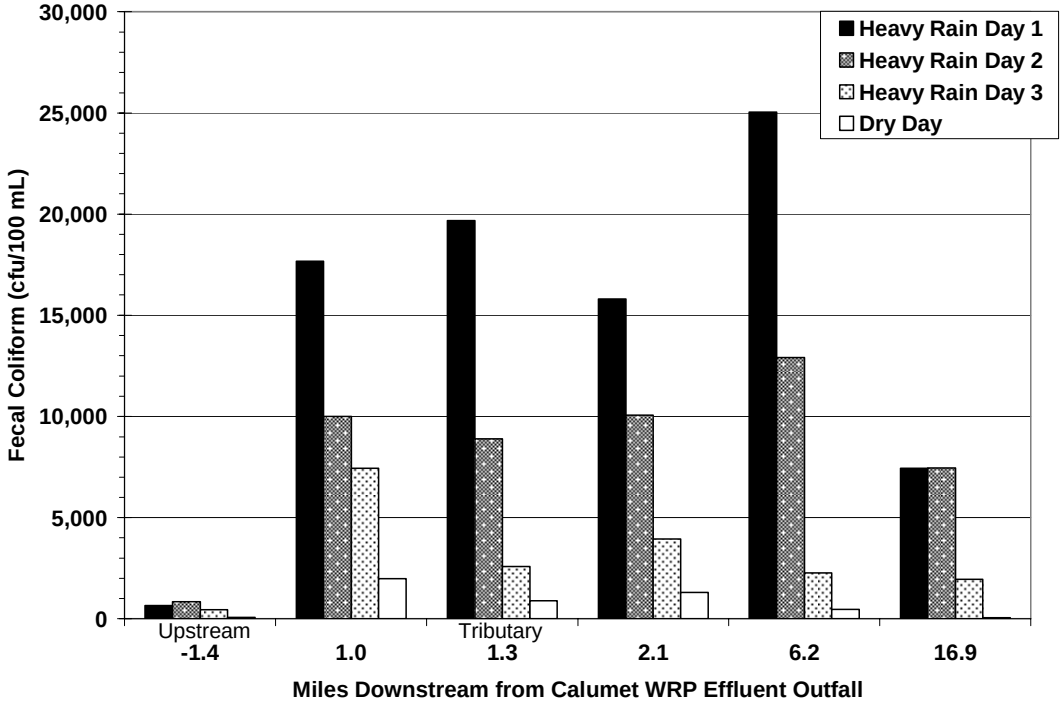
North Area. Results of statistical analysis of the trend in FC density downstream of the WRP outfalls, on each day following initiation of sampling during heavy and light rains, are shown in Figure 20 using linear regression of FC density measurements transformed to base 2 logarithms. The FC densities tested were at the North area waterway mainstream stations (i.e., the upstream and tributary stations were not included). Heavy rain FC density showed no significant reduction (rate of die-off) ($p>0.05$) among the stations on the first and second days of FC density measurement, i.e., the slope of the FC density trend line was not significantly different from zero on either day. The slope of the trend line was significantly different from zero ($p<0.05$) on the third day of heavy rain FC density. Also, the reduction (rate of die-off) was significant as distance increased from the North Side WRP for light rain FC density on the first, second, and third days of FC density measurement ($p<0.05$).

South Area. Results of statistical analysis of the trend in FC density downstream of the Calumet WRP outfall in the South area, on each day following initiation of sampling during heavy and light rains, are shown in Figure 21 with linear regression of FC density measurements transformed to base 2 logarithms. The FC densities tested were at the South area waterway mainstream stations. Heavy rain FC density showed no significant reduction (rate of die-off) among the stations on the first and second days of FC density measurement ($p>0.05$), i.e., the slope of the FC density trend line was not significantly different from zero ($p>0.05$) on either day. The slope of the trend line was significantly different from zero ($p<0.05$) on the third day of heavy rain FC density. Also, the reduction (rate of die-off) was significant ($p<0.05$) as distance increased from the Calumet WRP for light rain FC density on the first, second, and third days of FC density measurement.

Estimated Die-Off of Fecal Coliform Bacteria

In order to estimate waterway FC density that might occur during wet weather conditions if there was complete disinfection of WRP effluent outfalls, die-off equations were calculated using FC densities measured at main stream monitoring stations within both the North and South areas. Results of these calculations are presented below.

FIGURE 19: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT SOUTH AREA STATIONS EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES



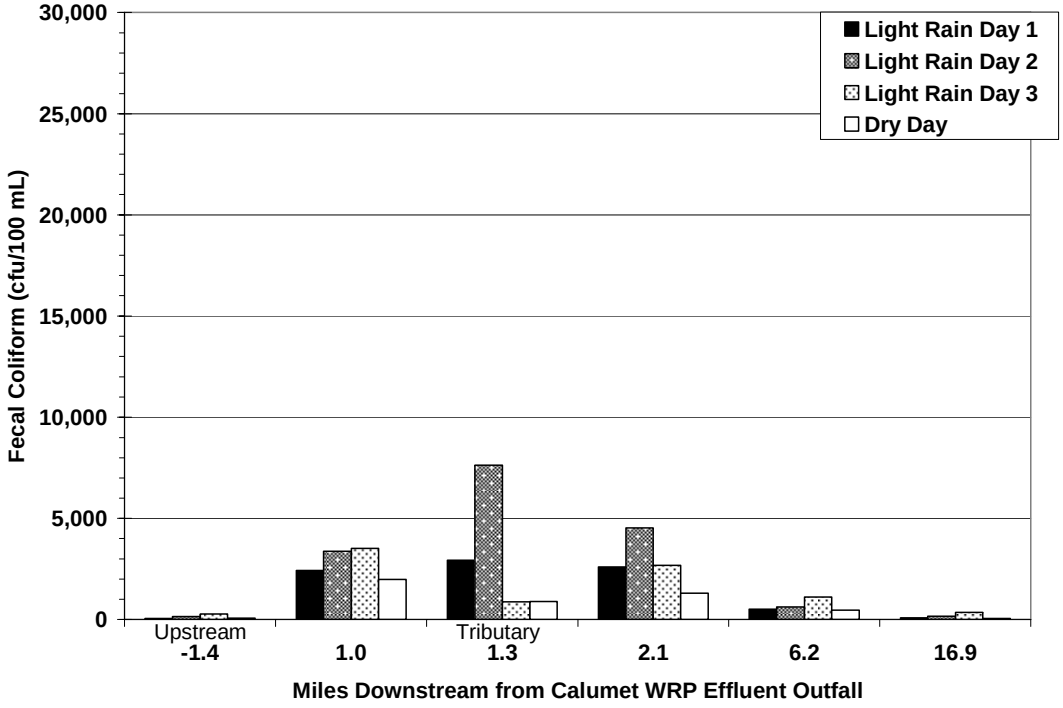
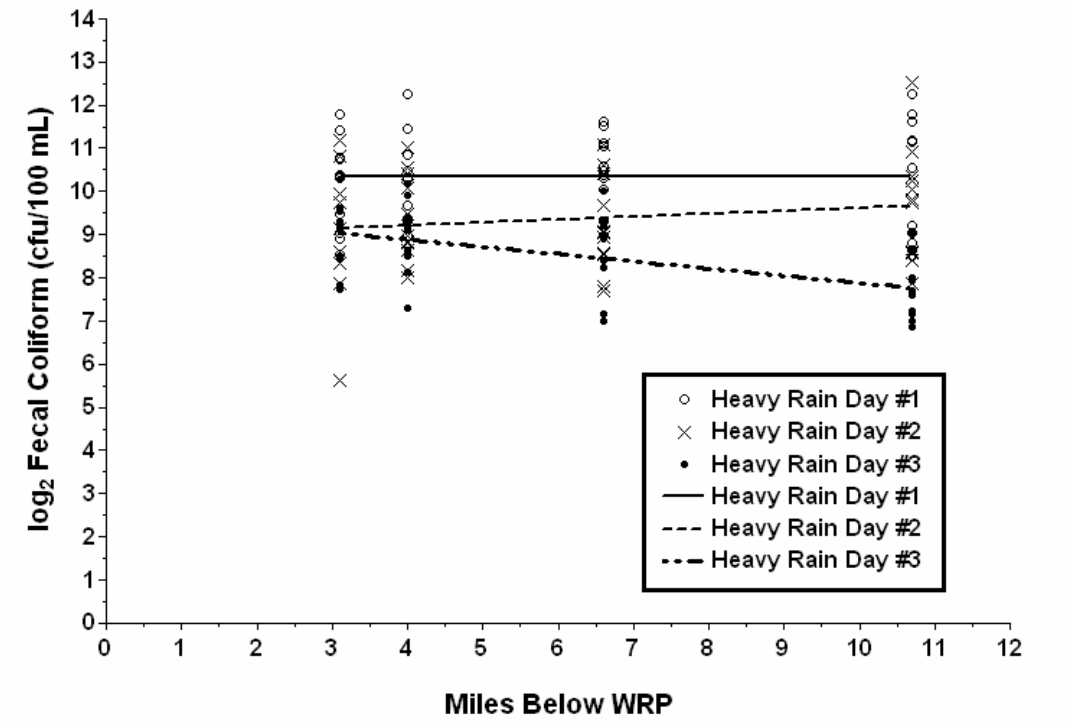


FIGURE 20: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG2 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE NORTH SIDE WRP EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES



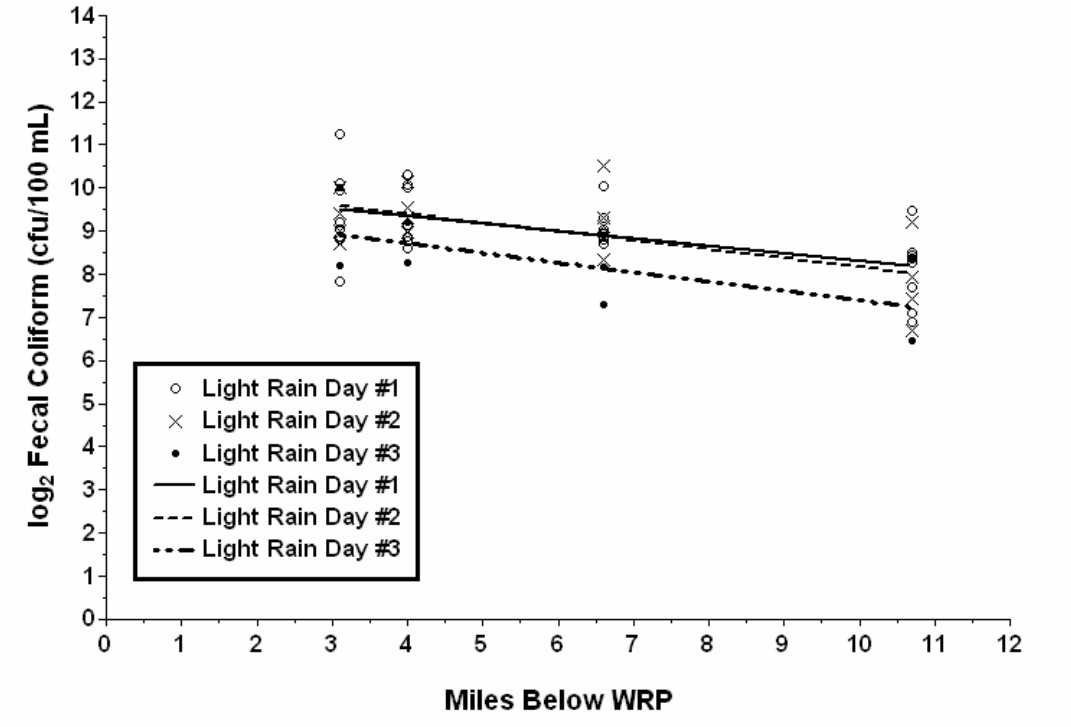
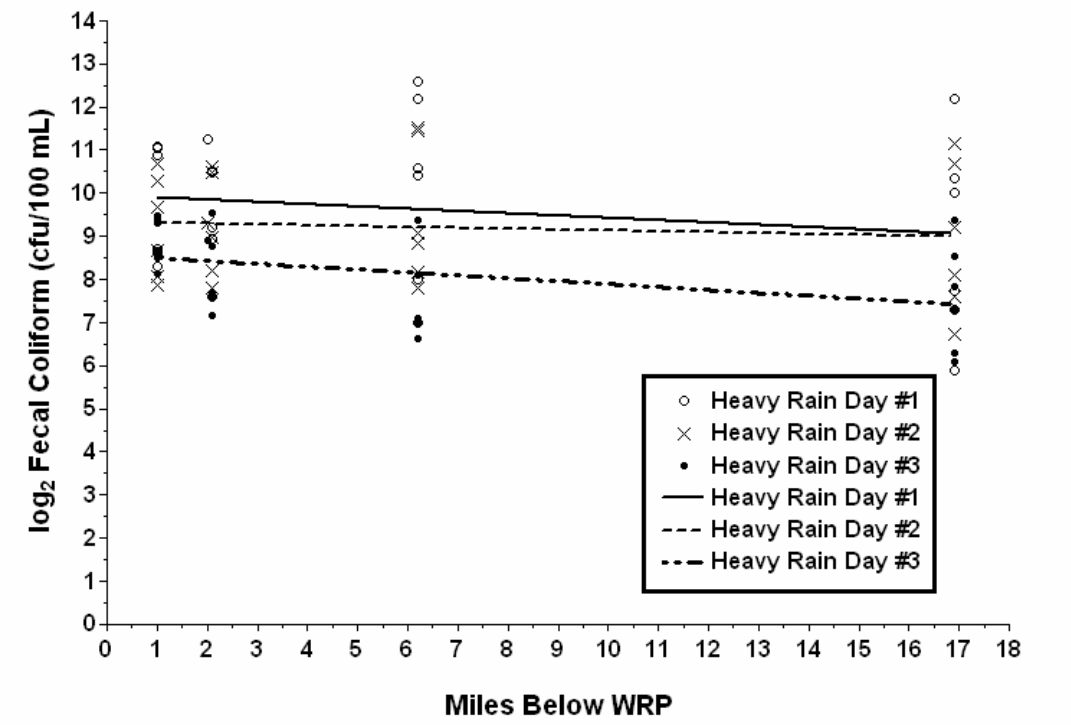
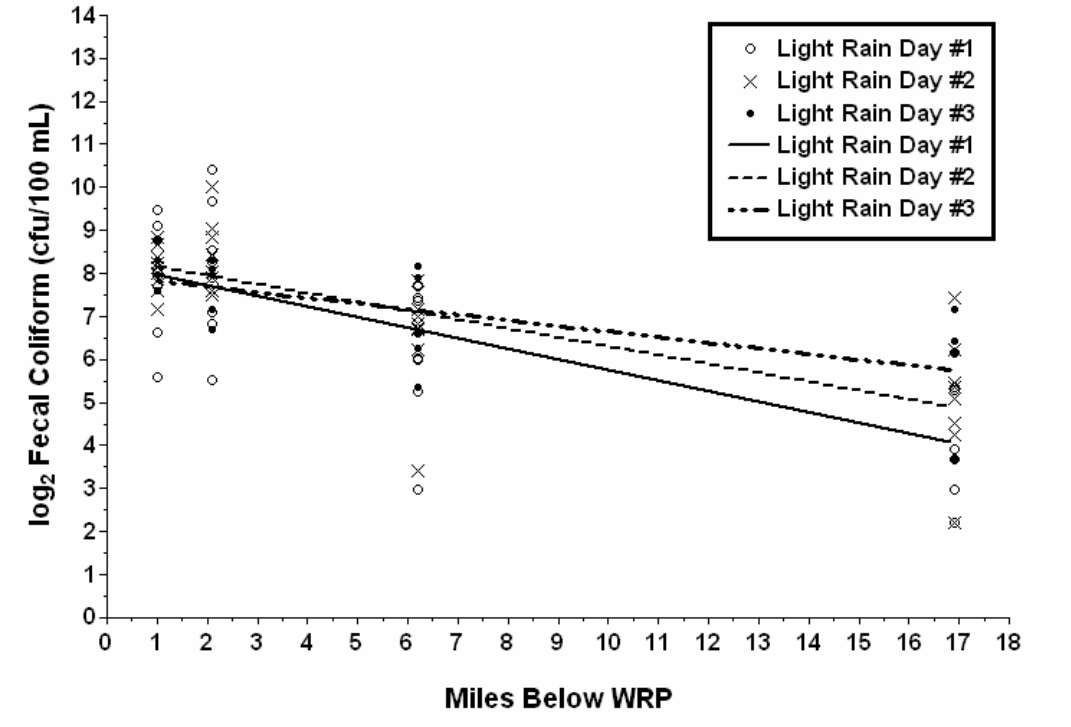


FIGURE 21: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG2 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE CALUMET WRP EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES





Fecal coliform densities downstream of these WRPs were shown to die-off at an exponential rate, and FC densities at specific locations downstream of these WRPs were predicted using the equation $FC_m = FC_0 \times e^{-km}$ where FC_m = FC concentration (cfu/100 mL) m miles downstream of the WRP outfall, FC_0 = FC concentration (cfu/100 mL) 0 miles downstream at the WRP outfall, m is distance downstream (miles) of the WRP outfall and k is the decay rate constant (1/miles). The FC decay equations derived from the data are shown below:

North Side Receiving Stream in Dry Weather

$$FC = 16{,}776 \times e^{-0.2396m}, R^2 = 0.9983$$

North Side Receiving Stream in Wet Weather with Light Rain

$$FC = 22{,}781 \times e^{-0.1889m}, R^2 = 0.9499$$

North Side Receiving Stream in Wet Weather with Heavy Rain, including CSO discharge from the North Branch Pumping Station

$$FC = 14{,}986 \times e^{-0.0337m}, R^2 = 0.6989$$

Calumet Receiving Stream in Dry Weather

$$FC = 2{,}233 \times e^{-0.2361m}, R^2 = 0.9968$$

Calumet Receiving Stream in Wet Weather with Light Rain

$$FC = 3{,}725 \times e^{-0.2062m}, R^2 = 0.9580$$

Calumet Receiving Stream in Wet Weather with Heavy Rain, including CSO discharge from the 125th Street Pumping Station

$$FC = 11{,}766 \times e^{-0.0485m}, R^2 = 0.8938$$

Predicted dry weather FC values were subtracted from the predicted wet weather FC values to estimate FC densities that might occur in the waterways during wet weather if disinfection eliminated the FC burden in the WRP outfalls.

North Area. Comparisons of geometric means of FC bacteria, with calculated die-off density estimates for wet and dry weather, are shown in Figure 22 for the North area stations. Data for the Oakton Street Station, located upstream of the North Side WRP on the North Shore Channel, and data for the tributary station at Albany Avenue, on the North Branch Chicago River, were not included in the plots or the die-off equations. Estimated FC densities calculated from these die-off equations are shown in Table 4 at distances of 5 miles and at mile points downstream of WRP effluent outfalls at which the proposed IEPA WRP effluent standards are first predicted to be met. Fecal coliform densities less than the 400 cfu/100 mL proposed IEPA

FIGURE 22: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA DENSITIES AT NORTH AREA STATIONS WITH ESTIMATED DIE-OFF DENSITIES (UPSTREAM AND TRIBUTARY DENSITIES NOT INCLUDED IN DIE-OFF ESTIMATES)

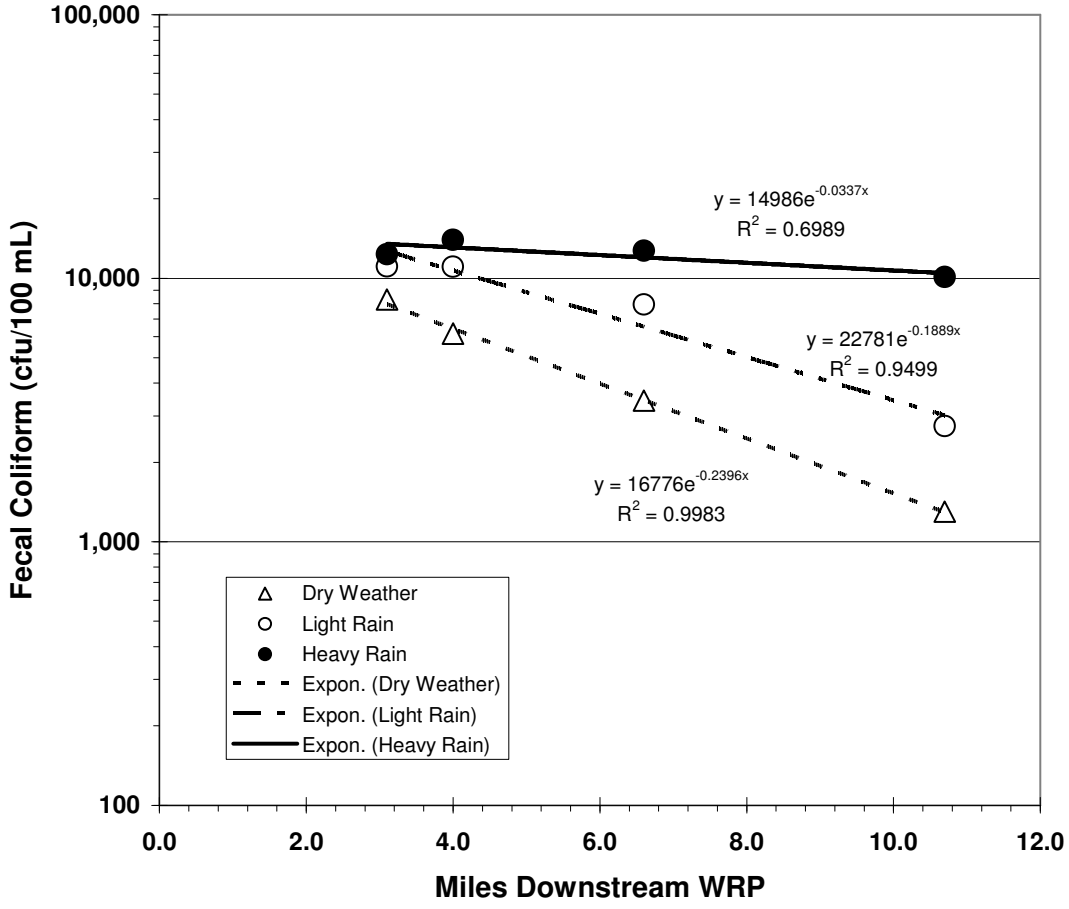


TABLE 4: FECAL COLIFORM DENSITIES[1] CALCULATED FROM DIE-OFF EQUATIONS AT FIVE MILES AND AT FIRST POINT OF COMPLIANCE WITH GENERAL USE WATER QUALITY STANDARD DOWNSTREAM OF WATER RECLAMATION PLANT EFFLUENT OUTFALLS

Weather Type	Miles Downstream Water Reclamation Plant Effluent Outfall							
	5	8	11	16	19	22	70	108
2004-2006 North Area								
Heavy Rain	12,662	11,445	10,344	8,740	7,638	7,140	1,416	**394**
Light Rain	8,859	5,027	2,852	1,109	521	**357**	0	0
Dry Weather	5,063	2,467	1,202	**363**	139	86	0	0
Heavy Rain minus Dry	7,599	8,977	9,142	8,377	7,499	7,054	1,416	**394**
Light Rain minus Dry	3,796	2,559	1,650	746	**382**	271	0	0
2004-2006 South Area								
Heavy Rain	9,232	7,982	6,901	5,415	4,460	4,048	**395**	62
Light Rain	1,329	716	**386**	138	60	40	0	0
Dry Weather	686	**338**	166	51	20	12	0	0
Heavy Rain minus Dry	8,546	7,644	6,735	5,364	4,440	4,036	**395**	62
Light Rain minus Dry	643	**378**	219	86	40	28	0	0

[1]Values in bold type indicate first occurrence of a calculated fecal coliform density less than the proposed 400 cfu/100 mL WRP effluent standard.

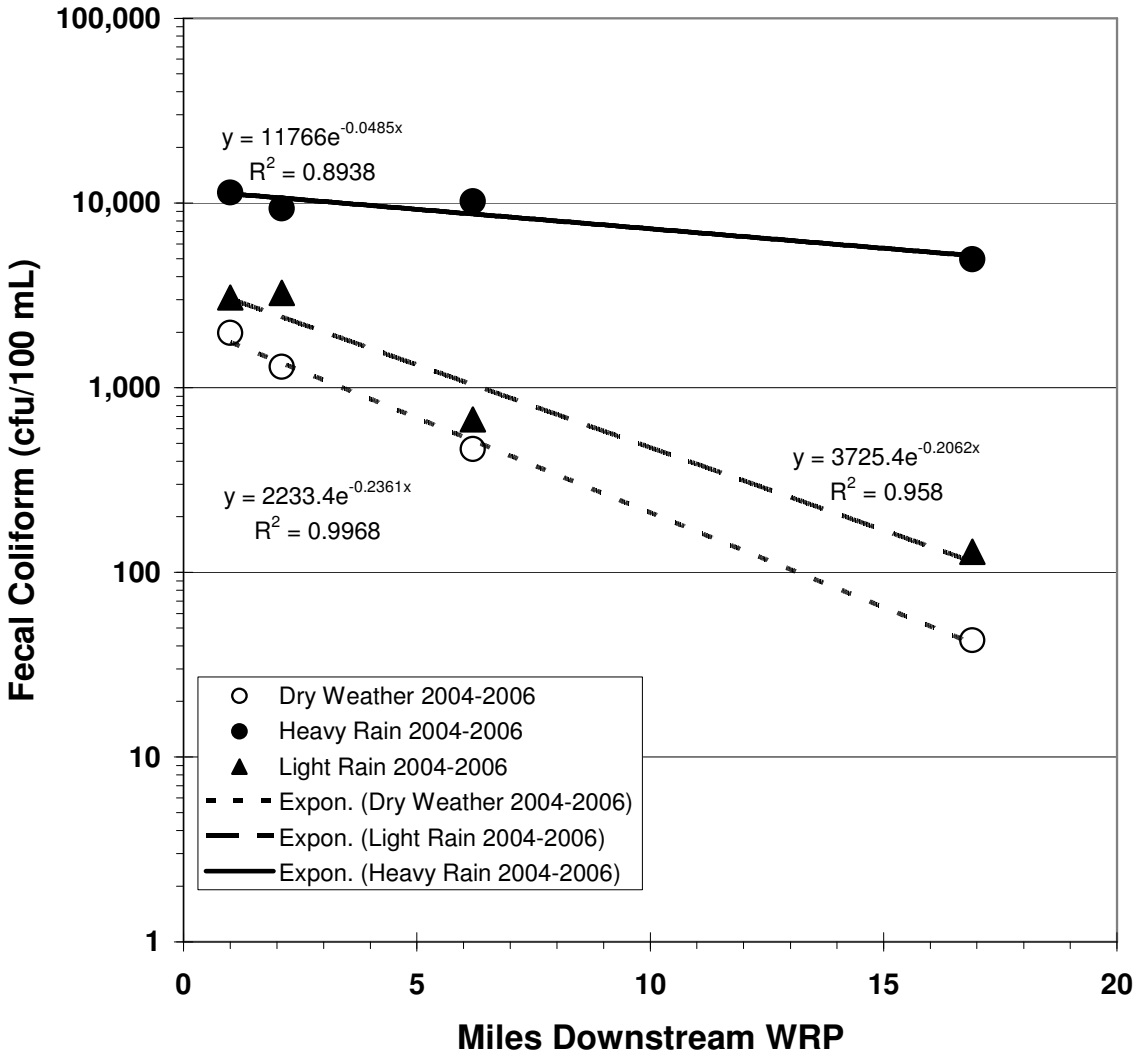
effluent standard at North area stations were predicted to occur 16 miles downstream of the North Side WRP during dry weather, 22 miles downstream during light rain wet weather, 19 miles downstream if disinfection eliminated FC density from the North Side WRP during light rain wet weather, 108 miles downstream during heavy rain wet weather, and also 108 miles downstream if disinfection eliminated FC density from the North Side WRP effluent outfall during heavy rain wet weather.

South Area. Comparisons of geometric means of FC bacteria, with calculated die-off density estimates for wet and dry weather, are shown in Figure 23 for South area stations. Data for the Indiana Avenue Station, located upstream of the Calumet WRP on the Little Calumet River, and data for the Ashland Avenue Tributary Station, located on the shallow portion of the Little Calumet River, were not included in the plots or the die-off equations. Estimated FC densities calculated from these die-off equations are shown in Table 4 at distances of 5 miles and at mile points downstream of WRP effluent outfalls at which proposed IEPA WRP effluent standards are first predicted to be met. Fecal coliform densities less than the 400 cfu/100 mL proposed IEPA effluent standard at South area stations were predicted to occur 8 miles downstream of the Calumet WRP during dry weather, 11 miles downstream during light rain wet weather, 8 miles downstream if disinfection eliminated FC density from the Calumet WRP during light rain wet weather, 70 miles downstream during heavy rain wet weather, and also, 70 miles downstream if disinfection eliminated FC density from the Calumet WRP effluent outfall during heavy rain wet weather.

Impacts of Fecal Coliform Concentrations in the Chicago Sanitary and Ship Canal on the Des Plaines River

In early 2002, the District conducted a sampling program in cooperation with the United States Environmental Protection Agency, Region V, to compare FC concentrations in two urban waterways: the Des Plaines River (DPR) and the Chicago Sanitary and Ship Canal (CSSC) (Rijal et al., 2003). The results of this study provided a comparative assessment of FC concentrations for the 2000–2001 period at DPR Station 91 and CSSC Station 92. DPR Station 91 is upstream of the junction with the CSSC and is classified as General Use. Chicago Sanitary and Ship Canal Station 92 is classified as Secondary Contact. The General Use FC bacteria standard of 400 cfu/100 mL (no more than 10 percent of the samples during any 30-day period are allowed to exceed this limit in General Use water) was applied to grab samples collected during the sampling period. The two year cumulative FC data were analyzed within the framework of wet/dry weather conditions and seasonal disinfection periods. The results from this study indicated that DPR Station 91 had a higher percentage of FC concentrations that exceeded the single sample advisory limit of 400 cfu/100 mL than CSSC Station 92. This observation suggested that by the time any FC contained in the Stickney WRP effluent reach location CSSC Station 92, even without disinfection, the resulting FC concentration at that point was lower than the FC concentration at DPR Station 91, a General Use water. This finding indicated that the secondary treated effluent from Stickney WRP, discharging into the CSSC upstream of the junction with the DPR, was not adversely affecting the microbial quality of the DPR downstream of the junction. Based on this document, there is good evidence that the microbiological quality of CSSC at Station 92,

FIGURE 23: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA DENSITIES AT SOUTH AREA STATIONS WITH ESTIMATED DIE-OFF DENSITIES (UPSTREAM AND TRIBUTARY DENSITIES NOT INCLUDED IN DIE-OFF ESTIMATES)



which is classified as a Secondary Contact water, is comparable to the DPR at Station 91, which is classified as a General Use water.

Escherichia coli/Fecal Coliform Ratio

It is expected that the IEPA may eventually replace FC density limits in District National Pollution Discharge Elimination System (NPDES) permits and water quality standards with limits for *Escherichia coli* (EC) densities. In anticipation of this, Zmuda, Gore, and Abedin (2004) formulated ratios from which EC densities could be converted from FC densities for both the Chicago River and Calumet River Systems. Their best estimates for EC/FC density ratios were 0.93 for the Calumet River System and 0.83 for the Chicago River System.

Effectiveness of Disinfecting Water Reclamation Plant Final Effluent During Wet Weather

During wet weather, elimination of the FC contributions from the WRPs (dry weather FC density) made little difference to the waterway FC density in either the North or the South areas. Estimated wet weather FC density, with or without disinfection, would not meet proposed IEPA effluent standards for at least a distance of 19 miles downstream from the North Side WRP in the North area (or 8 miles downstream from the Calumet WRP in the South area). Densities of FC bacteria, with or without disinfection, would be equivalent at these distances downstream of the respective WRPs. Based on this analysis, WRP effluent disinfection is not effective for improving water quality during wet weather. Disinfection of WRP effluent during wet weather would not improve water quality below either the North Side or Calumet WRPs such that proposed IEPA WRP effluent standards would be met in the CWS.

REFERENCES

APHA (American Public Health Association), SM 9222D, Fecal Coliform Membrane Filter Procedure, Standard Methods for the Examination of Water and Wastewater, 18th Ed., A. E. Greenberg, L. S. Clesceri, and A. D. Eaton, Editors, American Public Health Association, Washington, DC, 1992.

CDM (Camp, Dresser & McKee, Inc.), *Chicago Area Waterway System Use Attainability Analysis,* Draft Report, Available at www.chicagoareawaterways.org, Prepared for the Illinois Environmental Protection Agency, November 2004.

IEPA (Illinois Environmental Protection Agency), Draft January 18, 2007, Title 35, Subtitle C, Part 304, Subpart B, Section 304.224, *Effluent Bacterial Standards for Discharges to the Chicago Area Waterway System and Lower Des Plaines River*, available from www.chicagoareawaterways.org/ proposed-standards/ proposed-standards.pdf,2007

Rijal, G., Z. Abedin, J. Zmuda, and B. Sawyer, *Comparison of Fecal Coliform Concentrations and Trends in Two Urban Rivers: The Chicago Sanitary and Ship Canal and the Des Plaines River,* Research and Development Department Report Number 03-20, Metropolitan Water Reclamation District of Greater Chicago, October 2003.

Zmuda, J. T., R. Gore, and Z. Abedin, *Estimation of the Escherichia coli to Fecal Coliform Ratio in Wastewater Effluents and Ambient Waters of the Metropolitan Water Reclamation District of Greater Chicago*, Research and Development Department Report Number 04-10, Metropolitan Water Reclamation District of Greater Chicago, July 2004.

APPENDIX A1

FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AND SOUTH AREA SAMPLE STATIONS 2004–2006

TABLE AI-1: FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at North Area Stations					
			North Shore Channel		North Branch Chicago River			
	North Side WRP	North Branch Pumping Station	Oakton St.	Foster Ave.	Albany Ave.	Wilson Ave.	Diversey Pkwy.	Grand Ave.
Heavy Rain #1								
05/14/04*	0.54	0.38	NS	NS	NS	NS	NS	NS
05/15/04	0	0	NS	NS	NS	NS	NS	NS
05/16/04	0	0	NS	NS	NS	NS	NS	NS
05/17/04	0	0	NS	NS	NS	NS	NS	NS
05/18/04	0.65	0.48	69,000	130,000	35,000	95,000	32,000	5,600
05/19/04	0	0	2,100	21,000	14,000	13,000	16,000	31,000
05/20/04	1.02	0.89	700	14,000	990	11,000	4,500	2,800
05/21/04	0.09	0.19	NS	NS	NS	NS	NS	NS
05/21/04	0.29	0.07	NS	NS	NS	NS	NS	NS
05/22/04*	0.21	0.29	NS	NS	NS	NS	NS	NS
Heavy Rain #2								
05/30/04*	1.69	1.55	NS	NS	NS	NS	NS	NS
05/31/04*	0.04	0.09	NS	NS	NS	NS	NS	NS
06/01/04	0	0	200,000	13,000	9,300	12,000	7,800	10,000
06/02/04	0.01	0	8,300	17,000	1,400	8,000	5,300	4,500
06/03/04	0	0	1,100	15,000	1,800	12,000	7,700	2,000
06/04/04	0	0	NS	NS	NS	NS	NS	NS
06/05/04	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #3								
08/01/04	0	0	NS	NS	NS	NS	NS	NS
08/02/04	0	0	NS	NS	NS	NS	NS	NS
08/03/04	0.87	0.98	340	5,200	760	6,000	4,900	1,400
08/04/04*	0.45	0.38	470,000	90,000	130,000	210,000	67,000	110,000
08/05/04	0	0	14,000	49,000	20,000	60,000	33,000	18,000
08/06/04	0	0	2,400	10,000	2,500	10,000	7,900	1,400
08/07/04	0	0	NS	NS	NS	NS	NS	NS
08/08/04	0	0	NS	NS	NS	NS	NS	NS

TABLE AI-1 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at North Area Stations					
			North Shore Channel		North Branch Chicago River			
	North Side WRP	North Branch Pumping Station	Oakton St.	Foster Ave.	Albany Ave.	Wilson Ave.	Diversey Pkwy.	Grand Ave.
Heavy Rain #4								
07/25/05	0.08	0.03	NS	NS	NS	NS	NS	NS
07/26/05*	0.39	0.84	NS	NS	NS	NS	NS	NS
07/27/05	0	0	2,000	31,000	4,000	30,000	40,000	8,600
07/28/05	0	0	21,000	280	1,500	24,000	8,600	2,600
07/29/05	0	0	290	29,000	800	26,000	10,000	960
07/30/05	0	0	NS	NS	NS	NS	NS	NS
07/31/05	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #5								
03/11/06	0	0	NS	NS	NS	NS	NS	NS
03/12/06	0.18	0.11	NS	NS	NS	NS	NS	NS
03/13/06*	0.81	0.80	4,450	7,500	7,850	6,800	36,000	38,500
03/14/06	0	0	970	4,200	1,100	3,000	2,200	5,200
03/15/06	0	0	100	2,300	320	1,500	1,300	1,100
03/16/06	0.13	0.06	NS	NS	NS	NS	NS	NS
03/17/06	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #6								
04/01/06	0	0	NS	NS	NS	NS	NS	NS
04/02/06	0.68	0.65	NS	NS	NS	NS	NS	NS
04/03/06*	0.30	0.13	2,700	5,100	78,000	210,000	110,000	73,000
04/04/06	0	0	64,000	2,600	3,400	3,500	2,400	23,000
04/05/06	0	0	14,000	2,500	1,000	1,500	1,100	1,400
04/06/06	0	0	NS	NS	NS	NS	NS	NS
04/07/06	0.08	0.03	NS	NS	NS	NS	NS	NS

TABLE AI-1 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at North Area Stations					
			North Shore Channel		North Branch Chicago River			
	North Side WRP	North Branch Pumping Station	Oakton St.	Foster Ave.	Albany Ave.	Wilson Ave.	Diversey Pkwy.	Grand Ave.
Heavy Rain #7								
04/15/06	0	0	NS	NS	NS	NS	NS	NS
04/16/06*	0.32	0.46	NS	NS	NS	NS	NS	NS
04/17/06*	0.66	0.41	110,000	8600	22,000	11,000	11,000	130,000
04/18/06	0	0	7,700	9,400	1,000	5,700	5,100	5,500
04/19/06	0	0	2,200	4,700	740	3,400	3,800	2,200
04/20/06	0.04	0	NS	NS	NS	NS	NS	NS
04/21/06	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #8								
06/24/06	0	0	NS	NS	NS	NS	NS	NS
06/25/06	0.12	0.01	NS	NS	NS	NS	NS	NS
06/26/06*	0.82	0.96	23,000	32,000	12,000	29,000	30,000	6,800
06/27/06	0.19	0.07	2,700	5,500	8,400	6,900	8,300	17,000
06/28/06	0.22	0.11	5,600	5,000	3,200	5,000	7,400	1,300
06/29/06	0.03	0.01	NS	NS	NS	NS	NS	NS
06/30/06	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #9								
08/26/06	0	0	NS	NS	NS	NS	NS	NS
08/27/06	0	0	NS	NS	NS	NS	NS	NS
08/28/06*	0.81	1.12	NS	NS	NS	NS	NS	NS
08/29/06*	0.48	0.29	1,200	30,000	25,000	16,000	23,000	69,000
08/30/06	0.11	0.08	1,500	21,000	23,000	38,000	65,000	270,000
08/31/06	0	0	110	9,400	1,400	5,600	11,000	8,600
09/01/06	0	0	NS	NS	NS	NS	NS	NS
09/02/06	0	0	NS	NS	NS	NS	NS	NS

TABLE AI-1 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at North Area Stations					
			North Shore Channel		North Branch Chicago River			
	North Side WRP	North Branch Pumping Station	Oakton St.	Foster Ave.	Albany Ave.	Wilson Ave.	Diversey Pkwy.	Grand Ave.
Heavy Rain #10								
10/01/06	0.11	0.01	NS	NS	NS	NS	NS	NS
10/02/06*	1.43	2.16	NS	NS	NS	NS	NS	NS
10/03/06*	0	0	170,000	48,000	66,000	52,000	63,000	210,000
10/04/06	0	0	330,000	71,000	21,000	33,000	41,000	54,000
10/05/06	0	0	140,000	11,000	4,600	8,900	7,600	5,700
10/06/06	0	0	NS	NS	NS	NS	NS	NS
10/07/06	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #11								
10/15/06	0	0	NS	NS	NS	NS	NS	NS
10/16/06	0.45	0.33	NS	NS	NS	NS	NS	NS
10/17/06*	0.54	0.57	34,000	46,000	81,000	36,000	100,000	5,000
10/18/06	0.22	0.05	9,600	9,400	3,000	6,600	7,600	28,000
10/19/06	0	0	320	9,600	360,000	20,000	22,000	3,000
10/20/06	0	0	NS	NS	NS	NS	NS	NS
10/21/06	0.22	0.13	NS	NS	NS	NS	NS	NS

TABLE AI-1 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at North Area Stations					
			North Shore Channel		North Branch Chicago River			
	North Side WRP	North Branch Pumping Station	Oakton St.	Foster Ave.	Albany Ave.	Wilson Ave.	Diversey Pkwy.	Grand Ave.
Light Rain #1								
05/10/04	0.24	0.01	720	25,000	680	22,000	6,600	1,000
06/14/04	0.15	0.28	850	8,400	100,000	5,400	8,500	2,200
01/04/05	0.05	0.09	3,700	7,200	3,600	6,400	7,600	4,400
02/14/05	0.09	0.04	42,000	21,000	21,000	24,000	23,000	13,000
11/08/05	0.15	0.05	6,100	2,500	10,000	7,200	6,100	4,900
11/14/05	0.09	0.03	5,600	10,000	2,000	9,300	11,000	3,900
03/07/06	0.06	0.06	970	6,800	3,100	9,400	7,200	1,200
09/05/06	0.11	0.12	2,500	76,000	4,300	30,000	11,000	4,600
Light Rain #2								
07/05/05	0.16	0.05	1,600	12,000	15,000	14,000	8,900	800
10/04/05	0.03	0.03	4,100	22,000	1,800	25,000	11,000	10,000
12/12/05	0.02	0.02	2,900	6,000		8,000	4,100	1,700
01/03/06	0.31	0.4	2,100	8,100	2,600	11,000	37,000	2,800
Light Rain #3								
05/02/06	0	0.15	120	22,000	40	9,900	3,500	4,300
07/05/06	0.42	0.37	210	3,700	650	3,900	1,500	650

TABLE AI-1 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT NORTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at North Area Stations					
			North Shore Channel		North Branch Chicago River			
	North Side WRP	North Branch Pumping Station	Oakton St.	Foster Ave.	Albany Ave.	Wilson Ave.	Diversey Pkwy.	Grand Ave.
Dry Weather								
04/06/04	0	0	40	22,000	420	14,000	5,500	2,100
04/12/04	0	0	280	20,000	200	17,000	8,800	1,300
05/04/04	0	0	3,700	6,800	460	3,500	2,300	1,300
08/09/04	0	0	770	5,600	1,100	5,300	4,000	2,100
10/05/04	0	0	60	9,500	2,000	7,100	4,100	550
10/11/04	0	0	140	5,800	1,300	5,300	2,500	1,100
11/08/04	0	0	630	7,100	420	4,800	3,400	3,600
12/13/04	0	0	570	4,200	890	3,400	2,000	2,100
01/10/05	0	0	4,200	6,200	1,600	5,600	3,600	3,200
04/05/05	0	0	700	5,100	390	4,100	2,600	970
05/03/05	0	0	20	6,200	300	6,200	3,100	1,700
05/09/05	0	0	30	8,600	460	6,000	3,700	1,600
09/06/05	0	0	120	11,000	910	9,000	3,900	1,300
09/12/05	0	0	370	31,000	710	11,000	5,500	650
01/09/06	0	0	1,200	4,800	650	3,300	2,800	1,500
02/14/06	0	0	2,300	3,500	140	3,800	1,600	1,100
04/10/06	0	0	2,000	3,900	210	2,600	890	200
05/08/06	0	0	30	5,500	420	2,400	1,200	290
06/06/06	0	0	110	8,100	440	8,100	3,000	760
08/08/06	0	0	170	11,000	920	10,000	9,000	910
08/14/06	0	0	90	30,000	460	20,000	7,600	2,600
12/05/06	0	0	9,800	11,000	3,500	8,300	8,800	7,800

NS = No Fecal Coliform sample.
*North Branch Pumping Station CSO discharge to North Branch Chicago River.

TABLE AI-2: FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT SOUTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at South Area Stations					
			Little Calumet River			Calumet-Sag Channel		
	Calumet WRP	Melvina Pumping Station	Indiana Ave.	Halsted St.	Ashland Ave.	Ashland Ave.	Cicero Ave.	Route 83
Heavy Rain #1								
05/14/04*	0.81	0.78	NS	NS	NS	NS	NS	NS
05/15/04*	0.01	0.17	NS	NS	NS	NS	NS	NS
05/16/04	0	0	NS	NS	NS	NS	NS	NS
05/17/04	0	0	NS	NS	NS	NS	NS	NS
05/18/04	0.90	0.32	200	4,100	80,000	10,000	3,000	360
05/19/04	0	0	200	2,600	14,000	7,800	6,800	840
05/20/04	0	0	140	3,400	990	2,200	770	540
05/21/04	0.03	0.28	NS	NS	NS	NS	NS	NS
05/22/04	0.10	0.01	NS	NS	NS	NS	NS	NS
Heavy Rain #2								
05/30/04*	1.01	1.50	NS	NS	NS	NS	NS	NS
05/31/04*	0.42	0.32	NS	NS	NS	NS	NS	NS
06/01/04*	0	0.03	360	54,000	9,500	36,000	39,000	31,000
06/02/04	0.03	0.11	440	3,200	3,700	2,400	3,500	3,300
06/03/04	0	0	140	5,800	2,000	2,000	1,200	2,500
06/04/04	0	0	NS	NS	NS	NS	NS	NS
06/05/04	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #3								
06/12/04*	0	0	NS	NS	NS	NS	NS	NS
06/13/04	0	0	NS	NS	NS	NS	NS	NS
06/14/04	0.36	0.61	560	5,600	1,600	2,000	1,100	2,300
06/15/04	0	0	370	5,900	3,000	3,600	2,400	2,000
06/16/04	0	0	240	5,000	2,100	1,300	1,100	440
06/17/04	0	0	NS	NS	NS	NS	NS	NS
06/18/04	0	0	NS	NS	NS	NS	NS	NS

TABLE AI-2 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT SOUTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at South Area Stations					
			Little Calumet River			Calumet-Sag Channel		
	Calumet WRP	Melvina Pumping Station	Indiana Ave.	Halsted St.	Ashland Ave.	Ashland Ave.	Cicero Ave.	Route 83
Heavy Rain #4								
08/26/06	0	0	NS	NS	NS	NS	NS	NS
08/27/06	0	0	NS	NS	NS	NS	NS	NS
08/28/06*	0.42	0.99	30	1,600	440	1,100	500	260
08/29/06	0.87	0.03	410	65,000	37,000	76,000	200,000	200,000
08/30/06	0	0	1,600	16,000	9,300	11,000	8,600	10,000
08/31/06	0	0	560	11,000	4,900	7,400	3,300	1,500
09/01/06	0	0	NS	NS	NS	NS	NS	NS
09/02/06	0	0	NS	NS	NS	NS	NS	NS
Heavy Rain #5								
09/10/06	0.34	0.2	NS	NS	NS	NS	NS	NS
09/11/06	0.70	1.09	NS	NS	NS	NS	NS	NS
09/12/06	0.48	0.12	NS	NS	NS	NS	NS	NS
09/13/06*	1.23	0.89	12,000	6,000	34,000	37,000	290,000	1,500
09/14/06	0	0	13,000	44,000	31,000	40,000	100,000	70,000
09/15/06	0	0	5,900	12,000	9,000	14,000	12,000	12,000
09/16/06	0	0	NS	NS	NS	NS	NS	NS
09/17/06	0.44	0.69	NS	NS	NS	NS	NS	NS
Heavy Rain #6								
10/01/06	0.06	0.02	NS	NS	NS	NS	NS	NS
10/02/06	1.99	3.09	NS	NS	NS	NS	NS	NS
10/03/06*	0	0	380	63,000	38,000	7,700	33,000	22,000
10/04/06	0	0	550	29,000	11,000	35,000	94,000	44,000
10/05/06	0	0	480	13,000	1,600	6,400	3,300	5,200
10/06/06	0	0	NS	NS	NS	NS	NS	NS
10/07/06	0	0	NS	NS	NS	NS	NS	NS

TABLE AI-2 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT SOUTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at South Area Stations					
			Little Calumet River			Calumet-Sag Channel		
	Calumet WRP	Melvina Pumping Station	Indiana Ave.	Halsted St.	Ashland Ave.	Ashland Ave.	Cicero Ave.	Route 83
Light Rain #1								
04/20/04	0.66	0.57	40	270	140	250	20	40
05/25/04	0.43	0.21	80	3,100	9,900	16,000	2,300	210
06/28/04	0.18	0.03	50	6,500	410	3,900	400	20
02/28/05	0.03	0.05	170	2,800	29,000	2,700	2,200	470
07/25/05	0.12	0.60	40	2,200	510	930	410	200
10/24/05	0.65	0.22	170	13,000	66,000	33,000	1,700	9
11/28/05	0.44	0.77	70	9,000	68,000	5,200	1,600	50
07/18/06	0.45	0.01	10	760	1,200	1,200	190	40
Light Rain #2								
05/26/04	0.43	0.21	240	4,300	4,700	3,100	1,100	210
06/22/04	0.28	0.42	30	3,000	7,600	1,800	500	90
11/16/04	0.09	0.00	7,200	5,800	16,000	8,500	2,500	230
07/19/05	0.16	0.01	60	1,300	130,000	22,000	30	9
09/20/05	0.19	0.80	50	2,000	2,900	2,000	810	1,700
09/26/05	0.26	0.15	20	3,400	32,000	6,900	830	70
05/16/06	0.20	0.14	90	3,800	2,200	2,700	1,300	160
10/23/06	0.11	0.11	590	6,800	760	4,600	910	510
Light Rain #3								
01/24/05	0.11	0.10	NS	2,000	NS	800	530	NS
02/22/05	0.08	0.06	140	2,900	1,400	2,900	3,600	630
06/20/06	0.07	0.07	180	4,100	140	3,300	210	40
09/19/06	0.44	0.69	1,000	6,400	2,000	4,100	2,700	1,300
09/25/06	0.24	0.09	220	2,000	1,500	1,300	740	480

TABLE AI-2 (Continued): FECAL COLIFORM DENSITIES DURING WET AND DRY WEATHER AT SOUTH AREA SAMPLE STATIONS 2004–2006

Date	Rainfall (inches)		Fecal Coliform (cfu/100 mL) at South Area Stations					
			Little Calumet River			Calumet-Sag Channel		
	Calumet WRP	Melvina Pumping Station	Indiana Ave.	Halsted St.	Ashland Ave.	Ashland Ave.	Cicero Ave.	Route 83
Dry Weather								
09/27/04	0	0	40	3500	220000	2100	340	20
12/21/04	0	0	140	2900	5200	3000	2200	510
03/28/05	0	0	20	2100	970	2400	2100	100
04/25/05	0	0	NS	6000	1100	3600	1500	40
05/17/05	0	0	20	670	550	270	110	10
05/23/05	0	0	NS	710	410	880	250	30
06/21/05	0	0	120	2000	300	550	110	20
06/27/05	0	0	99	1100	150	480	120	9
08/16/05	0	0	30	1400	1200	1200	740	60
02/21/06	0	0	490	1500	360	1200	980	210
02/27/06	0	0	20	1200	150	860	180	9
03/21/06	0	0	170	3600	2400	3100	1000	160
05/22/06	0	0	110	2700	370	3100	420	9
08/22/06	0	0	50	2500	390	930	490	120
11/27/06	0	0	390	3400	550	1300	450	70

NS = No Fecal Coliform sample.
*125th St. Pumping Station CSO discharge to Calumet-Sag Channel.