BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	R08-9
CHICAGO AREA WATERWAY SYSTEM	)	(Rulemaking - Water)
AND THE LOWER DES PLAINES RIVER:	)	
PROPOSED AMENDMENTS TO 35 Ill.	)	
Adm. Code Parts 301, 302, 303 and 304	)	

PRE-FILED TESTIMONY OF GEETA K. RIJAL

Mr. Chairman and Members of the IPCB Committee, I am Geeta K. Rijal, Section Head of the Analytical Microbiology and Biomonitoring Section at the Metropolitan Water Reclamation District of Greater Chicago (District). I thank you for the opportunity to appear before the committee to provide information on the Chicago Area Waterways System (CAWS) microbial water quality.

I am an environmental microbiologist by training. I have a master's degree in environmental science from the University of Philippines at Los Banos, a Master's and a PhD degree in environmental microbiology from the University of Hawaii. I have been involved in a number of microbiological research studies assessing the public health significance of pathogenic microorganisms in various water sources (drinking water, groundwater, recreation water, rainwater catchment systems, sewage water, reclaimed sewage water, streams, storm drains, estuaries, harbors, beach water, ocean water near sewage outfalls, aquarium water, and aquaculture water) using traditional and advance molecular methods. At the District, I manage the Analytical Microbiology and Biomonitoring Section which includes whole effluent toxicity, parasitology, virology, and microbiology laboratories. I am a member of the American Society of Microbiology and a board certified national registered microbiologist (NRM) in clinical and public health microbiology. I am also certified by the Illinois Department of Public Health for microbiological evaluation of water, water supplies and their sources. I am actively involved with the Water Environment Research Foundation (WERF) serving as a project subcommittee (PSC) member for projects related to pathogen analyses in urban rivers, wastewater and biosolids. I have also been selected to serve as one of the Pathogen Workgroup (PW) members by the National Association of Clean Water Agencies (NACWA). NACWA nominated PW experts in 2006 to provide Environmental Protection Agency (EPA) with scientific and technical input on the complications associated with wet weather flows, the relative risk to humans from various sources of pathogens and other variables in relation to the implementation of recreational water quality criteria.

For more than fifteen years, I have worked on water and wastewater and have extensive background and experience in various facets of indicators for pathogens in wastewater, recreation water, biosolids, and river water. A resume is attached (ATTACHMENT I).

My testimony addresses the District's special study on fecal coliform (FC) bacteria distribution in the CAWS and the relationship between water quality and point and non-point source contributions during dry and wet weather conditions. I have provided a summary overview of the FC distribution studies in my testimony. I have also included a detailed supplementary literature review on non-point source (microbial contamination) information in an appendix (ATTACHMENT II).

Fecal Coliform Distribution Study

The District participated and supported the Use Attainability Analysis Study conducted by Illinois EPA (IEPA) by providing structured scientific information on the potential recreational use classification for the CAWS. The IEPA and the District recognized that a microbiological understanding of the CAWS is required before scientifically sound recommendations concerning the recreational use potential and protective standards can be established for the man-made waterways. In this regard, IEPA requested the District undertake and support a structured microbiological assessment approach designed to evaluate the need and, if necessary, provide the basis for generating numeric water quality standards for the proposed recreational use designations. In order to assist the IEPA in making this determination, the District conducted fecal coliform distribution studies which are cited and described in the order they were conducted.

- District Report No. 2003-20: Comparison of Fecal Coliform Concentrations and Trends in Two Urban Rivers: The Chicago Sanitary and Ship Canal (CSSC) and the Des Plaines River (ATTACHMENT III).

In early 2002, the District conducted a sampling program in cooperation with the United States Environmental Protection Agency, Region V, to compare fecal coliform (FC) concentrations in two urban waterways: the Des Plaines River (DPR) and the Chicago Sanitary and Ship Canal (CSSC). It was assumed that the District Water Reclamation Plants (WRPs) were the dominant sources of FC reaching the lower DPR. The District recognized that a thorough understanding of the trends and variation of fecal coliform concentrations both in the DPR and the CSSC at Lockport are required before sound recommendations regarding recreational potential of the lower DPR can be made.

This study was undertaken to compare the FC concentrations at the DPR upstream of Lockport (District monitoring location 91) and at the CSSC at Lockport (District monitoring location 92) for the 2000-2001 period. 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. Existing water quality monitoring data (FC, Total Suspended Solids [TSS], temperature and turbidity) as well as river flow and rainfall data for the 2000 through 2001 period were put into a single database. Statistical analysis was conducted to determine the seasonal effects and the relationship to weather conditions (wet and dry) and the seasonal disinfection period (May through October with disinfection and November through April with no-disinfection) on FC concentrations. Regression analysis was performed to study the relationship of FC concentrations with river flow, rainfall, TSS, turbidity and temperature at locations 91(DPR) and 92 (CSSC). Regression models were developed to predict FC concentrations at the two waterway locations. The results of this study provided a comparative assessment of FC concentrations for the 2000-2001 periods at DPR Station 91 and CSSC Station 92

The results from this study indicated that DPR Station 91, which is designated General Use and receives disinfected wastewater effluent from upstream suburban communities, had a higher percentage of FC concentrations which exceeded the single sample advisory limit of 400 CFU/100 mL than CSSC Station 92 which is dominated by undisinfected effluents of the District's Stickney, North Side and Calumet WRPs. This observation suggested that by the time any FC contained in the Stickney, North Side and Calumet WRP effluent reached location CSSC Station 92, even without disinfection, the resulting FC concentration, at that point, was lower than the FC concentration at DPR Station 91, which is classified as General Use water. The secondary treated effluent from the District WRPs, discharging into the Chicago Area Waterway System (CAWS) upstream of the junction with DPR, was not adversely impacting the microbial quality of the DPR downstream of the junction. Based on this document, there is good evidence that the microbial quality of the CSSC at Station 92, which is classified as Secondary Contact water, is comparable with respect to FC of the DPR at Station 91, which is classified as General Use water.

- District Report No. 2007-79: Fecal Coliform Densities in Chicago Area Waterway System During Dry and Wet Weather 2004-2006 (ATTACHMENTS IV and V).

In 2004, the District undertook a three-year study to predict the die-off of FC in the receiving streams downstream of the North Side and Calumet WRPs. The North Area of the study sampling occurred on the: North Shore Channel upstream of the North Side WRP at Oakton Street, and downstream of the North Side WRP at Foster Avenue; at Wilson Avenue on the North Branch Chicago River; Diversey Parkway on the North Branch Chicago River; at Grand Avenue on the North Branch Chicago River; and at Albany Avenue on the North Branch of the Chicago River upstream of the North Branch dam; and the confluence with the North Shore Channel. This last station enabled us to assess the water quality of the North Branch of the Chicago River at a point that is tributary to the CAWS. For the South Area of the study sampling occurred on the: Little Calumet River: upstream of the Calumet WRP at Indiana Avenue; and downstream of the Calumet WRP at Halsted Avenue; Ashland Avenue on the Calumet-Sag Channel; Cicero Avenue on the Calumet-Sag Channel; and Route 83 on the Calumet-Sag Channel. In addition samples were collected from the Little Calumet River at Ashland Avenue at a point that is tributary to the CAWS.

Currently, the effluents of these WRPs are not disinfected. The purpose of this study was to determine, from the collected data, whether disinfection of the effluents from these WRPs would significantly reduce the FC load in the receiving streams during wet weather and how the FC concentration in the waterways compares to the effluent disinfection standard proposed in this rulemaking.

Water samples were collected at each location described above as grab samples from mid-channel at a 1-m depth twice a month between April and December 2004 through 2006, and the FC density was measured. In addition, water samples were collected for FC each day, for a maximum of three days, following any rain event sufficient to cause an overflow at the North Side Pumping Station or at the 122nd Street, 125th Street or 95th Street Pumping Stations (for South Area Stations). Water samples were analyzed for FC by the District's Illinois Department of Public Health certified Analytical Microbiology Laboratory using the FC membrane filter procedure (SM 9222D, SM 18th ed. [APHA, 1992]). Rainfall was recorded at rain gauge stations in the North and South areas during 2004, 2005 and 2006. Dry weather FC values were conservatively assumed to result entirely from WRP effluents and were subtracted from the wet weather FC values to estimate FC densities which might occur in the waterways during wet weather if disinfection eliminated the FC burden in the WRP outfalls. Equations for FC die-off curves and corresponding R^2 values were calculated using Microsoft Excel and all statistical decisions were made using the 0.05 level of probability.

Trends in Fecal Coliform Densities From Non-WRP Sources with Rainfall

FC densities 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. "**Light rain**" was defined as any measurable rainfall that occurred on the same day, or on one or two days prior, to the collection of a routine fecal coliform sample. "**Heavy rain**" was defined as a 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. "**Dry weather**" was defined as any day on which no measurable rainfall occurred, including no rainfall two days prior and one day after the day on which a routine fecal coliform sample was collected.

In the North area, heavy rains averaged 0.5 inch, with a maximum of 2.2 inches. Light rains averaged 0.1 inch, with a maximum of 0.4 inch. In the South area, heavy rains averaged 0.7 inch, with a maximum of 3.1 inches. Light rains averaged 0.3 inch, with a maximum of 0.8 inch. Measurable rainfall occurred for the March through November period in the North area: 40.5 percent of the calendar days in 2004; 33.5 percent of the calendar days in 2005; and 46 percent of the calendar days in 2006. Similarly, rainfall occurred for the March through November period in the South area: 42 percent of the calendar days in 2004; 30.5 percent of the calendar days in 2005; and 46 percent of the calendar days in 2006.

We observed that upstream of the North Side WRP, fecal coliform densities were greater than the proposed effluent limit of 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. In the North Branch of the Chicago River, where it is tributary to the CAWS at Albany Avenue, fecal coliform densities were greater than the proposed effluent limit of 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. These sources of bacteria will not be reduced or eliminated if the proposed fecal coliform effluent limit is adopted.

In the South study area, upstream of the Calumet WRP at Indiana Avenue, fecal coliform densities were greater than the proposed effluent limit of 400 CFU/100 mL, 53 percent of the time during heavy rainfall periods, 15 percent of the time during light rainfall and 8 percent of the time during dry weather periods. In the Little Calumet River at Ashland Avenue, a tributary which feeds into the CAWS downstream of the Calumet WRP effluent outfall, fecal coliform densities were greater than the proposed effluent limit of 400 CFU/100 mL, 95 percent of the time during heavy rainfall, 90 percent of the time during light rainfall and 60 percent of the time during dry weather periods. These sources of bacteria will not be reduced or eliminated if the proposed fecal coliform effluent limit is adopted

Lingering Effects of Wet Weather Impact on FC Densities

In the North area during heavy rain periods, geometric mean FC density on the first and second days of measurement were approximately 10 to 100 times greater than the proposed 400 CFU/100 mL effluent standard and much higher than during dry weather. The FC density did not show a pattern of reduction with downstream distance from the WRPs. This was likely due to FC loads from the North Branch Pumping Station discharges, as well as FC input from other combined sewer overflows (CSOs) and storm water inflows that would have been greatest 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. Geometric mean FC density on the first and second days of measurement were approximately 10 to 30 times greater than the proposed 400 CFU/100 mL effluent standard and much higher than during dry weather.

In the South area during heavy rain periods, geometric mean FC density on the first and second days of measurement were approximately 20 to 60 times greater than the proposed 400 CFU/100 mL effluent standard and much higher than during dry weather. The FC density did not show a pattern of reduction with downstream distance from the WRPs. This was likely due to FC loads from the 125th Street Pumping Station discharges, as well as FC input from other CSOs and storm water inflows that would have been greatest during or immediately following the storms. Light rain FC density varied, and the pattern of FC reduction was more apparent with distance below the Calumet WRP. Geometric mean FC density on the first and second days of measurement were approximately 10 to 20 times greater than the proposed 400 CFU/100 mL effluent standard and much higher than during dry weather.

Evaluation of Water Quality Improvement Resulting from Disinfection During Wet Weather

In order to estimate waterway FC that might occur during wet weather conditions if there was complete disinfection of WRP effluent outfalls, dry weather FC were subtracted from wet weather FC, and the results are shown in <u>Figure 1</u> with the calculated wet (with and without disinfection) and dry weather FC.

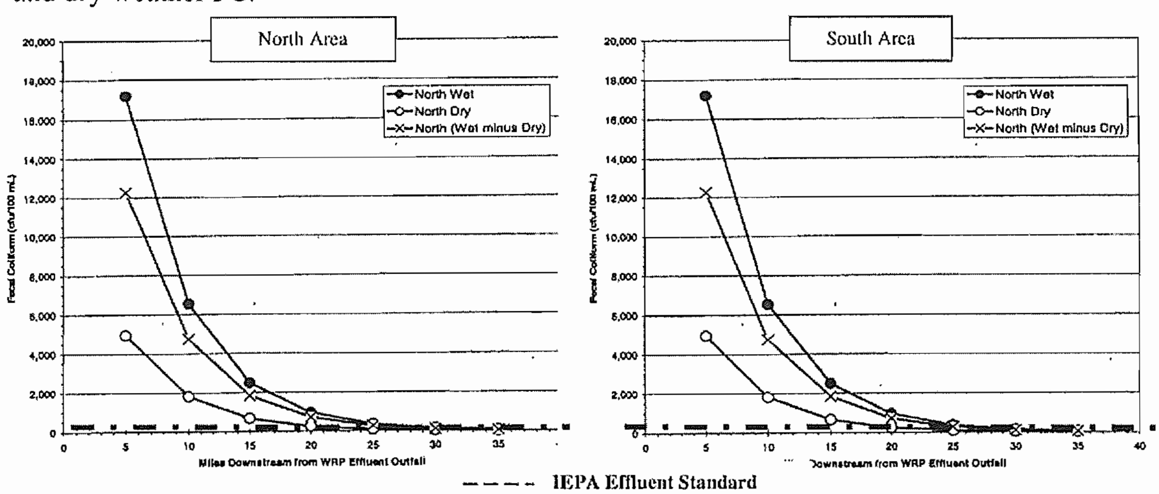

Figure 1: Estimated FC densities downstream of the North Side and Calumet WRPs during dry weather (o) and wet weather ([X with] or [● without] disinfection) conditions.

During wet weather elimination of the FC, contributions from the WRPs (dry weather FC density) made little difference to the CAWS density in either the North or the South areas. Estimated wet weather FC density, with or without disinfection, would not meet proposed 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. The FC densities, with or without disinfection, would be equivalent at these distances downstream of the respective WRPs. It is evident from this analysis that disinfection of the North Side and Calumet WRP effluents during wet weather would not improve the CAWS microbiological water quality downstream of these WRPs in terms of compliance with the proposed effluent standard.

FC Distribution Study Conclusion

This study demonstrates that the North Side and Calumet WRPs are not the only significant sources of FC to the CAWS. During wet weather, even light rainfall periods, the CAWS receive CSO, municipal separate storm water sewer system and non-point bacteria loads that result in elevation of FC concentrations in the CAWS to levels much higher than are observed during dry weather, such that disinfecting WRP effluents will not result in a substantial reduction in FC concentration in the waterways. During dry weather periods, lingering effects of wet weather, as well as tributary loads, maintain elevated levels of FC in the CAWS. In the North study area, FC concentrations in the tributary North Branch of the Chicago River above the low head dam at Albany Avenue were as high as 360,000, 100,000 and 3,500 CFU/100 mL during heavy rain, light rain and dry weather. In the North Shore Channel upstream of the North Side WRP at Oakton Street, FC densities were as high as 470,000, 42,000 and 9,800 CFU/100 mL during heavy rain, light rain and dry weather. In the south area, FC concentrations in the Little Calumet River, a downstream tributary to the Calumet WRP effluent outfall were as high as 76,000, 33,000 and 3,600 CFU/100 mL during heavy rain, light rain and dry weather.

These results indicate that even if effluent disinfection were completely effective at reducing fecal bacteria, the microbiological water quality downstream of these WRPs would still be much higher than 400 fecal coliform CFU/100 mL a great deal of the time. This is due to the fact that elevated FC concentrations result from rainfall events, even light rain events, and measurable rainfall occurs approximately 145 days (about 40 %) each year. In addition, wet weather effects linger well after the rainfall ends. The elevated FC densities that occur during wet weather conditions, including the March through November period when the proposed IEPA effluent standard would be in effect, will not be mitigated by disinfection of WRP effluents. This protective measure would, therefore, be ineffective at significantly reducing CAWS bacteria concentrations for a substantial portion of the year.

Summary Testimony

In closing, Mr. Chairman, the findings presented above and in the attachments are many of the credible facts that leads to final conclusion that the proposed disinfection standard should not be adopted until IEPA can demonstrate that reducing fecal coliform in the WRP effluents will result in some public health benefit.

This concludes my testimony. I appreciate the opportunity to appear before the IPCB committee, and I would be pleased to answer any questions.

Respectfully submitted,

Geeta K. Rijal, Ph.D., RM (NRM)
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Metropolitan Water Reclamation District of Greater Chicago

REFERENCES

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

CDM (Camp, Dresser & Mc Kee, Inc.), *Chicago Area Waterway System Use Attainability Analysis*, Draft Report, Available at www.chicagoareawaterways.org, Prepared for the Illinois Environmental Protection Agency, 2007.

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.

ATTACHMENTS

I. Geeta Rijal Resume

II. Non-point Sources of Bacterial Pollution in the Chicago Area Waterway System (CAWS)

III. District Report No. 2003-20: Comparison of Fecal Coliform Concentrations and Trends in Two Urban Rivers: The Chicago Sanitary and Ship Canal and the Des Plaines River, Rijal, G., Z. Abedin, J. Zmuda, and B. Sawyer, Research and Development Department, Metropolitan Water Reclamation District of Greater Chicago, October 2003.

IV. District Interim Report No. 2005-15: Fecal coliform Densities in Chicago Area Waterways During Dry and Wet Weather, 2004.

V. District Report No. 2007-79: Fecal coliform Densities in the Chicago Waterway System During Dry and Wet Weather 2004-2006.

Attachment 1

ATTACHMENT I

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ACADEMIC QUALIFICATIONS

- Ph.D., Dept. of Microbiology, Univ. of Hawaii at Manoa,
- MS in Microbiology - Dept. of Microbiology, Univ. of Hawaii at Manoa
- MS in Environmental Science - Dept. of Environmental Studies, Univ. of Philippines at Los Banos
- BS, Department of Microbiology, University of Bombay, India

AWARDS RECIEVED

- Water Environment Federation (Hawaii) Scholarship award for the year 1994-95.
- East-West Center (1989-1993) Scholarship award for Master & Ph.D. Degree at University of Hawaii
- WINROCK International Fellowship (1985-87) Master Degree at University of Philippines
- Gamma Sigma Delta, Honor award in recognition of high scholarship, outstanding achievement /service to Agricultural Science (University of Philippines at Los Banos).

EMPLOYMENT & RESEARCH EXPERIENCE

2006-Present	Microbiologist IV, Section Head of Analytical Microbiology & Biomonitoring Section of Environmental Monitoring & Research Division of the Metropolitan Water Reclamation District of Greater Chicago Supervise Microbiology, Virology, Biomonitoring, Microbiology, & Parasitology Monitoring and Research Activities; Review District policies and District plans; Research on Antibiotic Resistant Bacteria, Microbial Risk Assessment of Chicago Area Waterways; Epidemiology Study of Chicago Area Waterways; and Wet weather and CSO impact on the Chicago Area Waterways.
2001-2005	Microbiologist III, Analytical Microbiology & Biomonitoring Laboratory Manager of Environmental Monitoring & Research Division of the Metropolitan Water Reclamation District of Greater Chicago Supervise and provide support to Aquatic Biology, Virology, Biomonitoring (Whole Effluent Toxicity), Soil, and Analytical Microbiology Group; supervise microbiological and related analyses, and research and methods development; and research projects.
1997-2001	Post Doctorate Research Fellow, Water Resources Research Center at Univ. of Hawaii. Writing Research Grant Proposals; Identification of environmental microbes by gene probe technology; Evaluation of treatment technologies for small-scale drinking water systems; Evaluation of treatment technologies -pilot scale and full-scale UV systems for wastewater treatment; Training Dept. of

Health and City Personnel's of Hawaii on Environmental PCR Methods.

Lecturer, Microbiology Department, University of Hawaii
Taught MICR 351, MICR 431 advance graduate microbiology course (bacteriology and physiology); Taught Biology 171 introductory biology course

1996-1997 Researcher, Water Quality Laboratory at Centers for Disease Control & Prevention, Atlanta Georgia
Literature review study for project requirement on existing State Regulations
Detection of indicator and infectious organisms (*Giardia* & *Cryptosporidium*)

1989-1996 Graduate Research Assistant, University of Hawaii at Manoa
Research on microbiological water quality of tropical streams, cistern water, drinking water, and soil using multiple indicator organisms belonging to different classes of microorganisms (bacteria and viruses); Evaluation of Ultraviolet light as a means to disinfect wastewater and drinking water; Evaluation of solar powered UV treatment and solar pasteurization system; Conducted microbiological water quality test of drinking water in Nepal water in rural regions and remote islands of US; Collaborated with Hach Company to evaluate simple hydrogen sulfide test .

1985-1989 Senior Research Scientist, Royal Nepal Academy of Science & Technology
Conducted/ Coordinated environmental and biotechnological research at University and Government laboratories. Lecturer in Department of Microbiology at Tribhuvan University, Nepal. Lecturer at Medical School at Tribhuvan University Nepal

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PUBLICATIONS

- G. Rijal, J.T. Zmuda, R. Gore, T. Granato, and, R. Lanyon. 2007. Antibiotic Resistant Bacteria in Wastewater Processed by the Metropolitan Water Reclamation District of Greater Chicago System. Health Related Microbiology Conference Proceedings, Tokyo Japan. To be published in Wat. Sci. Tech.
- S. Dennison, G. Rijal and T. Granato. 2007. Fecal Coliform Densities in the Chicago Area Waterway System During Dry and Wet Weather 2004-2006. MWRDGC Report No. 07-79. www.mwrd.org
- G. Rijal, J.T. Zmuda, R. Gore, T. Granato, and, R. Lanyon. 2006. Densities of Pathogens & Indicator Microorganisms in Class B Biosolids Produced at the Metropolitan Water Reclamation District of Greater Chicago. The American Society for Microbiology Abstract Proceedings.
- G. K. Rijal, Z. Abedin, J. Zmuda, R. Gore, B. Sawyer, & R. Lanyon. 2005. Comparison of Fecal Coliform (FC) Concentrations in Two Urban Rivers: The Chicago Sanitary and Ship Canal (CC) and The Des Plaines River (DR). The American Society for Microbiology Abstract Proceedings.
- G. Rijal and J.T. Zmuda, 2004. Usefulness of Monitoring Class A Biosolids for FRNA Coliphages The American Society for Microbiology Abstract Proceedings.
- G. Rijal , Z. Abedin, J.T. Zmuda , and B. Sawyer. 2003. Comparison of Fecal Coliform Concentrations And Trends In Two Urban Rivers: The Chicago Sanitary And Ship Canal And The Des Plaines River. Report No. 03-20. Metropolitan Water Reclamation District of Greater Chicago.

- G. Rijal , J.T. Zmuda , R. Gore, B. Sawyer, P. Tata, R. Lanyon, and C. Lue-Hing. 2002. Part 503 Compliance Monitoring Of Biosolids For Pathogen Reduction Requirements At The Metropolitan Water Reclamation District Of Greater Chicago, In *Abstracts of the 102nd General Meeting of the American Society for Microbiology*, Utah May 19-23, pp. 430.
- Rijal, G. and R. Fujioka, 2002. Use Of Reflectors to Enhance the Synergistic Effects of Solar Heating and Solar Wavelengths to Disinfect Drinking Water Sources. Accepted paper for oral presentation in *Small Water and Wastewater Treatment System Conference*, Sept. 24-26 in Istanbul, Turkey. Conference sponsored by International Water Association.
- Rijal, G. and R. Fujioka, 2002. Synergistic effect of solar radiation and solar heating to disinfect drinking water sources. Water Sci. Technol. Vol. 43(12):155-62.
- Rijal, G., A. Bonilla, and R. Fujioka. 2002. The Establishment and Application of PCR technology at State (DOH) and City (CCH) Water Quality Laboratories. WRRC Project Completion Report: WRRC-2002-01.
- Roger, F., G.K. Rijal, and A. Bonilla. 2002. Monitoring of Honolulu Groundwater Sources for Human Enteric viruses using cell culture and cell culture PCR Method. Paper Accepted for Presentation at Water Quality Technical Conference, November 10-14, Seattle. Paper will be published in WQTC Journal.
- Rijal, G., A. Bonilla, and R. Fujioka. 2002. Detection of *Bacteroides* species by Polymerase Chain Reaction (PCR) for Identifying Sewage Contamination in Recreational Water. Poster presentation at the WEFTEC 2002 Symposium, Chicago, October 2002.
- Rijal, G. and R. Fujioka, 2001. Synergistic effect of solar radiation and solar heating to disinfect drinking water sources. Water Sci. Technol. Vol. 43(12):155-62.
- Rijal, G., & R. Fujioka. 1998. Assessing the microbial quality of drinking water sources in Kathmandu, Nepal. Health Related Microbiology 1998, International Association of Water Quality Conference Proceedings. Vancouver Canada June 26-30, 1998.
- Fujioka, R.S., A.J. Bonilla, and G.K. Rijal. 1998. The Microbial Quality of a Water Hyacinth Wastewater Treatment Scheme to Produce an Effluent for Unrestricted Use. Water Sci Technol. Vol. 40(4-5):369-374.
- Bonilla, A. J., G. K. Rijal, and R.S. Fujioka. 1998. Sensitivity and specificity of a PCR Assay for *Bacteroides fragilis* Grouped as a reliable tracer of sewage in Environmental waters. In *Abstracts of the 98th General Meeting of the American Society for Microbiology*, Atlanta May 17-21, pp. 440.
- Fujioka, R.S., A.J. Bonilla, and G.K. Rijal. 1998. Microbial assessment of the Lanai Auxiliary Reclamation Facility to produce wastewater effluent for un-restricted, non-potable re-use. Water Resources Research Center, University of Hawaii Project Completion Report Contract No P435155.
- Rijal, G., & R. Fujioka. 1997. Evaluation of simple, inexpensive prototype solar water heater disinfection system for remote households. The 97th General Meeting of the American Society for Microbiology, at Miami Florida, May 4-9, 1997.
- Rijal, G., & R. Fujioka. 1996. Evaluation of Multiple Bacterial Species & F RNA Phage as Indicators to Assess the Effectiveness of Full Scale UV as a Disinfectant for Wastewater Re-use. The 96th General Meeting of the American Society for Microbiology, at New Orleans May 19-23 1996.

- Moreland, V., G. Rijal., & R. Fujioka. 1996. UV Disinfection of Six Microbial Indicators at a 3 MGD Water . In Proceedings of the 1996 Reuse Project 96, Jointly sponsored by AWWA/WEF, Sandiego Feb. 25-28.
- Rijal, G., & R. Fujioka. 1996. Disinfection of water using solar and ultraviolet technologies. In: Water Resources Research Center Conference Proceedings: Appropriate technologies and issues for water resources management on tropical islands in the Asia/Pacific region. June 12-14.
- Rijal, G. & R. Fujioka. 1995. A Homeowners Test for Bacteria in Cistern Waters, In Proceedings of the 1995 Regional Conference on International Rainwater Catchment Systems Association. Vol. 2, pp. 9-58 to 9-64, Beijing, P.R. China, June 19-25, 1995.
- Fujioka, R., G. Rijal, & BoLing. 1995. A Solar Powered UV System to Disinfect Cistern Waters, In *Proceedings of the 1995 Regional Conference on International Rainwater Catchment Systems Association*. Vol. 2, pp. 9-48 to 9-57, Beijing, P.R. China, June 19-25, 1995.
- Rijal G., R. Fujioka, and C. Ziel. 1995. Use of Multiple Tests to Assess the Bacterial Quality of Water in Kathmandu, Nepal. The 95th General Meeting of the American Society for Microbiology, at Washington DC May 20-25
- Rijal, G. & R. Fujioka. 1994. Evaluation of UV Disinfection System in the Inactivation of Various Indicator Organisms in Wastewater Effluents. The 94th General Meeting of the American Society for Microbiology, at Las Vegas Nevada. May 23-27 1994.
- Rijal, G. 1994. Field-Tests for Evaluating Drinking Water Quality. International Seminar on `Water and Environment' Organized by Nepal Chemical Society. March 30-April 1, 1994 at Kathmandu Nepal. Published in Nepal Chemical Society Journal.
- Rijal, G. & R. Fujioka. 1993. Hydrogen Sulfide test: A simple & Reliable Method to Assess the Microbial Quality of Cistern Waters in Hawaii, The 93rd General Meeting of the American Society for Microbiology at Atlanta Georgia, May 16-21 1993.
- Rijal, G., and R. Fujioka, 1992. Effect of UV and Bacterial Tests on Cistern Waters. In *Proceedings of the 1992 Regional Conference on International Rainwater Catchment Systems Association*. Vol. 2, pp. 492- 502. Editor: I. Minami. Kyoto, Japan. October 4-10, 1992.

Attachment 2

ATTACHMENT II

Non-point Sources of Bacterial Pollution in the Chicago Area Waterway System (CAWS)

The microbiological quality of the CAWS depends on numerous interacting factors. It cannot be concluded or assumed that point sources (treated effluent from District WRPs) are solely responsible for the fecal coliform bacteria burden in the CAWS. The presence of high levels of fecal coliform (FC) bacteria in the CAWS is not always indicative of contamination by point sources of pollution. The delivery of microbial contaminants by upstream contributions greatly complicates understanding of the sources especially when fecal pollution originate upstream of the WRP outfall locations (District Report, 2005; District Report, 2007; CDM Report, 2007). The CAWS, situated near creek and river tributaries, is also subject to a highly complex source system, in addition to the numerous possible non-point sources.

According to the U.S. Environmental Protection Agency (EPA), non-point source pollution is the leading cause of water pollution in the United States. The USEPA Region V wrote in their 2002 State of the Waters Report that the primary source of impairments for rivers and streams is atmospheric deposition of pollutants. Agriculture is also listed as a major source of impairment because it leads to high nutrient loads, contamination with pathogens, low dissolved oxygen levels, habitat alterations and siltation. Habitat modifications and hydro-modifications (such as channelizing a river) are also major sources of impairment (USEPA Region V, 2002).

Non-point sources of pollution, which are caused by the movement of water originating in part from rainfall, snowmelt or irrigation practices across surfaces and through soil, as well as from urban storm water, are of particular concern and are a source of FC that are not regulated. Non-point sources of fecal coliform bacteria include: urban runoff, agricultural farm waste runoff, discarded trash, domestic pets fecal droppings, birds fecal droppings, animal feedlots, wildlife, land application of manure, landfills, improperly maintained sanitary systems on boats, erosions from impervious land cover, construction sites, and unprotected exposed areas, impoundments, and removal of stream side vegetation

In Illinois, there are over 27.3 million acres under cultivation. The animal census in Illinois in 2007 was 4.05 million hogs and pigs (USDA, 2007). The CAWS microbiological quality is impacted by the abundance of impervious surfaces which cover about 42 percent of Cook County[1]. Other factors in the CAWS, like industrial land use and commercial barge traffic, also contribute to non-point source pollution. In addition, birds roosting on the surface water have direct access and excrete feces into waterways which directly impact the microbiological quality of the CAWS.

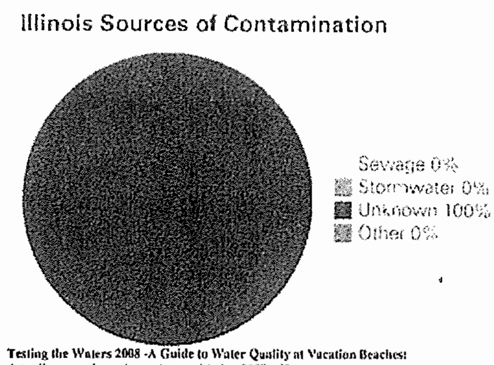

Figure 1: Illinois Sources of Contamination

The Natural Resources Defense Council (NRDC) survey reports that heavy and persistent rains in the greater Chicago and Lake County areas caused a number of beach closures in Illinois in 2007(Figure 1). Additionally, the report indicated that large resident gull populations impact the beach's water quality during swim season (NRDC, 2008). Furthermore, domesticated animals

[1]2001 National Land Cover Data Set Maps of Impervious Surfaces in Cook County.

(e.g., cats and dogs), along with run-off from dog parks, are additional non-point sources. Rainfall and snowmelt transport fecal microorganisms from non-point sources into CAWS. Dr. Richard Whitman, Chief of the Lake Michigan Ecological Research Station for the U.S Geological Survey, has concluded that fecal bacteria contamination can come from diverse sources. Birds, dogs, cows on nearby farms, sand, sediment, soil, pitcher plants, Cladophora and babies in diapers can all contribute to the fecal indicator bacteria level. The following research by Dr. Whitman strongly suggests that soil runoff and/or re-suspension of sediment contributes to the increase of bacteria loading into freshwater environment.

- **Byappanahalli, M. N., R. L. Whitman, D. A. Shively, W. T. Evert Ting, C. C. Tseng, and M. B. Nevers.** 2006. Seasonal persistence and population characteristics of *Escherichia coli* and enterococci in deep backshore sand of two freshwater beaches. J. Water Health **4:**313-320.
- **Byappanahalli, M. N., R. L. Whitman, D. A. Shively, M. J. Sadowsky, and S. Ishii.** 2006. Population structure, persistence, and seasonality of autochthonous *Escherichia coli* in temperate, coastal forest soil from a Great Lakes watershed. Environ. Microbiol. **8:**504-513.
- **Whitman, R. L., M. B. Nevers, and M. N. Byappanahalli.** 2006. Examination of the watershed-wide distribution of *Escherichia coli* along southern Lake Michigan: An integrated approach. Appl. Environ. Microbiol. **72:**7301-7310.
- **Byappanahalli, M., M. Fowler, D. Shively, and R. Whitman.** 2003. Ubiquity and persistence of *Escherichia coli* in a midwestern coastal stream. Appl. Environ. Microbiol. **69:**4549-4555.
- **Whitman, R. L., and M. B. Nevers.** 2003. Foreshore sand as a source of *Escherichia coli* in nearshore water of a Lake Michigan beach. Appl. Environ. Microbiol. **69:**5555-5562.
- **Whitman** et al., 2001. Characterization of *E. coli* contamination at 63rd Street Beach. Report prepared for City of Chicago.

This point is further substantiated by Dr. Sandra McLellan, a scientist with University of Wisconsin-Milwaukee, who described her results based on molecular analyses of *E. coli* samples. She reported that the *E. coli* strains in the environment can be directly linked to birds and wild animals. The following research by Dr. McLellan strongly suggests non-point source pollution and persistence of fecal indicator bacteria in surface water.

- Beversdorf, L. J., S. M. Bornstein-Forst, **SL McLellan,** et al. (2007). "The potential for beach sand to serve as a reservoir for Escherichia coli and the physical influences on cell die-off." J Appl Microbiol **102**(5): 1372-81.
- Bower, P. A., C. O. Scopel, **SL McLellan**, et al. (2005). "Detection of genetic markers of fecal indicator bacteria in Lake Michigan and determination of their relationship to Escherichia coli densities using standard microbiological methods." Appl Environ Microbiol **71**(12): 8305-13.
- Kinzelman, J., **SL. McLellan**, et al. (2004). "Non-point source pollution: determination of replication versus persistence of *Escherichia coli* in surface water and sediments with correlation of levels to readily measurable environmental parameters." J Water Health **2**(2): 103-14.

- **McLellan,** SL (2005). "Recovery is about being involved with people--it's what you would want for yourself. Interview by Suzy Johnson." Ment Health Today: 24.
- **McLellan**, SL. (2004). "Genetic diversity of *Escherichia coli* isolated from urban rivers and beach water." Appl Environ Microbiol **70**(8): 4658-65.
- **McLellan**, SL., A. D. Daniels, et al. (2003). "Genetic characterization of Escherichia coli populations from host sources of fecal pollution by using DNA fingerprinting." Appl Environ Microbiol **69**(5): 2587-94.
- **McLellan**, SL. and A. K. Salmore (2003). "Evidence for localized bacterial loading as the cause of chronic beach closings in a freshwater marina." Water Res **37**(11): 2700-8.
- Olapade, O. A., M. M. Depas, SL **McLellan**, et al. (2006). "Microbial communities and fecal indicator bacteria associated with Cladophora mats on beach sites along Lake Michigan shores." Appl Environ Microbiol **72**(3): 1932-8.
- Salmore, A. K., E. J. Hollis, SL **McLellan** (2006). "Delineation of a chemical and biological signature for stormwater pollution in an urban river." J Water Health **4**(2): 247-62.

The USGS studies and the research done in Milwaukee clearly indicate that the presence of fecal indicator bacteria such as fecal coliform or *E. coli* is not always a determinant of point source pollution. There have been numerous other scientific studies which suggest non-point sources of fecal bacteria in the environment. Most significantly, many researchers have reported that the non-point source pollution has a significant effect on bacterial levels in runoff water. Following are some articles that suggest non-sewage related sources of fecal indicator bacteria:

- **Noble,** R.T., S.B. Weisberg, M.K. Leecaster, C.D. McGee, J.H. Dorsey, P. Vainik and V.Orozco-Borbón. 2003. Storm effects on regional beach water quality along the southern California shoreline. *Journal of Water and Health* 1: 23-31.
- **Calderon,** R.L., E.W. Mood and A.P. Dufour. 1991. Health effects of swimmers and nonpoint sources of contaminated water. International Journal of Environmental Health Research 1: 21-31.
- **Alderisio, K. A. and DeLuca N., 1999.** Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (*Larus delawarensis*) and Canada Geese (*Branta canadensis*). Applied and Environmental Microbiology, p. 5628-5630, Vol. 65, No. 12
- **Olyphant, G. A**., J. Thomas, et al. (2003). "Characterization and statistical modeling of bacterial (*Escherichia coli*) outflows from watersheds that discharge into southern Lake Michigan." Environ Monit Assess **81**(1-3): 289-300.
- **Schultze,** S., 2001. Research ties gulls to beach pollution:Birds are major source of *E. coli* at South Shore, preliminary findings say. In Milwaukee Journal Sentinel: http://www.isonline.com.
- **Leevesque** et al., 1993. Impact of the ring-billed gull (Larus delawarensis) on the microbiological quality of recreational water. Appl. Environ. Microbiol., 1228-1230, Vol 59, No. 4
- **Roll, B. M.** and R. S. Fujioka. 1997. Sources of faecal indicator bacteria in a brackish tropical stream and their impact on recreational water quality. Water Sci. Technol. 35:179-186. 25.

- **Solo-Gabriele**, H. M., M. A. Wolfert, T. R. Desmarais, and C. J. Palmer. 2000. Sources of *Escherichia coli* in a coastal subtropical environment. Appl. Environ. Microbiol. 66:230-237
- **Standridge JH**, Delfino JJ, Kleppe LB, and Butler R.1979. Effect of waterfowl (Anas platyrhynchos) on indicator bacteria populations in a recreational lake Madison, Wisconsin. Appl Environ Microbiol;38(3):547-50
- **Toranzos, G. A.,** and G. A. McFeters. 1997. Detection of indicator microorganisms in environmental freshwaters and drinking waters, p. 184-194. *In* C. J. Hurst, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, and M. V. Walter (ed.), Manual of environmental microbiology. American Society for Microbiology, Washington, D.C.
- **Chen,** C. H., W. L. Liu, et al. (2006). "Sustainable water quality management framework and a strategy planning system for a river basin." Environ Manage **38**(6): 952-73.
- **Fujioka,** R. S. (2001). "Monitoring coastal marine waters for spore-forming bacteria of fecal and soil origin to determine point from non-point source pollution." Water Sci Technol **44**(7): 181-8.
- **Hill,** D. D., W. E. Owens, et al. (2005). "Comparative assessment of the physico-chemical and bacteriological qualities of selected streams in Louisiana." Int J Environ Res Public Health **2**(1): 94-100.
- **Lewis,** D. J., E. R. Atwill, et al. (2005). "Linking on-farm dairy management practices to storm-flow fecal coliform loading for California coastal watersheds." Environ Monit Assess **107**(1-3): 407-25.
- **Tang,** Z., B. A. Engel, et al. (2005). "Forecasting land use change and its environmental impact at a watershed scale." J Environ Manage **76**(1): 35-45.

It is clear from these scientific studies that there are large contributions of FC from non-point sources. Runoff is the mechanism by which the fecal bacteria in soil are transported to environmental water. In addition, re-growth of microorganisms, including coliforms, occurs in receiving streams post-effluent disinfection. When the microbial content of the receiving stream is dictated by soil run-off, sediment persistence, re-suspension and re-growth, it is difficult to control water quality through disinfection of effluents.

References:

- CDM (Camp, Dresser & Mc Kee, Inc.), *Chicago Area Waterway System Use Attainability Analysis*, Draft Report, Available at www.chicagoareawaterways.org, Prepared for the Illinois Environmental Protection Agency, 2007.
- District Interim Report No. 2005-15: Fecal coliform Densities in Chicago Area Waterways During Dry and Wet Weather, 2004.
- District Report No. 2007-79: Fecal coliform Densities in the Chicago Waterway System During Dry and Wet Weather 2004-2006.
- EPA Region 5, 2002. State of the Waters 2002 Region 5. September 2002. (http://www.epa.gov/r5water/pdf/sotw2002.pdf)
- Natural Resources Defense Council (NRDC) Report, 2008. A Guide to Water Quality at Vacation Beaches. Eighteenth Edition. Authors: Mark Dorfman, Kirsten Sinclair Rosselot. http://www.nrdc.org/water/oceans/ttw/ttw2008.pdf
- U.S. Department of Agriculture National Agricultural Statistics Service Statistical Bulletin 1007, Statistical Highlights of U.S. Agriculture for 2006 and 2007-October 2007.

Attachment 3

Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 03-20

COMPARISON OF FECAL COLIFORM CONCENTRATIONS AND TRENDS IN TWO URBAN RIVERS: THE CHICAGO SANITARY AND SHIP CANAL AND THE DES PLAINES RIVER

October 2003

Metropolitan Water Reclamation District of Greater Chicago
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COMPARISON OF FECAL COLIFORM CONCENTRATIONS AND TRENDS IN TWO URBAN RIVERS: THE CHICAGO SANITARY AND SHIP CANAL AND THE DES PLAINES RIVER

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October 2003

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

ACKNOWLEDGMENTS

Ms. Jean Bradford, Temporary Laboratory Technician, Ms. Kathleen Jackowski, Laboratory Technician II, Ms. Andrea Maka, Laboratory Technician II, and Mr. David Roberts, Laboratory Technician I, of the Analytical Microbiology Section are acknowledged for conducting fecal coliform (FC) assays. Mr. Rick Gore, Microbiologist II, is acknowledged for providing tabulated FC data. Ms. Hemangini N. Shukla, Laboratory Technician II, and Mr. Syed Hussaini, Laboratory Technician I, are also acknowledged for tabulating and checking the data. Ms. Joan Scrima is acknowledged for formatting this report.

The data in this report were presented at the Illinois Water Environment Association Conference in Rockford, Illinois, March 2003.

DISCLAIMER

SUMMARY AND CONCLUSIONS

The Metropolitan Water Reclamation District of Greater Chicago (District) developed a cooperative relationship with the Illinois Environmental Protection Agency (IEPA) in early 2002 to provide information on the potential recreational use classification of the Lower Des Plaines River (LDPR). It was apparently assumed that the District water reclamation plants (WRPs) were the dominant sources of fecal coliform (FC) reaching the LDPR. The District recognized that a thorough understanding of the trends and variation of FC concentrations both in the Des Plaines River (DPR) and the Chicago Sanitary and Ship Canal (CSSC) at Lockport are required before sound recommendations regarding recreational potential of the LDPR can be made.

This study was undertaken to explore the physical and chemical factors that help account for FC variations in the two waterways. The main purpose of this study was to compare the FC concentrations at the DPR upstream of Lockport (District monitoring location 91) and at the CSSC at Lockport (District monitoring location 92) for the 2000 - 2001 period. Existing water quality monitoring data [FC, total suspended solids (TSS), temperature, and turbidity] as well as river

flow and rainfall data for the 2000 through 2001 period were put into a single database.

Statistical analysis was conducted to determine the seasonal effects and the relationship to weather conditions (wet and dry) and seasonal disinfection (May through October - disinfection and November through April - no disinfection) on FC concentrations. Multiple regression analysis was performed to study the relationship of FC concentrations at locations 91 (DPR) and 92 (CSSC) with river flow, rainfall, TSS, turbidity, and water temperature. Regression models were developed to predict FC concentrations at the two waterway locations.

The specific conclusions drawn from this study are enumerated below.

1. The 30-day period geometric mean (GM) measurements of FC concentrations at both locations 91 (DPR) and 92 (CSSC), were often above the Illinois General Use water quality standard of less than or equal to 200 CFU/100 mL. Location 91 (DPR) had a larger percentage (70 percent) of GMs exceeding the General Use standard than location 92 (CSSC) which exceeded the standard 55 percent of the 30-day periods.

2. The two-year cumulative GM concentration of FC bacteria at location 91 (DPR) was 330 CFU/100 mL, and at location 92 (CSSC) it was 274 CFU/100 mL. Based on the results of analysis of variance (ANOVA), it is concluded that the GM concentrations of FC bacteria at location 91 (DPR) and at location 92 (CSSC) were not significantly different over the two-year period.

3. The ANOVA results related to the comparison of the seasonal disinfection period [P1 (May - October)] versus the no disinfection period [P2 (November - April)] relative to FC indicated the following:

   a. There is a statistically significant difference in the FC concentrations measured at location 91 (DPR) in the P1 (GM=228 CFU/100 mL) versus the P2 (GM=467 CFU/100 mL) period ($p = 0.0094$). The FC concentrations were higher in P2.

   b. There is a statistically significant difference in the FC concentrations measured at location 92 (CSSC) in the P1 (GM=381 CFU/100 mL) versus the P2 (GM=179 CFU/100 mL) period ($p = 0.0078$). The FC concentrations were higher in P1.

c. There is no statistically significant difference in the FC concentrations measured at location 91 (GM=228 CFU/100 mL) and location 92 (GM=381 CFU/100 mL) in P1.

d. There is a statistically significant difference in the FC concentrations measured at location 91 (GM=467 CFU/100 mL) and location 92 (GM=179 CFU/100 mL) in P2 ($p = 0.0001$).

4. The results of the simple regression model developed in this study to predict FC concentration at locations 91 (DPR) and 92 (CSSC) indicated the following:

a. The simple regression equations are:

Location 91 (DPR):

$$\ln(FC)=0.88647*\ln(Flow), R^2 = 0.95$$

Location 92 (CSSC):

$$\ln(FC)=0.71086*\ln(Flow), R^2 = 0.95$$

b. Statistical analysis indicated that the slope of the regression equation for location 91 (DPR) is significantly higher ($p = <0.05$) than the slope of the regression equation for location 92 (CSSC). This confirms the probability of higher FC concentrations at location 91 (DPR) with an increase in river flow rate when compared to location 92 (CSSC).

5. The microbial quality of the CSSC at location 92 which is classified as a Secondary Contact water was comparable to the microbial quality of the Des Plaines River at location 91 which is classified as a General Use water. This finding indicates that the unchlorinated effluents from District WRPs discharging into the CSSC upstream of Lockport are not adversely affecting the microbial quality of the LDPR downstream of Lockport.
6. The microbiological water quality standards for freshwater recreational use in the LDPR should be reevaluated with a focus on nonpoint sources and point sources of pollution downstream of location 91 and 92 when determining water quality standards and the microbiological assessments of the LDPR.

INTRODUCTION

Description of the Des Plaines River and the Chicago Sanitary and Ship Canal

The DPR is a 130 mile long waterway originating in Kenosha County, Wisconsin (Terrio, 1995). It runs through four counties in Illinois to its confluence with the Kankakee River at Channahon, where the two form the Illinois River. Along the way its character changes from a rural creek draining agricultural areas, to a suburban stream, to a large urbanized river, to a major industrial waterway (Figure 1). The DPR forms one of the headwater streams of the Illinois River, a large tributary of the Mississippi River. The river corridor through most of Cook, DuPage, and Lake Counties in Illinois is in county Forest Preserve Districts.

The DPR is one of the most utilized water resources in Illinois. The northern DPR watershed is mostly rural with areas of urban development in progress. The southern part of the DPR is highly urbanized. Near Lyons, Illinois, the DPR flows southwest parallel to the CSSC. The CSSC is a man-made conveyance of the treated wastewater from the Metropolitan Chicago area. The Chicago River, Calumet-Sag Channel, Calumet, and Little Calumet Rivers drain into the CSSC (Figures 1 and 2). The CSSC joins with the DPR below the Lockport Lock and

FIGURE 1

DES PLAINES RIVER WATERSHED

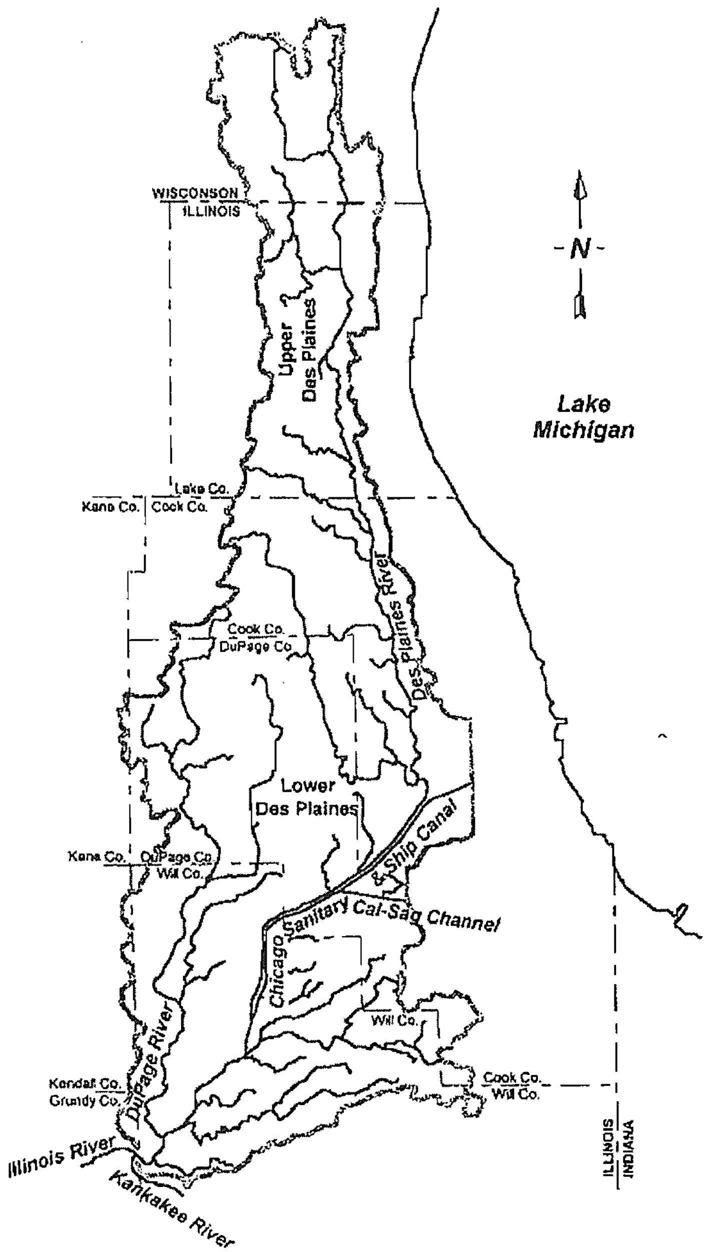
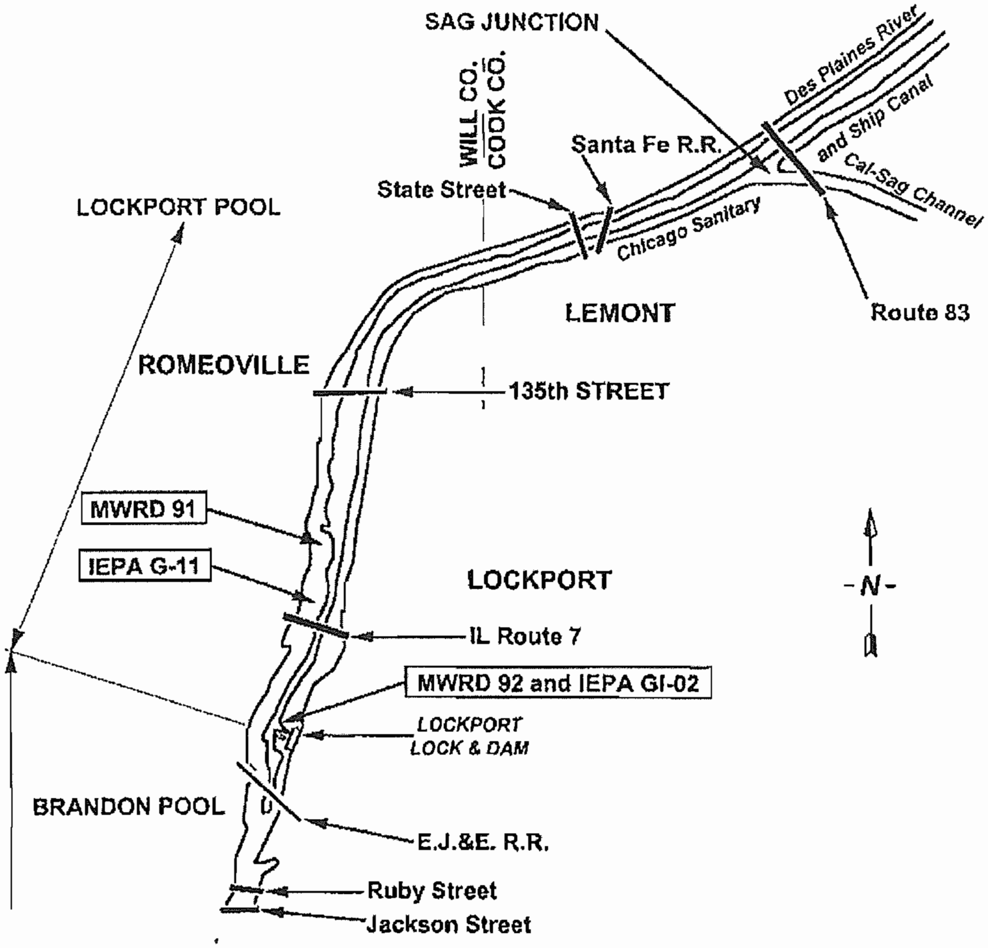


FIGURE 2

ENLARGED MAP OF SAMPLING LOCATIONS (91 AND 92) ON THE DES PLAINES RIVER AND THE CHICAGO SANITARY AND SHIP CANAL



Dam (Figure 3). The DPR from the junction with the CSSC to the Illinois River is referred to as the LDPR. The LDPR is 18 miles in length and covers the Brandon Road and Dresden Island navigation pools. The LDPR is on the IEPA's 303(d) list of impaired waters.

Current Illinois General Use and Secondary Contact Microbial Water Quality Standard

Water quality indicators are chosen based on the type of land use evident in a watershed. The IEPA has established water quality classifications for waterways in Illinois. The DPR is classified as General Use. According to the IEPA, water designated as General Use must meet the following microbial water quality limits during the months May through October (IEPA, 1972):

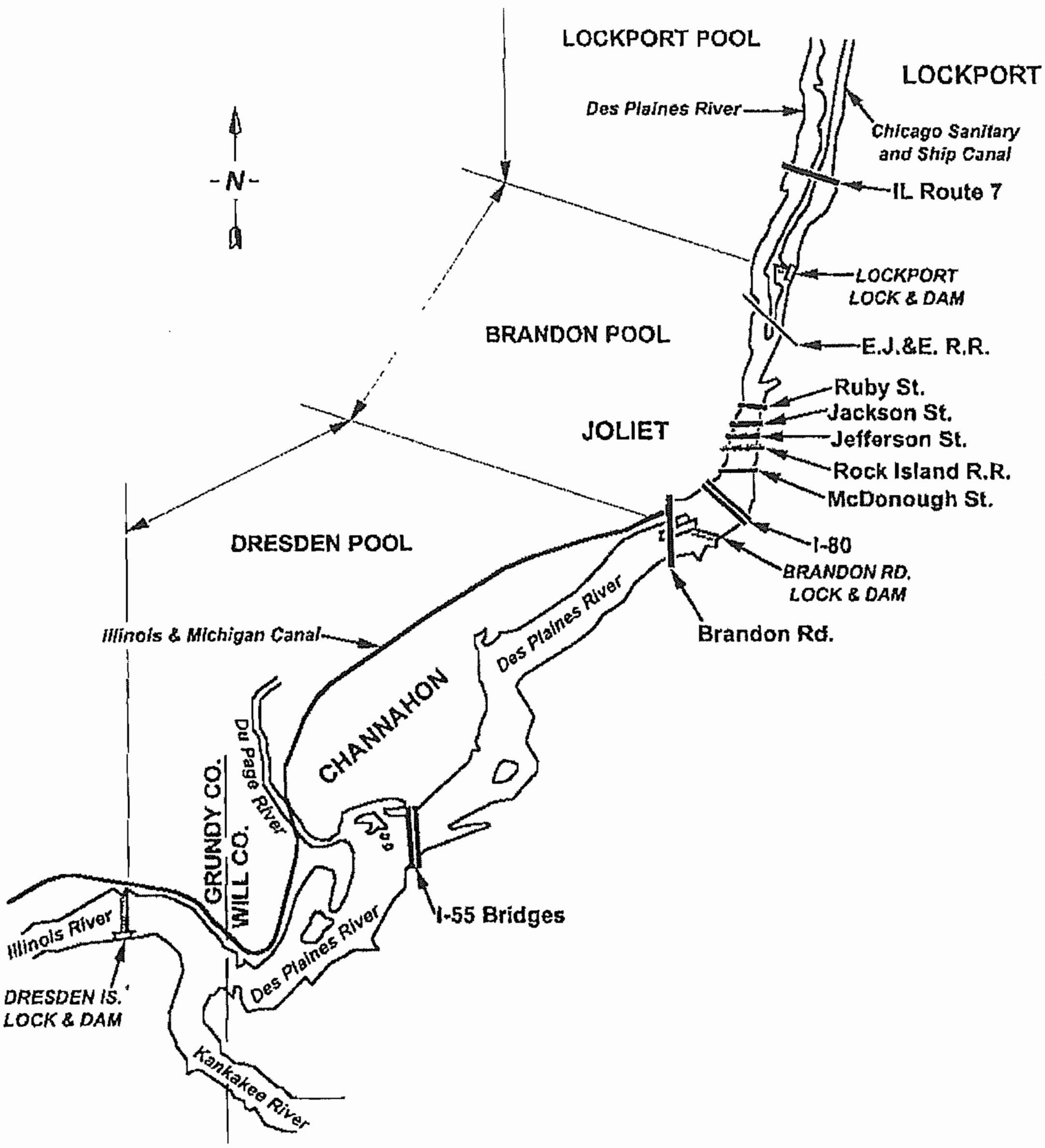
a. Based on minimum of five samples taken over not more than a 30-day period, FC shall not exceed a geometric mean (GM) of 200/100 mL;

b. nor shall more than 10 percent of the samples during any 30-day period exceed 400/100 mL.

The CSSC is a man-made waterway excavated in rock with vertical walls to handle WRP effluent, combined sewer overflows, and urban nonpoint run-off water. The CSSC is an effluent dominated water body, therefore, it is not suited for

FIGURE 3

MAP OF THE LOWER DES PLAINES RIVER (LDPR)



General Use activities and is classified as Secondary Contact by the IEPA. The navigable depths created by the Lockport Dam allow the CSSC to be used for secondary contact activities, mainly commercial navigation and recreational boating.

During the early 1970's the CSSC was classified as Restricted Use water (IEPA, 1972). This indicated that certain uses were not protected. The restricted use standard for bacteria was:

a. Based on a minimum of five samples taken over not more than a 30-day period, FC shall not exceed a GM of 1000/100 mL,

b. nor shall more than 10 percent of samples during any 30-day period exceed 2000/100 mL.

In 1982 this standard was repealed and currently no standards for bacterial pollution is in force for Secondary Contact water (the entire CSSC).

Use Attainability Analysis (UAA)

The IEPA has started introducing regulatory requirements for designated and existing water uses; the role of water quality standards; and the need for UAAs. The UAA is defined as a structured scientific assessment of the factors affecting the attainment of the use, which may include physical, chemical, biological, and economic factors. The UAA is required for water bodies where designated uses are lower than the statutory fish and aquatic life protection and propagation, and primary contact recreation. The UAA being performed on the LDPR will determine whether the current lower use classification could be upgraded.

Historically the LDPR has had poor water quality. This was mainly due to various wastewater effluent discharges and channel modifications. The LDPR has been classified as Secondary Contact water. An argument can be made for upgrading the designated use of the LDPR below its confluence with the CSSC. Significant progress has been made since the 1970s in improving the quality of the effluent from the North Side WRP, which is discharged to the CSSC via the North Shore Channel and the North and South Branches of the Chicago River; the effluent from the Stickney WRP, which is discharged directly into the CSSC; and the effluent from the Calumet WRP, which flows into the CSSC via the Calumet-Sag Channel. The District's Tunnel and Reservoir Plan (TARP) has significantly reduced the number of combined sewer overflows (CSOs) discharged into the CSSC and into the DPR system. As of 2001, TARP cumulatively captured 565 billion gallons of CSO that would otherwise have flowed into area receiving waters (USEPA, 2001). It is hoped that the eventual construction of the TARP reservoirs, now scheduled for completion by 2014, will virtually eliminate CSOs.

A meeting of the UAA Stakeholders Group, the IEPA, and the IEPA consultant was held on May 16, 2002, to discuss the designated use goals for the waterways. The IEPA consultant assumed that the treated effluents from the Stickney and Calumet WRPs are the dominant sources of bacteria reaching the LDPR. The IEPA consultant suggested the possibility of final effluent disinfection at these two District WRPs to meet some possible future standard for bacteria in the LDPR.

In determining the need for disinfection at the two WRPs, the District wanted to explore the FC bacteria distribution in the DPR and the CSSC during 2000 - 2001. Some of the FC bacteria issues of concern were:

1. What are the general water quality characteristics at two locations, in terms of flow, temperature, TSS, turbidity, and rainfall?
2. What are the factors that contribute to the density of indicator bacteria?
3. What are the concentrations and loads of FC bacteria?

4. Are there any statistical differences in FC concentrations?
5. How do the distributions and concentrations of FC bacteria change over time?
6. Can a model be developed to predict FC concentrations?
7. What are the sources of FC bacteria in these two waterways?

At this time there is limited understanding of the environmental factors that lead to seasonal variations in concentration of FC bacteria. An analysis of FC bacteria concentrations in these waterways may help determine if a proposed FC bacteria standard could be statistically attainable and if there is a need of resumption of disinfection practices to prevent pollution of the LDPR.

OBJECTIVES

The overall objective of this study was to conduct statistical analyses of the FC bacteria data collected by the District for the DPR near Lockport (location 91) and the CSSC at the Lockport Powerhouse (location 92) for the 2000 through 2001 period, in order to assess the impacts from these two waterways on the bacterial quality of the LDPR. The following statistical analyses were performed:

1. The arithmetic mean and range of water quality parameters such as river flow, turbidity, TSS, and temperature.
2. The 30-day period GM concentrations of FC bacteria.
3. The statistical differences between FC concentrations at both locations during rainy and dry periods in the Chicago area.
4. The statistical differences between FC concentrations under seasonal disinfection months.
5. The feasibility of statistical regression models as a tool for forecasting FC bacteria concentrations at the two locations.

MATERIALS AND METHODS

Data Used in Analysis

Data for this study were obtained from the following agencies:

1. Weekly FC data were obtained from the District Analytical Microbiology Laboratory for the period January 2000 to December 2001. The District's Analytical Microbiological Laboratory is certified by the Illinois Department of Public Health (IDPH), Registry Number 17508.
2. The TSS, temperature, and turbidity data for water samples taken from the two locations were obtained from the District's Analytical Laboratory which has been accredited by the IEPA, under National Environmental Laboratory Accreditation (NELAC), for the inorganic analysis of wastewater since 2001.
3. Daily mean stream flow values in cubic feet per second for the CSSC at Romeoville and the DPR at Riverside were obtained from the United States Geological Survey (USGS) NWISWeb internet based retrieval system using the "File of Site Numbers"

search criteria. Romeoville and Riverside are the locations closest to locations 92 and 91, respectively, where flow data have been collected. Flow data at locations 91 and 92 are not available.

4. Rainfall data in inches were collected by the District as part of normal operations. Average rainfall readings in inches were taken at 12:00 midnight from Glenview, North Side WRP, North Branch Pumping Station, Wilmette, Stickney West Side Plant, Springfield Ave., Racine Ave., 100 E. Erie, E. Melvina Ave., 87th and Western, Calumet WRP, 95th St. Pumping Station, and Lockport.
5. Storm data were collected by the District as part of normal operations.

Description of the Sampling Locations

For this investigation, the data collected from two sampling locations upstream of the Lockport Dam were chosen (Figures 2 and 3). The DPR upstream of Lockport sampling point is located directly above the IEPA station G-11. This sampling point is designated as location 91. Data collected at location 91 were used to assess the ambient water quality in the

General Use portion of the DPR. The CSSC sampling point is located at the Lockport Power House. This sampling point is designated as location 92 and is a Secondary Contact water. Location 92 is approximately 25 miles downstream from the Stickney WRP and 30.5 miles downstream from the Calumet WRP.

The DPR and CSSC merge just below Lockport to form the LDPR which is classified as a Secondary Contact water (Figure 3).

Number of Observations

During the two-year investigation (2000 through 2001), a total of 202 FC bacterial samples were collected and analyzed (Table 1). In 2000, a total of 50 water samples were analyzed for FC at each of the two locations 91 (DPR) and 92 (CSSC). In 2001, a total of 52 water samples were analyzed for FC at location 92 (CSSC) and 50 samples at location 91 (DPR).

All the data were compiled in a single database within the framework of wet/dry weather conditions and seasonal disinfection periods (P1 and P2).

Wet and Dry Weather Conditions

Rainfall varies as to intensity, duration, and volume. For this study rainfall that resulted in greater than 0.1 inches of rain within 24 hours was defined as a wet weather

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1

NUMBER OF OBSERVATIONS AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Year/Condition	Number of Observations	
	Location 91 (DPR)	Location 92 (CSSC)
Total 2000	50	50
Total 2001	50	52
2000 through 2001		
Dry Weather Conditions	75	77
Wet Weather Conditions	25	25
Disinfection Period P1, (May - October)	52	52[1]
No Disinfection Period P2, (November - April)	48	50

[1]No Seasonal Disinfection (Stickney, Calumet, and North Side WRPs discharge undisinfected effluent year round).

event. For the statistical calculations, a wet event was determined from the weekly mean values of rainfall data in the Chicago area.

Seasonal Disinfection Period

The DPR upstream of Lockport receives discharges from urban run-off and treated municipal and industrial sewage effluents from several sewage treatment plants (STPs). Effluent from these STPs is discharged into the DPR at an average of 153.70 cubic feet per second (Hey and Associates, Inc., Draft Report, April 2002). All of these treatment plants disinfect final effluent between May and October. The effluent is not disinfected from November through April.

The CSSC, however, is an effluent dominated water body. It receives treated effluents from the Stickney, North Side, and Calumet WRPs. Effluent from these WRPs is discharged into the CSSC at an average of 1666.8 cubic feet per second (Hey and Associates, Inc., Draft Report, April 2002). The effluents from the Stickney, North Side, and Calumet WRPs are not disinfected.

For the purpose of this study the FC data were grouped in two seasonal periods, P1 and P2. The period one (P1) was classified as months when DPR (location 91) receives disinfected effluents. The P1 period included FC concentration data obtained from May through October. The period two (P2) is when undisinfected effluents are discharged into the DPR. The P2 period included FC concentration data obtained from November through April.

Statistical Methods

For the period of 2000 - 2001, arithmetic mean and range values of TSS, turbidity, and temperature were calculated for each waterway. Graphs were used to summarize and display data characteristics of river flow, rainfall, and FC concentrations.

The GM of the FC density at each location was calculated from five FC measurements made in a 30-day period to assess compliance with the General Use standard. In this study, a 30-day period was defined as any 30-day period at each location that had five FC samples. Due to this interpretation, the data were not grouped by month, but after every five samples. Twenty 30-day GMs were calculated for each location.

Multiple linear regression to predict FC concentrations at locations 91 (DPR) and 92 (CSSC) was performed using untransformed and transformed data as presented in the following equation (Rao, 2002; Walpole and Myers, 1989):

$$FC = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + + \beta_5 x_5$$

Where α = the y-axis intercept

x_1 = temperature (°C)

x_2 = turbidity (NTU)

x_3 = TSS (mg/L)

x_4 = rainfall (inches)

x_5 = flow (cubic feet per second)

and β_1 through β_5 = coefficients assigned to x_1 through x_5 and x_1 through x_5 represent the explanatory variables for inclusion in the multiple linear regression model.

The best model of all possible models was chosen on the basis of R^2 values and Mallow's CP statistics (Walpole and Myers, 1989).

Time series models were developed using the *ln* (FC) from the three previous *ln* (FC) measurements with flow as an explanatory variable (Box and Jenkins, 1970). These models are referred to as auto regressive models.

Akaike Information Criterion (AIC) were calculated to determine whether the linear regression model or the auto regressive model was better for each location (Khattree and Naik, 1999).

The Kolmogorov-Smirnov (K-S) test was used to test the collected data (transformed and untransformed) for normality (Gibbons and Chakraborti, 1992). Bartlett's test or the F test for homogeneity of variance (Walpole and Meyers, 1989;

Dyer and Keating, 1980) was performed on *ln* (FC) and *ln* (flow) data for which there was no reason to question the assumption of normality. Standard parametric ANOVA was used to test the equalities of GMs of FC concentrations at locations 91 (DPR) and 92 (CSSC) (SAS Institute, 2000; Khattree and Dayanand, 1999). Parametric analysis of covariance (ANCOVA) was performed to assess the relationship between FC concentrations and flow (Khatree and Naik, 1999; Rao, 2002).

RESULTS AND DISCUSSION

The results of this study provide a comparative assessment of FC concentrations at two waterway locations, 91 (DPR) and 92 (CSSC) for the two-year period (2000 - 2001). The following sections provide descriptive information on the waterways water quality characteristics such as river flow, rainfall, turbidity, TSS, and temperature during 2000 - 2001. These descriptions are followed by a series of statistical analyses of the FC concentrations at two locations during wet/dry weather and seasonal disinfection periods.

Fecal coliform, river flow, and rainfall data used for the statistical analyses are presented in Table AI-1. Total suspended solids, temperature, and turbidity data are presented in Table AI-2. The complete set of rainfall data for 2000 and 2001 are presented in Tables AI-3 and AI-4, respectively. The storm data for 2000 and 2001 are presented in Table AI-5. The calculated 30-day period, GM concentrations of FC bacteria are presented in Table AI-6. Predicted FC concentrations by time series and regression models are provided in Tables AII-1 (location 91) and AII-2 (location 92).

River Flow

The flow data for 2000 and 2001 are shown in Figures 4 and 5. The flow measurements were not obtained directly from the study locations 91 (DPR) and 92 (CSSC). The flow rates at the DPR Riverside and the CSSC Romeoville determined the estimated flow rates at locations 91 (DPR) and 92 (CSSC), respectively. These flow measurements are provided by the U.S. Geological Survey and are the closest locations to the study area.

The river flow rate measured at the DPR Riverside location ranged from 178 cubic feet per second to a high of 4,380 cubic feet per second. The average flow rate at this location was 854.6 cubic feet per second. The river flow rate measured at CSSC at Romeoville ranged from a low of 1,192 cubic feet per second to a high of 11,563 cubic feet per second. The average flow rate at this location was 2,289 cubic feet per second, three times higher than the average flow at DPR Riverside location during the 24-month period.

Rainfall

A bar graph characterizing monthly precipitation data in the Chicago area during the two-year period 2000 and 2001 is

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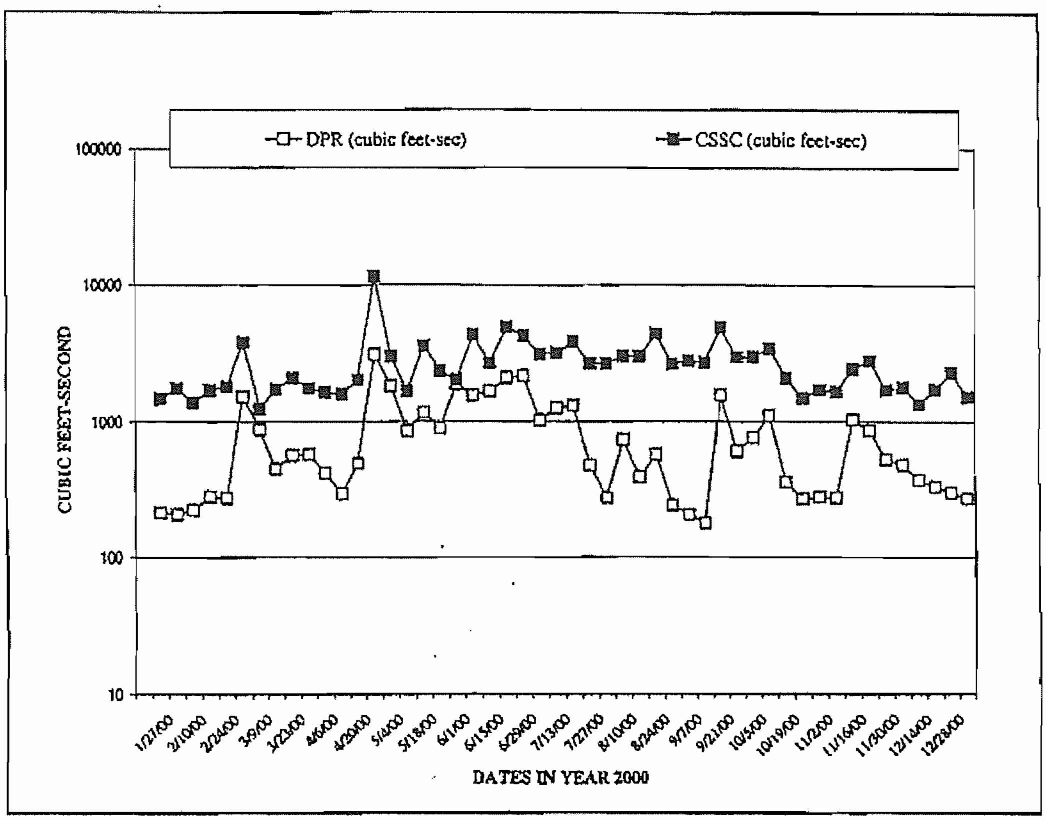
FIGURE 4

FLOW DATA FOR THE YEAR 2000



Source: http://waterdata.usgs.gov/nwis/measurements

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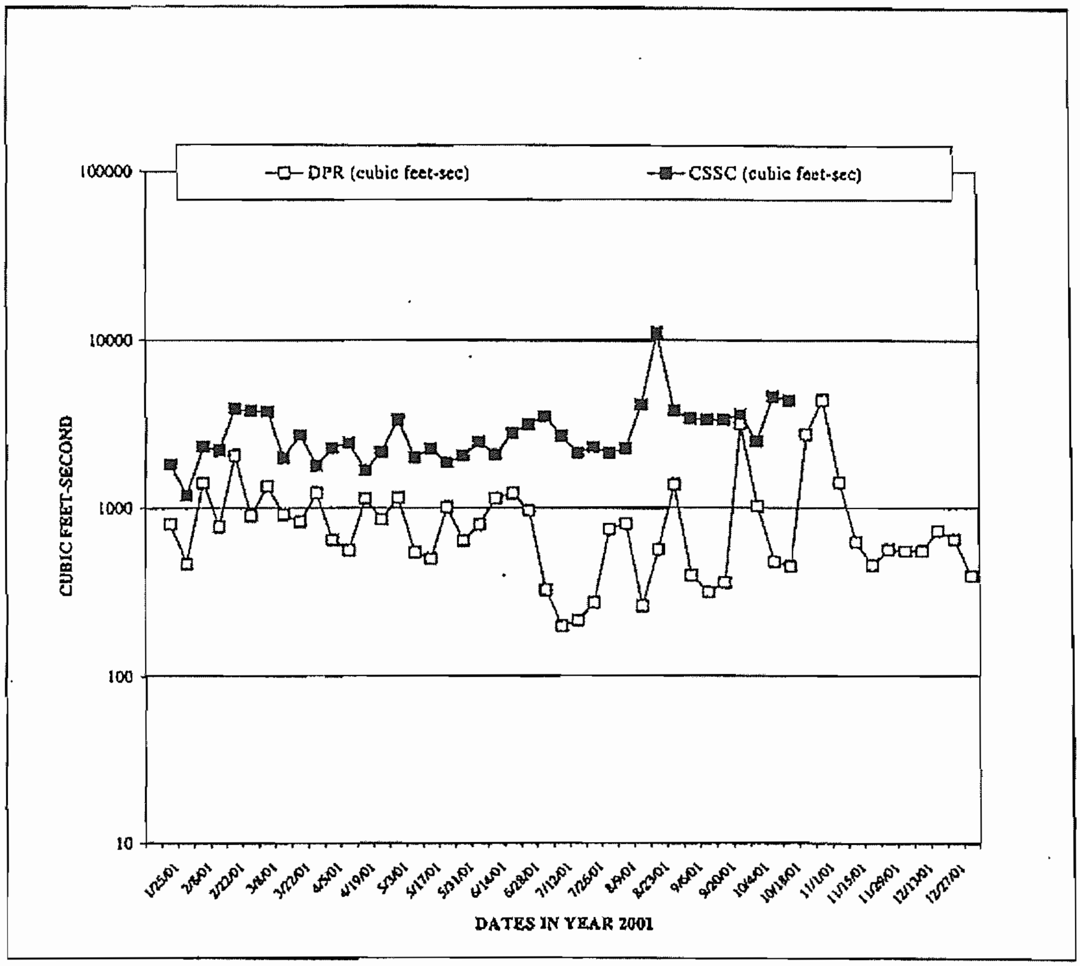
FIGURE 5

FLOW DATA FOR THE YEAR 2001



Source: http://waterdata.usgs.gov/nwis/measurements shown in Figure 6. The total annual precipitation was 28.5 inches in 2000 and 34.5 inches in 2001, (Table AI-1). The total precipitation was greater than 2.0 inches per month from April through September of 2000. In 2001, the total precipitation was greater than 2.0 inches per month from April through October. The total annual precipitation was greater in 2001 than 2000.

In 2001, there were five major rainstorm events, three in the month of August and two in October. The largest rainstorm on August 2, 2001, lasted more than 8 hours, and an overall average of 2.61 inches of rainfall was recorded (Table AI-5). There were no major rainstorm events in 2000.

Turbidity and Total Suspended Solids

Turbidity and TSS data at location 91 (DPR) and 92 (CSSC) for 2000 - 2001 are shown in Table 2. At location 91 (DPR), the turbidity ranged from 6-57 NTU and the arithmetic mean was 25 NTU. At location 92 (CSSC), the turbidity ranged from 5 to 35 NTU and the arithmetic mean was 11.5 NTU. It is clear that the means and maxima turbidity at location 92 (CSSC) were below the corresponding values obtained for the location 91 (DPR) samples.

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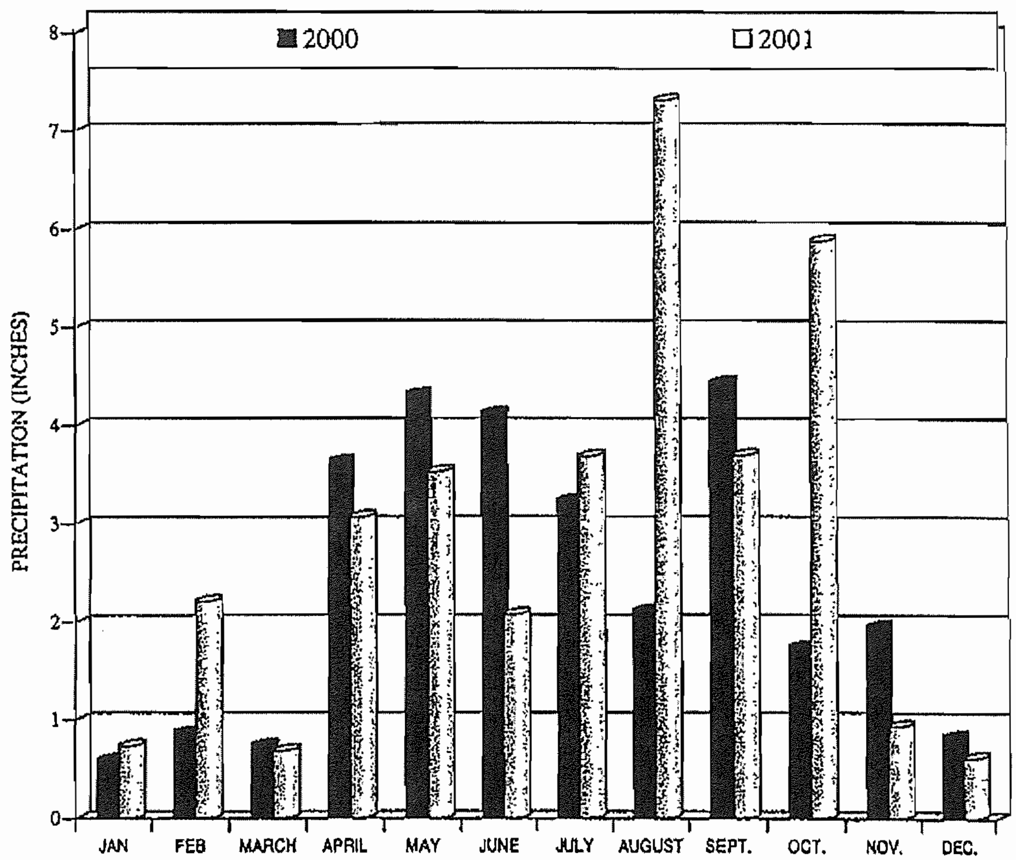
FIGURE 6

MONTHLY PRECIPITATION DATA FOR THE YEARS 2000 AND 2001



Source: MWRDGC Normal Operations Rainfall Data (rainfall readings in inches were taken at 12:00 midnight from Glenview, North Side WRP, North Branch Pumping Station, Wilmette, Stickney West Side Plant, Springfield Ave., Racine Ave., 100 E. Erie, E Melvina Ave., 87th and Western, Calumet WRP, 95th St. Pumping Station, and Lockport).

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TABLE 2

TOTAL SUSPENDED SOLIDS AND TURBIDITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Location/ Year	Turbidity (NTU)		Total Suspended Solids (mg/L)	
	Range	Average	Range	Average
91 (DPR)				
2000	6-51	25	4-76	39
2001	7-57	25	2-120	45
92 (CSSC)				
2000	6-35	12	3-59	16
2001	5-31	11	5-39	16

Turbidity is an indicator of the amount of sediment and related solid particulate matter transported by a river. Turbidity and river flow are related because flow can affect the suspension of soil constituents in a water column.

The TSS measurement represents suspended material in the water sample. Measured TSS values at location 91 (DPR) ranged from 2-120 mg/L and the arithmetic mean was 42 mg/L. Measured TSS values at location 92 (CSSC) ranged from 3-59 and the arithmetic mean was 16 mg/L. The mean TSS at location 91 (DPR) exceeded the mean TSS at location 92 (CSSC).

Temperature

Water temperature readings at two sampling locations, 91 (DPR) and 92 (CSSC) varied with seasonal months in 2000 and 2001 (Table AI-2). Water temperature readings during cold weather months (January through the third week of June; October through December of 2000 and 2001) at location 91 (DPR) and 92 (CSSC) ranged from 0.3-30°C, and the arithmetic mean was 13°C (Table 3). Water temperature readings during warm weather months (last week of June through September of 2000 and 2001) at location 91 (DPR) and 92 (CSSC) ranged from 17-36°C, and the arithmetic mean was 26°C.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3

WATER TEMPERATURES AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Location/Year/Month	Temperature (°C)	
	Range	Average
91 (DPR) and 92 (CSSC) 2000 - 2001		
(January - Third Week of June; October - December)	0.3 - 30	13
(Last Week of June - September)	17 - 36	26
91 (DPR)		
2000	0 - 32	15.5
2001	1 - 33	
92 (CSSC)		
2000	5 - 31	18.5
2001	4 - 36	

Water temperatures at location 91 (DPR) ranged from 0-33°C, and the arithmetic mean was 15.5°C. Water temperatures at location 92 (CSSC) ranged from 4-36°C, and the arithmetic mean was 18.5°C.

Geometric Mean FC Concentrations at Locations 91 (DPR) and 92 (CSSC)

Statistical summaries for FC bacteria together with GM densities in water samples collected at locations 91 (DPR) and 92 (CSSC) are given in Table 4.

In 2000, FC concentrations ranged from 10-15,000 CFU/100 mL at location 91 (DPR); the geometric mean was 295 CFU/100 mL. At location 92 (CSSC), FC concentrations ranged from 10-21,000 CFU/100 mL; the geometric mean was 256 CFU/100 mL.

In 2001, FC concentrations ranged from 20-10,000 CFU/100 mL at location 91 (DPR); the geometric mean was 351 CFU/100 mL. At location 92 (CSSC), FC concentrations ranged from 10-50,000 CFU/100 mL; the geometric mean was 271 CFU/100 mL.

Fifty percent of the FC concentration values at both locations, 91 (DPR) and 92 (CSSC), were greater than 200 CFU/100 mL in 2000. In 2001, fifty percent of the FC concentration values at location 91 (DPR) were greater than 200 CFU/100 mL, while at location 92 (CSSC) the fifty percentile value was

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4

FC CONCENTRATIONS (CFU/100 mL) AT LOCATIONS
91 (DPR) AND 92 (CSSC)

YEAR/ LOCATION	GM FC[1]	MIN[2]	MAX[3]	PERCENTILE[4]				
				10	25	50	75	90
2000								
91 (DPR)	295	10	15,000	45	150	305	710	1450
92 (CSSC)	256	10	21,000	55	90	260	570	915
2001								
91 (DPR)	351	20	10,000	75	140	285	1000	2050
92 (CSSC)	271	10	50,000	40	95	190	715	1500

[1]Geometric mean FC concentrations in CFU/100 mL.
[2]Minimum FC concentrations in CFU/100 mL.
[3]Maximum FC concentrations in CFU/100 mL.
[4]Percentage of FC concentration data less than or equal to the value indicated.

190 CFU/100 mL. Some of the highest FC concentrations were found in water samples collected in 2001.

FC Bacteria Concentration in Comparison to GM Standard

The GM FC standard of the water designated for General Use requires that five samples be collected in a 30-day period. Figure 7 summarizes the 30-day period GM concentration of FC bacteria at locations 91 (DPR) and 92 (CSSC) for 2000 and 2001. For these two sites, there were twenty 30-day periods for which GMs were calculated. At location 91 (DPR), the GM FC concentration was greater than 200 CFU/100 mL for 14 of twenty 30-day periods, (70 percent). At location 92 (CSSC), the GM FC concentration was greater than 200 CFU/100 mL for 11 of twenty 30-day periods, (55 percent).

Thus, location 91 (DPR) had a larger percentage of GMs exceeding the General Use standard than location 92 (CSSC) even though location 91 (DPR) has a higher use classification than location 92 (CSSC).

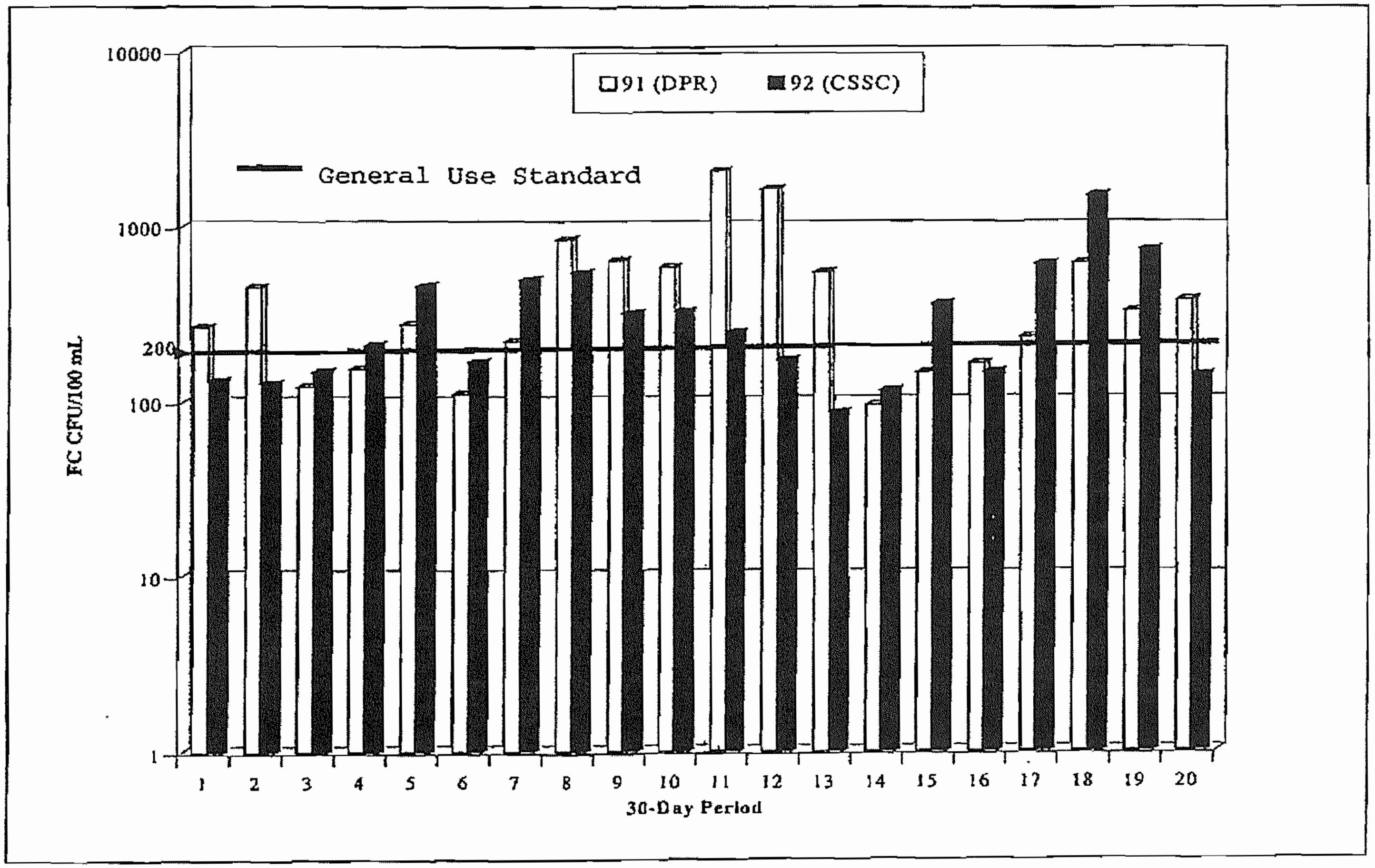
FC Bacteria Concentration in Comparison to the General Use Never to Exceed Standard

The General Use never to exceed FC bacteria standard of no more than 10 percent of the samples during any 30-day period to exceed 400 CFU/100 mL applies to all grab samples

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 7

30-DAY PERIOD GM CONCENTRATIONS OF FC BACTERIA AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001



collected during the sampling period. According to this standard, out of twenty 30-day periods, nineteen periods (95 percent) exceed the single grab sample limit of 400 CFU/100 mL at location 91 (DPR). At location 92 (CSSC), seventeen sampling periods out of twenty (85 percent) exceed the 10 percent criteria FC concentrations of 400 CFU/100 mL.

This indicates that location 91 (DPR) has a higher percentage of FC concentrations that exceed the single-sample advisory limit of 400 CFU/100 mL than location 92 (CSSC).

Comparison of the FC Concentrations Between Locations 91 (DPR) and 92 (CSSC)

Results of ANOVA shown in Table 5 indicate that there is no significant difference in the GM FC concentrations between locations 91 (DPR) and 92 (CSSC) when the entire two-year data set is compared. However, when ANOVA was performed with flow as a covariate (ANCOVA analysis), which in effect standardizes the flow, the results indicate that the flow-specific FC concentrations at location 91 (DPR) are higher than those at location 92 (CSSC).

FC Concentrations During Wet and Dry Weather Conditions

The results of the comparison of the FC concentrations at two locations during wet and dry weather conditions, as

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TABLE 5

COMPARISON OF THE FC CONCENTRATIONS BETWEEN LOCATIONS 91 (DPR) and 92 (CSSC)

Analysis	Covariate	Significance Probability of Equal Means (*ln* FC)	Conclusion
ANOVA	None	0.32	There is no significant difference in FC concentration between locations, 91 (DPR) & 92 (CSSC).
ANCOVA	River flow	0.0001	There is significant difference in FC concentration between locations, 91 (DPR) & 92 (CSSC) if the flows are standardized.

reflected by rainfall in the Chicago area, is summarized in Table 6.

Results of the K-S test for normality show that data came from normal populations at the 5 percent level of significance. Results of the F test show that variances of locations 91 (DPR) and 92 (CSSC) are equal in both wet and dry seasons. As log transformed FC came from normal populations, FC concentration follow log normal distribution.

At location 91 (DPR), under dry weather conditions, the GM FC concentration was 317 CFU/100 mL versus 337 CFU/100 mL during wet weather conditions. At location 92 (CSSC), under dry weather conditions, the GM FC concentration was 226 CFU/100 mL versus 424 CFU/100 mL during wet weather conditions.

The weather related results of ANOVA showed no significant difference in the FC concentrations between locations 91 (DPR) and 92 (CSSC). The results of ANOVA performed with flow as a covariate (ANCOVA) showed significant difference in the FC concentrations between locations 91 (DPR) and 92 (CSSC) during both dry and wet weather. The results of ANCOVA, which in effect standardized the flow at the two locations, indicated that the flow-specific FC concentrations at location

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 6

COMPARISON OF THE FC CONCENTRATIONS AT LOCATIONS 91 (DPR) AND 92 (CSSC) UNDER DRY AND WET WEATHER CONDITIONS

Location/ Condition	Obs[1]	GM FC[2]	Significance Probability of Normality[3] (*ln* FC)	Results of the F Test (*ln* FC)	Significance Probability of Equal Means[4] (*ln* FC)
91 (DPR)					
DRY	75	317	0.880[a]	0.132[b]	0.245[c]
WET	25	337	0.124[a]		
92 (CSSC)					
DRY	77	226	0.072[a]	0.066[b]	0.245[d]
WET	25	424	0.082[a]		

[1]Number of observations.
[2]Geometric Mean FC concentrations in CFU/100 mL.
[3]Results of K-S Test.
[4]Results of ANOVA.
[a]Data are from a normal population.
[b]Variances are equal.
[c]There is no significant difference in FC concentrations at location 91 (DPR) during dry and wet weather conditions.
[d]There is no significant difference in FC concentrations at location 92 (CSSC) during dry and wet weather conditions.

91 (DPR) are significantly higher than the flow-specific FC concentrations at location 92 (CSSC) during both dry and wet weather conditions. These results are shown in Table 7.

It is difficult to interpret the true significance of the wet weather/dry weather comparisons, as the effects of rainfall in the Chicago area on microbial water quality downstream can be confounded by the operation of the TARP system as well as variable time of travel as water flows downstream.

FC Concentrations During Seasonal Disinfection and No Disinfection Periods

The basic statistical results on the comparisons of FC concentrations during two periods, P1 (disinfection) and P2 (no disinfection) within locations 91 (DPR) and 92 (CSSC) are summarized in Table 8.

The results of ANOVA show that there is a significant statistical difference ($p = 0.009$) in GM FC concentration at location 91 (DPR) during the two periods tested, disinfection months (P1) and no disinfection months (P2). The calculated GM FC concentration at location 91 (DPR) during P2 (no disinfection months) was 467 CFU/100 mL which was higher compared to 228 CFU/100 mL during P1 (disinfection months).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 7

COMPARISON OF THE FC CONCENTRATIONS BETWEEN LOCATIONS 91 (DPR) AND 92 (CSSC) DURING DRY AND WET WEATHER CONDITIONS

Analysis/ Covariate	Weather Condition	Significance Probability of Equal Means (*ln* FC)	Conclusion
ANOVA/ None	Dry	0.1169	There is no significant difference in FC concentration between locations 91 (DPR) and 92 (CSSC).
	Wet	0.6140	There is no significant difference in FC concentration between locations 91 (DPR) and 92 (CSSC).
ANCOVA/ Flow	Dry	0.0001	Flow-specific FC concentrations are higher at location 91 (DPR) than at 92 (CSSC) in dry weather.
	Wet	0.0031	Flow-specific FC concentrations are higher at location 91 (DPR) than at 92 (CSSC) in wet weather.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 8

COMPARISON OF THE FC CONCENTRATIONS OF THE DISINFECTION (P1) AND NO DISINFECTION (P2) PERIOD AT LOCATIONS 91 (DPR) AND 92 (CSSC)

Analysis/ Location	P[1]	Obs[2]	GM FC[3]	Significance Probability of Normality[4] (*ln* FC)	Results of the F Test (*ln* FC)	Significance Probability of Equal Means[5] (*ln* FC)
ANOVA						
91 (DPR)	P1	52	228	0.1853[a]	0.2956[b]	0.0094[c]
	P2	48	467	0.7652[a]		
92 (CSSC)	P1	52	381	0.1744[a]	0.0772[b]	0.0078[d]
	P2	50	179	0.0956[a]		

[1]Period, P1: May - October; P2: November - April.
[2]Number of Observations.
[3]Geometric Mean FC concentrations in CFU/100 mL.
[4]Results of K-S Test.
[5]Results of ANOVA.
[a]Data are from a normal population.
[b]Variances are equal.
[c]There is a significant difference between the GMs FC at location 91 in the disinfection and no disinfection period.
[d]There is a significant difference between the GMs FC at location 92 in the disinfection and no disinfection period.

As mentioned earlier, the CSSC receives undisinfected effluent throughout periods P1 and P2. However, results observed at location 92 (CSSC) during the two periods were interesting. The calculated GM FC concentrations during P1 (May - October) was 381 CFU/100 mL, which is significantly higher than the FC mean concentration of 179 CFU/100 mL during P2 (November - April) ($p = 0.008$).

The ANOVA was also performed to compare the concentration of FC bacteria between the two locations during the two periods tested. The results are shown in Table 9. The GM FC density in P1 was 228 CFU/100 mL at location 91 (DPR) and 381 CFU/100 mL at location 92 (CSSC). There is no significant difference in these values during the disinfection months at the two locations. However, there is a significant difference in the GM FC concentrations between the two locations in P2 (no disinfection months). The GM FC concentration at location 91 (DPR) is significantly higher (467 CFU/100 mL) than the GM FC concentrations (179 CFU/100 mL) at location 92 (CSSC) during no disinfection months ($p = 0.0001$).

These results are consistent with the earlier comparison of the 30-day period GM data. The results in Table 10 show six out of ten 30-day periods (60 percent) during P1 and eight

TABLE 9

COMPARISON OF THE FC CONCENTRATIONS OF THE DISINFECTION (P1) AND NO DISINFECTION (P2) PERIOD BETWEEN LOCATIONS 91 (DPR) AND 92 (CSSC)

Analysis/ Period[1]	Location	Obs[2]	GM FC[3]	Significance Probability Normality[4] (*ln* FC)	Results of the F Test *ln* FC)	Significance Probability of Equal Means[5] (*ln* FC)
ANOVA						
P1	91	52	228	0.1853[a]		
	92	52	381	0.1744[a]	0.3211[b]	0.094[c]
P2						
	91	48	467	0.7652[a]	0.3378[b]	0.0001[d]
	92	50	179	0.0956[a]		

[1]P1: May - October; P2: November - April.
[2]Number of Observations.
[3]Geometric Mean concentrations of FC bacteria in CFU/100 mL.
[4]Results of K-S Test.
[5]Results of ANOVA.
[a]Data came from normal population.
[b]Variances are equal.
[c]There is no significant difference between the GMs FC at locations 91 (DPR) and 92 (CSSC) in the disinfection period.
[d]There is a significant difference between GMs FC at locations 91 (DPR) and 92 (CSSC) in the no disinfection period.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10

30-DAY PERIOD GM CONCENTRATION OF FC BACTERIA AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Periods/Five Samples 30-day Period Dates	FC(CFU/100 mL)[1] at Location 91	FC (CFU/100 mL)[1] at Location 92
P1 (May - October)		
5/4/00 through 6/1/00	153.493	210.875[a]
6/8/00 through 7/6/00	278.092[a]	462.068[a]
7/13/00 through 8/10/00	111.439	168.203
8/17/00 through 9/14/00	221.867[a]	501.261[a]
9/21/00 through 10/19/00	845.044[a]	547.999[a]
5/24/01 through 6/21/01	145.917	365.826[a]
6/28/01 through 7/26/01	163.806	146.724
8/2/01 through 8/30/01	235.202[a]	614.302[a]
9/6/01 through 10/4/01	621.857[a]	1524.439[a]
10/11/01 through 11/8/01	331.766[a]	744.414[a]
P2 (November - April)		
1/20/00 through 2/17/00	268.674[a]	132.279
2/24/00 through 3/23/00	455.070[a]	127.935
3/30/00 through 4/27/00	122.545	148.929
10/26/00 through 11/21/00	638.286[a]	322.377[a]
11/30/00 through 12/28/00	587.764[a]	329.771[a]
1/4/01 through 2/1/01[2]	2084.328[a]	249.295[a]
2/8/01 through 3/8/01	1635.450[a]	172.689
3/15/01 through 4/12/01	552.125[a]	86.588
4/19/01 through 5/17/01	95.513	115.542
11/15/01 through 12/13/01	382.338[a]	140.213

[1]GM calculated from five samples during 30-day period from locations 91 and 92.
[2]GM calculated from three samples during 30-day period from location 91 and five samples from location 92.
[a]Value exceeds the General Use FC standard.

out of ten 30-day periods during P2 (80 percent) exceed the General Use standard for FC bacteria (≤200 CFU/100 mL) at location 91 (DPR). At location 92 (CSSC), the percentage of General Use standard FC exceedances is higher during P1 (80 percent) and lower during P2 (30 percent). The results described above suggest that effluent disinfection is reducing the FC burden at location 91 (DPR). However, the effect of weather and the difference in the physical structure of the DPR must also be considered. The DPR is wide and shallow. The man-made CSSC is about 15-feet deep and is protected by concrete or sheet pile vertical embankments. The fate and survival of FC bacteria in the DPR at location 91 may be more influenced by environmental factors when compared to the deeper CSSC. For example, the disinfection months (May through October) are usually warmer with increased frequency of rainfall than the no disinfection months (November through April). Rainfalls greater than 2 inches (Figure 6) and the water temperatures greater than 15°C (Table AI-2) were observed during disinfection months (May through October).

A USGS report by Terrio (1994) concluded that discontinuing chlorination increased FC concentrations downstream of the Stickney WRP outfall. The results from the present study, however, reveal that by the time any FC contained in the Stickney WRP effluent reach location 92 (CSSC), even without chlorination, the resulting FC concentration at that point is similar to the FC concentration at location 91 (DPR), a General Use water. This observation is supported by the work of Hass et al. (1988) and Sedita et al. (1987) who concluded that resumption of chlorination at the District's Stickney and Calumet WRPs would not result in a statistically significant reduction in the concentrations of FC downstream of Lockport.

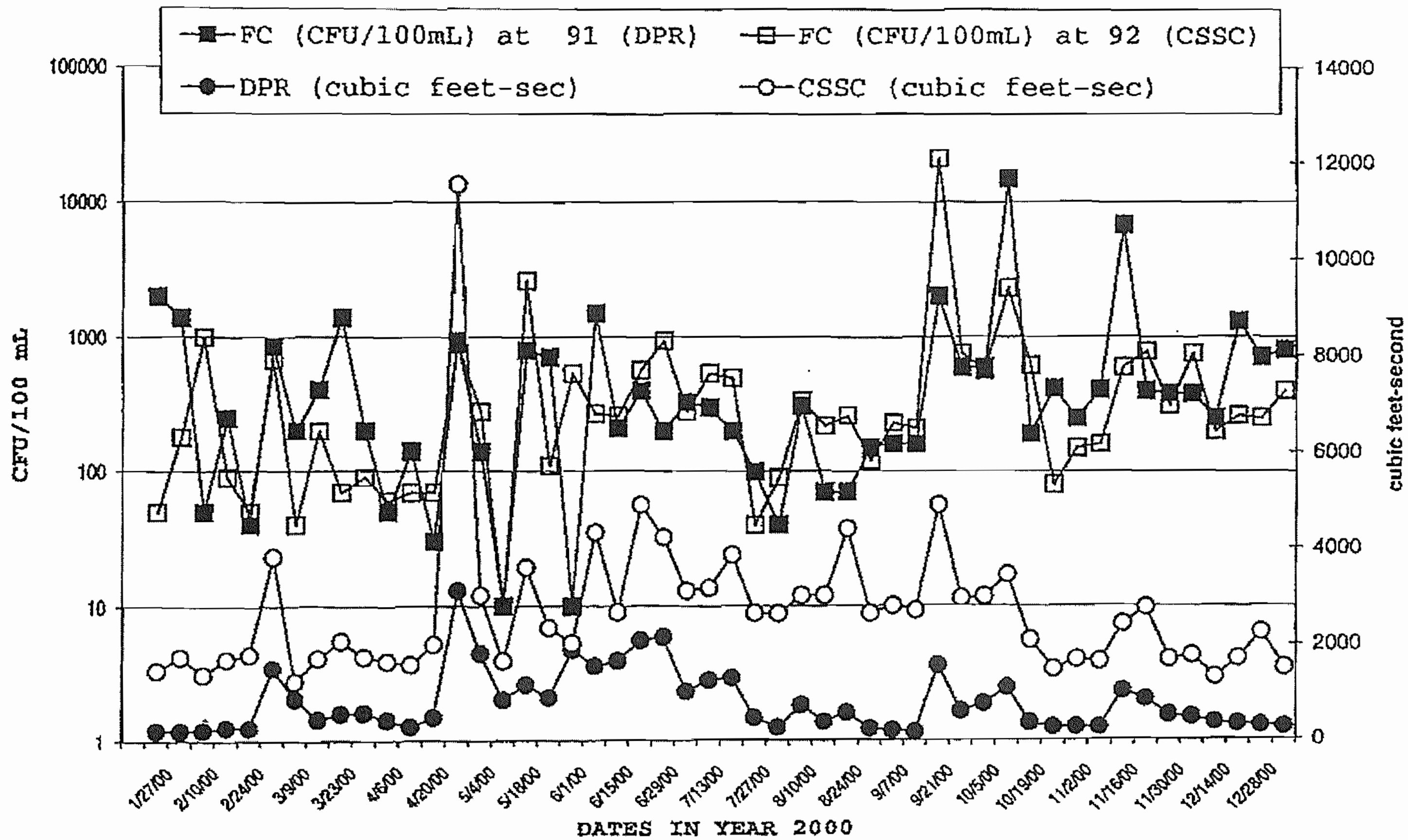
Derivation of Models to Predict FC Concentration at Locations 91 (DPR) and 92 (CSSC)

Locations 91 (DPR) and 92 (CSSC) represent two separate waterways and the water quality of these are affected by many variables such as rainfall, temperature, turbidity, TSS, and river flow. The possibility of all these variables affecting the FC concentration were considered in the development of models to predict FC concentrations. The TSS, temperature, and turbidity correlated with the *ln* flow at both locations 91 (DPR) and 92 (CSSC). However, flow was the only parameter that was found to contribute significantly to the models. Figures 8 and 9, suggest that FC concentrations were correlated with flow during the study period.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 8

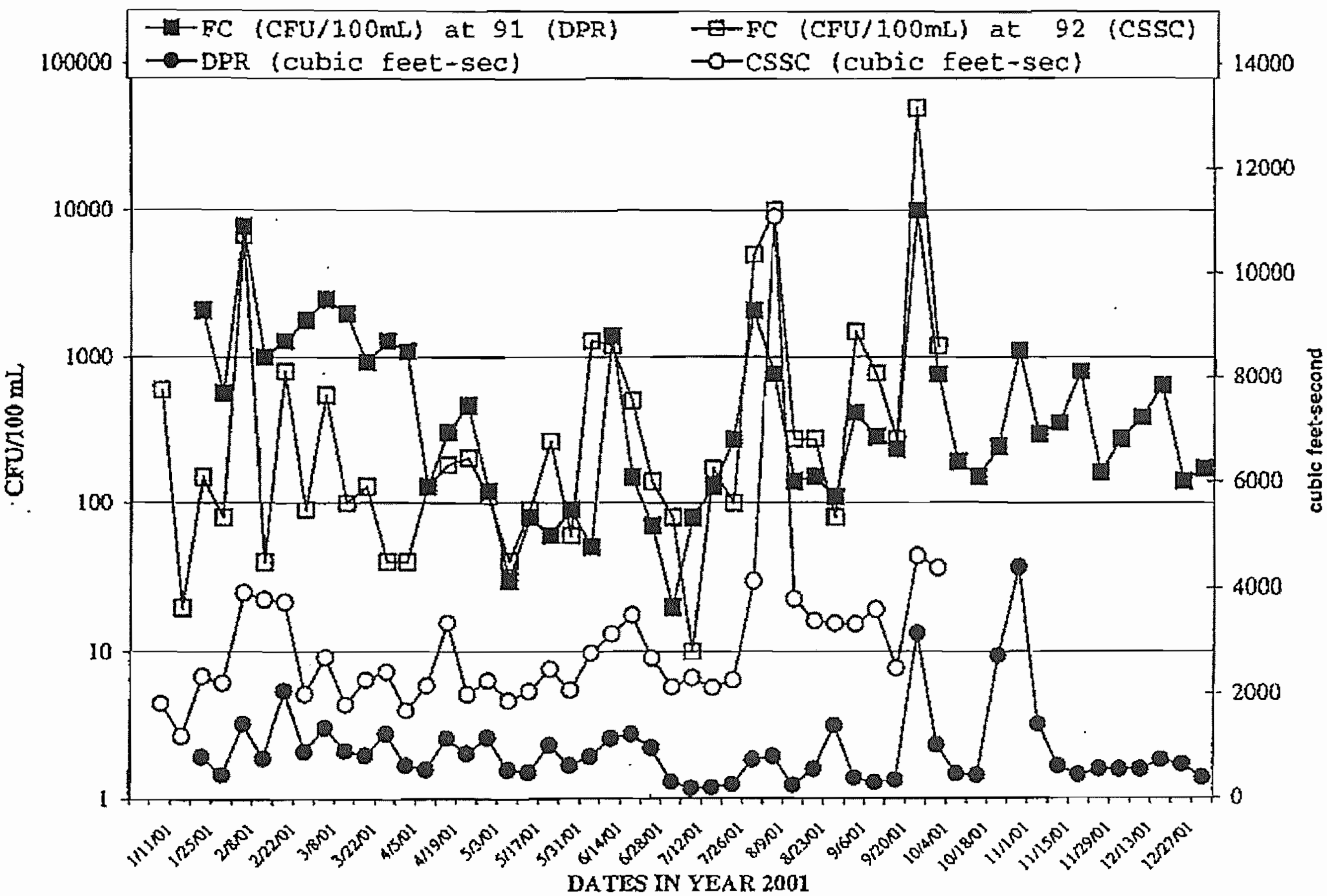
RELATIVE CONCENTRATION OF THE FC BACTERIA AND RIVER FLOW IN 2000



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 9

RELATIVE CONCENTRATION OF THE FC BACTERIA AND RIVER FLOW IN 2001



Forecast values of FC concentrations by the time series model and auto regression model at two locations 91 (DPR) and 92 (CSSC) are shown in Tables AII-1 and AII-2. At location 91 (DPR), the AIC value of the regression model is 343.7 and that of auto regressive model is 323.3. This implies that auto regressive model is slightly better than regression model. At location 92 (CSSC), the AIC value of regression model is 306.6 and that of auto regressive model is 308.8. This implies that regression model is slightly better than auto regressive model.

When the two models were tested to predict FC concentration at each location, the results revealed that forecast values are almost identical at each point. Therefore, for the purpose of simplicity, the regression model was selected as the best candidate model and the equation is summarized below:

Location 91 (DPR): $ln(FC) = 0.88647 * ln(Flow), R^2 = 0.95$ (1)

Location 92 (CSSC): $ln(FC) = 0.71086 * ln(Flow), R^2 = 0.95$ (2)

Where FC is the concentration of FC bacteria in CFU/100 mL, flow is the average river flow measured in cubic feet per second.

The intercept and slope were calculated by the least square method. The high R^2 value of 0.95 at each location indicates that each regression equation is very good in the sense that the regression model can explain 95 percent of the variability of FC concentration. The plotted graph of the predictive models at locations 91 (DPR) and 92 (CSSC) is shown in Figure 10.

Results of the t-test indicated that the slope of the regression equation for location 91 (DPR) was significantly higher than the slope at the regression equation for location 92 (CSSC) ($p = <0.05$). It is clear from Figure 10 that the probability of higher FC concentrations at location 91 (DPR) is predicted with an increase in river flow rate when compared to location 92 (CSSC).

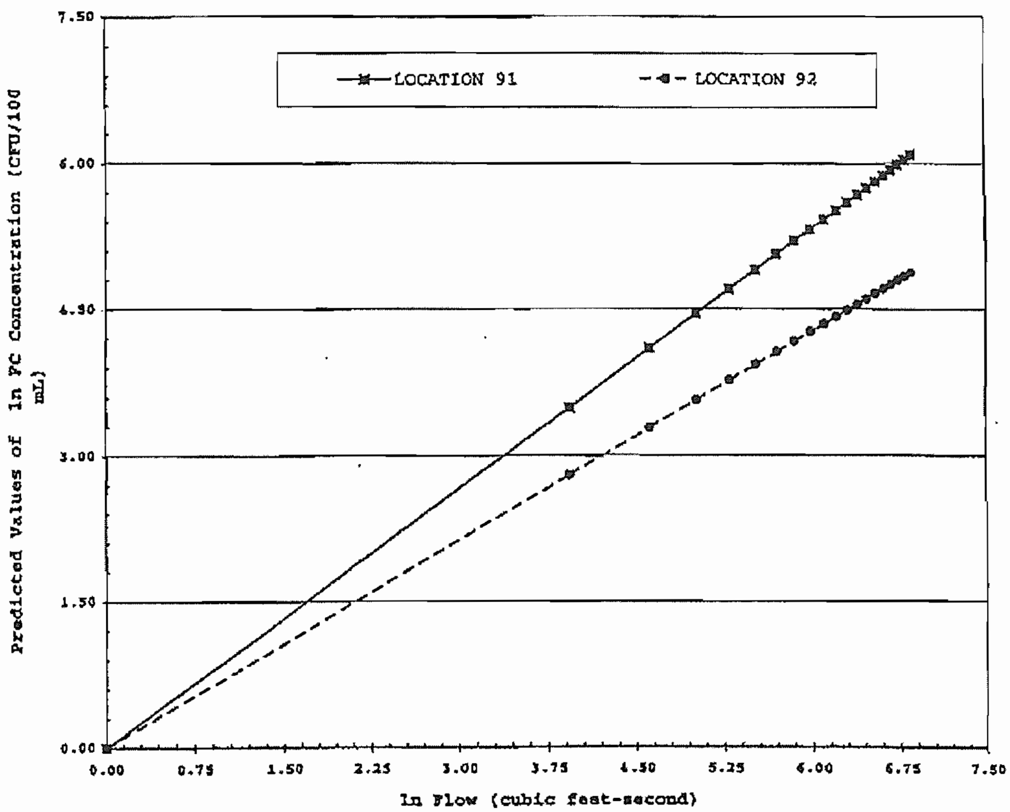
Evaluation of Bacteriological Standard for Recreational Uses of LDPR

The USEPA published ambient water quality criteria for bacteria in 1986 (EPA 440/5-84-002, January 1986). The federal bacteriological criteria for freshwater specify the use of fecal indicator bacteria suggested by Cabelli (1983) and Dufour (1984). These bacteriological criteria are based on the assumption that the class of fecal bacteria including FC, *E.coli*, and enterococci are found only in feces or sewage, and that when these fecal indicator bacteria are found in environmental waters (streams, lakes, rivers) designated

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 10

PREDICTION OF FECAL COLIFORM CONCENTRATIONS AT LOCATIONS 91 (DPR) AND 92 (CSSC)



for recreational use (swimming, wading), that water is considered contaminated with feces and represents a health risk to humans (USEPA, 1986).

The results of this study clearly indicate that the FC concentrations at the DPR upstream of Lockport (location 91) are often above the Illinois General Use water quality standard of 200 CFU/100 mL. Moreover, higher concentrations of FC bacteria were recorded at location 91 (DPR) than at location 92 (CSSC), an effluent dominated stream classified as Secondary Contact water. The GM concentrations of the FC bacteria observed in this study are consistent with USGS report data of FC densities in the DPR at Riverside and at the CSSC at Romeoville (Terrio, 1995). The USGS report indicates that the percentage of samples exceeding the Illinois General Use FC standard was substantially less in the CSSC than in the DPR basin. These measurements were made before TARP was built. After the construction of the TARP the number of CSOs discharged into the CSSC and into the DPR system has been significantly reduced. The IEPA consultant's draft report on the LDPR UAA study has acknowledged the beneficial impact of the TARP project on reduction of FC densities in the LDPR (Hey and Associates, Inc., Draft Report, April 2002).

The results presented here indicate that by using the FC bacteria criteria, the water of the DPR upstream of Lockport designated for recreational use does not meet the General Use bacteriological standards, but at the same time it cannot be concluded or assumed that point sources are solely responsible for the FC burden in the LDPR. It should be noted that the mere presence of high levels of FC in river or streams is not always an indicative of contamination by point source of pollution (Solo-Gabriele et al. 2000; Roll and Fujioka, 1997). Toronzos (1997) indicated that the FC bacteria are found in ambient waters in the absence of point source pollution and survive longer period when high levels of nutrients are available.

FC bacteria in any river system can originate from any of the following possible sources (USEPA, 2001):

1. Treated wastewater discharge from WRPs.
2. Combined Sewer Overflows (CSO).
3. Wastewater discharge from
    a. slaughterhouses
    b. meat processing facilities
    c. poultry processing facilities
    d. animal feedlots.
4. Leaking sewer lines.
5. Storm drains.

6. Failing septic systems.

7. Marinas and pump out facilities.

8. Illicit sewage connections.

9. Urban run-off.

10. Domestic pets fecal droppings.

11. Birds fecal droppings.

12. Wildlife.

13. Land application of manure.

14. Land application of biosolids.

15. Landfills.

Of these listed possible sources of pollution, most significantly, many researchers have reported hundreds or thousands of birds roosting on the surface water, which would have an adverse effect on the microbiological quality of the freshwaters (McLellan, 2001; Alderisio, K.A. and N. DeLuca, 1999; Benoit et al. 1993; Standridge et al. 1979). The recently issued, "State of the Waters 2002 Region 5" provide information about the causes of water body impairments for rivers and streams. This report designates nonpoint source pollution the leading cause of impairments to Illinois waters (USEPA, 2002).

The microbial water quality based on FC densities at location 92 (CSSC) which is classified as Secondary Contact is comparable to location 91 (DPR) which is classified as General

Use. It is appropriate to say that the primary sources of FC bacteria in the LDPR system (below the confluence of DPR and CSSC) are treated effluent from District WRPs, treated effluent from other sewage treatment plants, CSOs, and various environmental/nonpoint sources (storm drains, bird and animal feces, and soil run-off). There are currently no monitoring or analytical methods available that can distinguish between FC indicator bacteria originating from point sources from those originating from nonpoint sources. The identification and characterization of these nonpoint source(s) of the fecal pollution can provide a better understanding of the LDPR water resources and suggest ways to improve water quality. Effort should also be focused on exploring the microbial quality of treated effluents from other municipal sewage treatment plants that discharge directly into the LDPR.

The LDPR UAA study by IEPA is still in progress. The extent to which all sources of FC are affecting the water quality needs to be considered when determining the recreational use classification of the LDPR.

REFERENCES

Alderisio, K. A. and N. DeLuca, "Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (*Larus delawarensis*) and Canada Geese (*Branta canadensis*)," *Applied and Environmental Microbiology,* Vol. 65, No. 12, December 1999, pp. 5628-5630.

Benoit, L., P. Brousseau, P. Simard, E. Dewailly, M. Meisels, D. Ramsay, and J. Joly, "Impact of the Ring-Billed Gull (*Larus Delawarensis*) on the Microbiological Quality of Recreational Water," *Applied and Environmental Microbiology,* Vol 59, No. 4, April 1993, pp. 1228-1230.

Box, G. E. P. and G. M. Jenkins. Time Series Analysis, Forecasting and Control, Holden-Day Inc., San Francisco, California, 1970.

Butts, T. A., R. L. Evans, and S. Lin, "Water Quality Features of the Upper Illinois Waterway," *Illinois State Water Survey,* Report of Investigations, No. 79, Urbana, Illinois, 1975.

Cabelli, V. J., "Health Effects Criteria for Marine Recreational Waters," EPA-600/1-80-031, 1983.

Charles Hagedorn, Sandra L. Robinson, Jennifer R. Filtz, Sarah M. Grubbs, Theresa A. Angier, and Raymond B. Reneau Jr., "Determining Sources of Fecal Pollution in a Rural Virginia Watershed with Antibiotic Resistance Patterns in Fecal Streptococci," *Applied and Environmental Microbiology,* Vol. 65, No. 12, 1999, pp. 5522-5531.

Dufour, A. P., "Health Effects Criteria for Fresh Recreational Waters," United States Environmental Protection Agency, EPA-600/1-84-004, 1984.

Dyer, D. D. and J. P. Keating, "On the Determination of Critical Values for Barlett's Test,", *Journal of American Statistical Association*, Vol. 75, No. 370, 1980, pp. 313-319.

Gibbons, J. D. and S. Chakarborti, Non-Parametric Statistical Inference, 3rd ed., Marcel Dekker Inc., New York, 1992.

Haas, C. N., J. G. Sheerin, C. Lue-Hing, K. C. Rao, and P. O'Brien, "Effects of Discontinuing Disinfection on a Receiving Water," *Journal of WPCF*, Volume 60, Number 5, 1988, pp. 667-673.

Hey and Associates, Inc., Lower Des Plaines River Use Attainability Analysis, Draft Chapter, April, 2002.

Illinois Environmental Protection Agency, "Water Pollution Control Regulations of Illinois," Adopted by the Illinois Pollution Control Board, Springfield, Illinois, 1972.

Khattree, R. and N. N. Dayanand, Applied Multivariate Statistics, With SAS Software, 2nd ed., SAS Institute Inc., Cary, North Carolina, 1999.

Khattree, R and D.N. Naik, Applied Multivariate Statistics With SAS Software, 2nd. ed., SAS Institute Inc., Cary, North Carolina, 1999.

McLellan, S. L., Annette D. Daniels, and Alissa K. Salmore, "Clonal Populations of Thermotolerant *Enterobacteriaceae* in Recreational Water and Their Potential Interference with Fecal *Escherichia coli* Counts," *Applied and Environmental Microbiology*, Vol. 67, No. 10, 2001, pp. 4934-4938.

Rao, C. R., Linear Statistical Inference and its Applications, 2nd. ed., John Wiley and Sons, Inc., New York, 2002

Roll, B. M. and R. S. Fujioka, "Sources of Fecal Indicator Bacteria in a Brackish Tropical Stream and Their Impact on Recreational Water Quality," *Water Science Technology*, 35:179-186, 25, 1997.

Sedita, S. J., D. R. Zenz, C. Lue-Hing, and P. O'Brien, "Fecal Coliform Levels in the Man-made Waterways of the Metropolitan Sanitary District of Greater Chicago Before and After Cessation of Chlorination at the West-Southwest, Calumet, and North Side Sewage Treatment Works," Metropolitan Water Reclamation District of Greater Chicago, Report No. 87-22, 1987.

Solo-Gabriele, H. M., M. A. Wolfert, T. R. Desmarais, and C. J. Palmer, "Sources of *Escherichia coli* in a Coastal Subtropical Environment," *Applied Environmental Microbiology*, 66:230-237, 2000.

Standridge, J. H., J. J. Delfino, L. B. Kleppe, and R. Butler, "Effect of Waterfowl (*Anas platyrhynchos*) on Indicator Bacteria Populations in a Recreational Lake, Madison, Wisconsin," *Applied Environmental Microbiology*, 38(3):547-50, 1979.

Toranzos, G. A., and G. A. McFeters, "Detection of Indicator Microorganisms in Environmental Freshwaters and Drinking Waters," *In* C. J. Hurst, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, and M. V. Walter (eds.), *Manual of Environmental Microbiology*, American Society for Microbiology, Washington, D.C., 1997, pp. 184-194.

Terrio, P. J., "Water Quality Assessment of the Upper Illinois River Basin in Illinois, Indiana, and Wisconsin: Nutrients, Dissolved Oxygen, and Fecal-Indicator Bacteria in Surface Water, April 1987 through August 1990," U.S. Geological Survey, Water-Resources Investigations Report 95-4005, 1995.

Terrio, P. J., "Relations of Changes in Wastewater-Treatment Practices to Changes in Stream-water Quality During 1978-88 in the Chicago area, Illinois, and Implications for Regional and National Water Quality Assessments," U.S. Geological Survey, Water-Resources Investigations Report 93-4118, 1994.

Walpole, R. E. and R. H. Myers, <u>Probability and Statistics for Engineers and Scientists</u>, 4th ed., Macmillan Publishing Company, New York, 1999.

U. S. Environmental Protection Agency (USEPA), "Ambient Water Quality Criteria for Bacteria - 1986," United States Environmental Protection Agency, EPA-440/5-84-002, 1986.

USEPA, "Report to Congress: Implementation and Enforcement of the Combined Sewer Overflow Control Policy," U. S. Environmental Protection Agency, Office of Water, EPA 833-R-01-003, Washington, D.C., 2001.

USEPA, "Protocol for Developing Pathogen TMDLs," First Edition, U. S. Environmental Protection Agency, Office of Water, EPA 841-R-00-002, 2001.

USEPA, "State of the Waters 2002 Region 5," United States Environmental Protection Agency, EPA-905/-R-02-007, 2002.

APPENDIX AI

WATER QUALITY DATA FOR 2000 - 2001

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1

FECAL COLIFORM, RIVER FLOW, AND RAINFALL DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location Code	FC (CFU/100 mL)	Flow (cubic feet-sec)	Rainfall (inches)
10/20/00	91	2000	213	0.00
01/27/00	91	1400	207	0.00
02/03/00	91	50	222	0.00
02/10/00	91	250	279	0.00
02/17/00	91	40	272	0.00
02/24/00	91	850	1520	1.25
03/02/00	91	200	875	0.00
03/09/00	91	410	450	0.01
03/16/00	91	1400	566	0.59
03/23/00	91	200	575	0.00
03/30/00	91	50	419	0.00
04/06/00	91	140	294	0.55
04/13/00	91	30	490	0.00
04/20/00	91	940	3120	0.32
04/27/00	91	140	1830	0.00
05/04/00	91	10	855	0.00
05/11/00	91	800	1170	0.26
05/18/00	91	710	895	0.00
05/25/00	91	10	1890	0.12
06/01/00	91	1500	1560	0.00
06/08/00	91	210	1670	0.00
06/15/00	91	400	2100	0.00
06/22/00	91	200	2160	0.00
06/29/00	91	330	1020	0.00
07/06/00	91	300	1260	0.00
07/13/00	91	200	1310	0.00
07/20/00	91	99	473	0.00
07/27/00	91	40	273	0.00
08/03/00	91	310	738	0.00
08/10/00	91	70	389	0.00
08/17/00	91	70	574	0.00
08/24/00	91	150	242	0.33
08/31/00	91	160	206	0.44
09/07/00	91	160	178	0.66
09/14/00	91	2000	1570	0.01
09/21/00	91	600	610	0.00
09/28/00	91	600	771	0.00
10/05/00	91	15000	1110	0.57
10/12/00	91	190	359	1.34
10/19/00	91	420	270	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

FECAL COLIFORM, RIVER FLOW, AND RAINFALL DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location Code	FC (CFU/100 mL)	Flow (cubic feet-sec)	Rainfall (inches)
10/26/00	91	250	278	0.00
11/02/00	91	410	275	0.02
11/08/00	91	6800	1030	0.00
11/16/00	91	400	860	0.00
11/21/00	91	380	524	0.00
11/30/00	91	380.	477	ND
12/07/00	91	250	370	ND
12/14/00	91	1300	330	ND
12/21/00	91	710	300	ND
12/28/00	91	800	270	0.00
01/18/01	91	2100	802	0.01
01/25/01	91	560	462	0.00
02/01/01	91	7700	1420	0.00
02/08/01	91	1000	773	0.88
02/15/01	91	1300	2060	0.00
02/22/01	91	1800	897	0.02
03/01/01	91	2500	1350	0.00
03/08/01	91	2000	910	0.00
03/15/01	91	920	826	0.21
03/22/01	91	1300	1230	0.00
03/29/01	91	1100	640	0.02
04/05/01	91	130	555	0.28
04/12/01	91	300	1140	0.00
04/19/01	91	460	854	0.00
04/26/01	91	120	1150	0.00
05/03/01	91	30	539	0.00
05/10/01	91	80	494	0.01
05/17/01	91	60	1010	0.02
05/24/01	91	90	634	0.41
05/31/01	91	50	794	0.35
06/07/01	91	1400	1140	0.00
06/14/01	91	150	1220	0.08
06/21/01	91	70	962	0.44
06/28/01	91	20	320	0.00
07/05/01	91	80	196	0.00
07/12/01	91	130	212	0.00
07/19/01	91	270	270	0.00
07/26/01	91	2100	742	0.00
08/02/01	91	760	802	1.80
08/09/01	91	140	257	0.24
08/16/01	91	150	559	0.00
08/23/01	91	110	1380	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

FECAL COLIFORM, RIVER FLOW, AND RAINFALL DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location Code	FC (CFU/100 mL)	Flow (cubic feet-sec)	Rainfall (inches)
08/30/01	91	410	392	0.14
09/06/01	91	280	311	0.21
09/13/01	91	230	354	0.00
09/20/01	91	10000	3160	0.13
09/27/01	91	760	1020	0.00
10/04/01	91	190	473	1.03
10/11/01	91	150	443	0.05
10/18/01	91	240	2730	0.00
10/25/01	91	1100	4380	0.00
11/01/01	91	290	1410	0.00
11/08/01	91	350	620	0.00
11/15/01	91	790	452	0.10
11/20/01	91	160	558	0.19
11/29/01	91	270	550	ND
12/06/01	91	380	551	ND
12/13/01	91	630	728	ND
12/20/01	91	140	646	ND
12/27/01	91	170	390	0.00
01/20/00	92	50	1477	0.00
01/27/00	92	180	1757	0.00
02/03/00	92	1000	1385	0.00
02/10/00	92	90	1702	0.00
02/17/00	92	50	1802	0.00
02/24/00	92	680	3823	1.25
03/02/00	92	40	1239	0.00
03/09/00	92	200	1727	0.01
03/16/00	92	70	2083	0.59
03/23/00	92	90	1749	0.00
03/30/00	92	60	1647	0.00
04/06/00	92	70	1597	0.55
04/13/00	92	70	2019	0.00
04/20/00	92	890	11563	0.32
04/27/00	92	280	3027	0.00
05/04/00	92	10	1671	0.00
05/11/00	92	2600	3599	0.26
05/18/00	92	110	2353	0.00
05/25/00	92	540	2040	0.12
06/01/00	92	270	4331	0.00
06/08/00	92	260	2683	0.00
06/15/00	92	570	4909	0.00
06/22/00	92	940	4230	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

FECAL COLIFORM, RIVER FLOW, AND RAINFALL DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location Code	FC (CFU/100 mL)	Flow (cubic feet-sec)	Rainfall (inches)
06/29/00	92	280	3116	0.00
07/06/00	92	540	3172	0.00
07/13/00	92	500	3863	0.00
07/20/00	92	40	2611	0.00
07/27/00	92	90	2649	0.00
08/03/00	92	340	3017	0.00
08/10/00	92	220	3019	0.00
08/17/00	92	260	4407	0.00
08/24/00	92	120	2652	0.33
08/31/00	92	230	2806	0.44
09/07/00	92	210	2714	0.66
09/14/00	92	21000	4908	0.01
09/21/00	92	760	2963	0.00
09/28/00	92	570	3000	0.00
10/05/00	92	2300	3450	0.57
10/12/00	92	620	2100	1.34
10/19/00	92	80	1492	0.00
10/26/00	92	150	1705	0.00
11/02/00	92	160	1663	0.02
11/08/00	92	600	2437	0.00
11/16/00	92	780	2776	0.00
11/21/00	92	310	1704	0.00
11/30/00	92	750	1776	ND
12/07/00	92	200	1330	ND
12/14/00	92	260	1716	ND
12/21/00	92	250	2259	ND
12/28/00	92	400	1516	0.00
01/04/01	92	590	1829	0.00
01/11/01	92	20	1192	0.00
01/18/01	92	150	2330	0.01
01/25/01	92	80	2209	0.00
02/01/01	92	6800	3920	0.00
02/08/01	92	40	3793	0.88
02/15/01	92	790	3747	0.00
02/22/01	92	90	1997	0.02
03/01/01	92	540	2703	0.00
03/08/01	92	100	1794	0.00
03/15/01	92	130	2270	0.21
03/22/01	92	40	2426	0.00
03/29/01	92	40	1685	0.02
04/05/01	92	130	2160	0.28

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

FECAL COLIFORM, RIVER FLOW, AND RAINFALL DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location Code	FC (CFU/100 mL)	Flow (cubic feet-sec)	Rainfall (inches)
04/12/01	92	180	3356	0.00
04/19/01	92	200	1992	0.00
04/26/01	92	110	2250	0.00
05/03/01	92	40	1862	0.00
05/10/01	92	90	2041	0.01
05/17/01	92	260	2472	0.02
05/24/01	92	60	2076	0.41
05/31/01	92	1300	2774	0.35
06/07/01	92	1200	3145	0.00
06/14/01	92	500	3500	0.08
06/21/01	92	140	2684	0.44
06/28/01	92	80	2132	0.00
07/05/01	92	10	2301	0.00
07/12/01	92	170	2122	0.00
07/19/01	92	100	2260	0.00
07/26/01	92	5000	4130	0.00
08/02/01	92	10000	11087	1.80
08/09/01	92	270	3794	0.24
08/16/01	92	270	3386	0.00
08/23/01	92	80	3343	0.00
08/30/01	92	1500	3330	0.14
09/06/01	92	770	3602	0.21
09/13/01	92	270	2484	0.00
09/20/01	92	50000	4596	0.13
09/27/01	92	1200	4369	0.00
10/04/01	92	660	ND	1.03
10/11/01	92	980	ND	0.05
10/18/01	92	2100	ND	0.00
10/25/01	92	990	ND	0.00
11/01/01	92	660	ND	0.00
11/08/01	92	170	ND	0.00
11/15/01	92	230	ND	0.10
11/20/01	92	90	ND	0.19
11/29/01	92	140	ND	ND
12/06/01	92	110	ND	ND
12/13/01	92	170	ND	ND
12/20/01	92	230	ND	ND
12/27/01	92	220	ND	0.00

ND = No Data

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2

WATER QUALITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location	Total Suspended Solids (mg/L)	Temperature (°C)	Turbidity (NTU)
01/20/00	91	28	9.8	14
01/27/00	91	14	9.8	8
02/03/00	91	7	3.2	7
02/10/00	91	10	2.5	9
02/17/00	91	17	2.3	8
02/24/00	91	35	10	15
03/02/00	91	35	8.1	19
03/09/00	91	38	11.6	25
03/16/00	91	29	7.5	18
03/23/00	91	43	12.2	29
03/30/00	91	47	11.2	20
04/06/00	91	60	11.7	35
04/13/00	91	44	9.9	28
04/20/00	91	76	12.9	51
04/27/00	91	41	17.3	30
05/04/00	91	58	21.4	32
05/11/00	91	30	17.6	35
05/18/00	91	58	18.6	33
05/25/00	91	59	19.9	40
06/01/00	91	69	19	42
06/08/00	91	41	ND	28
06/15/00	91	48	20.5	28
06/22/00	91	31	23.7	22
06/29/00	91	47	22.3	27
07/06/00	91	42	24.7	27
07/13/00	91	41	31.9	22
07/20/00	91	60	22	34
07/27/00	91	51	26.5	34
08/03/00	91	59	22.5	30
08/10/00	91	55	26.8	35
08/17/00	91	50	23.4	32
08/24/00	91	54	27.3	34
08/31/00	91	54	28.4	32
09/07/00	91	42	24.7	27
09/14/00	91	53	20	32

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

WATER QUALITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location	Total Suspended Solids (mg/L)	Temperature (^oC)	Turbidity (NTU)
09/21/00	91	47	17.2	30
09/28/00	91	47	17.4	30
10/05/00	91	60	16.1	38
10/12/00	91	26	12.3	19
10/19/00	91	28	16.1	21
10/26/00	91	30	18.2	20
11/02/00	91	25	15.7	19
11/08/00	91	54	11.5	33
11/16/00	91	15	5.6	14
11/21/00	91	11	0.8	10
11/30/00	91	24	5.5	14
12/07/00	91	21	0.3	13
12/14/00	91	11	0.5	9
12/21/00	91	4	ND	8
12/28/00	91	6	7.8	6
01/18/01	91	19	1.9	13
01/25/01	91	2	0.7	8
02/01/01	91	50	3	21
02/08/01	91	12	4.3	9
02/15/01	91	19	8.2	18
02/22/01	91	17	7	14
03/01/01	91	25	2	22
03/08/01	91	12	2.6	12
03/15/01	91	16	6.6	12
03/22/01	91	34	11.1	17
03/29/01	91	11	7	7
04/05/01	91	17	15	10
04/12/01	91	49	13	27
04/19/01	91	39	10.1	21
04/26/01	91	59	15.3	17
05/03/01	91	58	20.2	26.6
05/10/01	91	85	21	36.9
05/17/01	91	80	22.2	31.4
05/24/01	91	62	17.8	27.8

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

WATER QUALITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location	Total Suspended Solids (mg/L)	Temperature (^{0}C)	Turbidity (NTU)
05/31/01	91	59	15.6	30.2
06/07/01	91	50	19	29.4
06/14/01	91	44	28.8	20.5
06/21/01	91	24	25.2	24.9
06/28/01	91	82	28.2	30.8
07/05/01	91	56	25.4	28.6
07/12/01	91	109	26.1	55.7
07/19/01	91	120	30.1	56.5
07/26/01	91	84	29.1	35.6
08/02/01	91	66	28	33.7
08/09/01	91	63	33.4	41.7
08/16/01	91	63	23.7	38.8
08/23/01	91	71	28.8	40.6
08/30/01	91	60	28.2	31.1
09/04/01	91	70	29.6	38.4
09/06/01	91	58	24.8	35.4
09/13/01	91	65	23.1	35.8
09/20/01	91	111	19.6	53.1
09/27/01	91	40	17	23.4
10/04/01	91	47	21.8	29
10/11/01	91	44	15.4	26.3
10/18/01	91	19	14.1	15.3
10/25/01	91	48	11.2	20.2
11/01/01	91	33	11.8	23.8
11/05/01	91	30	12.6	18.1
11/08/01	91	37	11	23.5
11/15/01	91	28	20.7	17.4
11/20/01	91	26	9.2	18.3
11/29/01	91	13	8.7	10.2
12/06/01	91	26	10.9	16.4
12/13/01	91	9	8.8	08.5
12/20/01	91	11	10.6	10.6
12/27/01	91	12	1	11.2
01/20/00	92	22	8.8	6

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

WATER QUALITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location	Total Suspended Solids (mg/L)	Temperature (^0C)	Turbidity (NTU)
01/27/00	92	10	8.6	7
02/03/00	92	3	9.4	8
02/10/00	92	21	7.4	14
02/17/00	92	12	13.8	8
02/24/00	92	24	12	10
03/02/00	92	15	14.3	12
03/09/00	92	7	16.1	8
03/16/00	92	13	12.1	11
03/23/00	92	18	19	9
03/30/00	92	11	19.8	7
04/06/00	92	12	17.8	15
04/13/00	92	11	14.8	14
04/20/00	92	59	15.3	35
04/27/00	92	6	18.8	11
05/04/00	92	11	23.3	7
05/11/00	92	15	21	12
05/18/00	92	15	23.3	15
05/25/00	92	10	22.9	10
06/01/00	92	24	20.9	16
06/08/00	92	10	ND	9
06/15/00	92	27	22.8	22
06/22/00	92	19	25.4	13
06/29/00	92	17	25.1	13
07/06/00	92	15	27.8	10
07/13/00	92	16	31.1	11
07/20/00	92	15	27.3	11
07/27/00	92	10	29.6	9
08/03/00	92	18	25.5	10
08/10/00	92	11	29.3	9
08/17/00	92	23	26.9	17
08/24/00	92	10	29.1	9
08/31/00	92	12	29.7	10
09/07/00	92	9	29.6	10
09/14/00	92	15	22.9	15
09/21/00	92	23	21.9	11

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

WATER QUALITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location	Total Suspended Solids (mg/L)	Temperature (^{0}C)	Turbidity (NTU)
09/28/00	92	13	20	10
10/05/00	92	10	22	11
10/12/00	92	11	17.1	9
10/19/00	92	8	23.4	9
10/26/00	92	12	22.5	10
11/02/00	92	16	20.6	9
11/08/00	92	21	18	14
11/16/00	92	24	11.1	15
11/21/00	92	11	7	9
11/30/00	92	18	12.8	14
12/07/00	92	36	8.5	13
12/14/00	92	14	4.5	13
12/21/00	92	7	ND	7
12/28/00	92	8	7.8	8
01/04/01	92	5	7.4	5
01/11/01	92	5	7.8	7
01/18/01	92	11	7.5	8
01/25/01	92	10	7.7	9
02/01/01	92	21	6.2	13
02/08/01	92	20	10.3	10
02/15/01	92	38	4.2	26
02/22/01	92	12	7.5	11
03/01/01	92	39	7.9	31
03/08/01	92	11	8.4	9
03/15/01	92	14	11.9	13
03/22/01	92	19	14.2	11
03/29/01	92	11	10	7
04/05/01	92	11	14	9
04/12/01	92	17	16	12
04/19/01	92	17	13.2	10
04/26/01	92	11	18	9
05/3/01	92	9	21.2	8.1
05/10/01	92	17	21.7	9.9
05/17/01	92	15	24.1	9.3

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

WATER QUALITY DATA
AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Date	Location	Total Suspended Solids (mg/L)	Temperature (^{0}C)	Turbidity (NTU)
05/24/01	92	15	23.4	9.9
05/31/01	92	9	18	8.1
06/07/01	92	6	20.8	11.6
06/14/01	92	9	30.3	7.8
06/21/01	92	10	25.2	8.1
06/28/01	92	10	31.4	13.5
07/05/01	92	19	28	14.2
07/12/01	92	12	28.1	9.2
07/19/01	92	11	34.1	9.3
07/26/01	92	11	30.4	9.9
08/02/01	92	27	27.6	17.4
08/09/01	92	10	36	9.1
08/16/01	92	15	29.3	12.3
08/23/01	92	11	29	9.6
08/30/01	92	10	27.1	10
09/06/01	92	15	27	11.3
09/13/01	92	11	28.2	10.8
09/20/01	92	13	23	12.6
09/27/01	92	18	18.3	11.5
10/04/01	92	22	21.6	11.5
10/11/01	92	10	18.4	9.9
10/15/01	92	16	15.9	14.2
10/18/01	92	18	15.6	12.6
10/25/01	92	13	16.3	8.7
11/01/01	92	17	16.1	11.7
11/08/01	92	13	16	11.6
11/15/01	92	22	17.9	12.9
11/19/01	92	30	15.4	11.6
11/20/01	92	16	13.7	11.6
11/29/01	92	39	15.1	19.6
12/06/01	92	20	16.1	11.9
12/13/01	92	20	14.8	12.7
12/20/01	92	17	11.2	12.2
12/27/01	92	10	9.2	8.7

ND = No Data

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-3

MWRDGC RAINFALL DATA (INCHES) FOR 2000

Day	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.00	0.00	0.02	0.00	0.18	0.09	0.00	0.02	0.00	0.00	0.00	0.00
2	0.01	0.00	0.00	0.01	0.00	0.00	0.59	0.07	0.00	0.00	0.00	0.00
3	0.09	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.45	0.00	0.00
4	0.01	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.02	0.64	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.26	0.00	0.09	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.56	0.00
7	0.00	0.00	0.00	0.31	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.08
8	0.00	0.00	0.02	0.05	0.57	0.00	0.00	0.00	0.05	0.33	0.03	0.00
9	0.08	0.00	0.01	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.75	0.00
10	0.08	0.00	0.00	0.02	0.00	0.05	1.00	0.00	0.14	0.00	0.00	0.00
11	0.00	0.00	0.00	0.01	0.22	0.37	0.00	0.00	2.56	0.00	0.00	0.38
12	0.00	0.00	0.00	0.00	0.34	0.57	0.00	0.00	0.24	0.00	0.05	0.01
13	0.01	0.01	0.01	0.00	0.00	0.27	0.00	0.01	0.00	0.00	0.28	0.19
14	0.00	0.02	0.00	0.00	0.00	0.51	0.00	0.00	0.35	0.00	0.00	0.00
15	0.00	0.00	0.24	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.00	0.00
16	0.00	0.00	0.00	0.84	0.12	0.00	0.00	0.00	0.00	0.00	0.02	0.00
17	0.00	0.00	0.00	0.07	0.67	0.00	0.00	0.89	0.00	0.00	0.00	0.00
18	0.00	0.27	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
19	0.13	0.01	0.08	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	0.01	0.00	0.17	1.32	0.00	0.50	0.01	0.00	0.32	0.00	0.00	0.00
21	0.00	0.00	0.00	0.36	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
22	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.61	0.00	0.00	0.00
23	0.00	0.00	0.00	0.12	0.00	0.06	0.00	0.12	0.01	0.01	0.00	0.00
24	0.00	0.47	0.08	0.00	0.00	1.08	0.00	0.00	0.13	0.11	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00
26	0.01	0.09	0.11	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.01	0.00
27	0.00	0.00	0.01	0.00	0.11	0.00	0.08	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.73	0.06	0.19	0.00	0.00	0.00	0.00	0.00
29	0.07		0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.07	0.08
30	0.05		0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.01	0.10
31	0.00		0.00		0.57		0.35	0.00		0.00		0.00
Month	0.59	0.87	0.74	3.63	4.31	4.12	3.23	2.11	4.43	1.74	1.95	0.83
Year	0.59	1.46	2.20	5.83	10.1	14.3	17.49	19.60	24.03	25.8	27.72	28.55

[1]Average Rainfall readings in inches taken at 12:00 midnight from Glenview, N. Side, N. Br. P.S., Wilmette, West Side, Springfield, Racine, 100 E. Erie, E. Melvina, 87[th] & Western, Calumet WRP, 95[th] St. PS, and Lockport.
Source: MWRDGC Normal Operations Rainfall Data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-4

MWRDGC RAINFALL DATA (INCHES) FOR 2001

Day	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.12	0.06	0.00	0.00	0.00	0.00	0.01
2	0.00	0.00	0.00	0.00	0.00	0.01	0.00	2.61	0.00	0.00	0.01	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.02	0.00	0.05	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00
5	0.00	0.00	0.00	0.33	0.00	0.55	0.00	0.00	0.00	0.41	0.00	0.06
6	0.00	0.03	0.00	0.40	0.08	0.00	0.00	0.00	0.41	0.00	0.00	0.00
7	0.00	0.02	0.00	0.00	0.25	0.00	0.56	0.14	0.25	0.00	0.00	0.00
8	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.36	0.00	0.15	0.00	0.00	0.00	0.50	0.44	0.00	0.00	0.00
10	0.00	0.01	0.03	0.00	0.07	0.00	0.00	0.00	0.00	0.14	0.00	0.00
11	0.00	0.00	0.06	0.39	0.46	0.02	0.00	0.00	0.00	0.02	0.00	0.00
12	0.00	0.00	0.12	0.00	0.00	0.81	0.00	0.00	0.00	0.86	0.00	0.19
13	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	1.85	0.00	0.00
14	0.15	0.13	0.01	0.01	0.30	0.16	0.00	0.00	0.00	0.14	0.00	0.12
15	0.01	0.00	0.17	0.48	0.00	0.01	0.00	0.00	0.00	0.00	0.10	0.00
16	0.00	0.00	0.21	0.00	0.17	0.00	0.00	0.00	0.00	0.06	0.00	0.10
17	0.00	0.00	0.00	0.00	0.02	0.00	0.17	0.00	0.16	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.30	0.11	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.18	0.00	0.03	0.06
20	0.00	0.04	0.00	0.28	0.00	0.00	0.00	0.00	0.45	0.00	0.09	0.00
21	0.00	0.00	0.00	0.52	0.19	0.31	0.17	0.11	0.00	0.00	0.00	0.00
22	0.00	0.01	0.00	0.29	0.06	0.00	0.63	0.39	0.00	0.19	0.00	0.08
23	0.00	0.00	0.00	0.19	0.16	0.00	0.52	0.00	0.53	0.65	0.00	0.00
24	0.00	1.00	0.00	0.00	0.17	0.00	0.00	0.11	0.10	0.66	0.00	0.00
25	0.00	0.01	0.00	0.00	0.06	0.00	1.31	1.53	0.03	0.00	0.18	0.00
26	0.03	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.09	0.00
27	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.11	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
29	0.45		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
30	0.10		0.00	0.01	0.00	0.00	0.00	0.89	0.00	0.02	0.28	0.00
31	0.00		0.08		0.38		0.00	0.40		0.00		0.00
Month	0.73	2.21	0.68	3.06	3.52	2.07	3.68	7.30	3.69	5.87	0.93	0.61
Year	0.73	2.94	3.62	6.68	10.2	12.3	15.95	23.25	26.93	32.8	33.73	34.34

[1]Average Rainfall readings in inches taken at 12:00 midnight from Glenview, N. Side, N. Br. P.S., Wilmette, West Side, Springfield, Racine, 100 E. Erie, E. Melvina, 87th & Western, Calumet WRP, 95th St. PS, and Lockport.
Source: MWRDGC Normal Operations Rainfall Data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-5

MWRDGC OFFICIAL RAINFALL[1] AND RECORD OF REVERSALS TO LAKE MICHIGAN

Date of Rainstorm and Reversal	Rainfall (inches)	Total Reversals (million gallons)
2000	No major rainstorm	0.0
2001		
7/25/01	1.31	No river reversals
8/2/01	2.61	973.1[a]
8/25/01	1.53	No river reversals
8/31/01	0.40	75.3[b]
10/13/01	1.85	90.7[b]

[1]Average Rainfall readings in inches taken at 12:00 midnight from Glenview, N. Side, N. Br. P.S., Wilmette, West Side, Springfield, Racine, 100 E. Erie, E. Melvina, 87th & Western, Calumet WRP, 95th St. PS, and Lockport.
[a]River reversals at Chicago River Controlling Works (CRCW) and at Wilmette Pumping Station.
[b]River reversal at Wilmette Pumping Station.
Source: MWRDGC Normal Operations Rainfall Data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-6

30-DAY PERIOD GM CONCENTRATIONS OF FC BACTERIA AT LOCATIONS 91 (DPR) AND 92 (CSSC) FOR 2000 AND 2001

Five Samples 30-day Period Dates	FC(CFU/100 mL)[1] at Location 91	FC (CFU/100 mL)[1] at Location 92
1/20/00 through 2/17/00	268.674	132.279
2/24/00 through 3/23/00	455.070	127.935
3/30/00 through 4/27/00	122.545	148.929
5/4/00 through 6/1/00	153.493	210.875
6/8/00 through 7/6/00	278.092	462.068
7/13/00 through 8/10/00	111.439	168.203
8/17/00 through 9/14/00	221.867	501.261
9/21/00 through 10/19/00	845.044	547.999
10/26/00 through 11/21/00	638.286	322.377
11/30/00 through 12/28/00	587.764	329.771
1/4/01 through 2/1/01[2]	2084.328	249.295
2/8/01 through 3/8/01	1635.450	172.689
3/15/01 through 4/12/01	552.125	86.588
4/19/01 through 5/17/01	95.513	115.542
5/24/01 through 6/21/01	145.917	365.826
6/28/01 through 7/26/01	163.806	146.724
8/2/01 through 8/30/01	235.202	614.302
9/6/01 through 10/4/01	621.857	1524.439
10/11/01 through 11/8/01	331.766	744.414
11/15/01 through 12/13/01	382.338	140.213

[1]GM calculated from five samples during 30-day period from locations 91 and 92.

[2]GM calculated from three samples during 30-day period from location 91 and five samples from location 92.

APPENDIX AII

STATISTICAL PREDICTION OF FC CONCENTRATIONS

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 91 (DPR)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL) REGRESSION MODEL[1]	TIME SERIES MODEL[2]
5.3613	4.7526	4.8175
5.3327	4.7273	5.8942
5.4027	4.7893	6.2399
5.6312	4.9919	5.6446
5.6058	4.9694	5.5207
7.3265	6.4947	6.5387
6.7742	6.0051	6.1005
6.1092	5.4157	5.2971
6.3386	5.6190	5.7088
6.3544	5.6330	6.1119
6.0379	5.3524	5.5733
5.6836	5.0383	4.8152
6.1944	5.4911	5.3407
8.0456	7.1322	6.5376
7.5121	6.6592	6.2180
6.7511	5.9846	5.2724
7.0648	6.2627	4.8926
6.7968	6.0252	5.2788
7.5443	6.6878	6.3751
7.3524	6.5177	5.2149
7.4206	6.5781	5.9734
7.6497	6.7812	6.1018
7.6779	6.8062	6.1900
6.9276	6.1411	5.3725
7.1389	6.3284	5.7712
7.1778	6.3629	5.8648
6.1591	5.4598	4.8743
5.6095	4.9726	4.3871
6.6039	5.8542	5.1801
5.9636	5.2865	4.8350
6.3526	5.6314	5.0971
5.4889	4.8658	4.1772
5.3279	4.7230	4.3333
5.1818	4.5935	4.4441
7.3588	6.5234	6.5857
6.4135	5.6853	5.9975
6.6477	5.8930	6.2819
7.0121	6.2160	6.6023

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 91 (DPR)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL) REGRESSION MODEL[1]	TIME SERIES MODEL[2]
5.8833	5.2154	6.3187
5.5984	4.9628	5.6687
5.6276	4.9887	5.7143
5.6168	4.9791	5.5781
6.9373	6.1497	6.8136
6.7569	5.9898	7.0945
6.2615	5.5506	6.2485
6.1675	5.4673	6.0124
5.9135	5.2421	5.7104
5.7991	5.1407	5.5129
5.7038	5.0562	5.8130
5.5984	4.9628	5.8286
6.6871	5.9279	6.9306
6.1356	5.4390	6.5093
7.2584	6.4344	7.3549
6.6503	5.8953	7.1157
7.6305	6.7642	7.8094
6.7991	6.0272	6.7876
7.2079	6.3895	7.2551
6.8134	6.0399	6.9537
6.7166	5.9541	6.9334
7.1148	6.3070	7.1577
6.4615	5.7279	6.4838
6.3190	5.6016	6.4080
7.0388	6.2397	6.5772
6.7499	5.9836	6.0659
7.0475	6.2474	6.3498
6.2897	5.5756	5.2697
6.2025	5.4984	4.7613
6.9177	6.1323	5.4031
6.4520	5.7195	4.7476
6.6771	5.9190	5.0104
7.0388	6.2397	5.1727
7.1066	6.2998	5.8959
6.8690	6.0892	5.5150
5.7683	5.1134	4.2813
5.2781	4.6789	3.6202
5.3566	4.7484	4.0165

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 91 (DPR)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL)	
	REGRESSION MODEL[1]	TIME SERIES MODEL[2]
5.5984	4.9628	4.5440
6.6093	5.8590	5.7778
6.6871	5.9279	6.3425
5.5491	4.9191	5.3546
6.3261	5.6079	5.9045
7.2298	6.4090	6.4634
5.9713	5.2933	4.8881
5.7398	5.0881	5.0232
5.8693	5.2029	5.3109
8.0583	7.1435	7.3059
6.9276	6.1411	6.7663
6.1591	5.4598	5.9783
6.0936	5.4018	5.6812
7.9121	7.0138	7.1205
8.3848	7.4329	7.1271
7.2513	6.4281	6.1250
6.4297	5.6997	5.3170
6.1137	5.4196	5.2248
6.3244	5.6063	5.8137
6.3099	5.5935	5.5976
6.3117	5.5952	5.6079
6.5903	5.8421	5.9502
6.4708	5.7362	5.9655
5.9661	5.2888	5.2339

[1]Model: $ln(FC)=0.88647*ln(Flow)$

[2]Model: $(ln(FC))_t=0.8823*(ln(FC))_{t-1}+0.8986*ln(Flow)-.6280*(error)_{t-1}$

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-2

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 92 (CSSC)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL) REGRESSION MODEL[1]	TIME SERIES MODEL[2]
5.3613	4.7526	4.8175
5.3327	4.7273	5.8942
5.4027	4.7893	6.2399
5.6312	4.9919	5.6446
5.6058	4.9694	5.5207
7.3265	6.4947	6.5387
6.7742	6.0051	6.1005
6.1092	5.4157	5.2971
6.3386	5.6190	5.7088
6.3544	5.6330	6.1119
6.0379	5.3524	5.5733
5.6836	5.0383	4.8152
6.1944	5.4911	5.3407
8.0456	7.1322	6.5376
7.5121	6.6592	6.2180
6.7511	5.9846	5.2724
7.0648	6.2627	4.8926
6.7968	6.0252	5.2788
7.5443	6.6878	6.3751
7.3524	6.5177	5.2149
7.4206	6.5781	5.9734
7.6497	6.7812	6.1018
7.6779	6.8062	6.1900
6.9276	6.1411	5.3725
7.1389	6.3284	5.7712
7.1778	6.3629	5.8648
6.1591	5.4598	4.8743
5.6095	4.9726	4.3871
6.6039	5.8542	5.1801
5.9636	5.2865	4.8350
6.3526	5.6314	5.0971
5.4889	4.8658	4.1772
5.3279	4.7230	4.3333
5.1818	4.5935	4.4441
7.3588	6.5234	6.5857
6.4135	5.6853	5.9975
6.6477	5.8930	6.2819
7.0121	6.2160	6.6023

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-2 (Continued)

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 92 (CSSC)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL) REGRESSION MODEL[1]	TIME SERIES MODEL[2]
2.3026	5.2754	5.2754
4.7005	5.5187	5.5187
5.5984	5.9524	5.9524
5.5607	5.6120	5.6120
6.3456	6.0415	6.0415
6.8459	5.9357	5.9357
5.6348	5.7184	5.7184
6.2916	5.7311	5.7310
6.2146	5.8712	5.8711
3.6889	5.5927	5.5927
4.4998	5.6030	5.6030
5.8289	5.6954	5.6954
5.3936	5.6959	5.6959
5.5607	5.9648	5.9648
9.9523	6.0414	6.0413
6.6333	5.6826	5.6826
6.3456	5.6914	5.6914
4.3820	5.1949	5.1949
5.0106	5.2898	5.2897
3.6889	5.3524	5.3524
4.4998	5.4176	5.4176
5.5607	5.5538	5.5538
7.0901	5.7250	5.7250
6.2146	5.8010	5.8010
4.3820	5.4486	5.4486
2.3026	5.5029	5.5028
5.1358	5.4453	5.4453
4.6052	5.4901	5.4901
8.5172	5.9187	5.9186
5.5984	5.7775	5.7774
4.3820	5.7684	5.7684
5.5984	5.5573	5.5572
7.0901	5.9587	5.9586
3.9120	5.1877	5.1877
5.1930	5.3111	5.3111
6.9078	5.1420	5.1420
4.4998	5.2885	5.2885
3.9120	5.3291	5.3291
3.6889	5.0628	5.0628
5.2983	5.2989	5.2989
4.4998	5.3079	5.3078

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-2 (Continued)

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 92 (CSSC)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL)	
	REGRESSION MODEL[1]	TIME SERIES MODEL[2]
4.0943	5.2652	5.2651
4.2485	5.4099	5.4099
5.6348	5.6978	5.6978
5.0752	5.2720	5.2720
6.3969	5.5437	5.5437
6.6593	5.6363	5.6362
5.7366	5.2893	5.2893
6.6201	5.3188	5.3187
5.2983	5.1132	5.1132
5.5607	5.2943	5.2943
5.5215	5.4898	5.4897
5.9915	5.2062	5.2062
6.3801	5.3397	5.3396
2.9957	5.0353	5.0353
5.0106	5.5118	5.5117
4.3820	5.4739	5.4738
8.8247	5.8816	5.8815
6.6720	5.8495	5.8495
4.4998	5.4021	5.4021
6.2916	5.6173	5.6173
4.6052	5.3259	5.3259
3.6889	5.5405	5.5404
3.6889	5.2814	5.2813
5.1930	5.7711	5.7711
5.2983	5.4003	5.4003
4.7005	5.4869	5.4869
7.8633	5.8208	5.8208
6.2916	5.4173	5.4173
4.7875	5.6038	5.6038
5.4381	5.6439	5.6439
5.3471	5.6202	5.6202
7.7407	5.7908	5.7908
6.4297	5.4379	5.4379
4.0943	5.4297	5.4297
7.1701	5.6358	5.6357
4.9416	5.6123	5.6123
9.2103	6.6206	6.6206
5.5984	5.8583	5.8583
7.3132	5.7656	5.7656
6.6464	5.8214	5.8214
10.8198	5.9947	5.9946

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-2 (Continued)

PREDICTION OF FC CONCENTRATION BY TIME SERIES MODEL AND REGRESSION MODEL AT LOCATION 92 (CSSC)

ln (FLOW) cubic feet-sec	*ln* (FC) CONCENTRATION (CFU/100 mL) REGRESSION MODEL[1]	TIME SERIES MODEL[2]
6.5221	5.8638	5.8637
4.2485	5.4321	5.4321
4.2485	5.2432	5.2432
6.7912	6.6505	6.6505
3.6889	5.8582	5.8581
4.8675	5.4932	5.4932
4.8675	5.4579	5.4579

[1]Model: $ln(FC)=0.7109 * ln(Flow)$.

[2]Model: $(ln(FC))_t=0.83148 * (ln(FC))_{t-1} +0.7187 * ln(Flow)-0.7419 * (error)_{t-1}$.

Attachment 4

Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 05-15

INTERIM REPORT

FECAL COLIFORM DENSITIES IN CHICAGO AREA WATERWAYS DURING DRY AND WET WEATHER 2004

October 2005

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

INTERIM REPORT

FECAL COLIFORM DENSITIES IN CHICAGO AREA WATERWAYS DURING DRY AND WET WEATHER

2004

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October 2005

TABLE OF CONTENTS

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.

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

DISCLAIMER

SUMMARY AND CONCLUSIONS

In 2004 the Metropolitan Water Reclamation District of Greater Chicago (District) undertook a two-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.

The purpose of this study was to predict 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 Illinois Pollution Control Board (IPCB) General Use stream standard of less than 200 cfu/100 mL.

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 m miles downstream of the WRP outfall, FC_0 = FC concentration 0 miles downstream at the WRP outfall, m is miles downstream of the WRP outfall and k is the decay rate constant. The FC decay equations derived from the data are shown below:

North Side Receiving Stream in Dry Weather

$FC = 13{,}560 \times e^{-0.2018m}$, $R^2 = 0.9975$

North Side Receiving Stream in Wet Weather

$FC = 45{,}172 \times e^{-0.1932m}$, $R^2 = 0.9427$

Calumet Receiving Stream in Dry Weather

$FC = 3{,}072 \times e^{-0.2061m}$, $R^2 = 0.9930$

Calumet Receiving Stream in Wet Weather

$FC = 5{,}180 \times e^{-0.0881m}$, $R^2 = 0.9803$

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.

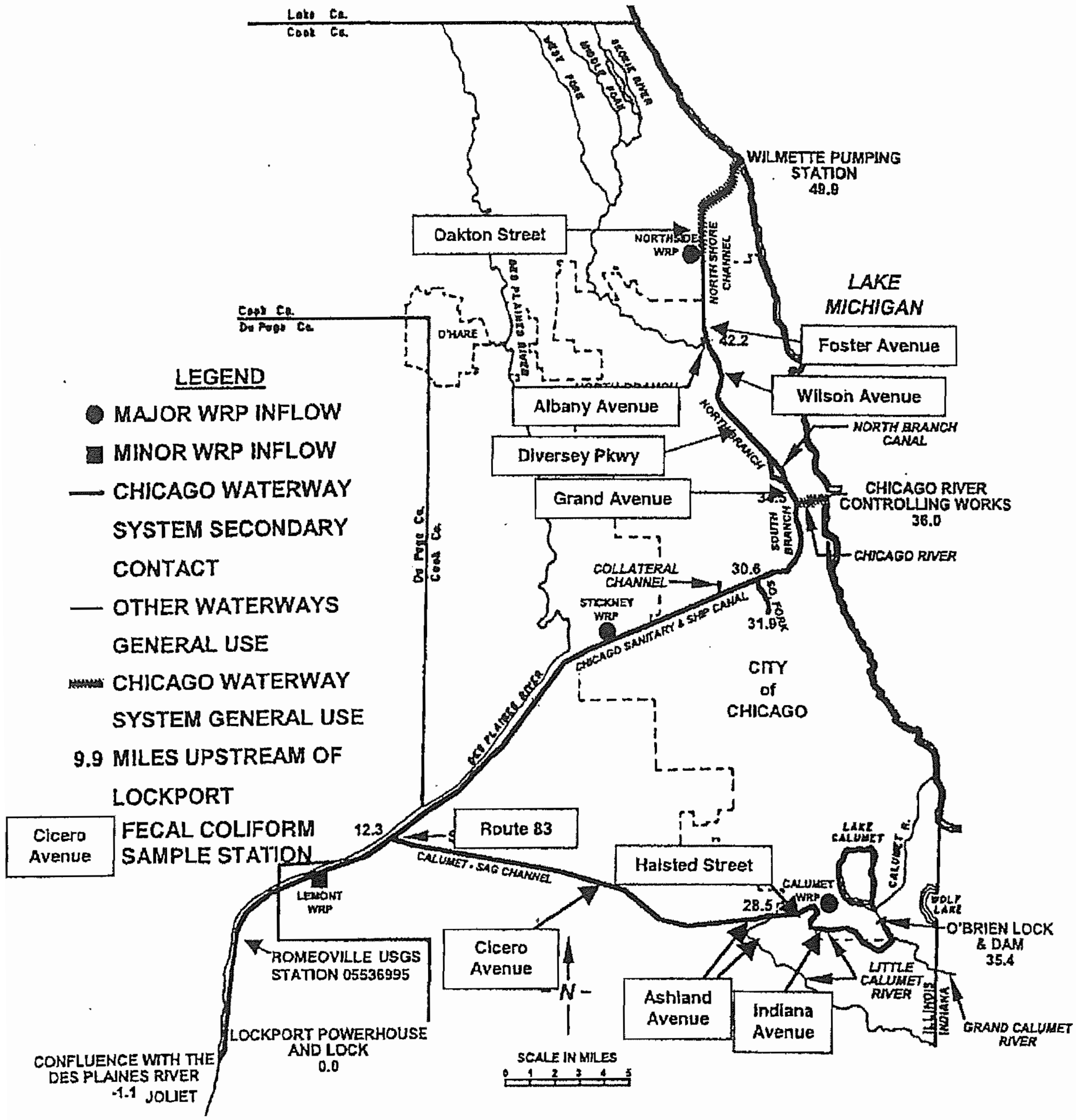
Analysis of the collected data indicated that FC densities less than the IPCB General Use stream standard were predicted to occur at North area stations 21 miles downstream of the North Side WRP during dry weather and 29 miles downstream during wet weather. The analysis predicted that disinfection of the North Side WRP effluent would only marginally improve the microbiological water quality downstream of the North Side WRP in that the IPCB standard could be met at 27 miles downstream of the WRP during wet weather. Fecal coliform densities less than the IPCB General Use stream standard were predicted to occur at South area stations 14 miles downstream of the Calumet WRP during dry weather and 37 miles downstream during wet weather. The analysis predicted that disinfection would not improve the microbiological water quality downstream of the Calumet WRP in that the IPCB standard could be met at 37 miles downstream of the WRP during wet weather, the same distance downstream predicted without disinfection.

The results of this study indicate 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 IPCB General Use standard. The results of this study are consistent with a previous study (Haas et al., 1988) which suggested that beyond a certain zone, disinfection of an effluent may not improve microbiological water quality.

INTRODUCTION

This study was initiated in 2004 to determine the distribution and die-off of fecal coliform bacteria in District waterways relative to issues raised by the Chicago Area Waterways Use Attainability Analysis (CDM, 2004). The FC was measured at each of twelve 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. While this study is still ongoing in 2005, this interim report presents the results of all of the sampling that was conducted in 2004.

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



MATERIALS AND METHODS

Water samples were collected twice a month between April 1 and December 31, 2004. 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 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. FC data from routine bridge run samples collected during January through March 2004 at the North and South area stations were also included as dry weather data in this study.

Water samples were analyzed for FC by the Analytical Microbiology Section of the Environmental Monitoring and Research Division using the FC membrane filter procedure (SM 9222 D, SM 18th ed. [APHA, 1992]).

Equations for fecal coliform die-off curves, and corresponding R^2 values, were formulated using the exponential curve fitting function of the computer program Microsoft Excel®.

RESULTS AND DISCUSSION

Results of dry and wet weather FC are shown for each station in the Appendix and summarized in Table 1. FC data are expressed as colony forming units (cfu) per 100 mL. For the 12 sampling stations, dry weather FC ranged from 9 to 220,000 cfu/100 mL. During wet weather, FC ranged from 80 to 470,000 cfu/100 mL. Geometric mean dry weather FC ranged from 70 to 7,400 cfu/100 mL. Geometric mean wet weather FC ranged from 240 to 26,000 cfu/100 mL.

Downstream from the North Side WRP effluent outfall, dry weather geometric mean FC decreased from 7,400 cfu/100 mL at Foster Avenue on the North Shore Channel to 1,600 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River. Wet weather geometric mean FC decreased from 21,000 cfu/100 mL at Foster Avenue on the North Shore Channel to 5,700 cfu/100 mL at Grand Avenue on the North Branch of the Chicago River

Downstream from the Calumet WRP effluent outfall, dry weather geometric mean FC decreased from 2,700 cfu/100 mL at Halsted Street on the Little Calumet River to 100 cfu/100 mL at Route 83 on the Calumet-Sag Channel. Wet weather geometric mean FC decreased from 4,600 cfu/100 mL at Halsted Street on the Little Calumet River to 1,200 cfu/100 mL at Route 83 on the Calumet-Sag Channel.

Comparisons of geometric means of fecal coliform bacteria, with calculated die-off density estimates for wet and dry weather, are shown in Figure 2 (North Area) and Figure 3 (South Area). The estimated die-off curves fit the sample geometric means well, with R^2 values all greater than 0.94. The data for stations located upstream of the WRPs (Oakton Street on the North Shore Channel and Indiana Avenue on the Little Calumet River) and for stations located in tributaries (i.e., Albany Avenue on the North Branch of the Chicago River and Ashland Avenue on the Little Calumet River) were plotted in Figures 2 and 3 but were not included in the die-off equation. It should be noted that the highest wet weather FC (470,000 cfu/100mL) during this study occurred upstream of the North Side WRP at Oakton Street on the North Shore Channel and the highest dry weather FC (220,000 cfu/100 mL) occurred at Ashland Avenue on the Little Calumet River. This highest dry weather FC result appears to be an anomaly, but it has not been excluded in the analysis of the data set.

In order to estimate waterway FC that might occur during wet weather conditions if there was complete disinfection of WRP effluent outfalls, dry weather FC were subtracted from wet weather FC and are shown in Figure 4 (North Area) and Figure 5 (South Area) with the calculated wet and dry weather FC. The calculated wet weather and calculated dry weather FC data displayed in Figures 4 and 5 were derived from the die-off equations determined from Figures 2 and 3. During wet weather, elimination of the fecal coliform contributions from the WRPs (dry weather FC) made little difference to the waterway FC in either area. Estimated wet weather FC, with or without disinfection, would not meet present General Use Water Quality Standards for at least a distance of 26 miles downstream of the WRPs. Densities of fecal coliform bacteria, with or without disinfection, would be equivalent at this distance downstream of the WRPs. WRP effluent disinfection is not effective for improving water quality during wet weather.

TABLE 1: FECAL COLIFORM DENSITY IN CHICAGO AREA WATERWAYS DURING DRY AND WET WEATHER
JANUARY THROUGH DECEMBER 2004

Sample Station (Miles from WRP)	Dry Weather Fecal Coliform (cfu/100 mL)				Wet Weather Fecal Coliform (cfu/100 mL)			
	Number of Samples	Minimum	Maximum	Geometric Mean	Number of Samples	Minimum	Maximum	Geometric Mean
North Shore Channel								
Oakton Street(0.6)[a]	18	40	19,000	670	12	700	470,000	7,800
Foster Avenue(3.1)[b]	18	1,800	25,000	7,400	12	4,600	130,000	21,000
North Branch Chicago River								
Albany Avenue(3.3)[c]	17	200	2,000	710	12	990	130,000	10,000
Wilson Avenue(4.0)[b]	18	2,200	22,000	6,100	12	5,400	380,000	26,000
Diversey Parkway(6.6)[b]	18	1,200	8,800	3,400	12	4,500	67,000	12,000
Grand Avenue(10.7)[b]	18	550	24,000	1,600	12	1,100	110,000	5,700
Little Calumet River								
Indiana Avenue(1.4)[a]	16	9	7,200	70	12	80	560	240
Halsted Street(1.0)[b]	19	270	15,000	2,700	12	2,200	54,000	4,600
Ashland Avenue(1.3)[c]	17	120	220,000	4,000	12	990	80,000	5,000
Calumet-Sag Channel								
Ashland Avenue(2.1)[b]	19	250	12,000	2,100	12	2,000	36,000	4,800
Cicero Avenue(6.2)[b]	19	20	9,300	710	12	770	39,000	2,700
Route 83(16.9)[b]	17	20	510	100	12	210	31,000	1,200

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

FIGURE 2: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT NORTH AREA STATIONS WITH ESTIMATED DIE-OFF DENSITIES (UPSTREAM AND TRIBUTARY DENSITIES NOT INCLUDED IN DIE-OFF ESTIMATES)

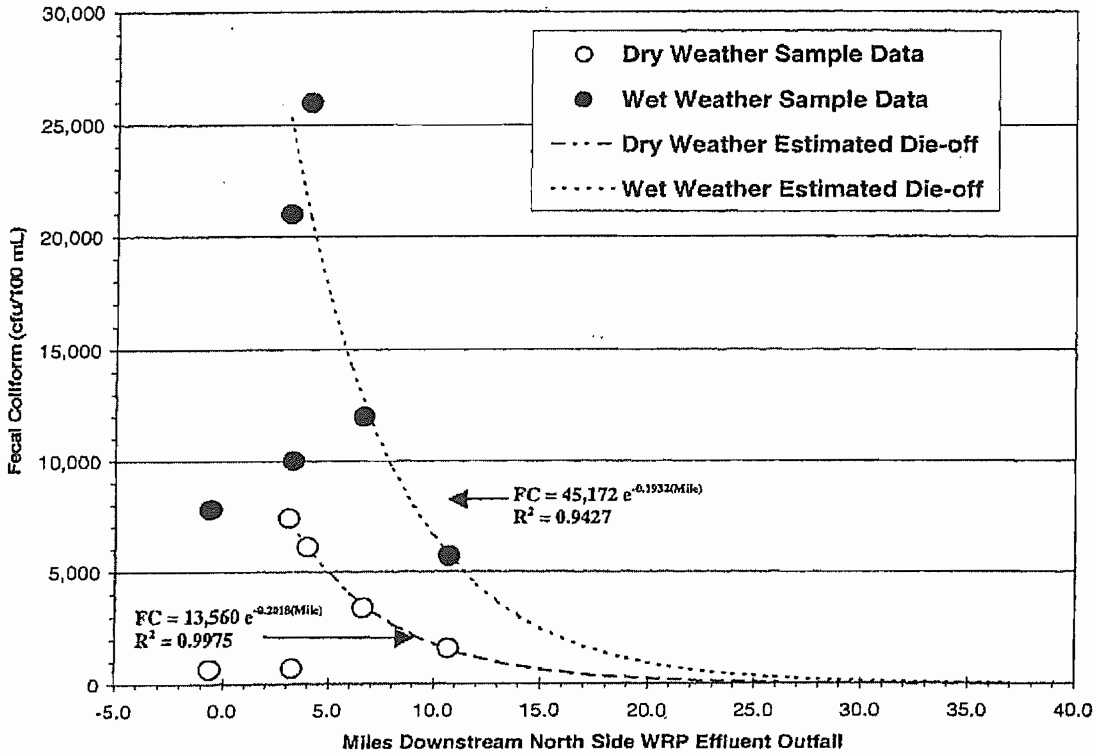


FIGURE 3: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT SOUTH AREA STATIONS WITH ESTIMATED DIE-OFF DENSITIES (UPSTREAM AND TRIBUTARY DENSITIES NOT INCLUDED IN DIE-OFF ESTIMATES)

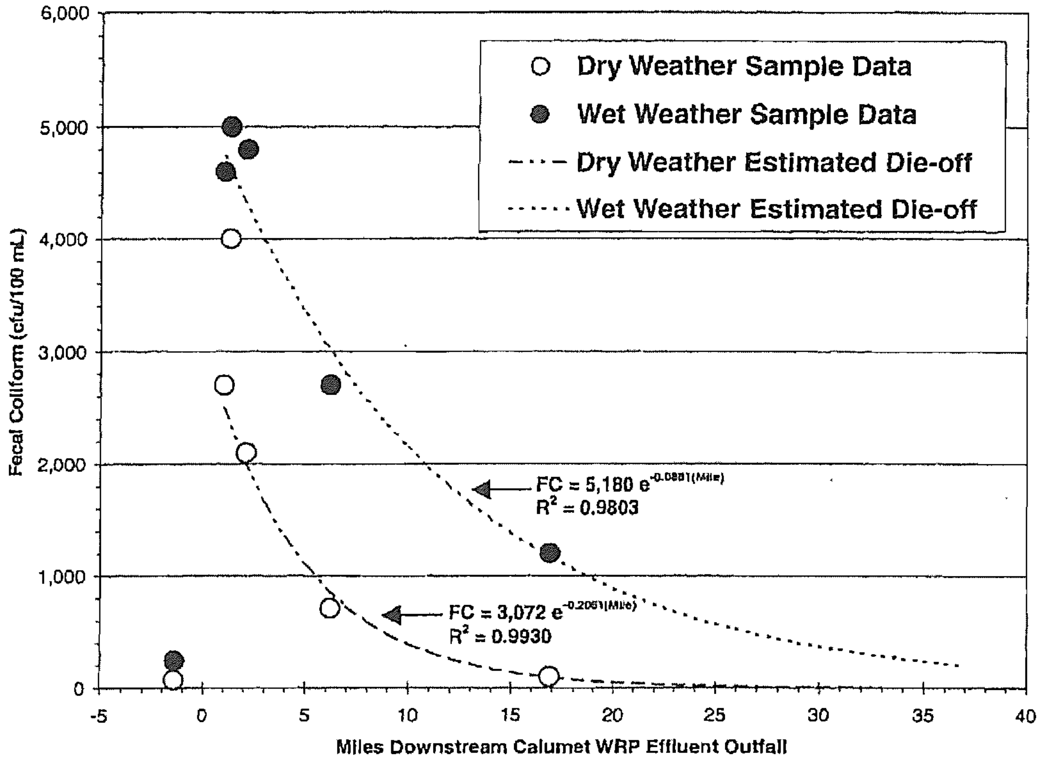


FIGURE 4: ESTIMATED FECAL COLIFORM BACTERIA DENSITIES DOWNSTREAM OF THE NORTH SIDE WATER RECLAMATION PLANT DURING WET AND DRY WEATHER, AND WHEN DRY WEATHER DENSITIES ARE SUBTRACTED FROM WET WEATHER DENSITIES

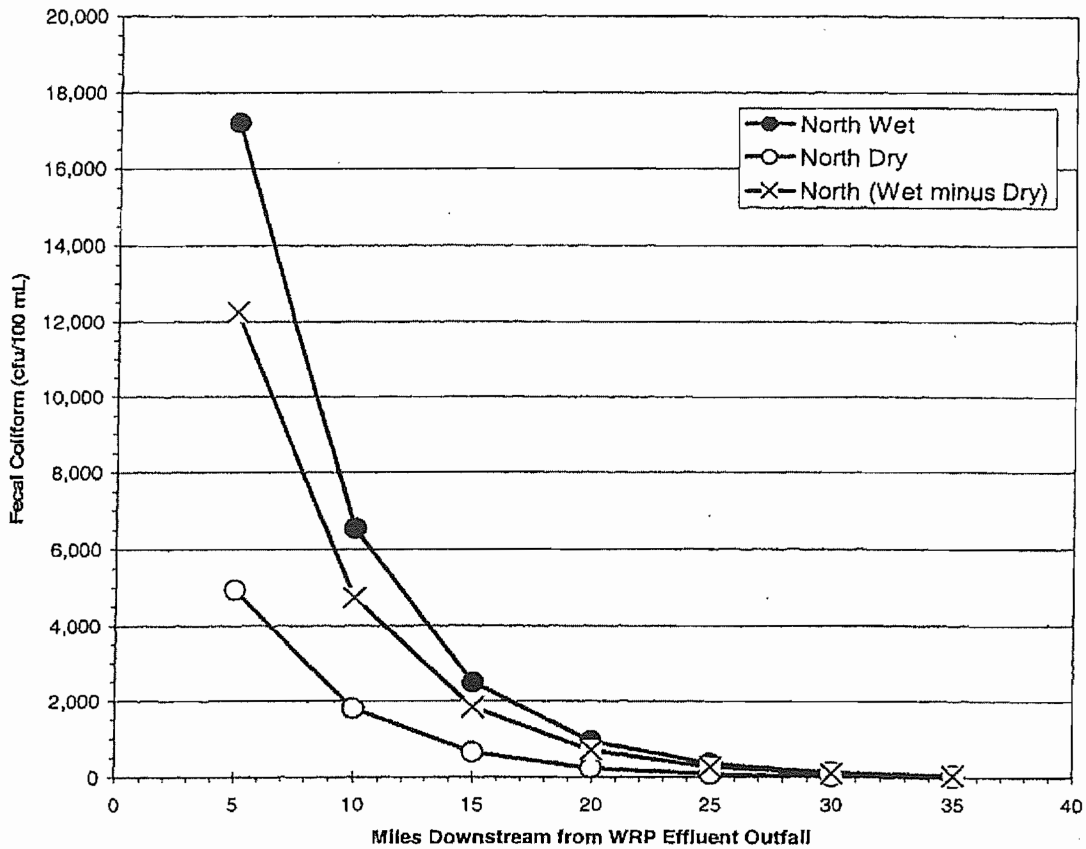


FIGURE 5: ESTIMATED FECAL COLIFORM BACTERIA DENSITIES DOWNSTREAM OF THE CALUMET WATER RECLAMATION PLANT DURING WET AND DRY WEATHER, AND WHEN DRY WEATHER DENSITIES ARE SUBTRACTED FROM WET WEATHER DENSITIES

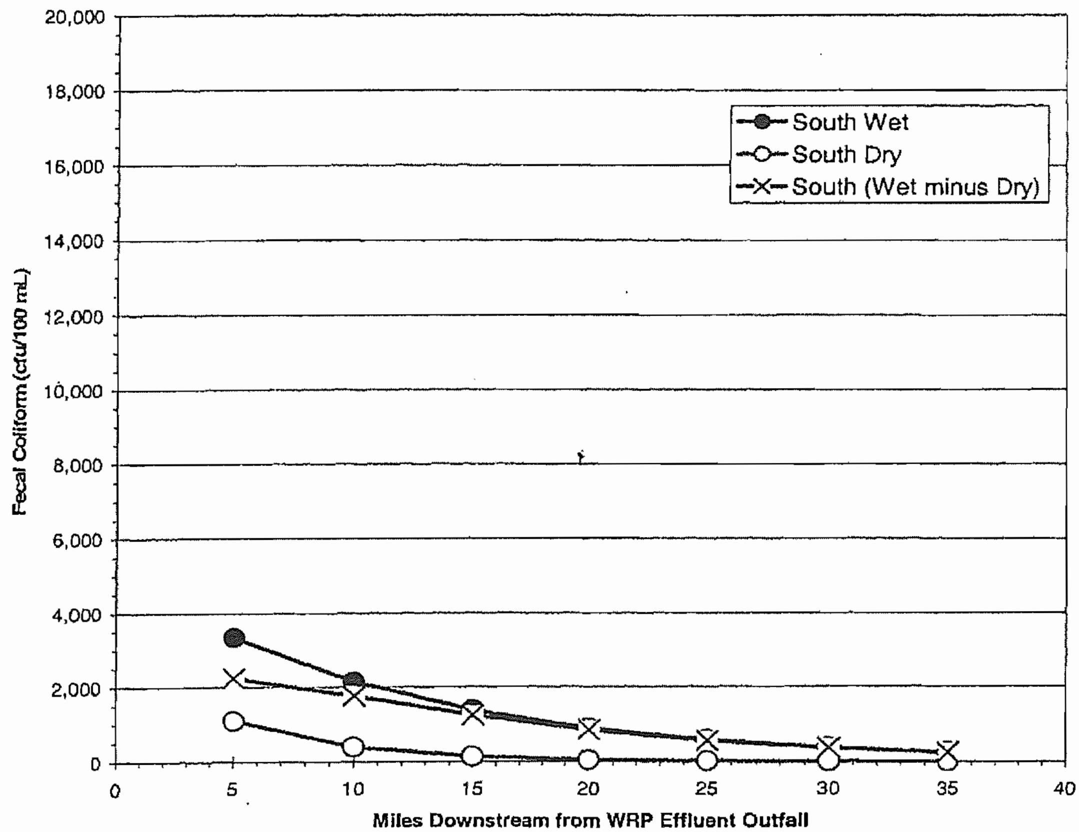


Table 2 shows estimated FC calculated from die-off equations at distances of 5 miles and at points downstream of WRP effluent outfalls at which General Use Water Quality Standards are first predicted to be met. FC less than the 200 cfu/100 mL IPCB General Use stream standard at North Area stations were predicted to occur 21 miles downstream of the North Side WRP during dry weather, 29 miles downstream during wet weather, and 27 miles downstream if disinfection eliminated FC from the North Side WRP effluent outfall during wet weather. FC less than the 200 cfu/100 mL IPCB General Use stream standard at South Area stations were predicted to occur 14 miles downstream of the Calumet WRP during dry weather and 37 miles downstream during wet weather, with or without disinfection having eliminated all FC from the Calumet WRP effluent outfall 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 present General Use Water Quality Standards would be met.

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

Given this relationship between FC and EC and the FC die-off equations developed for dry weather in this study, it is estimated that within 4.95 miles of the Calumet WRP and within 11.8 miles of the North Side WRP, the EC water quality standard of 1030 cfu/100 mL currently being considered for the new limited contact recreation use category would be met under dry weather conditions in their receiving streams.

TABLE 2: FECAL COLIFORM DENSITIES[1] CALCULATED FROM DIE-OFF EQUATIONS AT 5 MILES AND AT FIRST POINT OF COMPLIANCE WITH GENERAL USE WATER QUALITY STANDARD DOWNSTREAM OF WATER RECLAMATION PLANT EFFLUENT OUTFALLS

Weather Type	River Miles Below WRP Effluent Outfall					
	5	14	21	27	29	37
	cfu/100 mL					
North Area						
Wet	17,193	3,021	781	245	**167**	36
Dry	4,944	804	**196**	58	39	8
Wet minus Dry	12,249	2,217	585	**187**	128	28
South Area						
Wet	3,334	1,509	814	480	402	**199**
Dry	1,096	**171**	41	12	8	1
Wet minus Dry	2,238	1,338	773	468	394	**198**

[1]Values in bold type indicate first occurrence of a calculated fecal coliform density less than the 200 cfu/100 mL IPCB General Use stream standard.

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.

Haas, C. N., J. G. Sheerin, C. Lue-Hing, K. C. Rao, and P. O'Brien, "Effects of Discontinuing Disinfection on a Receiving Water," Journal of the Water Pollution Control Federation, Vol. 60, No. 5, pp. 667–673, 1988.

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 No. 04-10, Metropolitan Water Reclamation District of Greater Chicago, July 2004.

APPENDIX AI

FECAL COLIFORM BACTERIA DENSITIES AT EACH SAMPLING STATION IN THE NORTH AND SOUTH WATERWAY STUDY AREAS

FIGURE AI-1: FECAL COLIFORM BACTERIA IN THE NORTH SHORE CHANNEL AT OAKTON STREET IN DRY (O) AND WET (●) WEATHER

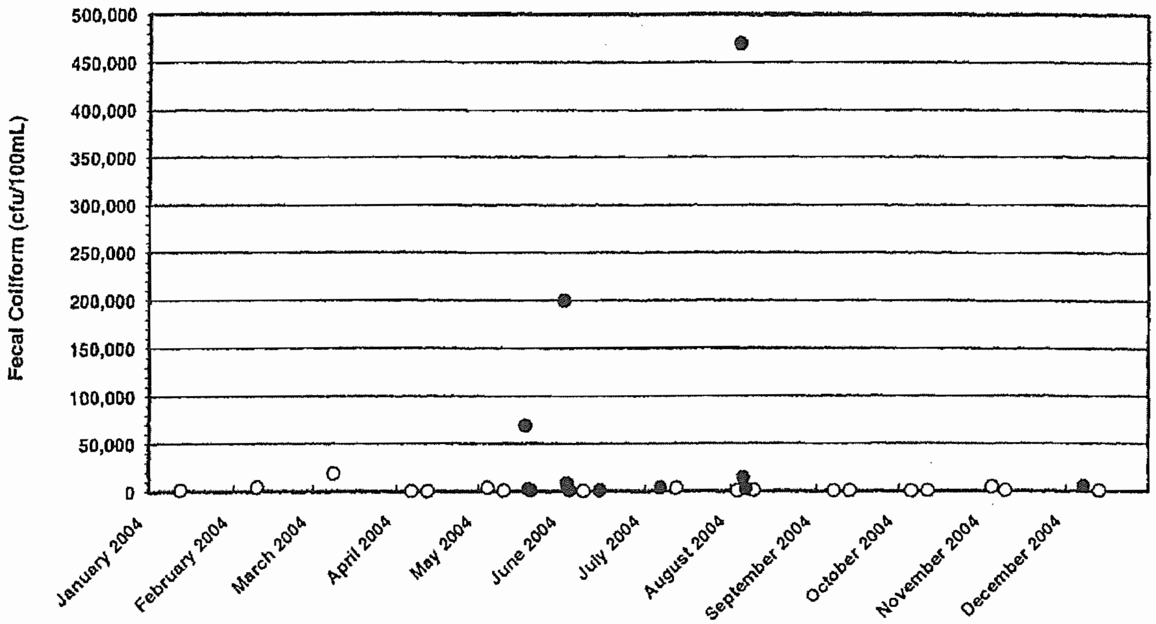


FIGURE AI-2: FECAL COLIFORM BACTERIA IN THE NORTH SHORE CHANNEL AT FOSTER AVENUE IN DRY (○) AND WET (●) WEATHER

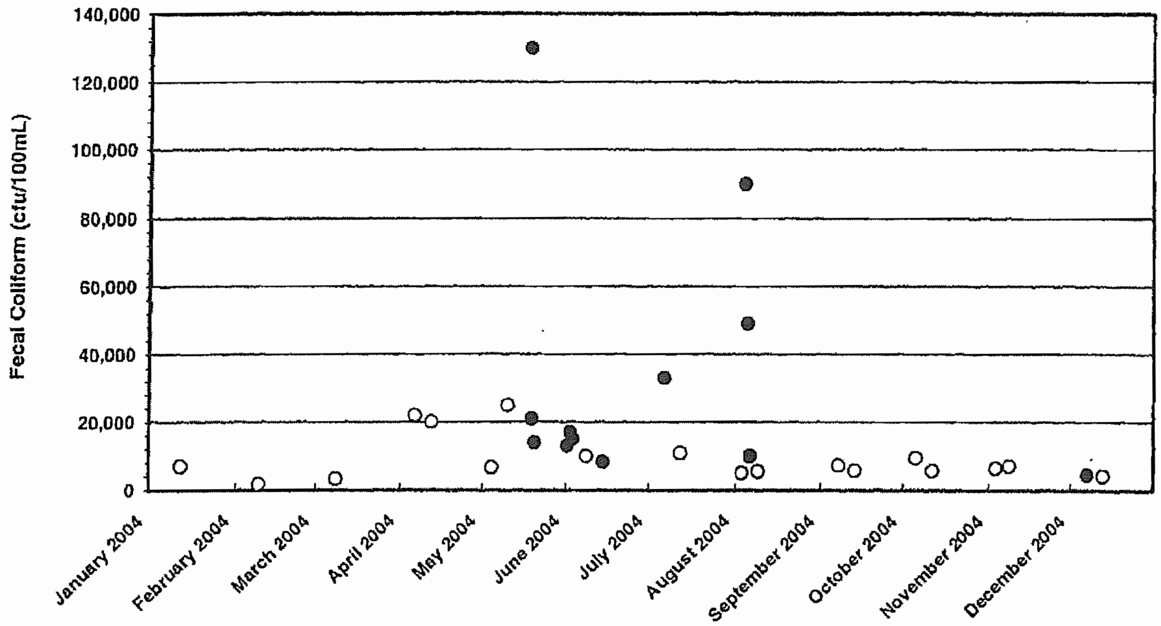


FIGURE AI-3: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT ALBANY AVENUE IN DRY (O) AND WET (●) WEATHER

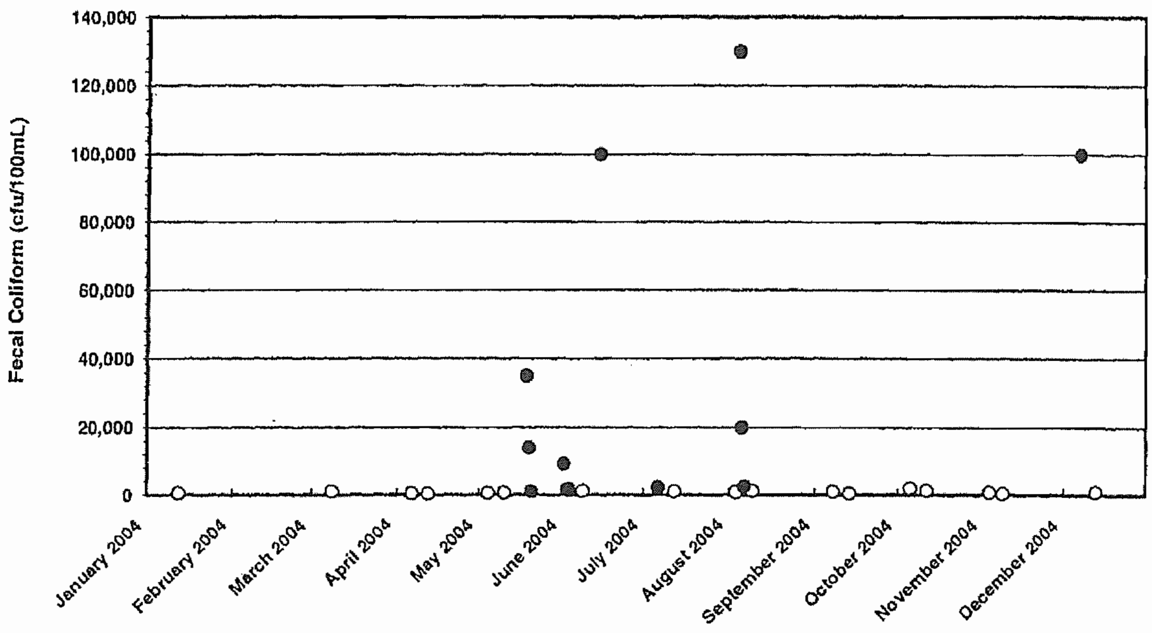


FIGURE AI-4: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT WILSON AVENUE IN DRY (O) AND WET (●) WEATHER

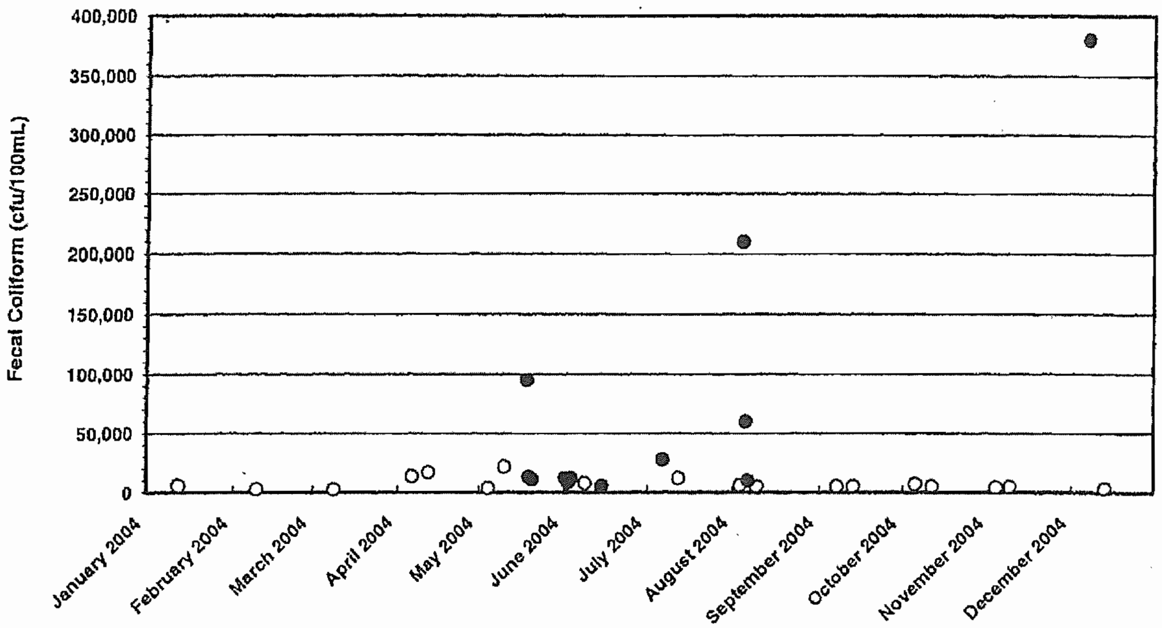


FIGURE AI-5: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT DIVERSEY PARKWAY IN DRY (O) AND WET (●) WEATHER

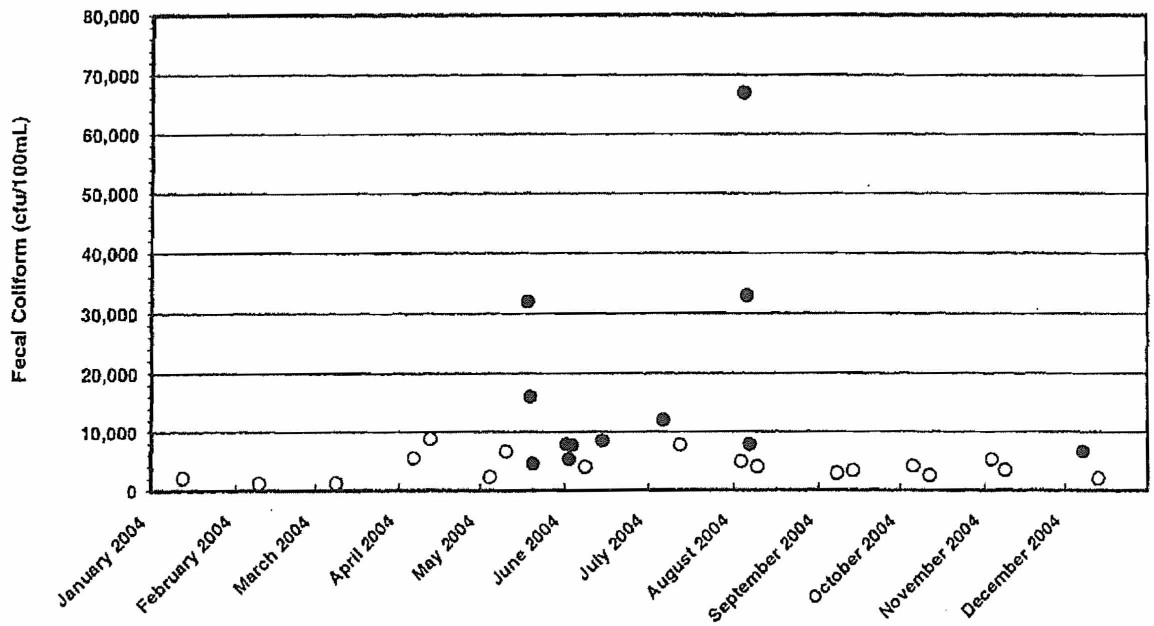


FIGURE AI-6: FECAL COLIFORM BACTERIA IN THE NORTH BRANCH CHICAGO RIVER AT GRAND AVENUE IN DRY (O) AND WET (●) WEATHER

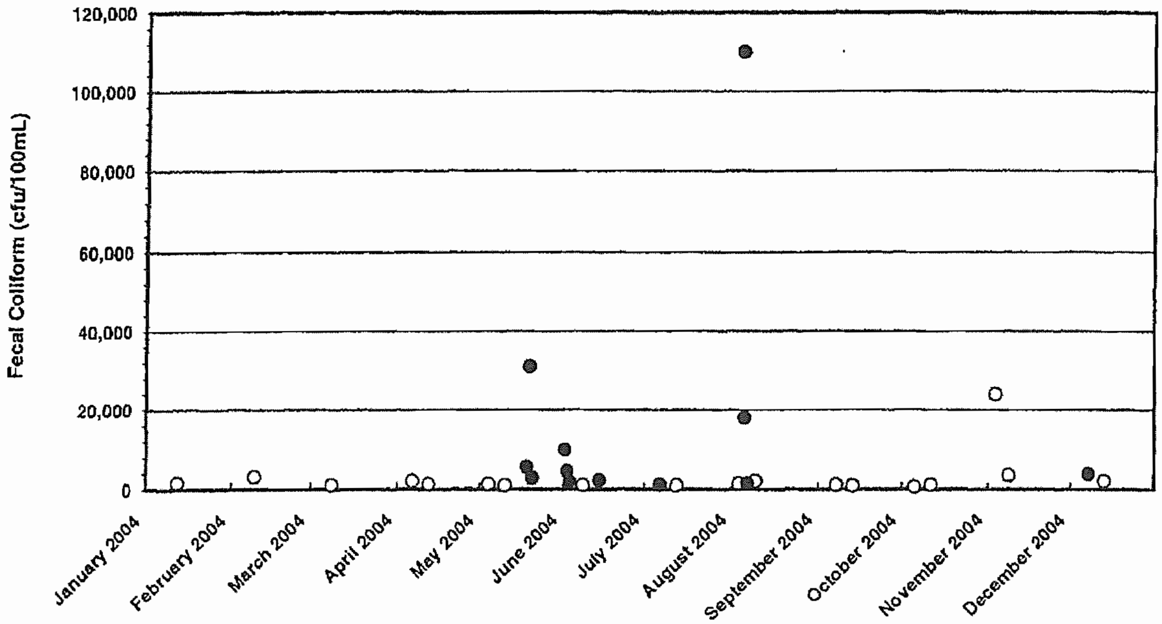


FIGURE AI-7: FECAL COLIFORM BACTERIA IN THE LITTLE CALUMET RIVER AT INDIANA AVENUE IN DRY (O) AND WET (●) WEATHER

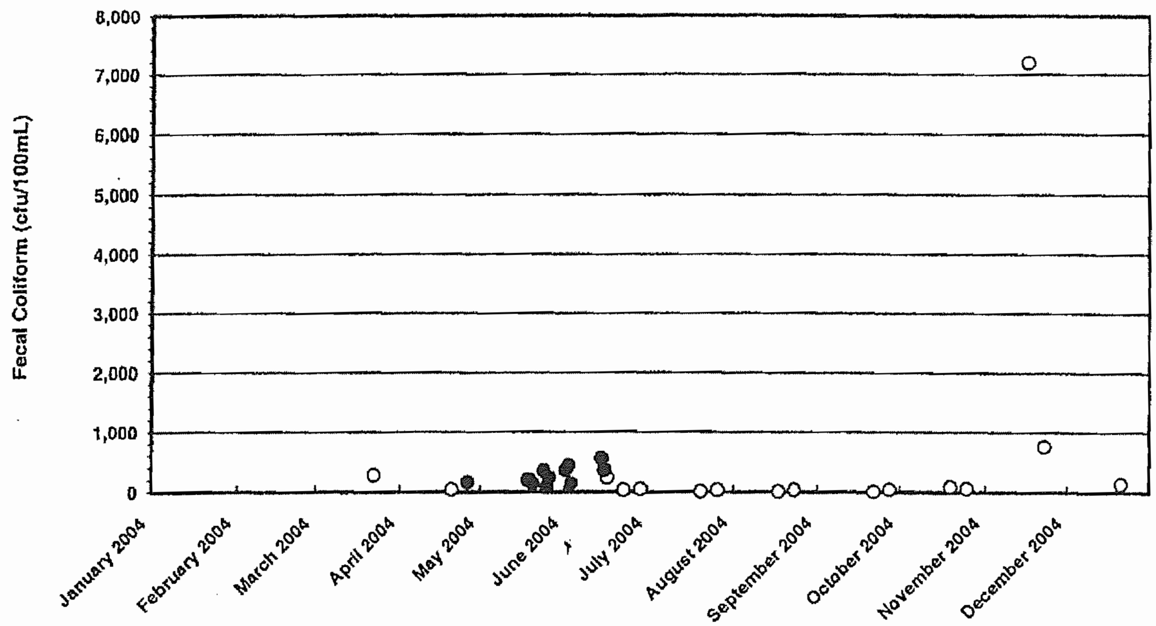


FIGURE AI-8: FECAL COLIFORM BACTERIA IN THE LITTLE CALUMET RIVER AT HALSTED STREET IN DRY (O) AND WET (●) WEATHER

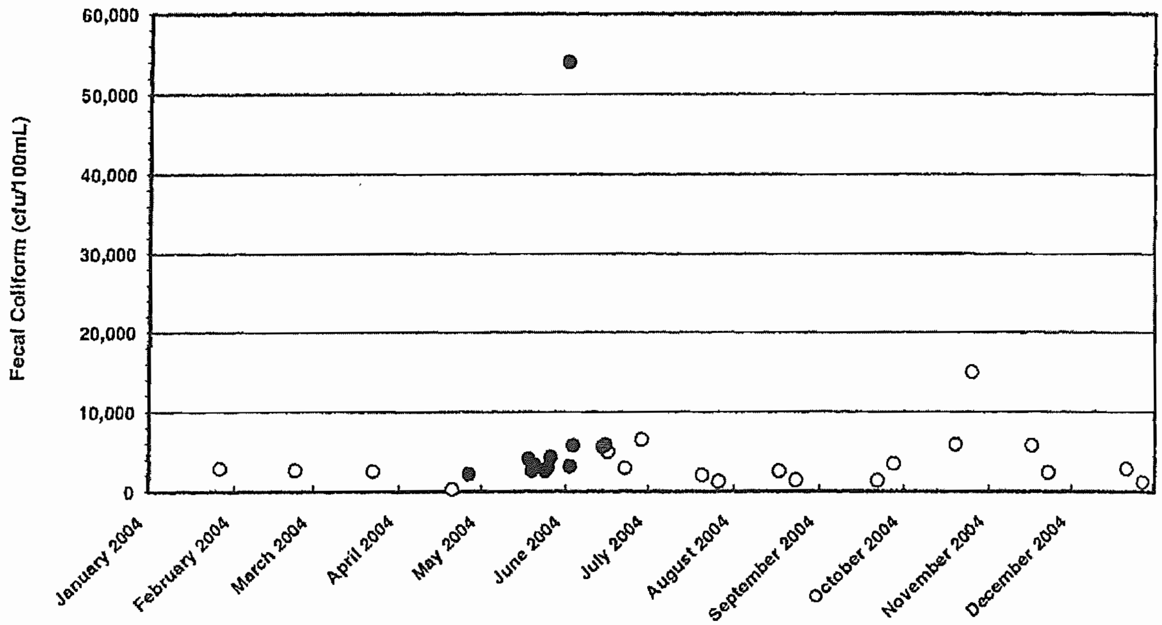


FIGURE AI-9: FECAL COLIFORM BACTERIA IN THE LITTLE CALUMET RIVER AT ASHLAND AVENUE IN DRY (O) AND WET (●) WEATHER

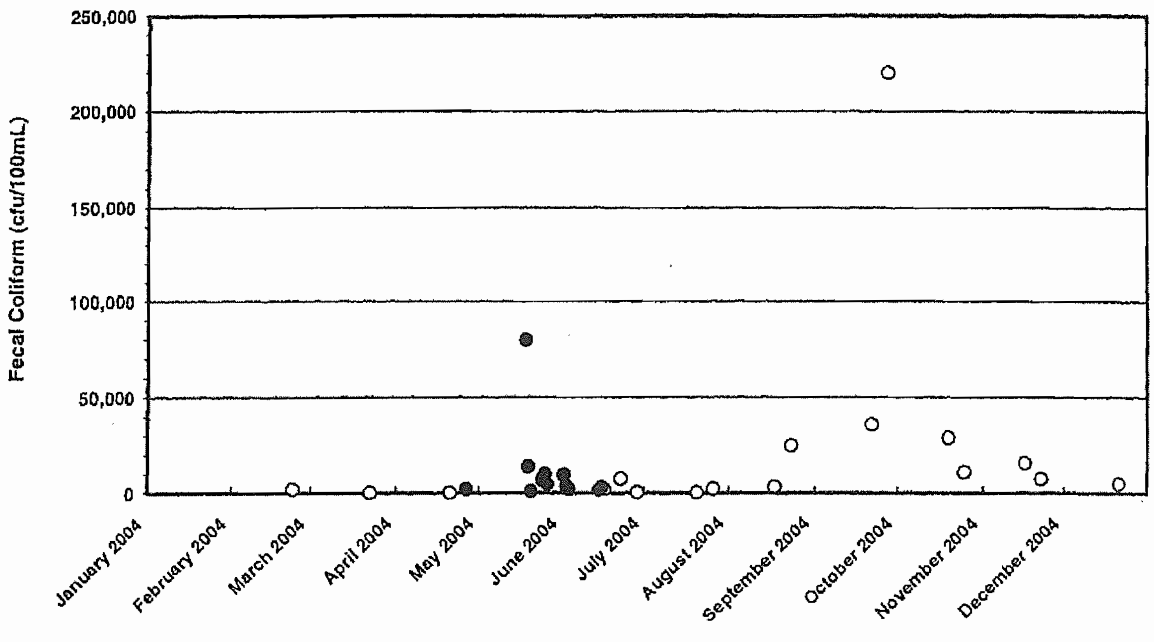


FIGURE AI-10: FECAL COLIFORM BACTERIA IN THE CALUMET-SAG CHANNEL AT ASHLAND AVENUE IN DRY (O) AND WET (●) WEATHER

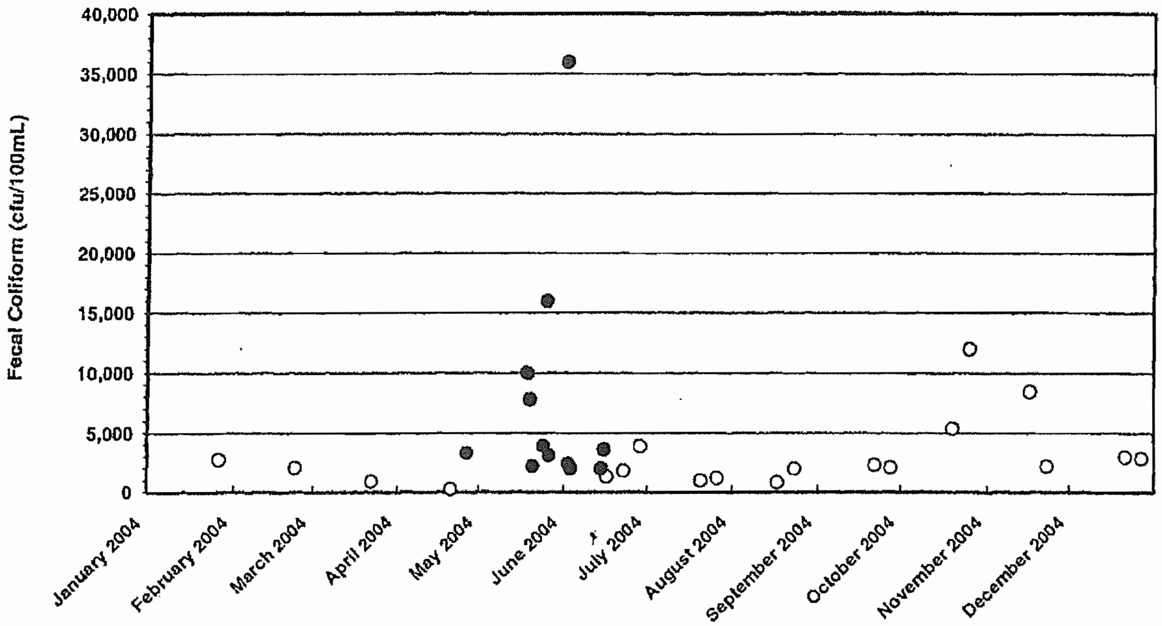


FIGURE AI-11: FECAL COLIFORM BACTERIA IN THE CALUMET-SAG CHANNEL AT CICERO AVENUE IN DRY (O) AND WET (●) WEATHER

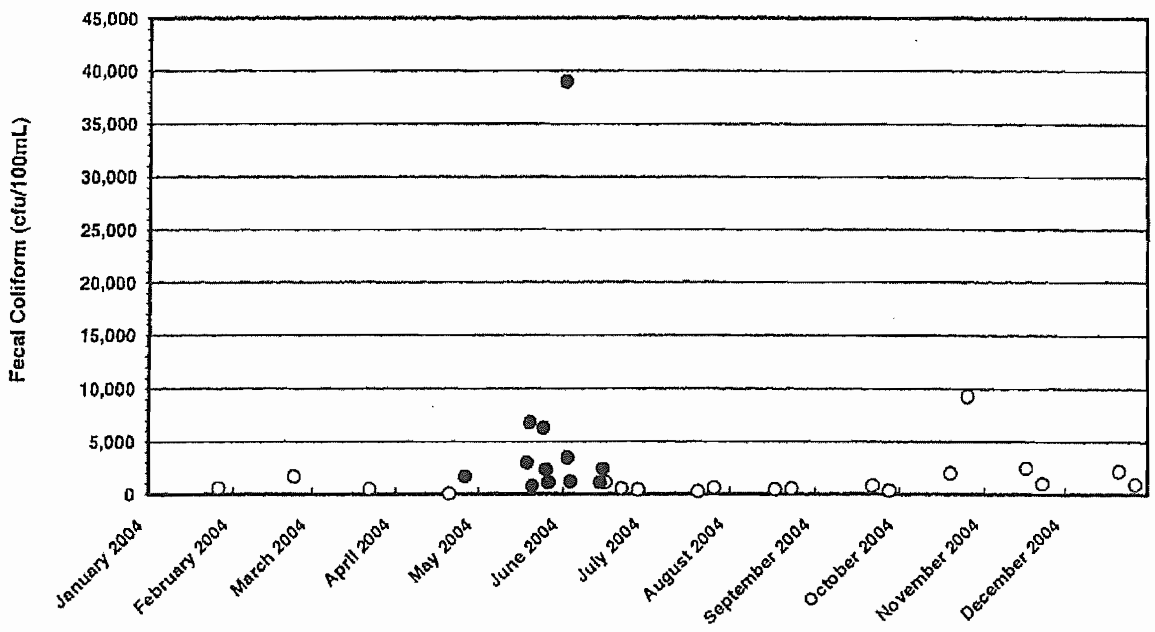
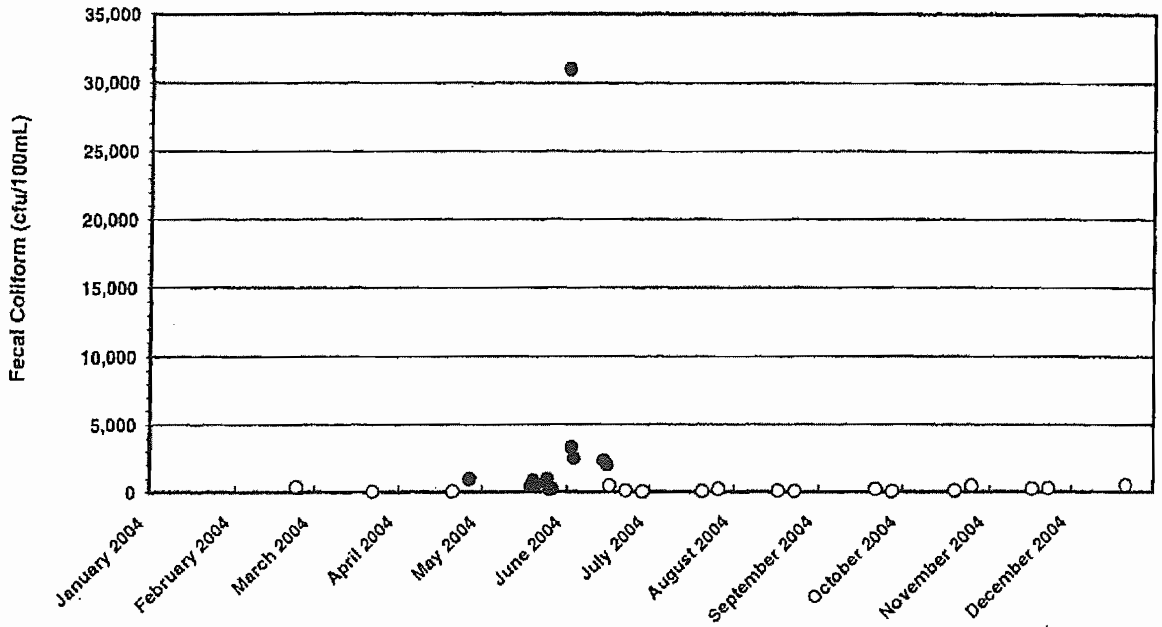


FIGURE AI-12: FECAL COLIFORM BACTERIA IN THE CALUMET-SAG CHANNEL AT ROUTE 83 IN DRY (O) AND WET (●) WEATHER



Attachment 5

Protecting Our Water Environment

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

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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.

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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.

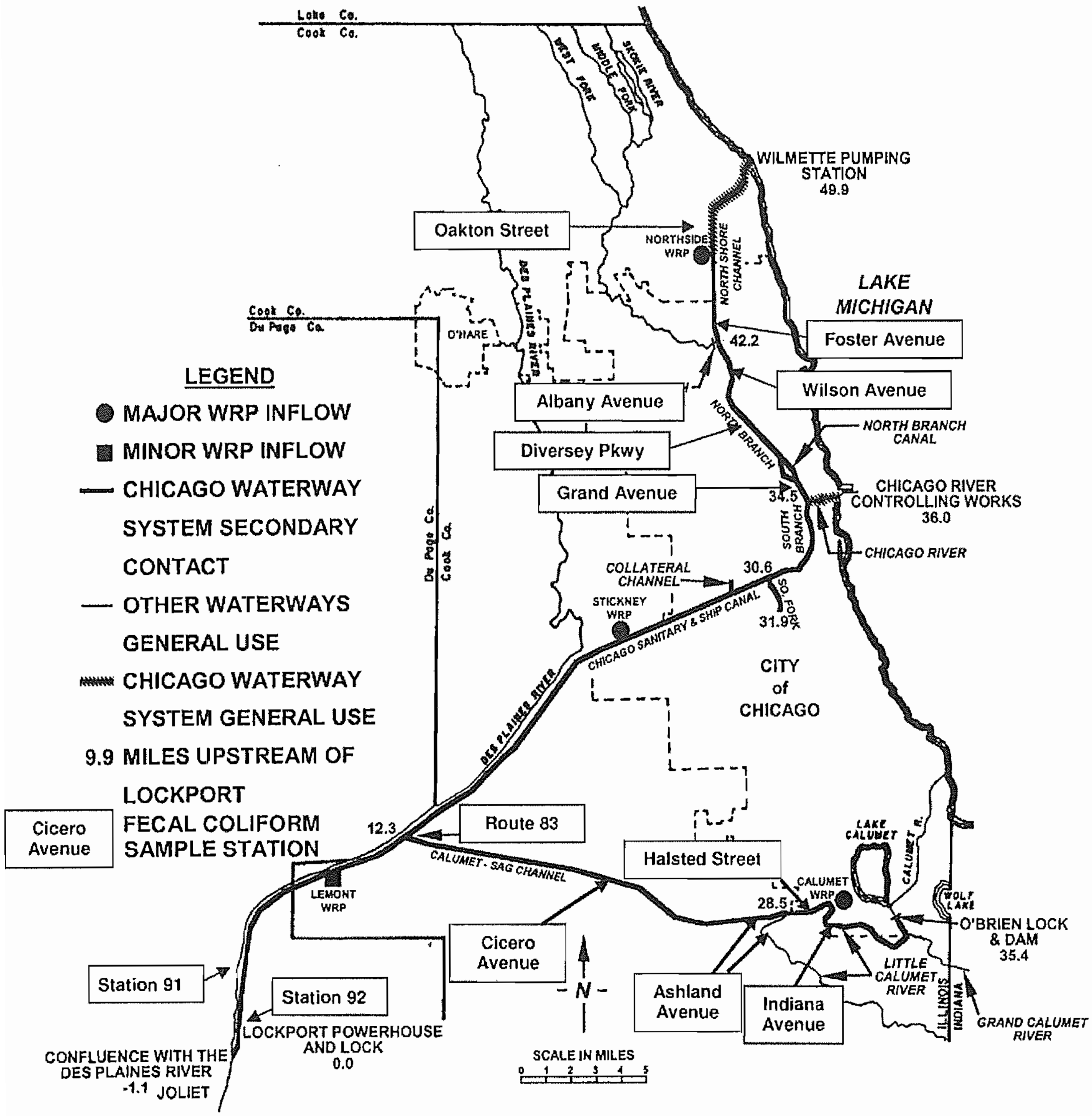
This study indicates that disinfection of the North Side and Calumet WRP effluents during wet weather would not improve the microbiological water quality downstream of these WRPs in terms of compliance with the proposed IEPA effluent standard.

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-**	**Entire Year**	**1,093**	**438**	**40.1**
	2006	**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-**	**Entire Year**	**1,093**	**420**	**38.4**
	2006	**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

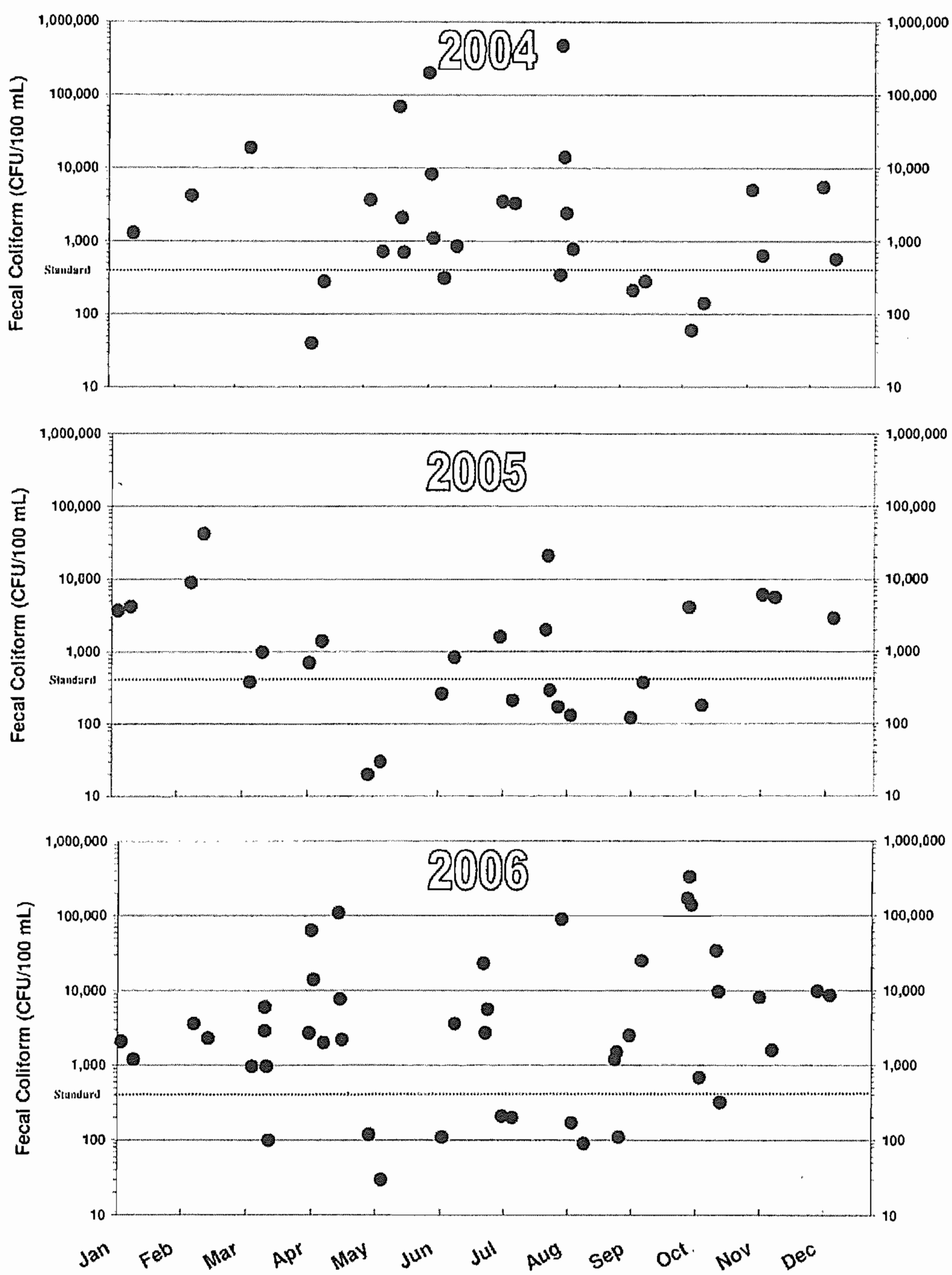


FIGURE 3: FECAL COLIFORM BACTERIA AT FOSTER AVENUE ON THE NORTH SHORE CHANNEL DURING THE YEARS 2004, 2005, AND 2006

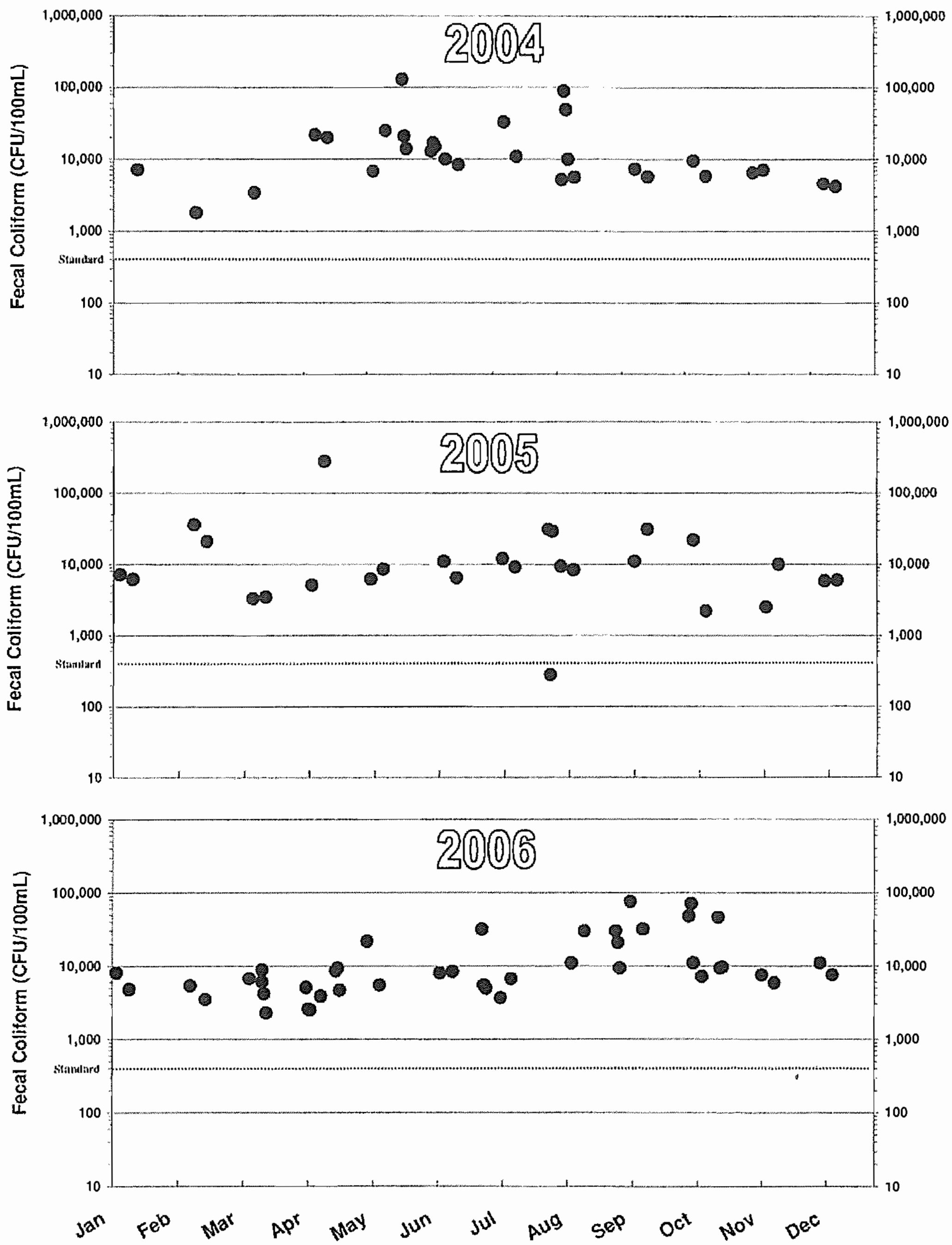


FIGURE 4: FECAL COLIFORM BACTERIA AT ALBANY AVENUE ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

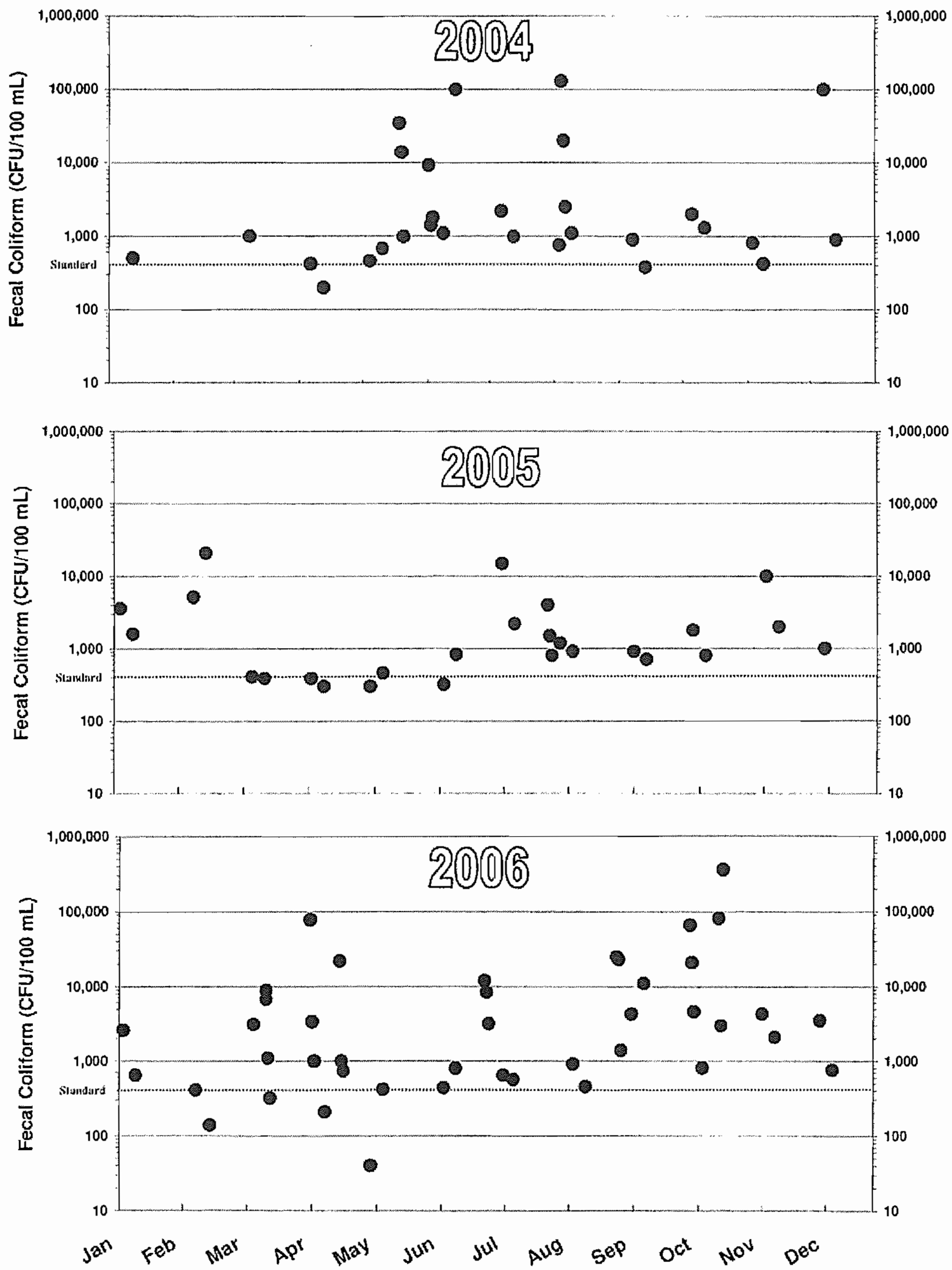


FIGURE 5: FECAL COLIFORM BACTERIA AT WILSON AVENUE ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

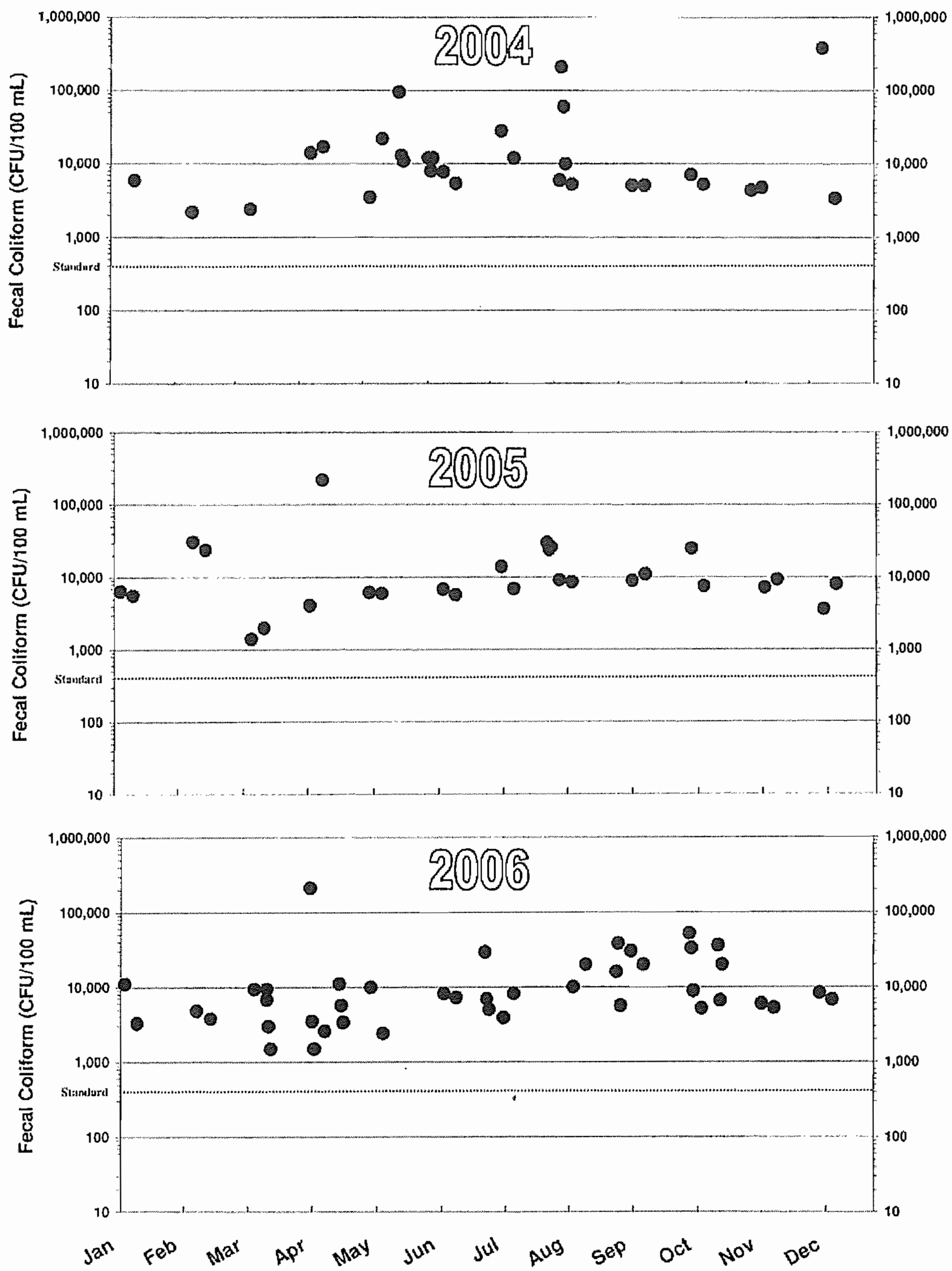


FIGURE 6: FECAL COLIFORM BACTERIA AT DIVERSEY PARKWAY ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

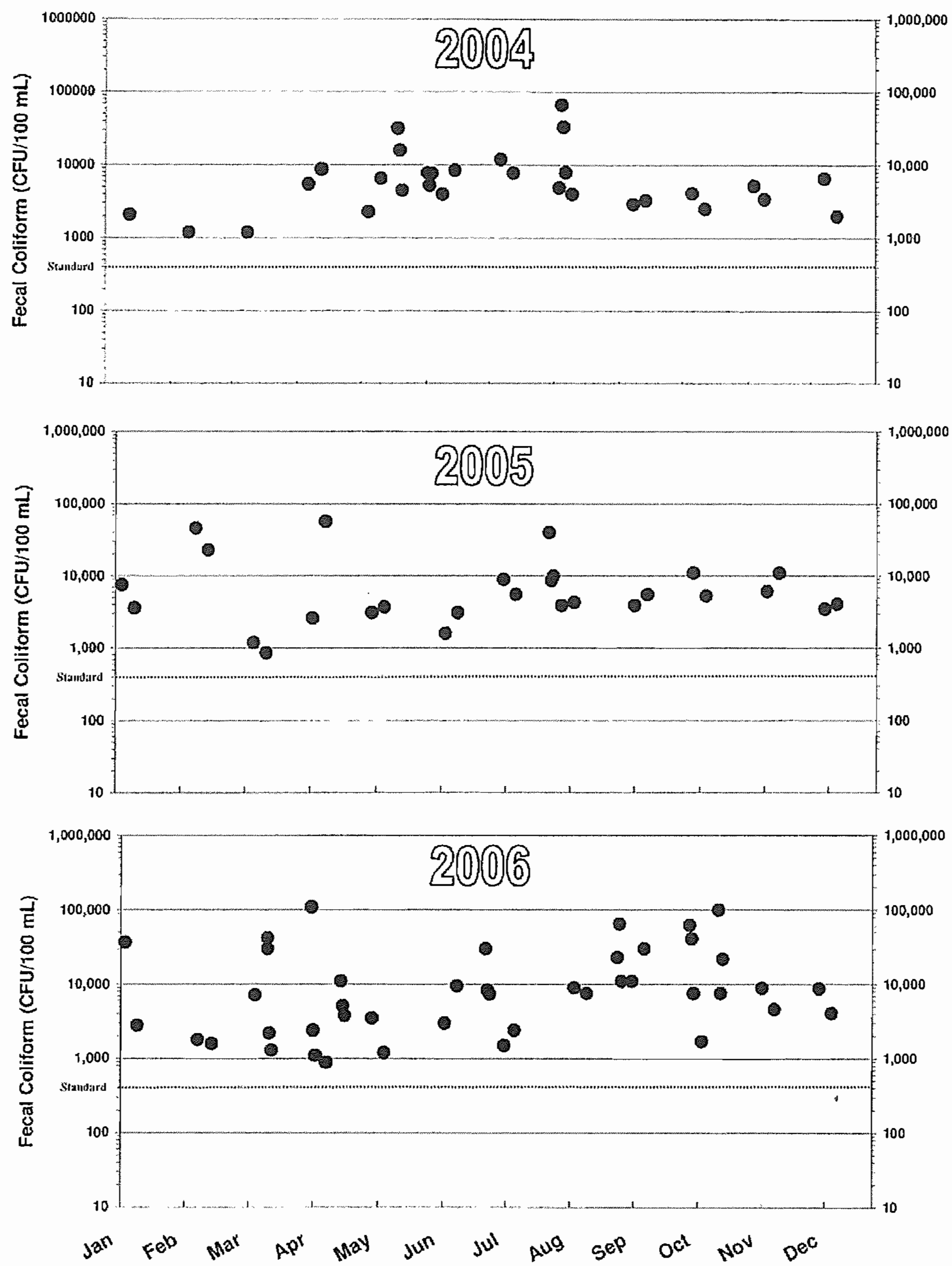


FIGURE 7: FECAL COLIFORM BACTERIA AT GRAND AVENUE ON THE NORTH BRANCH CHICAGO RIVER DURING THE YEARS 2004, 2005, AND 2006

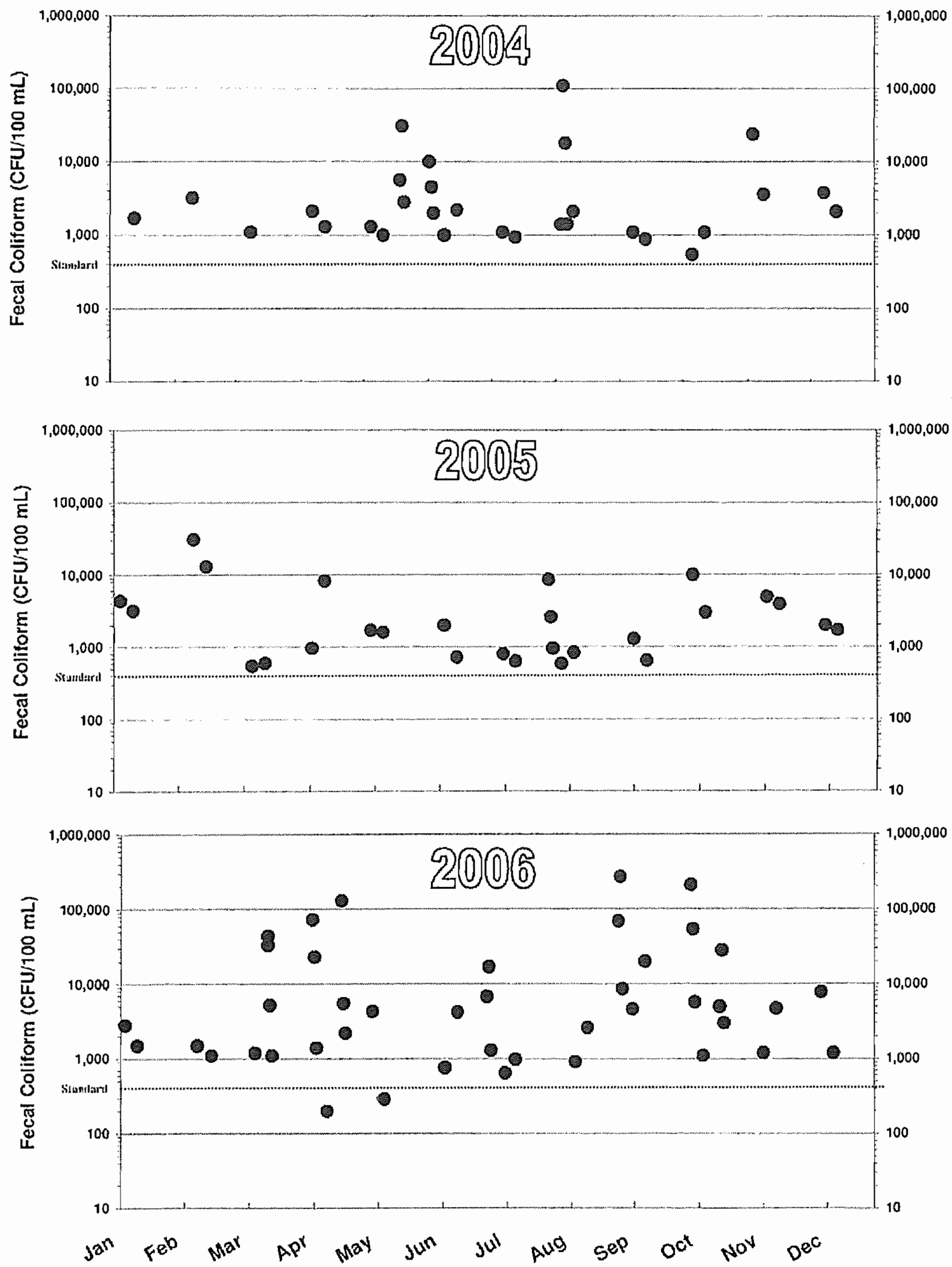


FIGURE 8: FECAL COLIFORM BACTERIA AT INDIANA AVENUE ON THE LITTLE CALUMET RIVER DURING THE YEARS 2004, 2005, AND 2006

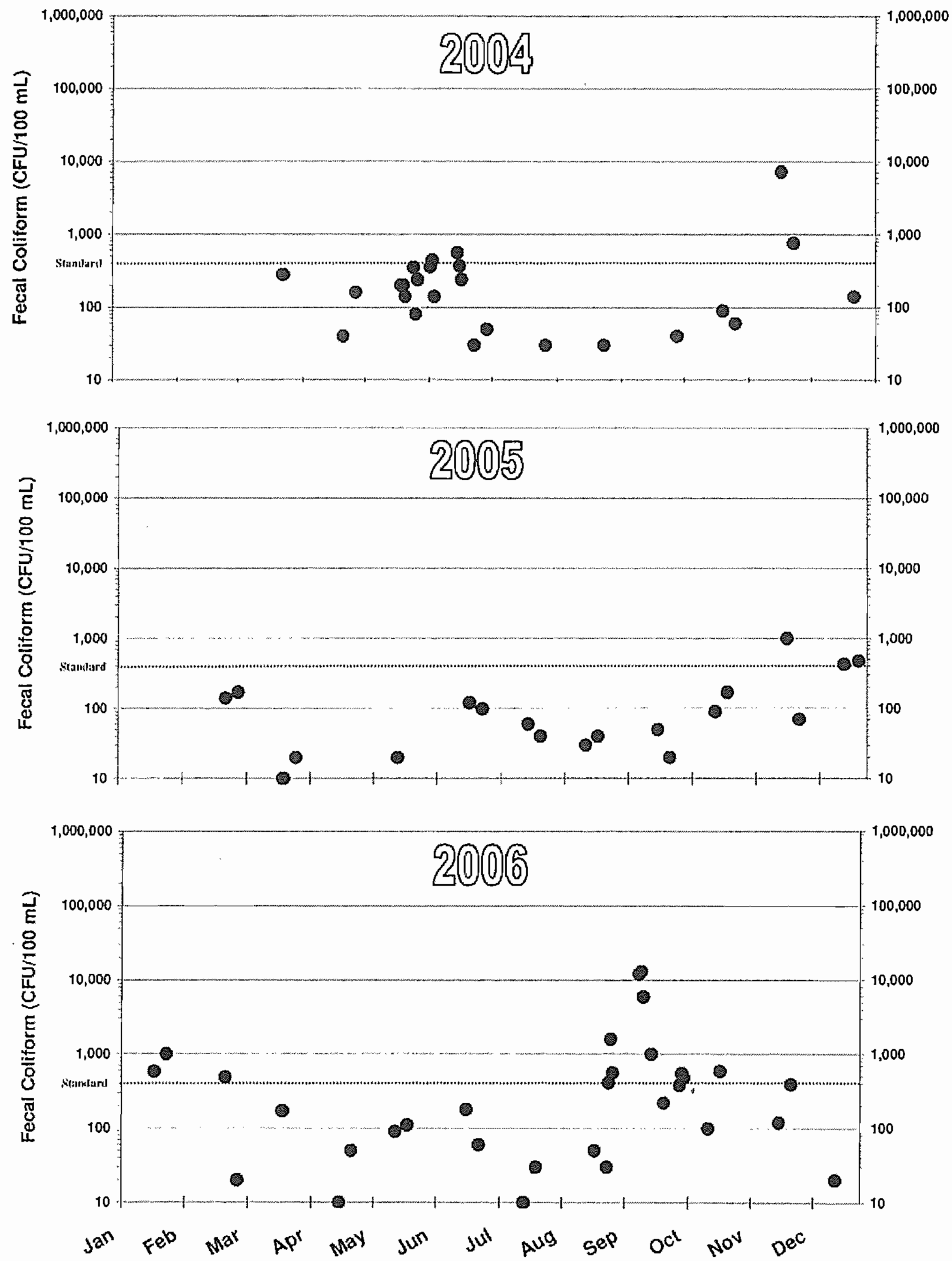


FIGURE 9: FECAL COLIFORM BACTERIA AT HALSTED STREET ON THE LITTLE CALUMET RIVER DURING THE YEARS 2004, 2005, AND 2006

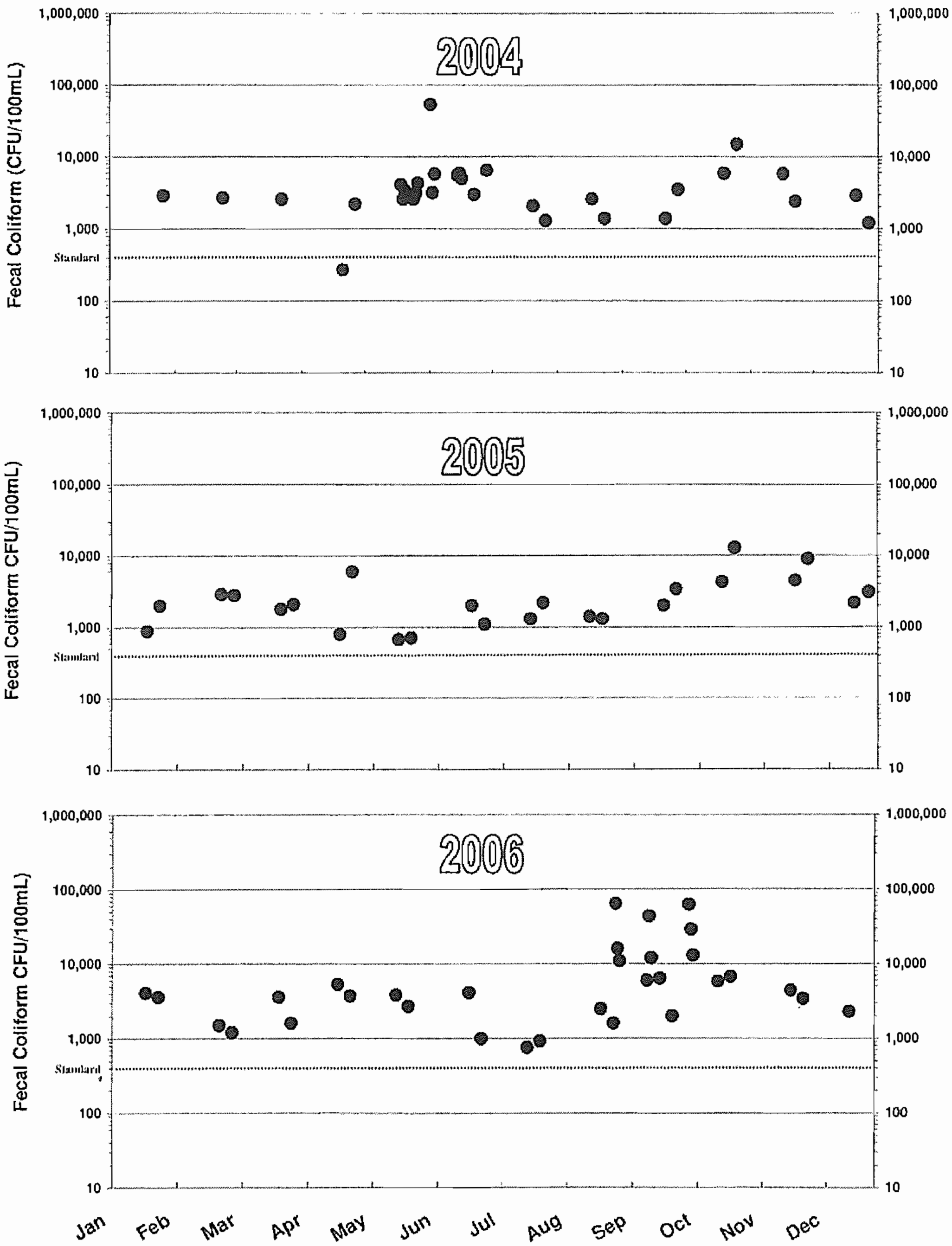


FIGURE 10: FECAL COLIFORM BACTERIA AT ASHLAND AVENUE ON THE LITTLE CALUMET RIVER DURING THE YEARS 2004, 2005, AND 2006

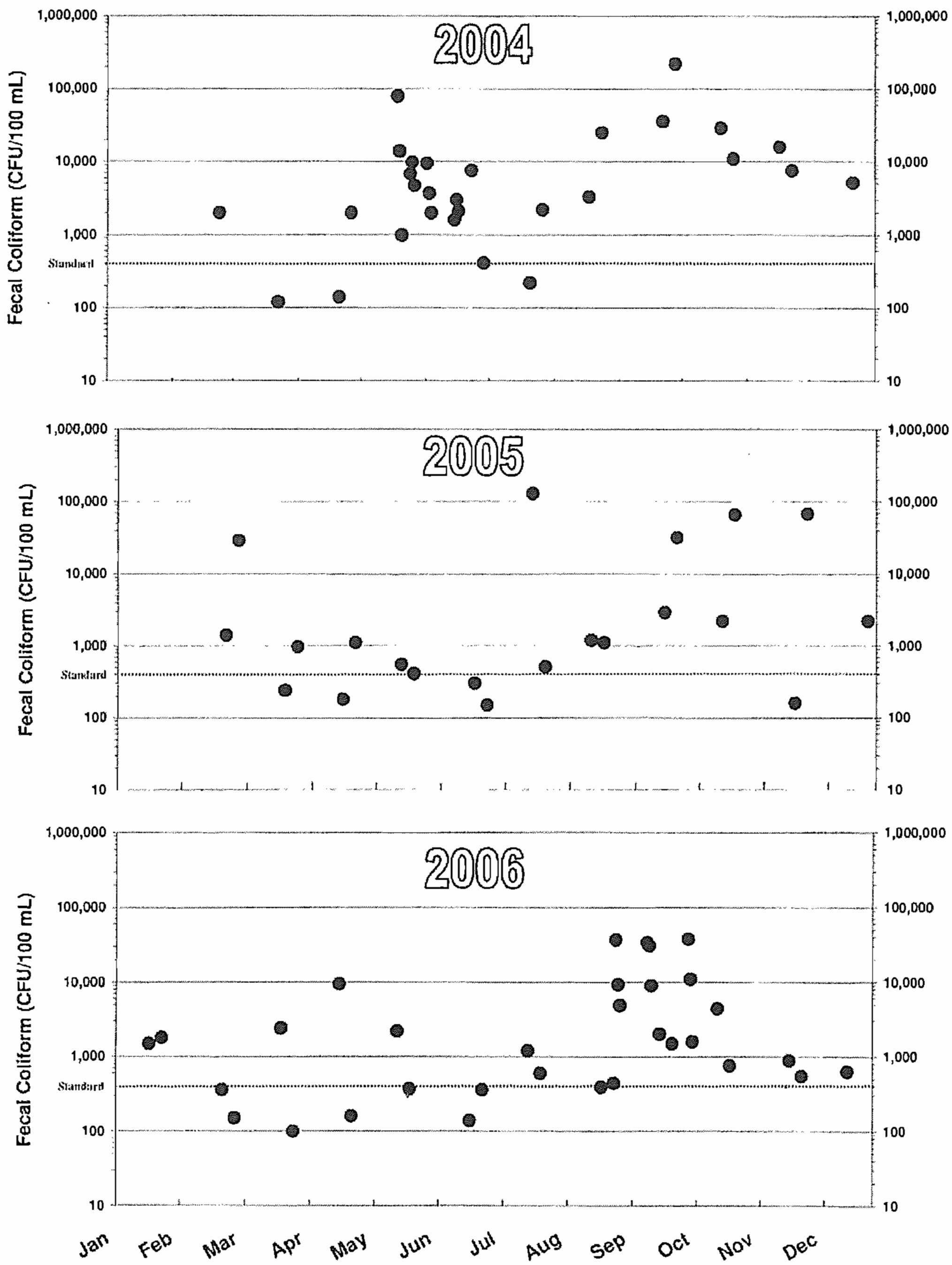


FIGURE 11: FECAL COLIFORM BACTERIA AT ASHLAND AVENUE ON THE CALUMET-SAG CHANNEL DURING THE YEARS 2004, 2005, AND 2006

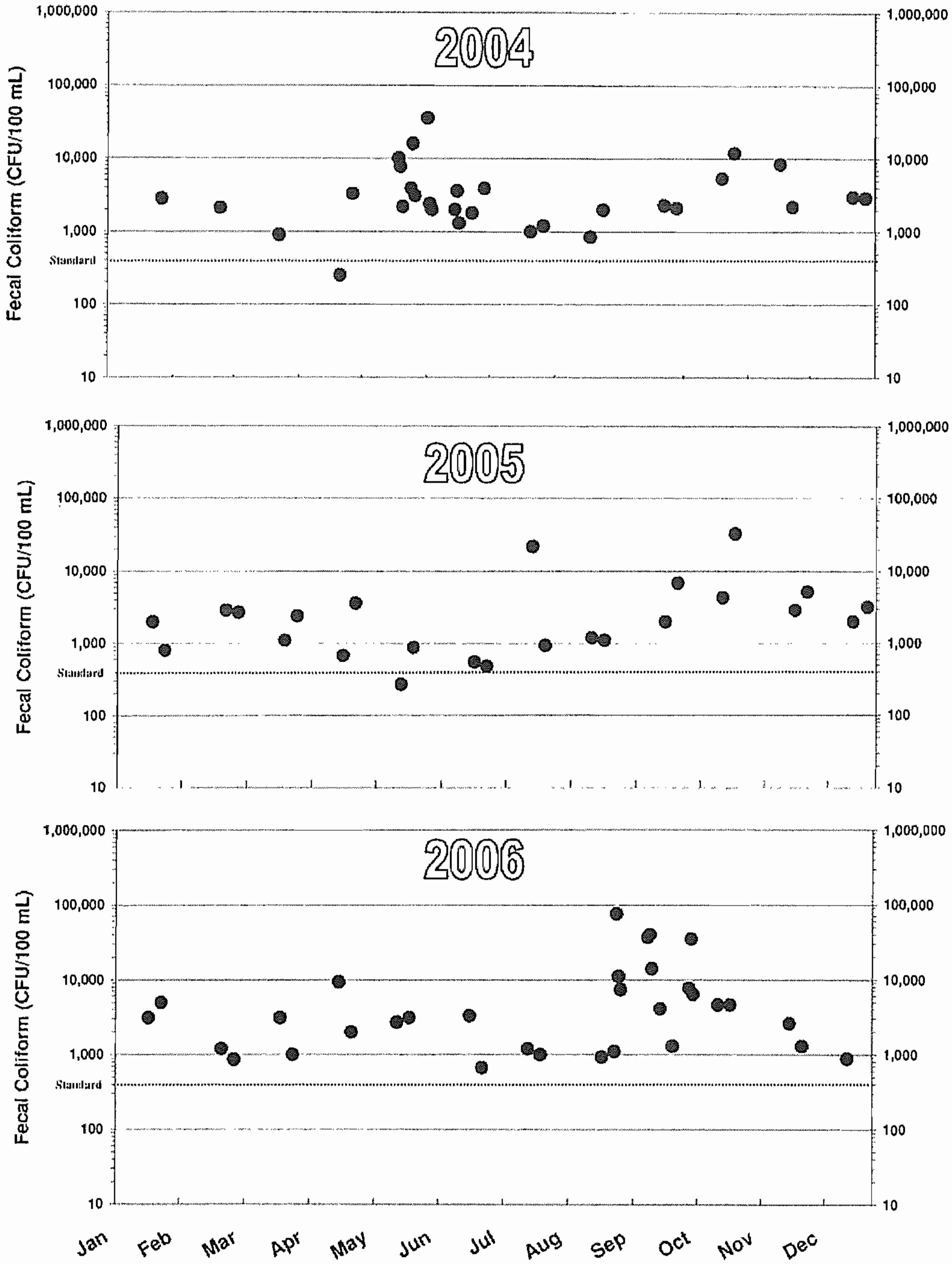


FIGURE 12: FECAL COLIFORM BACTERIA AT CICERO AVENUE ON THE CALUMET-SAG CHANNEL DURING THE YEARS 2004, 2005, AND 2006

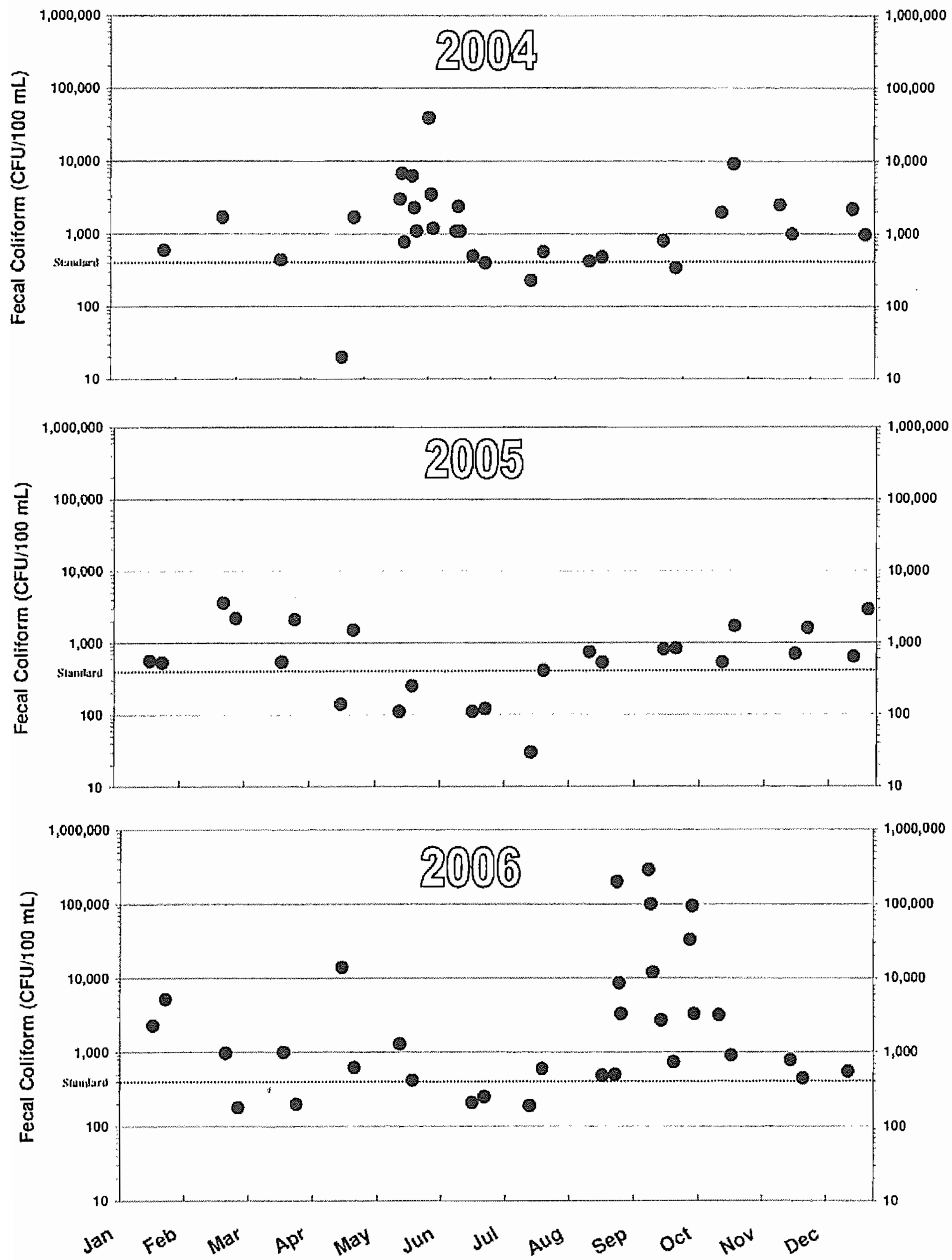


FIGURE 13: FECAL COLIFORM BACTERIA AT ROUTE 83 ON THE CALUMET-SAG CHANNEL DURING THE YEARS 2004, 2005, AND 2006

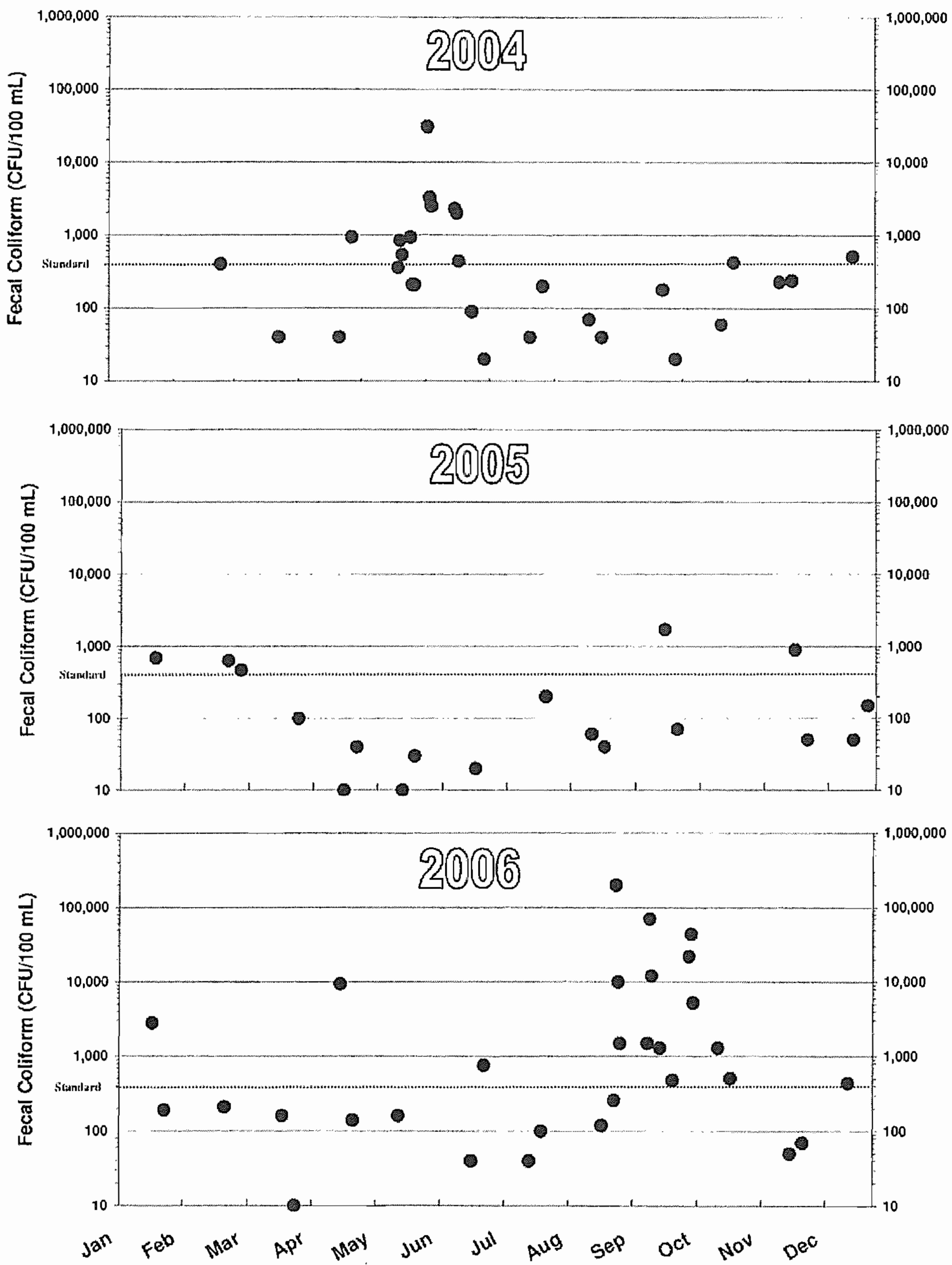


TABLE 2: RAINFALL MEASURED AT FOUR GAUGE LOCATIONS DURING HEAVY AND LIGHT RAINS FROM 2004 THROUGH 2006

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

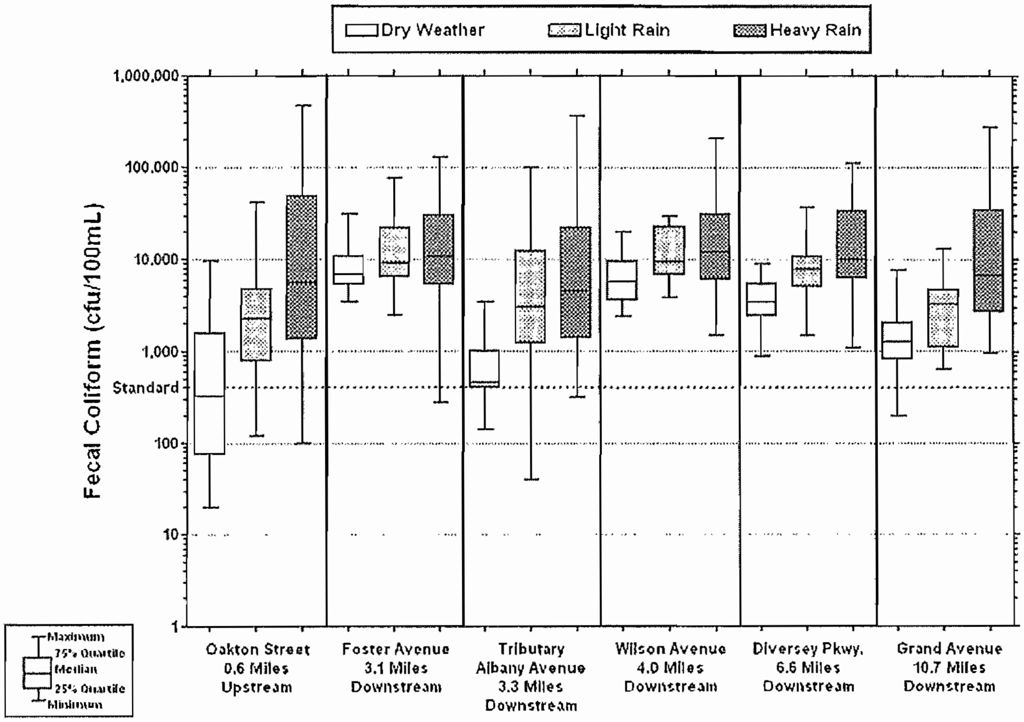
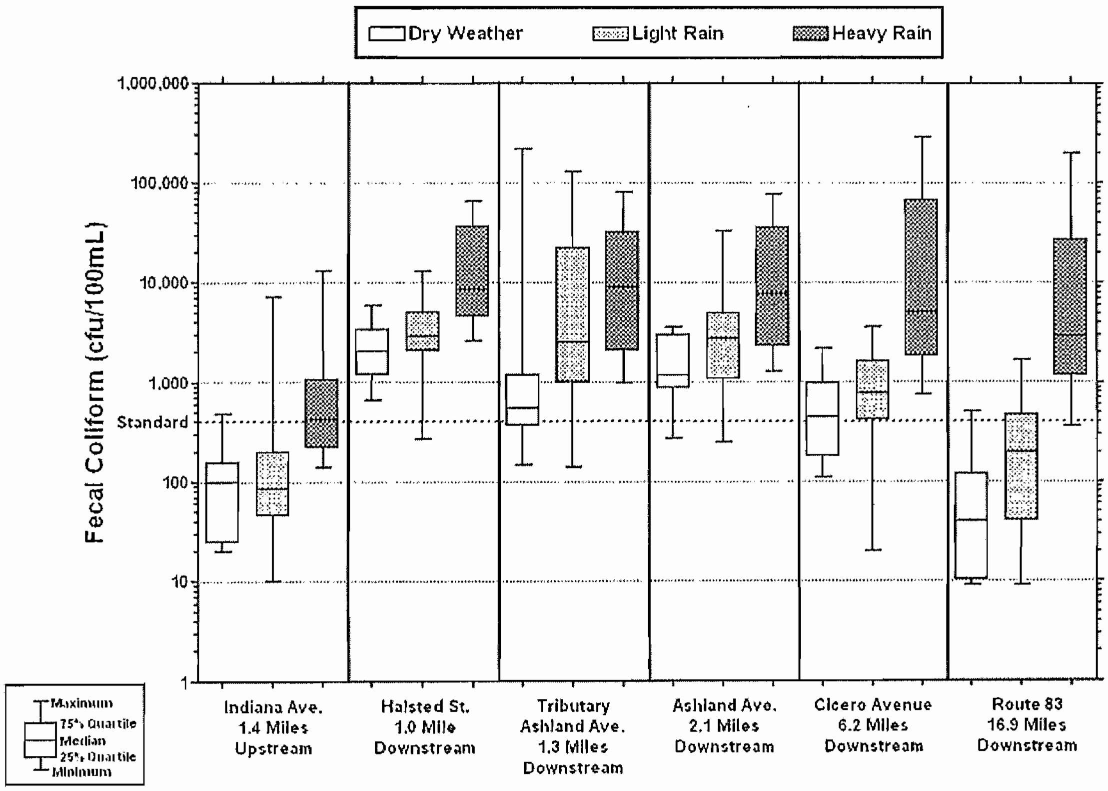


FIGURE 15: FECAL COLIFORM DENSITIES AT SOUTH AREA WATERWAY STATIONS DURING DRY AND WET WEATHER FROM 2004 THROUGH 2006



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

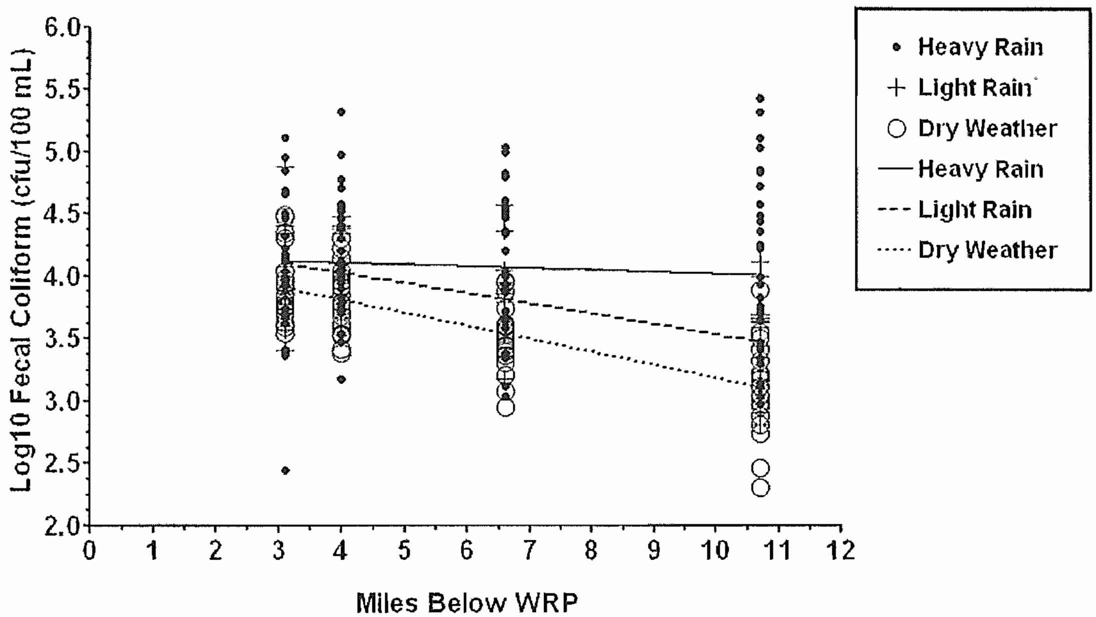


FIGURE 17: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG10 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE CALUMET WRP DURING WET AND DRY WEATHER 2004–2006

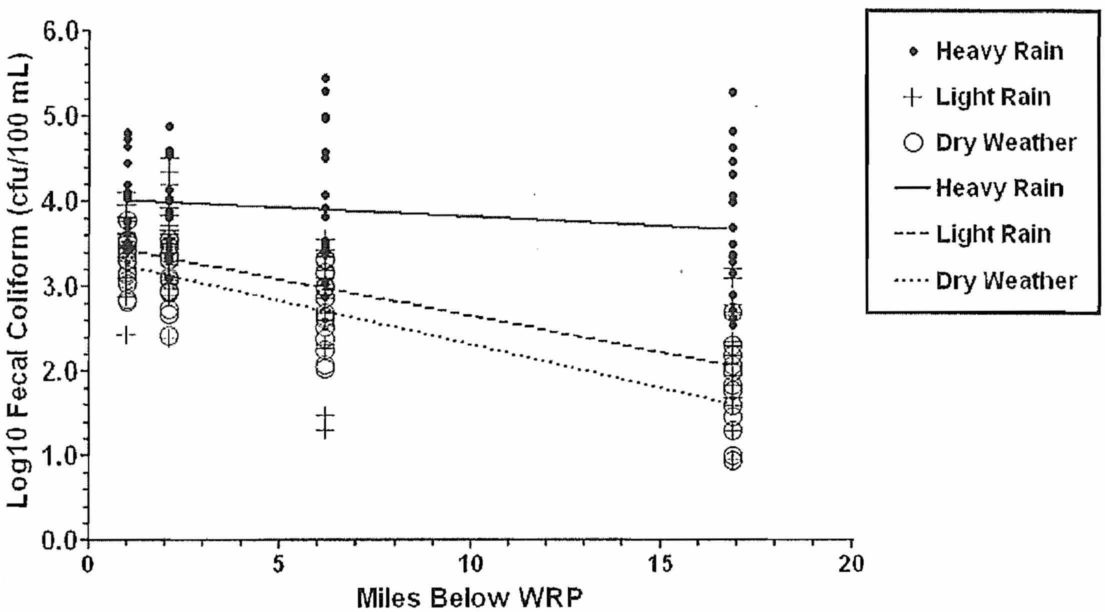
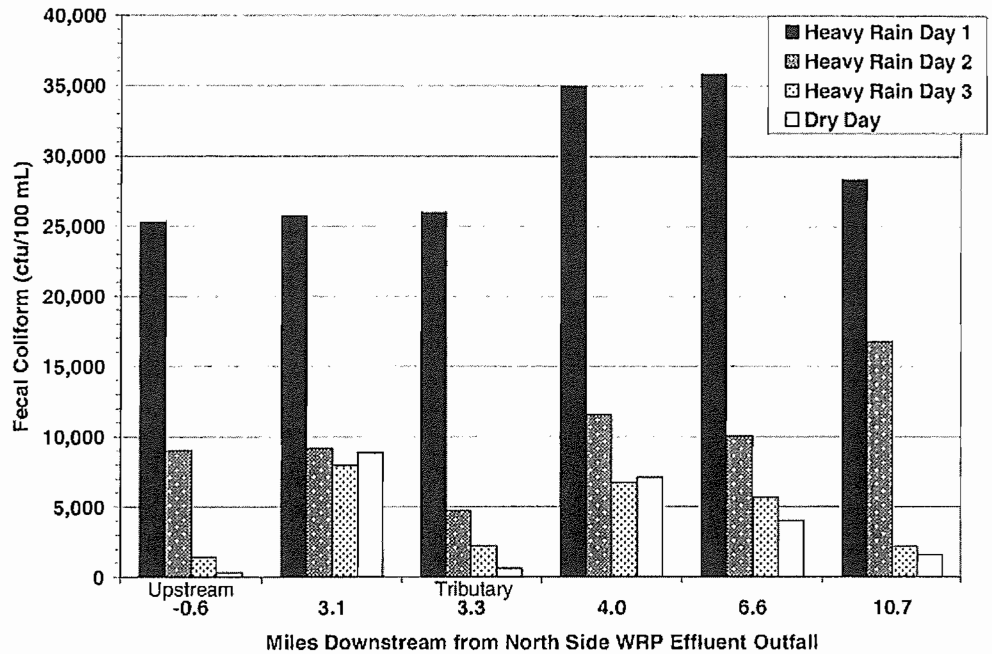
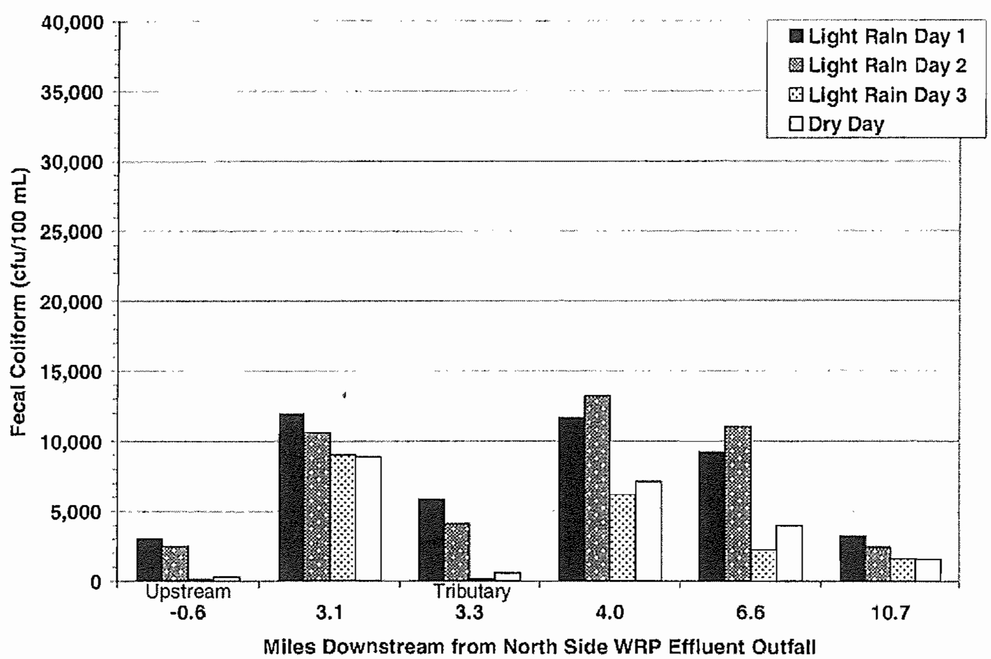


FIGURE 18: GEOMETRIC MEANS OF FECAL COLIFORM BACTERIA AT NORTH AREA STATIONS EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES





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

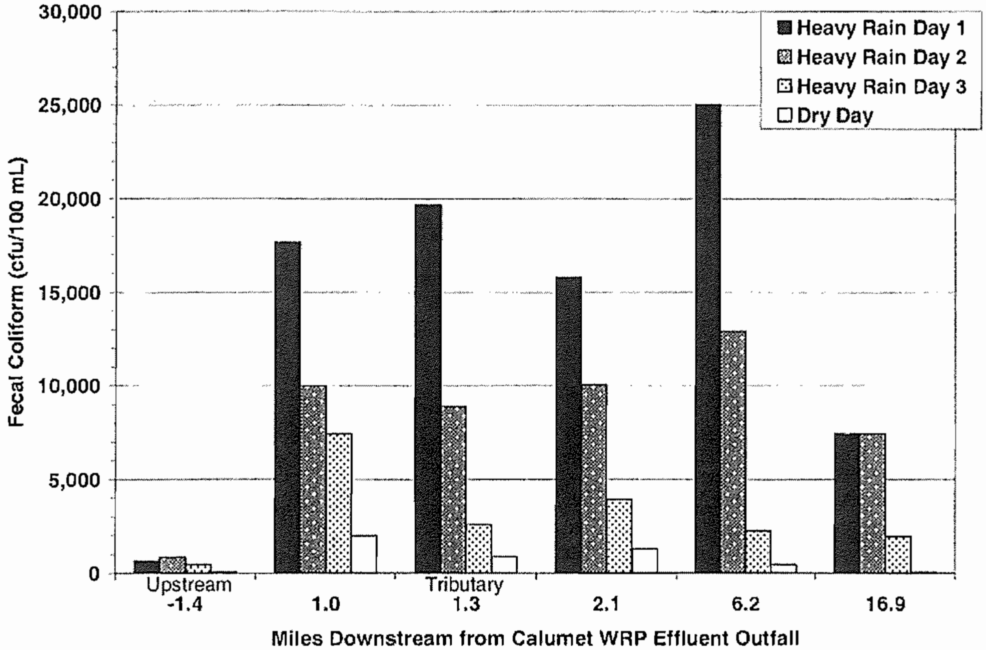
North Area. Results of statistical analysis of the trend in FC density downstream of the WRP outfalls, on each day following initiation of sampling during heavy and light rains, are shown in Figure 20 using linear regression of FC density measurements transformed to base 2 logarithms. The FC densities 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



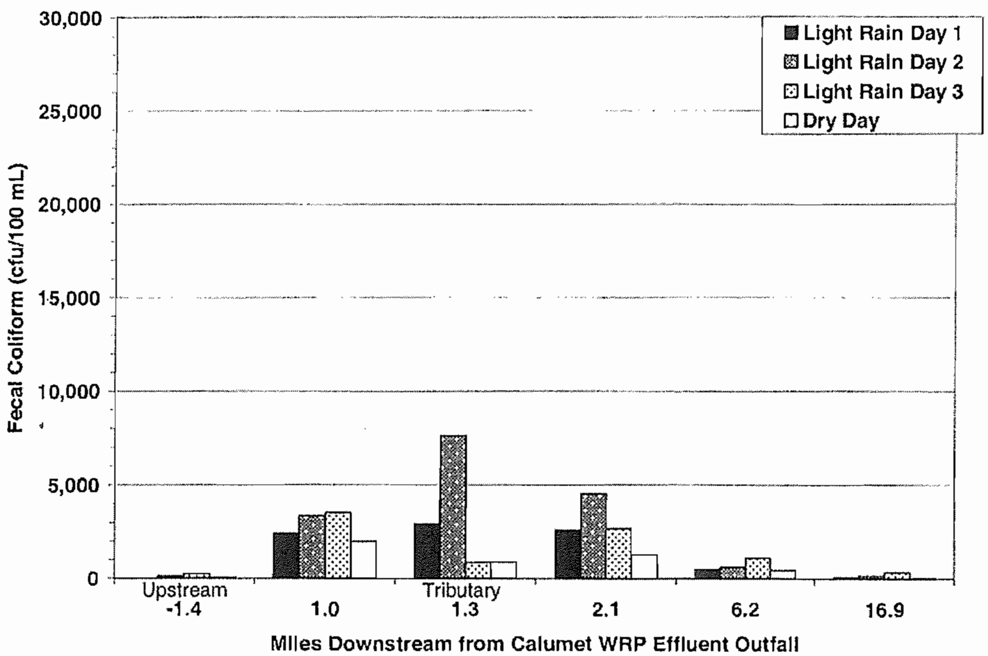
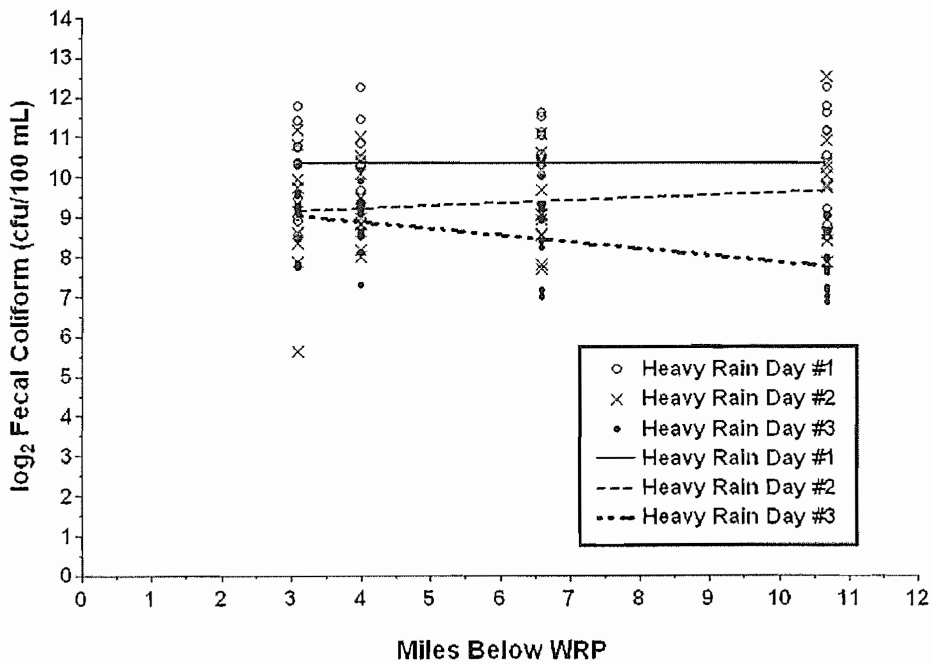


FIGURE 20: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG2 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE NORTH SIDE WRP EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES



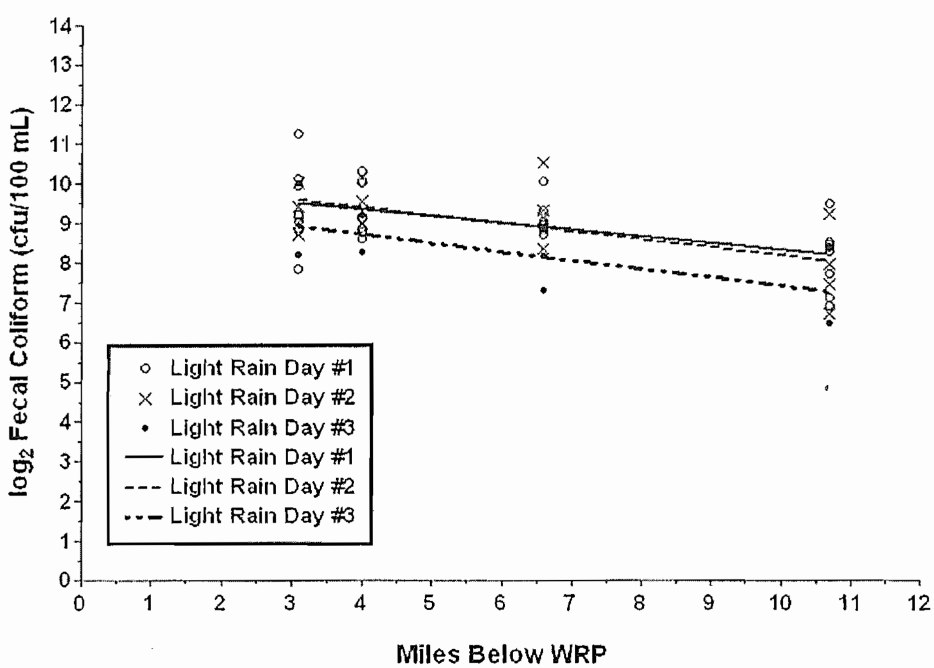
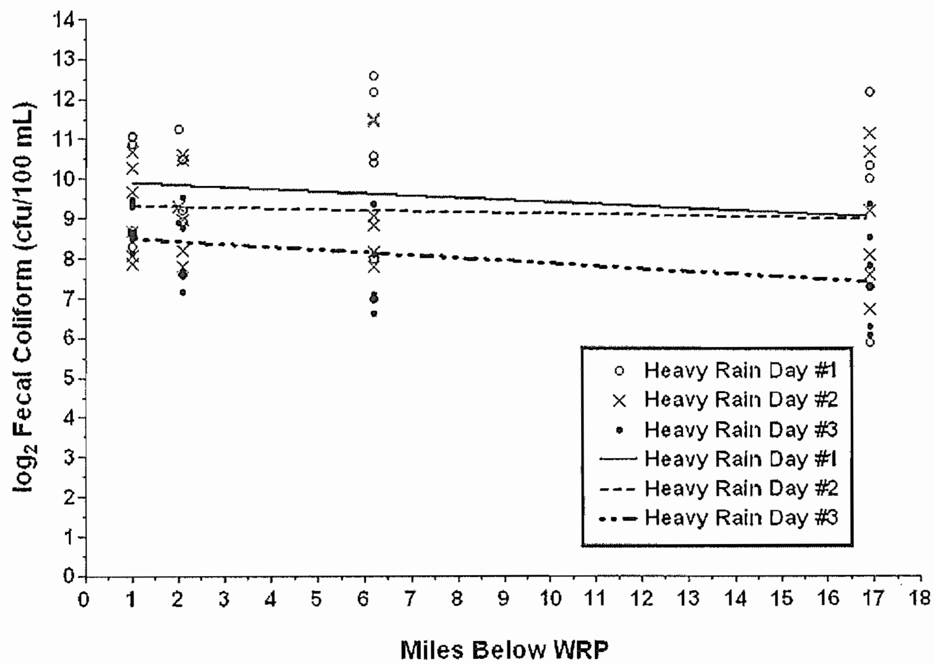
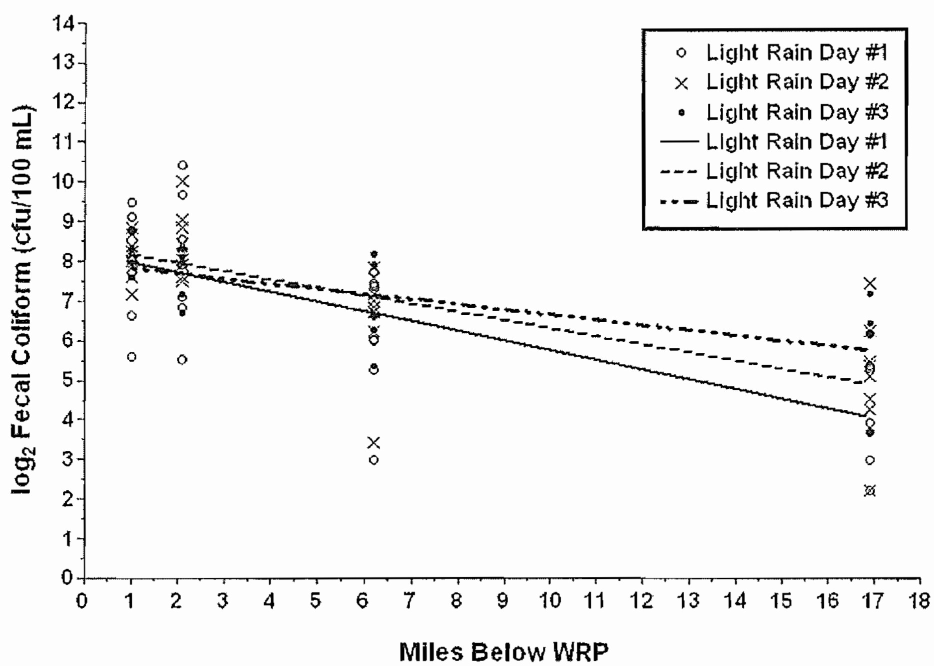


FIGURE 21: TREND (LINES) OF FECAL COLIFORM DENSITIES (LOG2 TRANSFORMED VALUES) AT STATIONS DOWNSTREAM FROM THE CALUMET WRP EACH DAY AFTER HEAVY AND LIGHT RAINFALLS FOR THREE-DAY PERIODS COMPARED WITH DRY WEATHER DENSITIES





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)

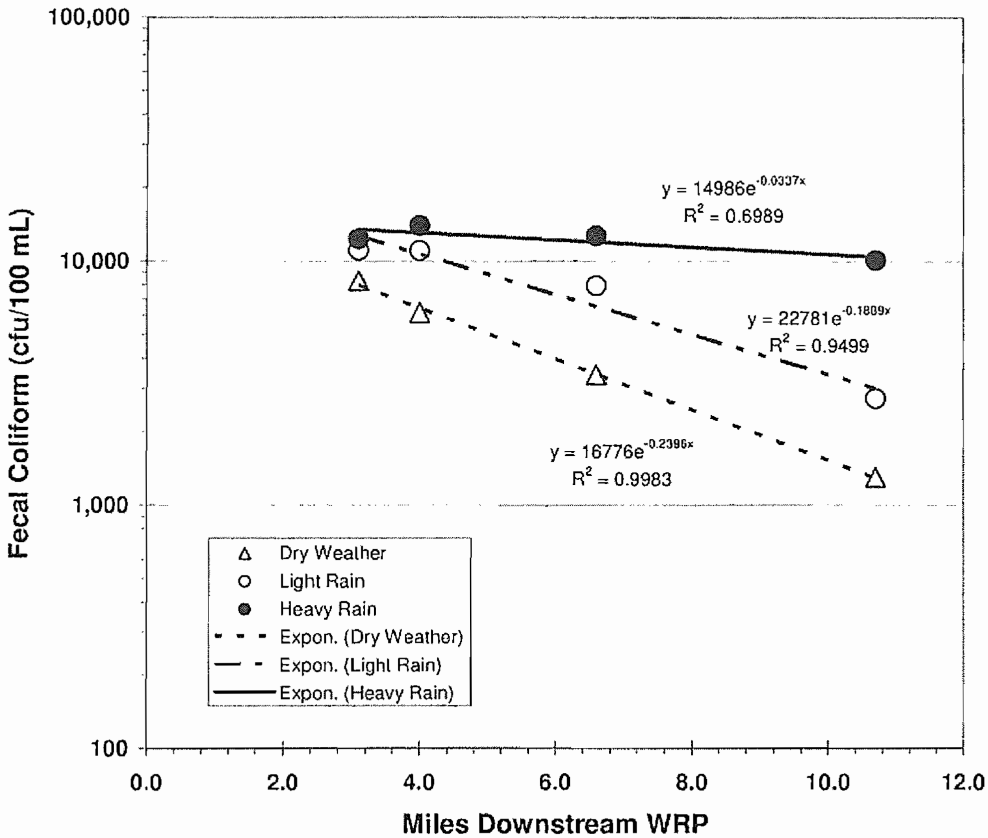


TABLE 4: FECAL COLIFORM DENSITIES[1] CALCULATED FROM DIE-OFF EQUATIONS AT FIVE MILES AND AT FIRST POINT OF COMPLIANCE WITH GENERAL USE WATER QUALITY STANDARD DOWNSTREAM OF WATER RECLAMATION PLANT EFFLUENT OUTFALLS

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.

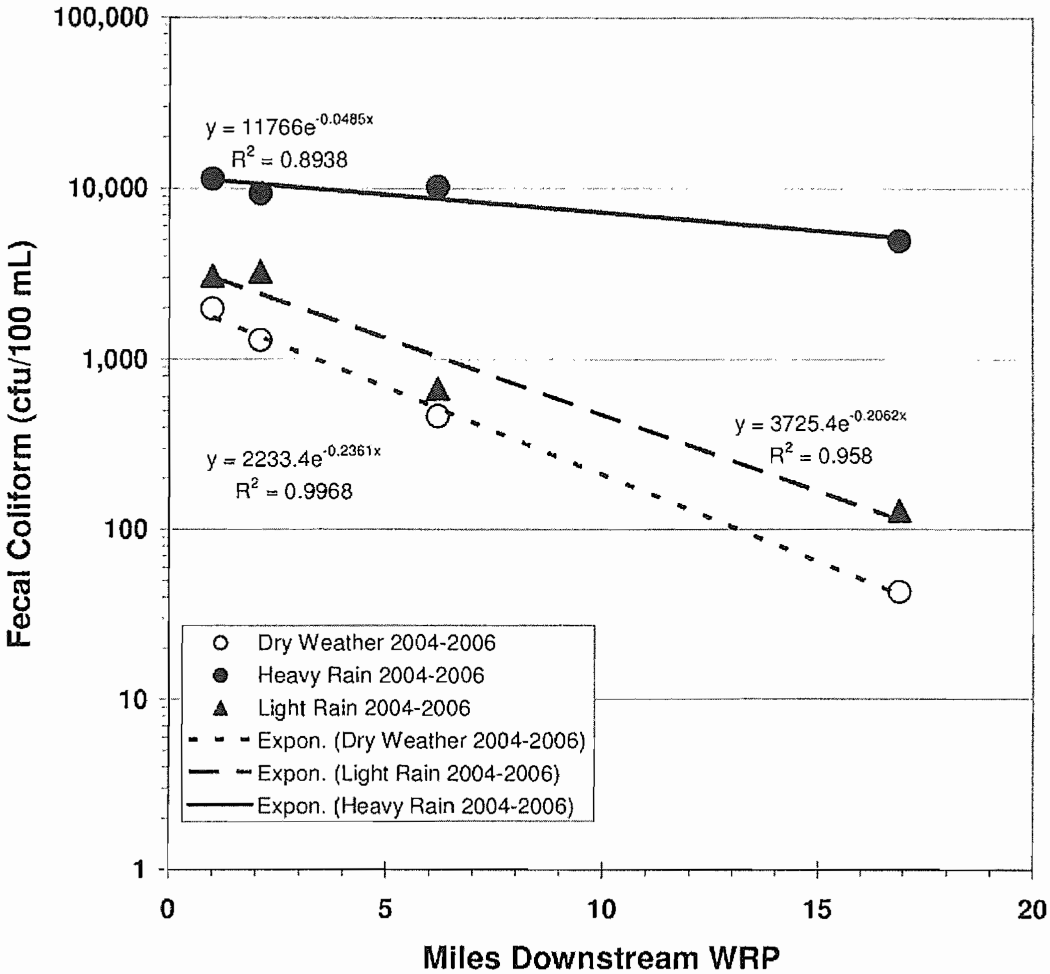
effluent standard at North area stations were predicted to occur 16 miles downstream of the North Side WRP during dry weather, 22 miles downstream during light rain wet weather, 19 miles downstream if disinfection eliminated FC density from the North Side WRP during light rain wet weather, 108 miles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