LAKE ERIE

LAKEWIDE MANAGEMENT PLAN

Lake Erie Lakewide Management Plan (LaMP) Technical Report Series

Recreational Water Quality Impairments (Bacterial Levels and Beach Postings)

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NOTE TO THE READER:

This technical report was prepared as one component of Stage 1, or "Problem Definition", for the Lake Erie LaMP. This report includes detailed technical and background information that provides the basis for the impairment conclusions recorded in the Lake Erie LaMP *Status Report*.

This document has been extensively reviewed, both by the government agencies that are partnering to produce the LaMP, and the Lake Erie LaMP Public Forum, a group of approximately 80 citizen volunteers. This review was designed to answer two questions:

- Is the document technically sound and defensible?
- Do the reviewers agree with the document conclusions?

In its present form, this report has been revised to address the comments received during that review process, and there is consensus agreement with the impairment conclusions presented.

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Keith Linn - Northeast Ohio Regional Sewer District
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12.1 Listing Criteria

Annex 1 of the Great Lakes Water Quality Agreement (GLWQA) states that: *"Waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections"* (International Joint Commission, 1994).

Annex 2 of the GLWQA lists "beach closings" as a beneficial use impairment related to recreational waters. According to the International Joint Commission (IJC), a beach closing impairment occurs "*when waters, which are commonly used for total body contact or partial body contact recreation, exceed standards, objectives, or guidelines for such use*" (IJC, 1989).

12.2 Application of the Listing Criteria

Federal, State and Provincial recreational water quality guidelines recommend bacterial levels below which the risk of human illness is considered to be minimal. For public beaches, the regional Public Health Units/Health Departments monitor beach water quality. When contaminant indicator levels in the bathing beach water reach levels that indicate contaminants may pose a risk to health, public beaches are posted with a sign warning bathers of these potential health risks.

The primary tool to evaluate beach water quality is the measurement of "indicator organisms", which indicate the level of bacterial contamination of the water. The bacterial contamination can come from various sources, and is not necessarily the result of human contamination. Beaches are part of the ecosystem, and in this way, are not a "closed" system. Indicator organism threshold levels vary between individual U.S. States and the Province of Ontario. The two indicator organisms most commonly used to measure bacterial levels are "fecal coliforms" (comprised of animal and human feces), and *Escherichia coli* (*E.coli*) (the predominant organism in human and animal feces). High levels of fecal coliforms or *E. coli* in recreational water are indicative of fecal contamination and the possible presence of intestinal-disease-causing organisms.

12.3 Scope of Beneficial Use Impairment Assessment

12.3.1 Geographic Scope

The geographic scope of the Lake Erie LaMP beneficial use impairment assessment (BUIA) includes open lake waters, near shore areas, river mouths and embayments, and the lake effect zone of Lake Erie tributaries. The lake effect zone is defined as that zone where the waters of the lake and the tributary river are mixed. Beaches evaluated in this assessment are limited to those directly along Lake Erie, but sources of impairment will be considered from all parts of the Lake Erie basin. The Detroit River will be considered as a source of impairment, but beaches along the Detroit River will not be considered when assessing impairment.

12.3.2 Data

The primary tool to evaluate beach water quality from a human health standpoint is the measurement of indicator organisms (either fecal coliforms or *E. coli*), which indicate the level of bacterial contamination in the water. Measurement of indicator organisms can be used to show trends in recreational water quality, and can also be used as an indicator for human health (i.e., to estimate human exposure to these contaminants, and the consequent impacts on human health). Use of jurisdictional bacterial level thresholds give a more direct indication of human health risks than do beach postings. This is because beaches can be posted for reasons other than bacterial contamination including presumptive closings until tests can be completed. Comparisons of bacterial levels can be made with a numeric guideline to determine exceedances.

Therefore, for the purposes of this assessment, levels of fecal coliforms or *E. coli*, as applicable, were plotted against their respective State or Provincial guideline. Guideline exceedances were used to assess whether beaches were impaired from a human health standpoint. Accompanying monitoring sheets and beach postings data provided additional useful information about recreational water quality, including other health hazards, visual observations, unusual occurrences, and potential sources.

As indicated in the IJC listing criteria, recreational water quality impairment includes situations where total body contact or partial body contact recreation standards are exceeded. Therefore, to be complete an assessment needs to evaluate all recreational water use activities where total or partial body water contact may occur. This includes primary activities such as swimming, windsurfing and water skiing, and also situations where swimming may occur in open waters during secondary contact activities, such as boating and fishing. Hence, this assessment considers both nearshore and open water activities in its evaluation of impairment.

Bacterial level exceedances above jurisdictional guidelines, regardless of their source (i.e., human or animal) represent use impairment, regardless of whether the recreationally used waters are part of a public or private beach monitored swimming area, or open waters. Data is not available for all private beaches in all the Lake Erie jurisdictions. Wherever available, data for private beaches has been included in the assessment.

"Further to this, pollution indicator bacteria levels data exist for open waters and embayments; however, these data are not collected specifically for the purpose of monitoring recreational use waters. An overview of existing open waters monitoring data indicates that pollution indicator bacteria levels in Lake Erie open waters are very low and therefore demonstrate the absence of a significant risk to health. In addition, water quality monitoring experts feel that, based on the sampling data, levels of pollution indicator bacteria in recreationally used open waters are not an issue. This is due in large part to the dilution effect of the large volume of water in these open locations, as well as, to a lesser extent, die-off of and predation on bacteria (K. Linn, NE Ohio Sewer District, personal comm; W. Robertson, Health Canada, personal comm). Therefore, limited open waters data are included in this assessment as an illustration of bacterial levels in these waters, but a comprehensive listing of these data was not undertaken for this assessment."

Since extensive data on beach postings and bacterial levels exist mainly for public beaches, this preliminary impairment assessment has focused, for the most part, on bathing beach water quality at public, monitored beaches. A small number of private beaches have also been included. As new data become available, they will be incorporated into the assessment.

Data were limited to 1992 onward, for two reasons. In Ontario, the jurisdictional guideline changed from fecal coliforms to *E. coli* in 1992. Second, over the past number of years, communities throughout the Lake Erie basin have been working to remediate many sources of microbiological contamination; thus, examining earlier data would not be reflective of these improvements.

12.4 Background to Issue

The major human health concern for recreational waters is microbiological contamination (bacteria, fungi, viruses, parasites). Human exposure occurs primarily through ingestion of polluted water, and can also occur through the entry of water through the ears, eyes, nose, broken skin, and through contact with the skin. Gastrointestinal disorders and minor skin, eye, ear, nose and throat infections have been associated with microbiological contamination.

12.4.1 Sources/causes of microbiological contamination

Many sources contribute to microbiological contamination. These include:

- Heavy rains, causing combined or sanitary sewers to overflow, and direct release of raw sewage. Metropolitan areas along the lake shore have serious problems with cross-connections between sanitary and storm sewers, dry weather/wet weather bypasses, and unsewered residential and commercial areas; failing private, household and commercial septic systems. It is important to note that simply because bacterial levels are present, it does not necessarily mean that sewage overflow is a problem;
- Fecal coliforms in soil that is washed out from heavy rains; animal/pet fecal waste either on the beach or residentially (washed into storm sewers); wildlife, such as large populations of seagulls or Canada geese, fouling the beach;
- Agricultural runoff (e.g. manure);
- High winds can cause increased wave action that can transport bacteria from contaminated, non-recreational areas to recreational-use areas. High winds can also stir up bacteria that are in the sediments. Windsor-Essex reported that a large proportion of their bacterial exceedances correlated with high wind conditions, which increased wave action (above), thereby stirring up sediment and/or sweeping bacteria in from contaminated areas.
- Calmer waters can slow dispersal (of the bacteria) and create excess concentrations of bacteria.
- Direct human contact (e.g. swimmers with illnesses, cuts or sores); number of swimmers/bathers in the water (more bathers are related to increased bacterial levels);
- Hot weather/higher temperatures

- Low (shallow) water levels
- Direct discharges (e.g., overboard discharge from holding tanks of recreational vessels)

Local sources of bacterial contamination and the extent to which they contribute to elevated bacterial levels, can help in understanding trends in exceedances and setting priorities for remediation. However, identifying individual sources of bacterial contamination is often a difficult process, particularly if there are multiple sources.

Uncharacteristically high bacterial levels near Maumee Bay State Park, Ohio in 1995 led to an extensive effort to sample and track down all of the potential sources to the area. Researchers at the University of Toledo began a study in 1996 to identify sources using a technique for fingerprinting E. coli (Glatzer, 1999). This technique shows promise but requires further refinement to be a practical tool for source track down in the field.

12.4.2 Beach postings data

The terms "beach posting", "beach closing", and "advisory" are often used interchangeably, to identify that an advisory sign has been posted at a beach. The sign contains advice to the recreational water user. In some cases, permanent signs are posted in areas where it is not possible, for economic reasons or otherwise, to post beaches when impairments occur. These signs offer advice as to when recreational use should be avoided. Other signs are posted only when a current hazard exists, such as bacterial exceedances, and these signs are removed when the hazard is no longer there. These signs may advise, for example, that bacteria levels may exceed recommended standards for 24 hours after a heavy rain. Other postings advise swimmers to "Swim at your own risk". Still others will bluntly state, "Warning - Unsafe for Bathing - High levels of Bacteria in these Waters may pose a Risk to your Health". Beaches are not usually physically closed when they are posted, since access to a beach can be difficult to restrict.

Beach postings data can be useful in supplementing information on bacterial levels. However, because this assessment criterion is based on bacterial levels, extensive beach postings data is not included.

12.5 Summary of Jurisdictional Criteria Used to Assess Beach Water Quality

Recreational water quality guidelines for individual States and the Province of Ontario are summarized in Tables 12-1 and 12-2.

Table 12-1. Jurisdictional Criteria for Measurement of Bacterial Levels in Recreational Waters along Lake Erie: Public Beaches, Canadian shoreline

Ontario	Who monitors?	Indicator Organism used	Guideline: bacterial levels should not exceed:	Method used to calculate bacterial levels for each beach *	Posting Criteria
Windsor-Essex region	Windsor-Essex Health Unit	*E. coli* 1992 on (fecal coliforms used before 1992)	100 *E. coli* / 100 ml of water	Sampled once weekly; geometric mean[+] of a minimum 5 samples taken from a minimum 5 sampling locations, for one day.	a) when *E. coli* exceedance occurs 2 days in a row, beach is closed until next weekly sampling b) a known hazard exists c) during high winds;
Kent-Chatham region	Kent-Chatham Health Unit	*E. coli* 1992 on (fecal coliforms used before 1992)	100 *E. coli* / 100 ml of water	Sampled once weekly; geometric mean of a minimum 5 samples taken from a minimum 5 sampling locations, for one day.	a) Permanent advice sign posted b) Posted "beach closed" only under abnormal circumstances
Elgin-St. Thomas region	Elgin-St. Thomas Health Unit	*E. coli* 1992 on (fecal coliforms used before 1992)	100 *E. coli* / 100 ml of water	Sampled once weekly; geometric mean of a minimum 5 samples taken from a minimum 5 sampling locations, for one day.	a) Permanent advice signs posted
Haldimand-Norfolk region	Haldimand-Norfolk Health Unit	*E. coli* 1992 on (fecal coliforms used before 1992)	100 *E. coli* / 100 ml of water	Sampled once weekly. Methods same as above, but for beaches greater than 1000 metres, geometric means are taken for every 200 metres of beach sampled.	a) A known hazard exists b) after heavy rain c) during high winds/wave height d) If *E. coli* exceedance occurs, re-sampled immediately, and posted if 2nd sample shows exceedance;
Niagara region	Niagara Regional Health Unit	*E. coli* 1992 on (fecal coliforms used before 1992)	100 *E. coli* / 100 ml of water	Sampled once weekly; geometric mean of 10 samples over 2 days (5 samples per day, sampling days one week apart)	a) A known hazard exists b) *E. coli* exceedance occurs
Health Canada Federal Guidelines		*E. coli*, as well as a choice of other indicators may be permitted for use.	200 *E. coli* / 100 ml of water		

*The description listed here is general. A detailed description of posting criteria is identified in "Beach Management Protocol, Water Quality Program". Per the "Beach Management Protocol", beaches are posted if there is evidence (bacteriological analysis, historical and epidemiological data, or the physical quality of the water) that the beach water poses a risk to the health of the bathers. "Posting should be **considered** when the daily geometric mean of the samples from a beach exceeds 100 *E. coli* per 100 ml water" (Ontario Ministry of Health, 1992). The "Beach Management Protocol" offers some flexibility in terms of sampling and posting. Sampling may be reduced to once a month if historic data and pollution surveys indicate water quality has been consistently well within limits set for recreational use. Sampling may be suspended for the season if a sample has been taken in the current year to verify no change has occurred since the last year. Private beaches are not required to be sampled.

[+] geometric mean (GM) $GMy = antilog \frac{1}{n} \sum \log y$

Table 12-2. Jurisdictional Criteria for Measurement of Bacterial Levels in Recreational Waters along Lake Erie: Public Beaches, U.S. shoreline

U.S. States	Who monitors?	Indicator Organism used	Guideline: bacterial levels should not exceed:	* method used to calculate bacterial levels for each beach	Posting Criteria
Michigan	Monroe County Health Department (Wayne County Health Department monitors beaches within Detroit River RAP)	May use either *E. coli* or Fecal coliforms; Fecal coliform data received from Monroe County Health Department; E.coli in process of becoming the standard;	Total Body contact=130 *E. coli* / 100 ml of water; Max *E. coli*=300 *E. coli*/100 ml water Adequate disinfection=200 fecal coliforms / 100 ml of water; Max Fecal coliform=400 fecal coliform/100ml water; (complete Michigan DEQ guidelines found in Rule 323.I062, Micro-organisms, known as Rule 62)	*E. coli* = geometric mean of all samples taken during 5 or more sampling events (min. 3 samples/event) representatively spread over a 30 day period; Max allowable E.coli = geometric mean of min. 3 samples in 1 event; Fecal coliforms and max = same as above;	a) when exceedance occurs; b) re-opened when re-sampling indicates no exceedances
Ohio	Ohio Dept. of Health: Lake, Ashtabula, Lorain, Erie, Lucas, Ottawa, Cleveland, and Cuyahoga County Health Depts; N.E. Ohio Regional Sewer District; Ohio Dept. of Natural Resources for State Parks	- *E. coli* used in 1996 - before 1996: Either *E. coli* or fecal coliforms depending on entity performing sample. (U.S. EPA also did selected sampling studies in Lorain County (Black River AOC^{+}) using fecal coliforms counts)	- geometric mean based on not less than 5 samples within a 30-day period shall not exceed 126 *E. coli* / 100 ml of water; and - shall not exceed 235 *E. coli* / 100 ml of water in more than 10% of all samples taken during any 30-day period. -geometric mean based on not less than 5 samples within a 30-day period shall not exceed 200 fecal coliforms / 100 ml of water; and -shall not exceed 400 fecal coliforms / 100 ml in more than 10% of all samples taken during any 30-day period.	-Geometric mean of at least 5 samples taken within 30 day period; -Cuyahoga: geometric mean of 5 most recent samples, regardless of time period; - max: shall not exceed max value in more than 10% of samples over the 30 day period; - Erie County different: has a rating system based on a weekly bacteria count.	bacterial levels exceedances; As per EPA; Except for Erie County = 3 "poor" ratings in 3 weeks results in an advisory; Some counties have advisories after a heavy rain, based on historical evidence;
Pennsylvania	Erie County Department of Health, PA Department of Conservation and Natural Resources, Presque Isle State Park.	Fecal coliforms;	200 fecal coliforms/100 ml of water on a 30-day running geometric mean (minimum of 5 consecutive samples) no one sample over 1,000 fecal coliforms / 100 ml water	sample twice weekly; a series of comprehensive beach survey studies have also been conducted, and sampling occurs more frequently for the purposes of these surveys; also precautionary sampling occurs when visual inspection indicates a substance or material is present in the bathing water that may be hazardous to human health.	1) When exceedances occur, signs posted, guards on duty, proper announcements to public 2) predictive closures occur based on historical evidence; after heavy rains; during high winds;

U.S. States	Who monitors?	Indicator Organism used	Guideline: bacterial levels should not exceed:	* method used to calculate bacterial levels for each beach	Posting Criteria
New York	Chautauqua County Health Department; Erie County Health Department	Fecal coliforms	200 fecal coliforms/ 100 ml of water; 2,400 total coliforms/ 100 ml water; 20 fecal strep/ 100 ml water;	Sample according to "New York Sanitary Code for Bathing Beaches" (NYS Dept of Health): a logarithmic mean of 2,400 total coliform/100 ml for 5 or more consecutive samples in any 30 day period; Chautauqua County: frequency of monitoring varies among beaches; weekly, biweekly, or monthly, depending upon attendance; Wright Park beach monitored more frequently because problematic; Erie County: samples monthly;	When exceedances, signs posted, advisories issued by TV, radio, newspaper;
U.S. EPA Federal Guidelines		*E. coli*	200 *E. coli* / 100 ml of water		
*Each State has detailed guidelines for measurement of bacterial levels and posting of beaches. The basic information is listed in this summary. References for the detailed guidelines are listed in Section 12.12. +AOC (Area of Concern)					

12.6 Summary of Exceedances

12.6.1 Method of Data collection

Data was requested from Ontario Public Health units, State Departments (of Health or Natural Resources), and the Ontario Ministry of Environment and Energy (information received is listed in Section 12.12). Requests for existing data included:

- a beach pollution survey or similar report, either historical, or done at the beginning of the bathing season, to include information on potential sources of contamination impacting on the bathing beach area;
- indicator organism data (*E. coli* or fecal coliforms, depending on jurisdiction);
- beach postings data;
- any additional information on beach conditions on the day of monitoring (rain, winds, temperature, visibility, etc.)
- a map identifying beach locations (maps of individual beach locations within Health Units along the Canadian shoreline available upon request)

12.6.2 Method of Analysis

A list of the number of recreational water quality guideline exceedances, the total number of samples and the frequency of guideline exceedances by month and year for beaches along the Canadian shoreline can be obtained from the Health Canada authors of this report.

Appendix A graphs bacterial levels against their respective jurisdictional guideline. Regions vary as to how they arrive at mean daily bacterial levels values. Tables 12-1 and 12-2 summarize the methodology each region uses to arrive at their bacterial levels values. For graphing purposes, to compare bacterial levels between regions using the same indicator organism, raw data was used wherever possible, and the geometric mean of all raw samples for one single sample day were plotted against the jurisdictional guideline. The Ohio graphs entitled 'Geometric Means of Fecal Coliform in Ohio Beaches, Lake Erie' and 'Geometric Mean of Fecal Coliform levels in Private Beaches, Cuyahoga County (Ohio)' reflect the geometric means of the last five weekly sample days within a 30 day period (with the exception of Cuyahoga County, which reflects the geometric mean of the last five weekly sample days).

For regions where there was not enough raw data to plot graphs, summary information was used to assess whether or not exceedances of the jurisdictional guideline were occurring. This summary information is reflected in Tables 12-3 and 12-4. Table 12-5 presents a summary of the bacterial level exceedances. Table 12-6 provides a comparison of beach closures for beaches at Presque Isle Bay State Park.

A database from the Ontario Ministry of Environment and Energy (OMEE, 1995) identifies total annual beach postings for public beaches on the Canadian shoreline of Lake Erie. These numbers are summarized in Figures 1, 2 and 3. Permanent beach postings are not reflected as postings in the OMEE database. However, these beaches are still monitored for bacterial levels. Bacterial level data for these beaches is graphed in Appendix A, and/or can be obtained from the individual health units/agencies who monitor the beaches.

Numerous databases exist that report on the quality of open/offshore waters. As one example, the Northeast Ohio Regional Sewer District monitors for a range of contaminants, including bacteriological water quality at selected offshore sites in the Central Basin of Lake Erie. Table 12-7 summarizes fecal coliform and *E. coli* data from three of these offshore sampling sites, for the period 1990 to 1998.

12.6.3 Exceedances

Tables 12-3 and 12-4 give an overview of bacterial levels exceedances, beach postings, and potential sources of microbiological contamination by region for Lake Erie beaches. Appendix A graphs bacterial levels by region and by beach for Ontario beaches, for New York State's Chautauqua County, and for Michigan beaches along Lake Erie. For Ohio, fecal coliform data were graphed by county, and also by beach for some of the public and private beaches in Cuyahoga County.

Bacterial level exceedances of respective jurisdictional guidelines occurred in all basins of Lake Erie. Some beaches, particularly in the Western and Central basins, had exceedances for upwards of 40% of their measurements per year. Other beaches had only a few or no exceedances per year. There were very few beaches that were closed permanently, as indicated in Tables 12-3 and 12-4.

Table 12-7, which summarizes bacterial levels data for three offshore sites in the Lake Erie Central Basin, is an example of the very low bacterial levels seen in open waters. No exceedances of the bacterial guidelines were found for these locations.

- The bacterial level data available for this assessment seem to indicate the following (observation only, no statistical analysis):

- For the Canadian shoreline when exceedances occur, the Western basin (Windsor-Essex region) and Central basin (Elgin - St.Thomas region) appear to have higher *E. coli* values, sometimes exceeding 600 *E. coli*/100ml water. As one moves into the Eastern basin, the level of *E. coli* values appears to diminish, often not rising above 200-300 *E. coli*/100ml water. These are still exceedances of the jurisdictional bacteria criteria, but are not as high. Some of the Haldimand-Norfolk beaches (easterly portion of Central basin) and some Niagara beaches (Eastern basin) have no exceedances at all.

- The US shoreline summary reports, as well as detailed fecal coliform data from Michigan, Ohio and New York, confirm that exceedances of the jurisdictional guideline are occurring in all regions (Table 12-4). In most cases, the reports identified that actions are taking place to remediate key sources of microbiological contamination. While it is possible that these actions have resulted in a lower number of exceedances in 1995 and 1996, it is doubtful that the limited data presented in this report are sufficient to conclude that such trends are occurring. This is especially true given the inconsistency in sampling methods and the inherent variability of bacterial levels in surface waters.

- Most Canadian beaches and many U.S. beaches in each of the Western, Central, and Eastern basins of Lake Erie, had at least one or more beach postings per year between

1992 and 1994. To understand any trend in bacterial level exceedances, a closer look must be taken of the local sources of microbiological contamination and the extent to which they may be contributing to elevated bacterial levels. These can be found in Section 12.4.1.

- Remediation activities to improve recreational water quality are occurring throughout the Lake Erie basin. For example, in the Cuyahoga Area of Concern (Ohio), the first phase of a master plan for combined sewer overflow reduction was released in 1994 and is entitled the *Northeast Ohio Regional Sewer District Areawide, CSO Facilities Plan, Phase 1 Study*. Upstream from the AOC, the city of Akron is working to eliminate a large portion of its sanitary sewer overflows. The Northeast Ohio Regional Sewer District has retrofitted some of the CSOs near city beaches, which has improved water quality. The Cuyahoga County Board of Health requires that septic tank owners apply for a permit, permitting thorough inspection of the county's 16,500 septic systems. This will permit faulty septic systems to be identified and remediated (adapted from Great Lakes United Newsletter, Winter 1995-96, p. 13).

Table 12-3. Bacterial Levels Exceedances in Recreational Waters along Lake Erie: Public Beaches, Canadian shoreline

Location	# beaches	*E. coli* guideline exceeded?	Extent of Exceedance	Sources/Comments	Beaches posted?
Western Basin					
Windsor-Essex region	7 (all graphed)	yes in 1992 to 1996;	up to 45% of measurements exceeded guideline; exceedances up to 600 *E. coli*/100ml water; lower counts in June, higher counts in July/August; see Appendix A graphs for details;	*E. coli* exceedances best correlated with high winds; visual evidence of combined sewer discharge/ overflow from Metro Detroit following heavy rain storms; strong winds that day; heavy rain previous day; cloudy water; "blobs" in the water; concern that a combination of a sandbar and low water level were causing an elevated *E. coli* count (Kingsville);	yes in 1995, 1994; no in 1993, 1992;
Central Basin					
Kent-Chatham region	14 (all graphed)	yes, in 1992 to 1995	Up to 27% of measurements exceeded guideline; exceedances between 400 and 600 *E. coli*/100ml water; few exceedances in 1994;	Rough wave action/turbulence; turbidity, debris; high winds; drain runoff onto beach; recent moderate/ heavy rain; stream water running into beach; seagulls; Two beaches are in Wheatley Harbour AOC;	No; permanently posted advice signs
Elgin - St.Thomas region	6 (all graphed)	yes in 1995 & 1996; no data available for 1992-94;	all beaches, up to 45% of all measurements exceeded guideline; exceedances up to between 400 and 600 *E. coli*/100ml water	*E. coli* exceedances; combined sewer overflows following heavy rain storms; large gull population (Port Stanley Main); concerns that dredging might be disturbing bacteria (Port Stanley Little Beach), but testing by Ontario Ministry of Environment and Energy did not demonstrate this; agricultural operations, private sewage systems and sewage effluent discharges are present in the region, but no evidence to indicate that they are contributing to bacterial loading of the Lake.	yes in 1995, for 2 of 6 beaches (32 days total)
Eastern Basin					
Haldimand-Norfolk region Haldimand-Norfolk region	37 (all graphed)	yes in 1992 to 1996	About 75% of beaches; up to 24% of all measurements exceeded guideline; Exceedances do not tend to exceed 300 *E. coli*/100ml; Turkey Point and Port Ryerse posted once each in 1994 due to exceedances; Inkerman has constant exceedances, but is no longer sampled because no longer considered a public beach; the Lynn River at Port Dover had consistent	No major pollution sources identified, except for: Combined sanitary and storm sewers that overflow after a heavy rain (Port Dover), presently being rectified, in the process of separating the 2 systems; droppings from Cliff swallows nesting last week of June and first week of July (Sandhills); some speculation that Big Otter Creek may contribute to *E. coli* levels at Port Burwell beaches (Sandhills), but not confirmed; other beaches rurally located, with no major industry or livestock operations within vicinity; Other: private system overflow; raw sewage plume; possibly agricultural runoff in specific situations; will not sample in rough water (waves over 3 feet);	yes (Sandhills last week of June and first week of July); most others remain "open" for the season;

(continued)			exceedances or borderline, but no postings;		
Niagara region	36 (all graphed)	yes in 1992 to 1995	15% of all measurements exceeded guideline; usually only up to 250 *E. coli*/100ml water	trouble spots are Sherkston Elco, Sherkston Quarry, Sherkston Wyldewood- overpopulation resulting in sewage treatment problems - trying to correct;	yes

Table 12-4. Bacterial Levels Exceedances in Recreational Waters along Lake Erie: Public Beaches, U.S. shoreline

Location	# beaches	Guideline exceeded?	Extent of Exceedance	Sources/Comments	Beaches posted?
Western Basin					
Michigan					
Monroe County	2 official beaches; 2 private beaches;	yes for 1993, 1994, 1995;	Each public beach posted once in 1995; Sterling State Park had exceedances several times in 1993;	1993 Sterling State Park: possibly due to increased number of geese at Park; all postings due to fecal coliform exceedances;	Yes, 1993, 1994, 1995. Posted "Closed".
Wayne County	4		no beach postings for 1992-95	within Detroit River Binational RAP.	None, 1992-95
Ohio					
Lucas County	2	yes in 1992, 1994, 1995; no in 1993 & 1996	Normally, water quality quite good; 1995 had more than normal exceedances due to hot, dry summer; this trend is not expected to continue;	Sources: some relation between fecal coliforms and rainfall; stormwater runoff; waterfowl; swimmers; sediment suspension from wave/swimmer action; septic tanks; sewage treatment plants; combined sewer overflows and treatment plant bypasses; substantial improvements have been made to wastewater treatment;	yes in 1992, 1993, 1995
Ottawa County	10	yes in 1995 & 1996; no in 1994	frequent, consistent exceedances in 1995, but not in 1996.		yes in 1992, 1993, 1994;

Location	# beaches	Guideline exceeded?	Extent of Exceedance	Sources/Comments	Beaches posted?
Central Basin					
Ohio (*For most counties, posting duration tended to last one week, since sampling only occurred once/week*)					
Lorain County	4	yes in 1993-1996; no in 1992	exceedances very infrequent at Century Beach, more frequent at Avon Lake & Lakeview Park; bacterial levels considered generally low.	AOC lists nearshore as occasionally impaired; recent heavy rains, sewer overflows, wash off from pet waste, farm animals, wildlife, faulty septic tank discharges; in 1994, discharge of raw sewage from Lorain Wastewater Treatment Plant, after lightning struck a power transformer; 3 homes had sanitary sewers mistakenly connected to storm water drainage lines - immediately fixed; stirred up sediment (bacteria reside in the sediment);(Black River Rap, Dec.5/95)	advisories issued in 1994; predictive advisories issued after heavy rains.
Cuyahoga County					
Bay Village	3	no for 1993,1994,1995; yes in 1996	infrequent exceedances only at Huntington.	storm water runoff measured at Columbia Road Park Beach had frequent bacterial levels exceedances, but not the bathing beach water itself	no
Cleveland City	2	yes in 1992, 1993, 1994; no in 1995 & 1996.	Frequent exceedances in 1992, up to 500 fecal coliforms/100 ml water; less frequent and less severe in 1993 and 1994;	recent heavy rains; other sources not specifically listed, but likely consistent with Cuyahoga County;	yes in 1992, 1993, 1994;
Euclid	7	yes for 1993,1994,1995, 1996	some exceedances at most beaches		no data
Rocky River	2	no in 1993, 1994, 1995, 1996.			
Ashtabula County	5	yes in 1996; no in 1995; yes in previous years, but minor; also for Strong Brook location on Lower Ashtabula River (not beaches, but used occasionally for recreation;)	recreational water not considered impaired by Ashtabula AOC; water quality considered quite good; some exceedances at one beach and also in areas that are not beaches, but may be used for recreation occasionally;	Fecal coliform levels were also relatively good in Lower Ashtabula River, except for Strong Brook location; may be related to sewage discharge, in which case corrective action will be taken;	Yes in 1992, 1994, no in 1993; Lower Ashtabula River not a beach; therefore no postings;
Lake County	6	yes for 1992, 1993, 1994,	exceedances very infrequent in 1993 - 1996, and not much	recent heavy rains; other sources not specifically listed, but likely consistent with Cuyahoga County;	yes in 1992, 1993, 1994;

		1995, 1996	above guideline; more frequent in 1992, and up to 570 fecal coliforms/100ml water	but likely consistent with Cuyahoga County;	

Location	# beaches	Guideline exceeded?	Extent of Exceedance	Sources/Comments	Beaches posted?
Erie County	4	yes in 1992, no in 1993	exceedances very infrequent; not much above guideline; specific data was not available for 1994; focus was placed on monitoring streams that enter Lake Erie	recent heavy rains; other sources not specifically listed, but likely consistent with Cuyahoga County;	yes in 1992, no in 1993, 1994;
Pennsylvania					
Presque Isle / Erie County	29	yes in 1992 - 1996	exceedances not frequent; up to 10% of measurements;	CSO's, sewage treatment plant discharges, waterfowl, stirred up sediment, inputs from streams, creeks; heavy rains; remediation work going on to reduce exceedances;	yes, in 1994 and earlier years
Eastern Basin					
New York *(Info now being collected via annual "Testing the Waters" surveys; should improve data collection)*					
Chautauqua County	15	yes in 1992, 1993, 1994 and 1995	1 closure, Wright Park Beach, for 63 days from July 3/95 to end of season; criteria exceeded 105 times in 1994, 117 times in 1993, 33 times in 1992;	For 1995, elevated bacteria levels, undetermined sources; for other years: raw sewage from surface run-off and/or sewage discharges from sewage treatment plants; Lake Erie State Park closed due to insufficient funds;	posted once in 1995 (63 days), twice in 1993 (5 days and 10 days); none in 1992 or 1994, even though criteria were exceeded;
Erie County Erie County (NY) continued	6 public beaches (including one new one in 1994- Lake Erie Beach); including one beach that closed in 1994-95 due to budgetary problems (Buffalo Beach); 30 miles of public and 8 miles of	yes in 1992(Evans, Buffalo and Wendt) yes in 1993 (Evans, Hamburg), yes in 1994 (Lake Erie Beach).	Lake Erie Beach had exceedances a number of times after a rainfall; exceedances were few for the other beaches	beach closure required after any rainfall exceeding 1/4 inch per day due to historical evidence of bacterial exceedances; bacterial problem at Lake Erie beach occurred after rainfalls, attributed to creek adjacent to Beach (Lake Erie Beach Creek)	no in 1992-93, yes in 1994 for Lake Erie Beach

	private beaches				

Table 12-5. Percentage of bacterial exceedances per year for Lake Erie beaches ** see comments below

Year	Bacterial indicator	Region	# beaches surveyed	# days measured	# days with exceedances	% exceedances
1992	*E. coli*	Windsor-Essex	5	65	21	32%
		Kent-Chatham	14	164	49	30%
		Elgin-St. Thomas	data not available			
		Haldimand-Norfolk	18	144	23	16%
		Niagara	36	463	67	14%
	Fecal coliform	Michigan	1	2	0	0%
		Ohio	21	196	67	34%
		Pennsylvania	data not available (see table below)			
		New York	16	81	18	22%
1993	*E. coli*	Windsor-Essex	5	60	26	43%
		Kent-Chatham	14	155	44	28%
		Elgin-St. Thomas	data not available			
		Haldimand-Norfolk	26	230	29	13%
		Niagara	28	323	65	20%
	Fecal coliform	Michigan	data not available			
		Ohio	27	237	21	9%
		Pennsylvania	data not available (see table below)			
		New York	8	94	36	38%
1994	*E. coli*	Windsor-Essex	7	102	47	46%
		Kent-Chatham	13	77	9	12%
		Elgin-St. Thomas	data not available			
		Haldimand-Norfolk	25	291	73	25%
		Niagara	23	302	50	17%
	Fecal coliform	Michigan	1	13	2	15%
		Ohio	28	245	30	12%
		Pennsylvania	data not available (see table below)			
		New York	8	59	39	66%
1995	*E. coli*	Windsor-Essex	7	84	24	29%
		Kent-Chatham	14	133	41	31%
		Haldimand-Norfolk	37	430	89	21%
		Niagara	33	376	67	18%
	Fecal coliform	Michigan	4	64	25	39%
		Ohio	44	416	74	18%
		Pennsylvania	data not available (see table below)			
1996	*E. coli*	Windsor-Essex	7	77	22	29%
		Kent-Chatham	data not available			
		Elgin-St. Thomas	7	76	19	25%
		Haldimand-Norfolk	37	415	95	23%
		Niagara	data not available			
		Ohio	32	344	22	6%
	Fecal coliform	Michigan	data not available			
		Pennsylvania	data not available (see table below)			
		Ohio	12	67	6	9%
		New York	data not available			

days measured = each measurement represents a geometric mean.
days with exceedances = each exceedance represents a geometric mean that was above the specified guideline.

The beaches surveyed that are included in this table can be found in Appendix A of the full report.

Presentation of the data above is not representative of "the whole picture". There are several limitations in presenting the data summarized, as above.

1) Measurements within each region are relatively (but not always) consistent. However measurements between regions may not be consistent due to sampling variability and number of beaches sampled.
2) Any geographic or seasonal patterns that may have emerged during a particular period of time are not depicted. For example, the frequency of exceedances (spread throughout the season, or concentrated in one or two weeks) cannot be displayed. More specific beach and trend data are available in Tables 12-3 and 12-4, and Appendix A.
3) The amount by which a bacterial level surpasses the guideline cannot be displayed above. Therefore, a guideline exceedance of one or two units is considered equivalent to an exceedance of 100 units.
4) There are limitations associated with using *E. coli* and fecal coliforms as indicator organisms, and in the interpretation of the data itself. Please see Sections 12.7 & 12.10.

Table 12-6. Presque Isle State Park - A Comparison of Beach Closures

Year	Total # days beaches closed due to:			Potential beach days++	# Incidents due to coliform+++	# Incidents due to Precaution +++
	high coliform*	high geo mean**	Precaution+			
1992	**14**	**19**	**0**	**1,944**	**12**	**0**
1993	**16**	**0**	**0**	**1,818**	**16**	**0**
1994	**7**	**0**	**0**	**1,818**	**4**	**0**
1995	**4**	**0**	**6**	**1,890**	**3**	**1**
1996	**2**	**0**	**4**	**1,890**	**1**	**1**
Data in this table is compiled from sampling results at 18 beaches within Presque Isle Bay State Park.						

* High coliform = daily sample greater than 1,000 / 100 ml
** High geometric mean = 30 day running geometric mean greater than 200 / ml
\+ Precaution = closing when conditions indicate that historically there may be unsafe swimming conditions. Samples are taken, and appropriate action performed depending upon results of the precautionary sampling.
++ Potential beach days = (days to swim) x (# beaches)
+++ The number of incidents = the actual number of events. One event may mean several beaches may be closed over several days.

Table 12-7. Northeast Ohio Regional Sewer District - Lake Erie Offshore Bacteriological Sampling Data

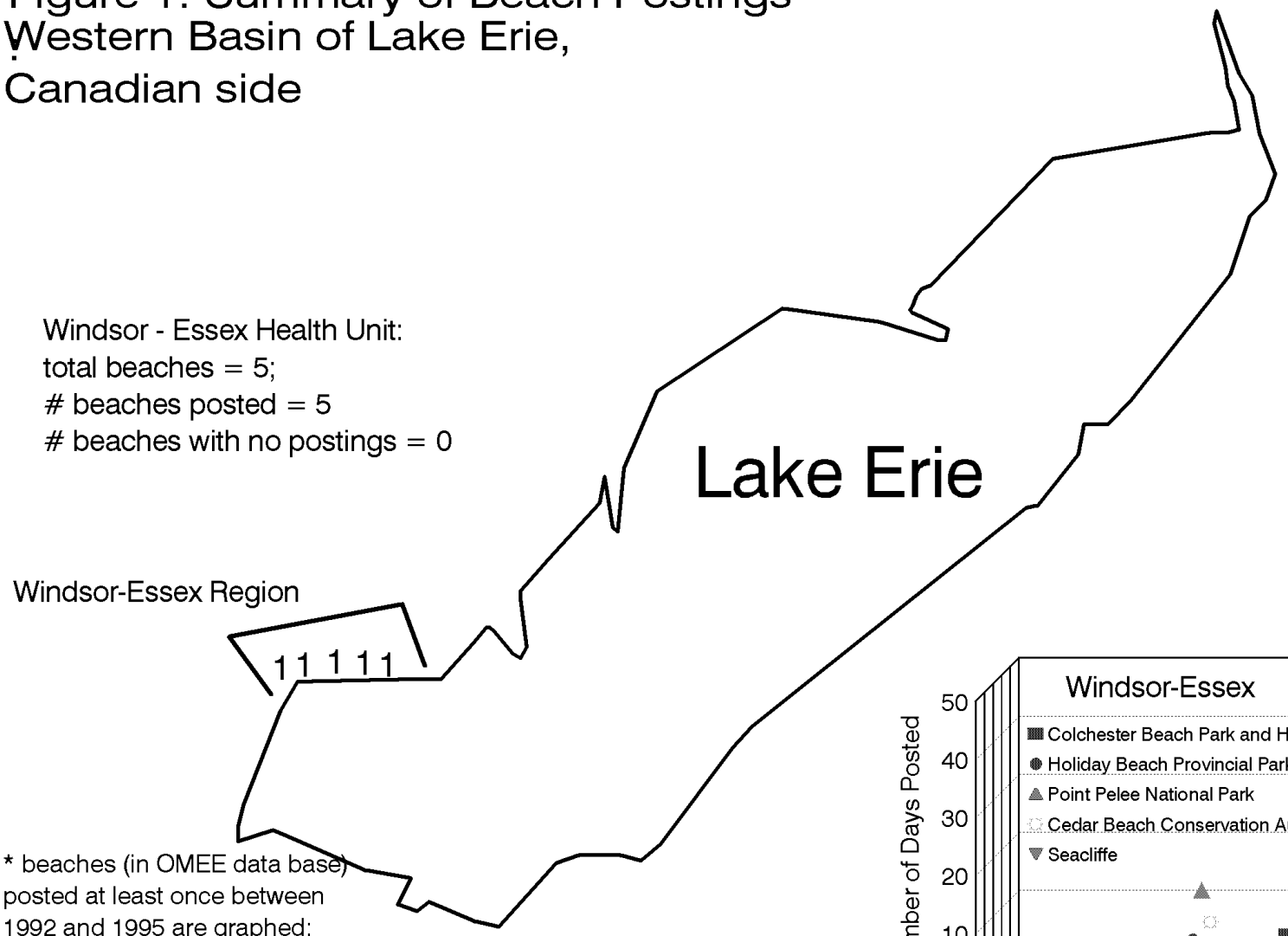
Sample Site Coordinates:	A 81E 52.80' N 41E 31.16' W		B 81E 45.00' N 41E 32.90' W		C 81E 37.05' N 41E 37.08' W	
Sample Dates	fecal coliform	*E. coli*	fecal coliform	*E. coli*	fecal coliform	*E. coli*
7/9/90	5	--	<5	--	<1	--
8/20/90	30	--	<2	--	<2	--
6/25/92	<1	<1	<1	<1	<1	<1
8/10/94	--	--	--	--	<4	<4
9/20/94	<2	<2	<5	<5	--	--
6/14/95	--	--	--	--	<4	--
8/29/95	<2	--	<2	--	--	--
8/28/97	<4	<4	2	<2	<2	<2
9/21/98	6	4	10	4	4	2

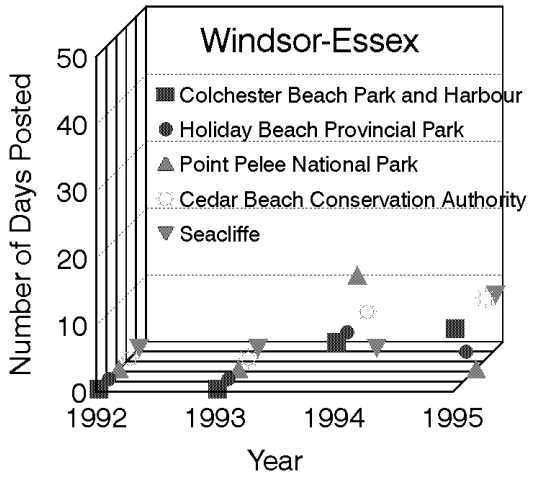
Notes:

- units in organisms per 100 ml
- no samples were collected from these sites for bacteriological analysis in 1991, 1993, and 1996.
- Lake Erie Sample site A is located near the Crown Water Intake, about 2.4 nautical miles offshore on a heading of 310 degrees northwest from the east side of the mouth of the Rocky River.
- Site B is located within 500 yards west of the Baldwin Water Intake Crib, approximately 3 nautical miles offshore on a heading of 323 degrees northwest of the mouth of the Cuyahoga River.
- Site C is located near the Nottingham Water Intake, about 2.6 nautical miles offshore on a heading of 315 degrees northwest of the mouth of Euclid Creek.
- Lake Erie samples were collected from boatside by direct immersion of the sample bottle below the water surface. Closed and labelled plastic containers were used to transport samples, on ice for preservation, to NEORSD Analytical Services. All bottles used to transport samples for bacteriological analysis had been sterilized prior to sampling. All samples were analyzed within 6 hours of collection using the standard membrane filtration methods prescribed by the USEPA.

Figure 1: Summary of Beach Postings*
Western Basin of Lake Erie, Canadian side

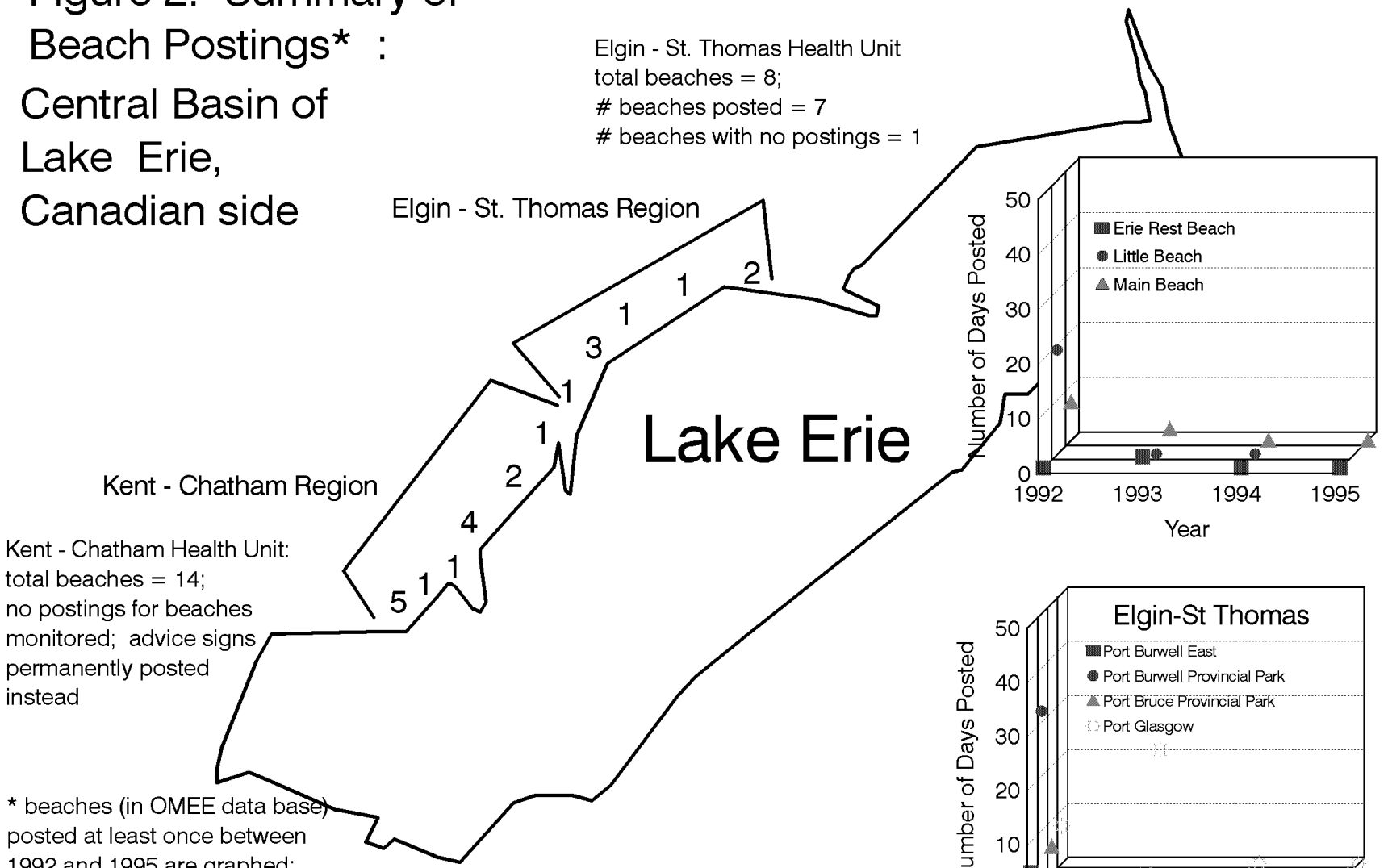
Windsor - Essex Health Unit:
total beaches = 5;
# beaches posted = 5
# beaches with no postings = 0





* beaches (in OMEE data base) posted at least once between 1992 and 1995 are graphed; beaches with no postings are not graphed. See text for further information on beaches with no postings

Figure 2: Summary of Beach Postings* : Central Basin of Lake Erie, Canadian side



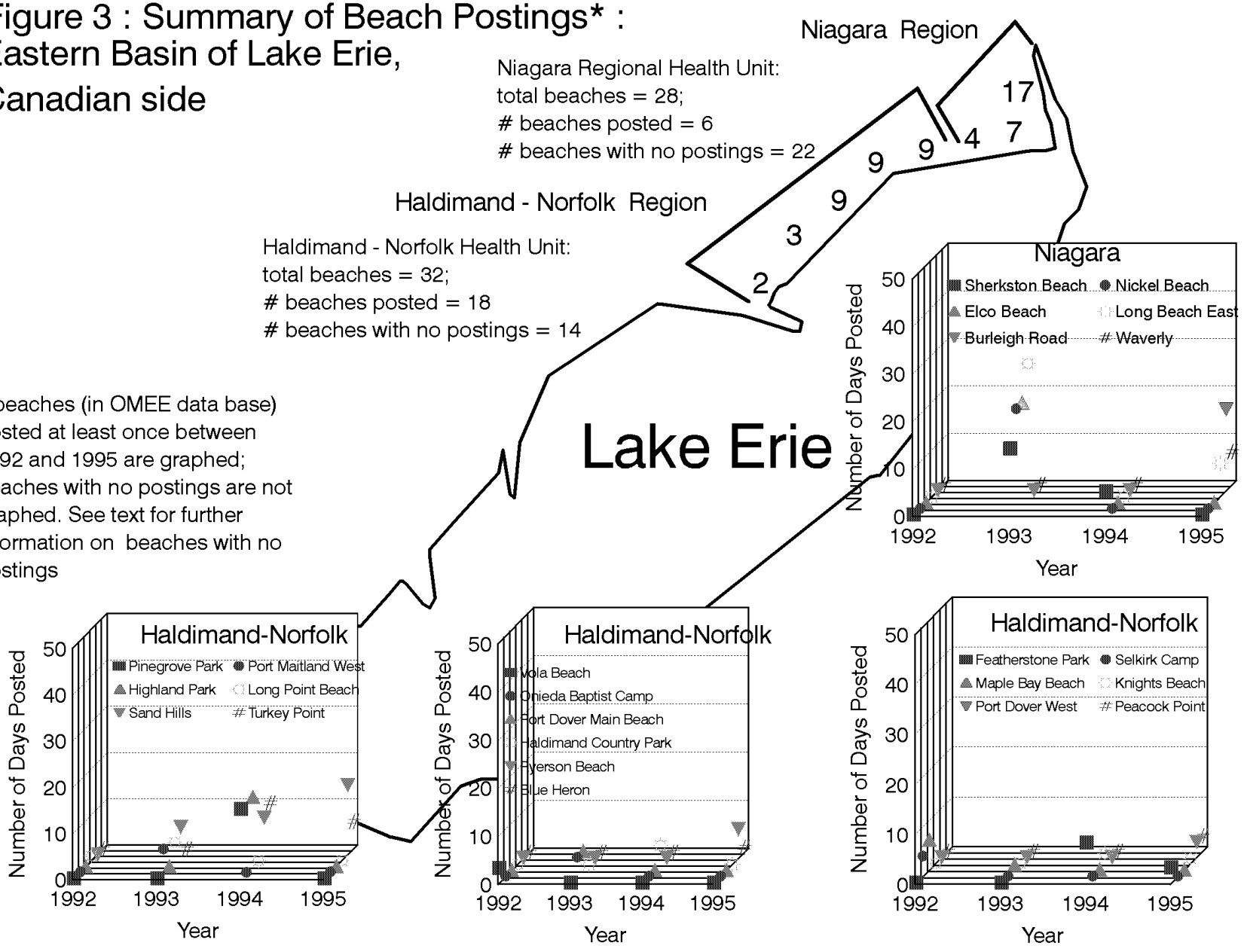
* beaches (in OMEE data base) posted at least once between 1992 and 1995 are graphed; beaches with no postings are not graphed. See text for further information on beaches with no postings

Figure 3 : Summary of Beach Postings* : Eastern Basin of Lake Erie, Canadian side

Niagara Regional Health Unit:
total beaches = 28;
# beaches posted = 6
# beaches with no postings = 22

Haldimand - Norfolk Health Unit:
total beaches = 32;
# beaches posted = 18
# beaches with no postings = 14

* beaches (in OMEE data base) posted at least once between 1992 and 1995 are graphed; beaches with no postings are not graphed. See text for further information on beaches with no postings



12.7 Limitations on the use of indicator organism data

Fecal coliforms and *E. coli* are both acceptable indicator organisms for assessing recreational water quality. However, they each have certain limitations:

- *E. coli* is better correlated with gastrointestinal illness than fecal coliforms (Robertson, 1993). Elevated fecal coliform counts do not always indicate a human health hazard. Fecal coliforms consist primarily of the organisms *E. coli* and *Klebsiella*. *Klebsiella*, present in pulp and paper mill effluents, can contaminate recreational waters, but is not considered to be a human health hazard in these waters (HWC, 1992). *Klebsiella* can sometimes be the predominant organism in a fecal coliform sample, causing an exceedance of the guideline and resulting in an unnecessary beach closure (Robertson, 1993). Some States (e.g. Ohio) and the Province of Ontario have switched to the use of *E. coli* as their indicator of choice.
- Neither *E. coli* nor fecal coliform testing differentiate between human or animal waste. This may pose a problem when the LaMP wants to identify sources.
- Neither fecal coliform counts nor *E. coli* counts measure levels of viruses, or non-fecal contaminants (e.g. *Staphylococcus*). Viruses and non-fecal contaminants are difficult to isolate and quantify at present (HWC, 1992), and feasible measurement techniques have yet to be developed.

12.8 Other Reasons for Beach Closures

There are other potential causes of recreational water quality impairment besides exceedances in bacterial levels. Bather illness or poisoning have been documented in Saskatoon (HWC, 1992) after immersion in lakes containing dense blooms of blue-green algae. Excessive growth of aquatic plants may cause entanglement and thereby constitute a hazard to recreational users. Extremes of alkaline and acidic waters could cause eye irritation. Recreational water should be clear enough so that swimmers can estimate depth and see subsurface hazards easily. In Ohio, other reasons cited included lack of lifeguards in one instance, and lightning in the area, requiring a temporary evacuation (Killinger unpublished report, 1995).

The beach monitoring reports filled in at the time of sampling are therefore helpful in identifying these other reasons for beach closures. As well, the annual or historical beach pollution surveys identify conditions with the potential to cause human health hazards.

12.9 Limitations on the Interpretation of Data

- Indicator organism data are limited, and therefore must be interpreted with caution. Measurements are generally taken only one to two times per week, and therefore only reflect the water quality for those days. If, for example, it rains every weekend, and samples are taken every Monday, there may be an exceedance of the guideline for every monitoring sample, even though the rest of the week is sunny and levels are likely to be within guidelines. Many beach monitoring protocols allow some flexibility for professional judgement as to when the beach is closed and re-opened (e.g. Ontario Ministry of Health, 1992).
- The monitoring criteria and the number of samples per month may have changed in some municipalities due to economic circumstances. Therefore, there is less data to work with, and therefore less statistical power to identify trends.
- Monitoring results take 24 hours or more to process. To protect health, beaches are often posted after heavy rainstorms, etc., until bacterial levels are confirmed. Conversely, beaches may not be posted until a series of consecutive samples demonstrates a continued exceedance of the guideline. A 1996 pilot study was conducted in Grand Bend, Ontario (Lake Huron basin), to test the efficacy of a new

sampling technique that provides results for fecal coliforms or *E. coli* in 6 hours or less (Palmateer *et al*, 1996). This rapid test yields accurate and timely results, allowing improved public health protection by prompt beach closures. This new technique, if adopted, will provide a more rapid evaluation of water quality so that Health Units can decide by early afternoon, before most people go swimming, if a beach should be closed.

- Bacterial levels data have been more difficult to obtain, especially electronic versions. Data must currently be obtained from each Health Unit, and has sometimes been in hard copy. Summary data were not available in some cases, and therefore there was a large amount of data that needed to be processed. This report includes the data summarized to date. Other data received will be included as it is processed.
- Historical data for *E. coli* counts in Ontario waters only goes back to 1992, because of the switch in monitoring from fecal coliform to *E. coli* from that year on. Therefore, Ontario data will only be considered from 1992 onward.
- "Indicator organism" counts can only be used at the individual beach level. Averaging bacterial counts to get a region-wide value would not give useful information on impairment.
- There may be subtle variations or regional differences in the collection methodology, or poor or variable reporting practices. Where and how each sample is taken is important in terms of a consistent or variable result.
- Indicator organisms only imply the relative chance that disease causing organisms may be present.

12.10 Data Gaps

To better assess this use impairment: a) a more comprehensive assessment of bacterial levels monitoring data could be considered for open recreational waters and embayments that are not necessarily public beaches, but are nevertheless used for total or partial body contact recreation, and b) bacterial levels data is needed for all private and unofficial beaches.

Beaches may not be sampled as often as protocol recommends, for economic reasons or otherwise. We may want to work with the Health Units to supplement the bacterial levels data, for the purpose of monitoring trends. We may want to work with the Health units who do not have a Beach Pollution Survey or related information to put one together. Dates and lengths of beach postings would be useful to have as well.

The information on microbial contaminant sources for beaches was provided by personal communication with each Health Unit based on historical information. Primary sources of microbial contamination need to be verified and documented for individual beaches to assist in the determination of which direction research, monitoring and remediation activities should take.

12.11 Future Analyses

Rain, wind, water temperature and bather load data would be useful for making correlations with bacterial levels. Historical data tend to correlate rainfall and wind with bacterial exceedances. Rain can cause combined sewers to overflow, causing an elevation of bacterial levels up to 48 hours after the rain event. High winds can increase wave action, which can suspend sands and result in elevated bacterial levels. Water temperature may play a role in bacterial growth. Possible future work by Health Canada includes collecting and graphing environmental data against bacterial levels exceedances.

Data on other contaminants in recreational water, such as viruses, parasites, and toxic chemicals, also need to be collected, but may be more difficult to obtain. Chemical contaminants such as polycyclic aromatic hydrocarbons (PAHs) are of concern for dermal (skin) exposure in recreational waters.

Unfortunately, a wealth of information is not available regarding adsorption (contaminants sticking to the skin, and the potential for skin rashes, etc.) or how much might be absorbed through the skin (and the potential to cause systemic effects). And finally, there is a need for unified sampling, reporting, and analytical methods.

A lifetime risk assessment from dermal exposure to PAHs in St. Marys River (ON) indicates that the lifetime health risk of skin cancer was well below the negligible risk range at inshore locations (Hussain et. al., 1995). However, some upstream sites had risk values higher than the negligible risk range and this may be cause for some concern. The report states that the risk can be significantly reduced, even to the point of becoming negligible, if recreational water use by the individual is modified (e.g. reducing the number of times the water is used, and/or showering soon thereafter). There are also human contact advisories issued by the Ohio Department of Health, for segments of the Black and Ottawa Rivers in Ohio. PAHs and PCBs, respectively, are responsible for these advisories. Due to elevated concentrations of these contaminants and their impact on the fish in these rivers, precautionary advisories against human contact were issued.

At present, the U.S. Geological Survey is investigating the importance of sediment-stored fecal coliforms and *E. coli* and the role of physical disturbances (i.e., wind, wave action, the swimmers themselves) on the recreational water-quality of nearshore zones of public bathing beaches of Lake Erie (Francy, 1996).

12.12 Making the link to health outcomes

Finally, more research is needed to correlate prevalence of waterborne illness with levels of bacterial contamination, a challenging task. Some preliminary reports have been written on this issue, and further research is ongoing to understand the relationship. For example, the US EPA has estimated that the use of an illness rate of 8 individuals per 1,000 swimmers for a geometric mean of 126 *E. coli* /100 ml water may be helpful in predicting the potential for waterborne illness as a result of bacterial contamination (D. Killinger, personal communication).

12.13 Impairment Conclusions

Bacterial levels exceedances are occurring throughout the Lake Erie basin. Therefore, it is recommended that Lake Erie basin nearshore recreational water quality be classified as impaired from a human health (i.e. bathing use) standpoint. The critical pollutant, defined as the cause of the beneficial use impairment discussed in this report, is microbiological contamination based on the *E. coli* and fecal coliform data reviewed.

Bacterial levels data examined in this assessment provide support for a conclusion that recreational use of Lake Erie offshore is unlikely to be impaired by bacteria. However, the Lake Erie LaMP has decided to classify the use impairment for recreationally used “open waters” as “inconclusive”, since a comprehensive assessment of the open waters data was not undertaken.

These conclusions are based on all sources of impairment, and are not dependent upon whether or not the sources can be remediated. Some remediation, such as separating combined sewers or building storm/sanitary sewer overflow tanks is expensive and therefore remediation is a long-term project. Other sources, such as seagulls and bather load may not be able to be remediated. It is recommended that a long-term plan be developed to identify the sources that can be remediated, the costs, and the time lines. Identification of sources is an important beginning to the remediation process. It should be noted that, although it may not be feasible to eliminate bacterial levels exceedances completely, much work has been done over the past number of years to remediate microbiological sources of contamination, and this is

likely a great contributor to the reduction of exceedances. As sources continue to be remediated, it is hypothesised that bacterial levels exceedances will continue to decline.

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Appendix A
Bacterial Levels Graphs

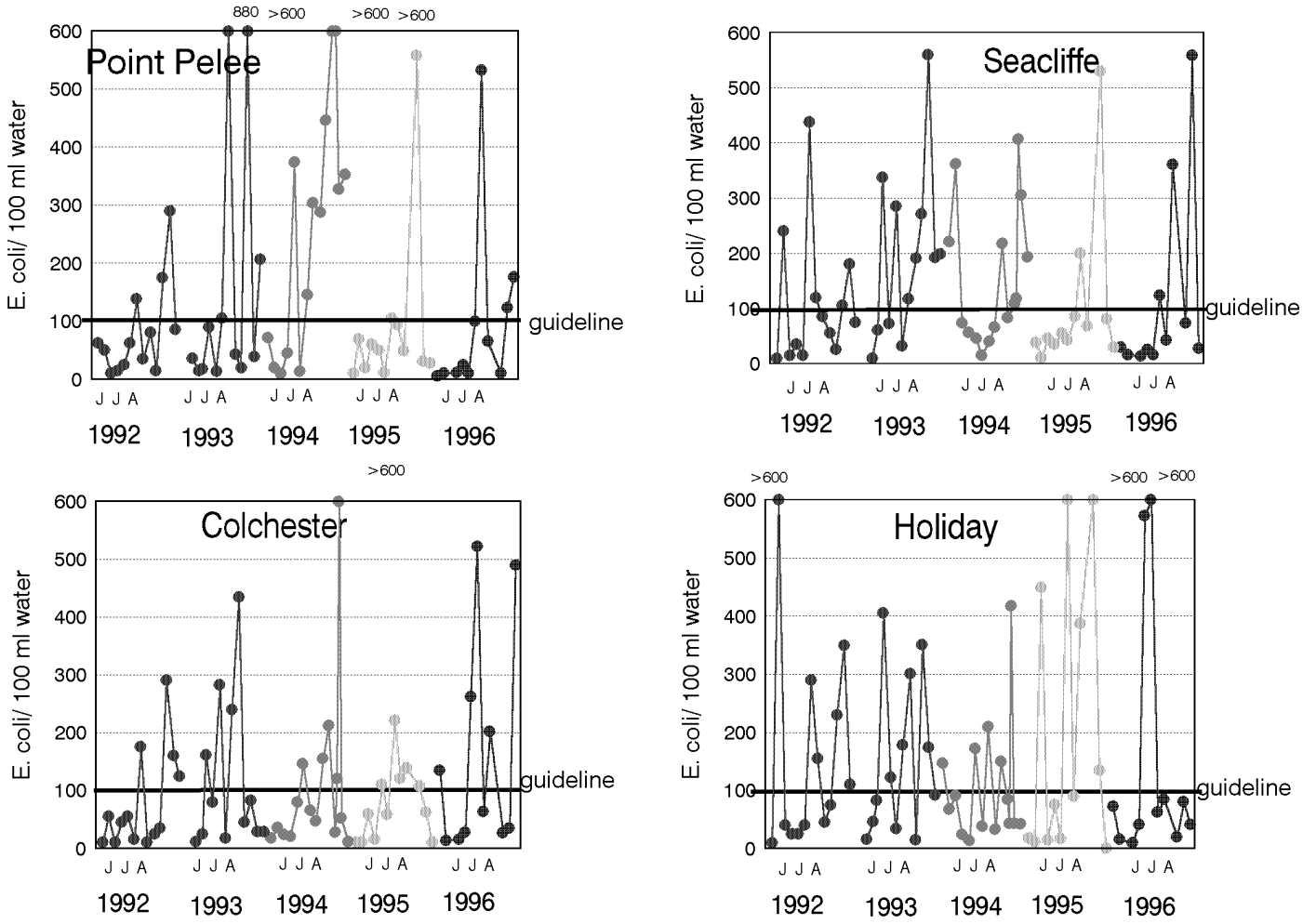

Figure 12-1: Geometric Mean of E. coli Levels in Windsor-Essex beaches, Lake Erie

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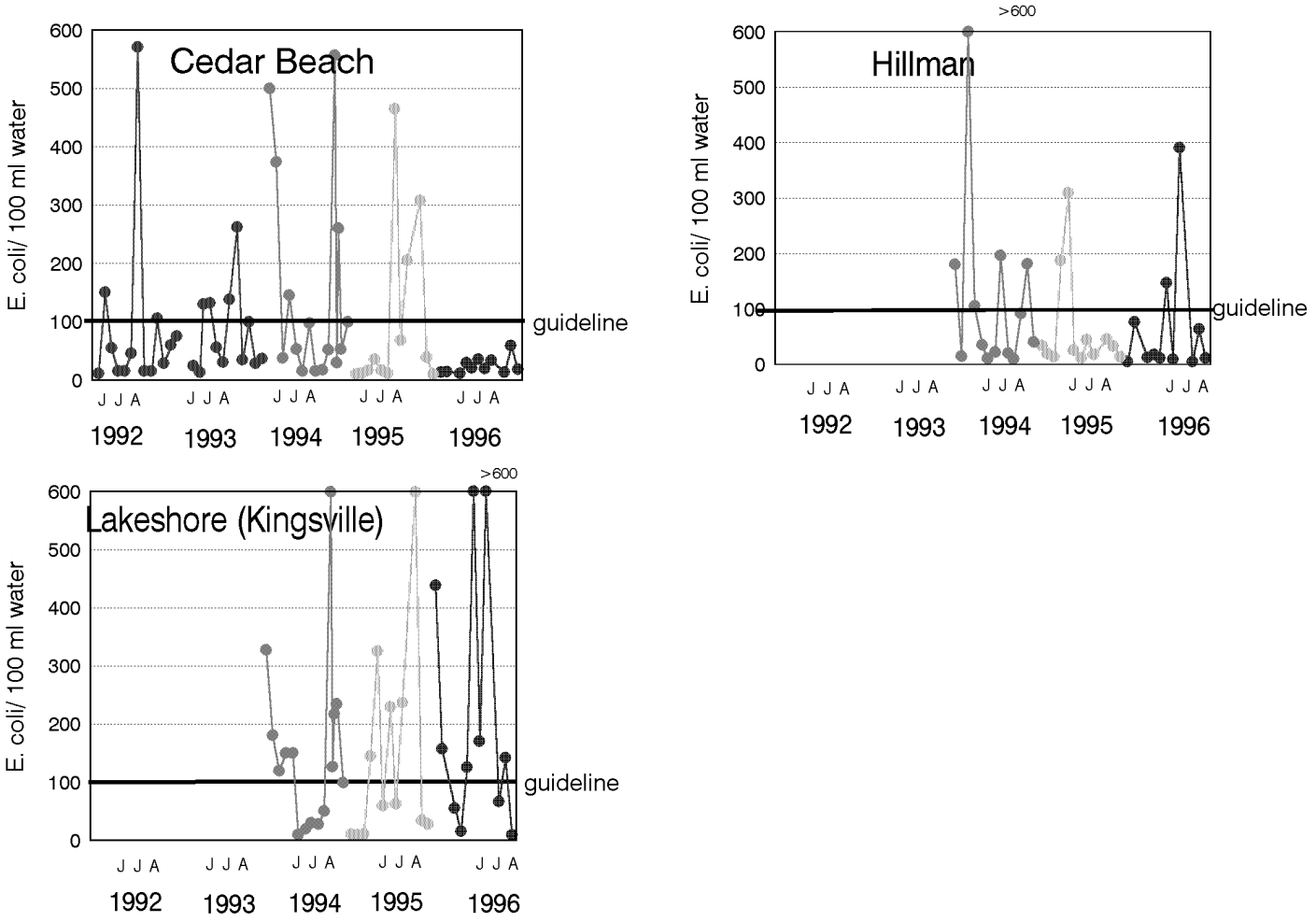

Figure 12-2: Geometric Mean of E. coli Levels in Windsor-Essex beaches, Lake Erie

c:\sberry\indicato\figures\new\windsor2.prs

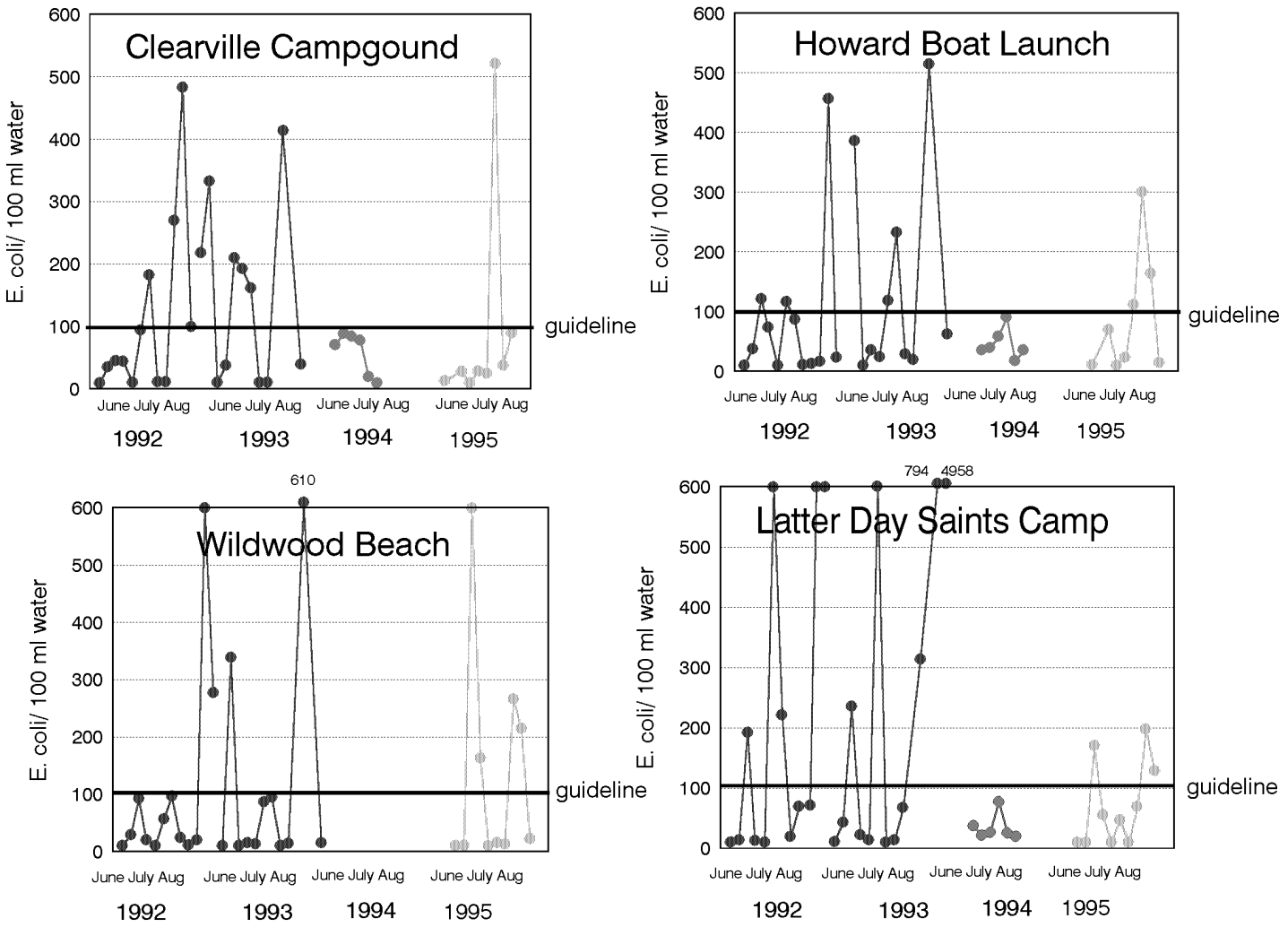

Figure 12-3: Geometric Mean of E. coli Levels in Kent-Chatham beaches, Lake Erie

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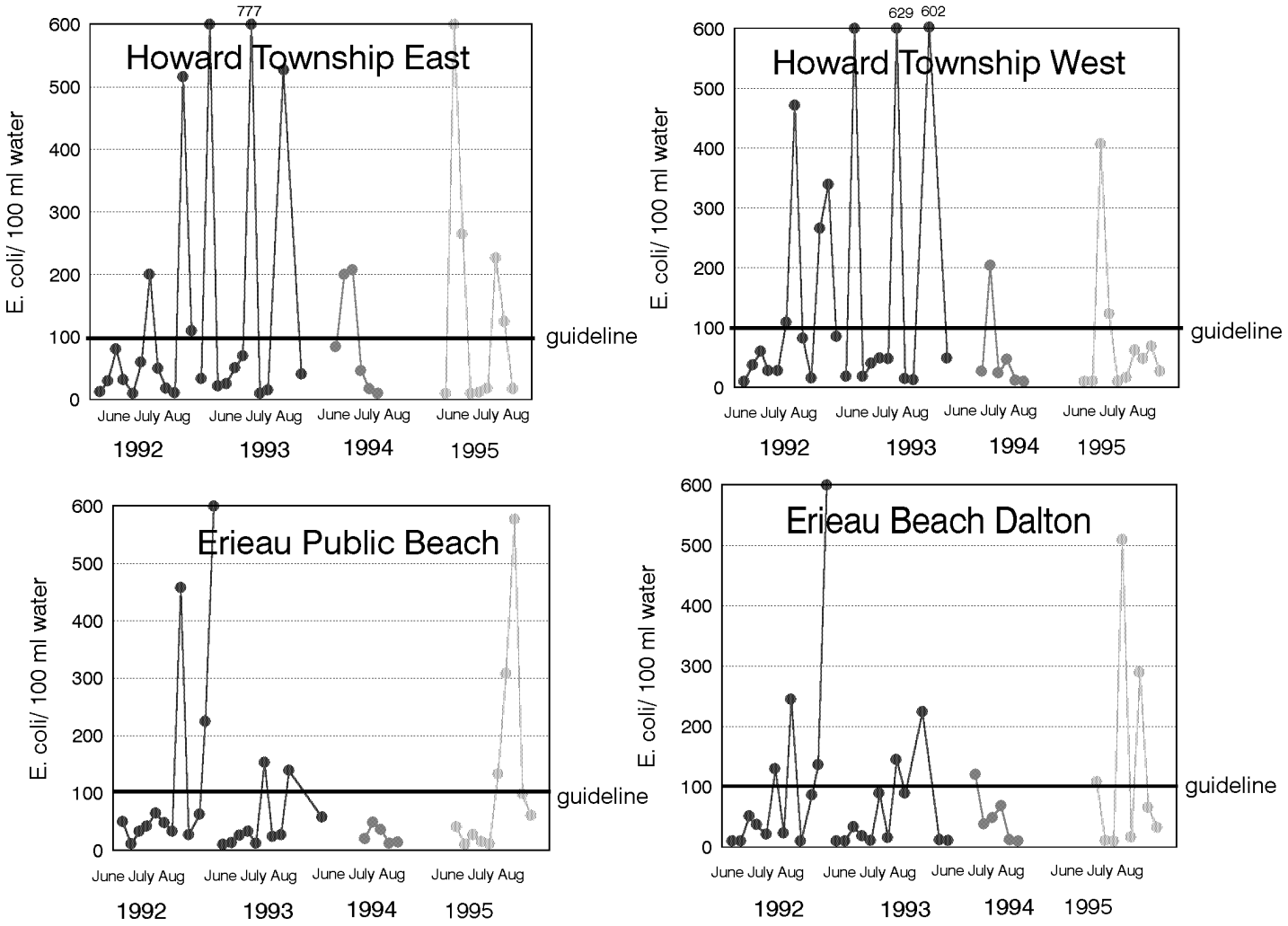

Figure 12-4: Geometric Mean of E. coli Levels in Kent-Chatham beaches, Lake Erie

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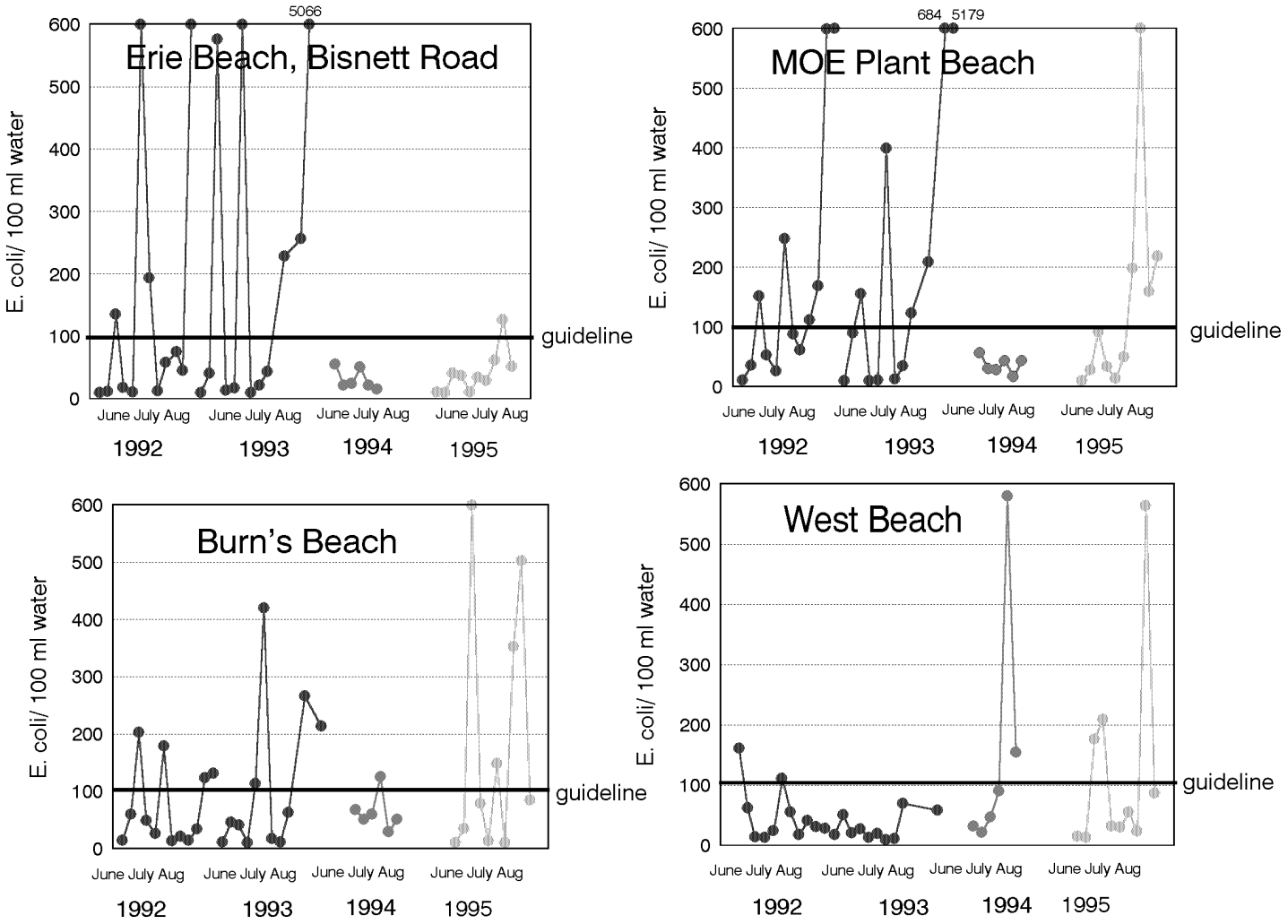

Figure 12-5: Geometric Mean of E. coli Levels in Kent-Chatham beaches, Lake Erie

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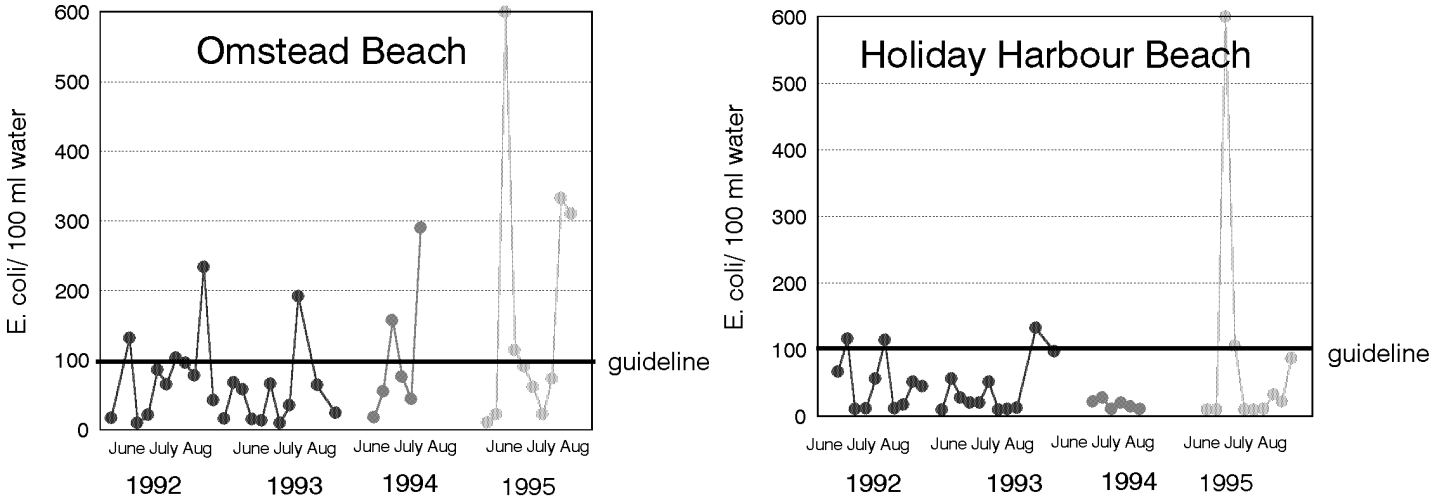

Figure 12-6: Geometric Mean of E. coli Levels in Kent-Chatham beaches, Lake Erie

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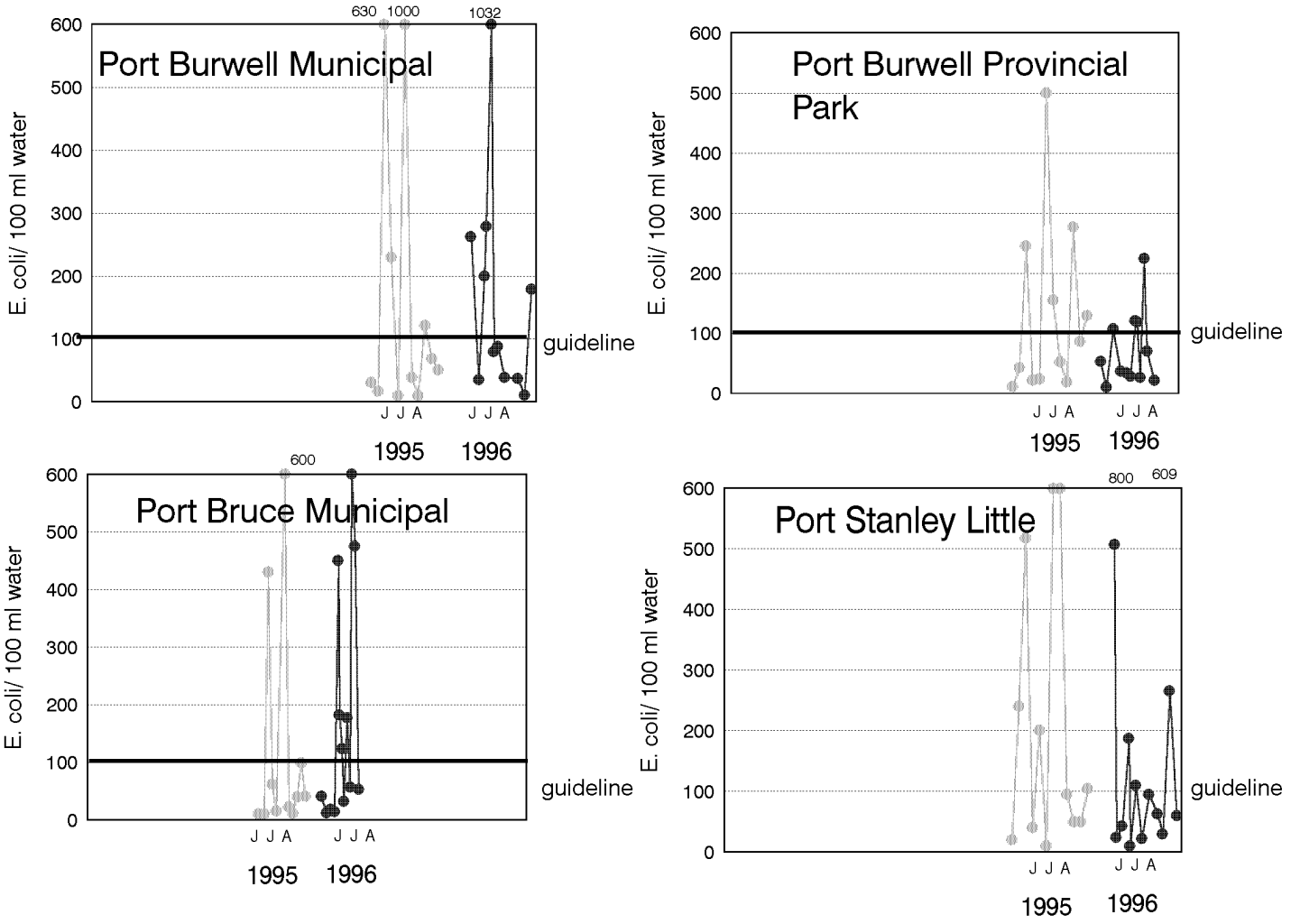

Figure 12-7: Geometric Mean of E. coli Levels in Elgin-St Thomas beaches, Lake Erie

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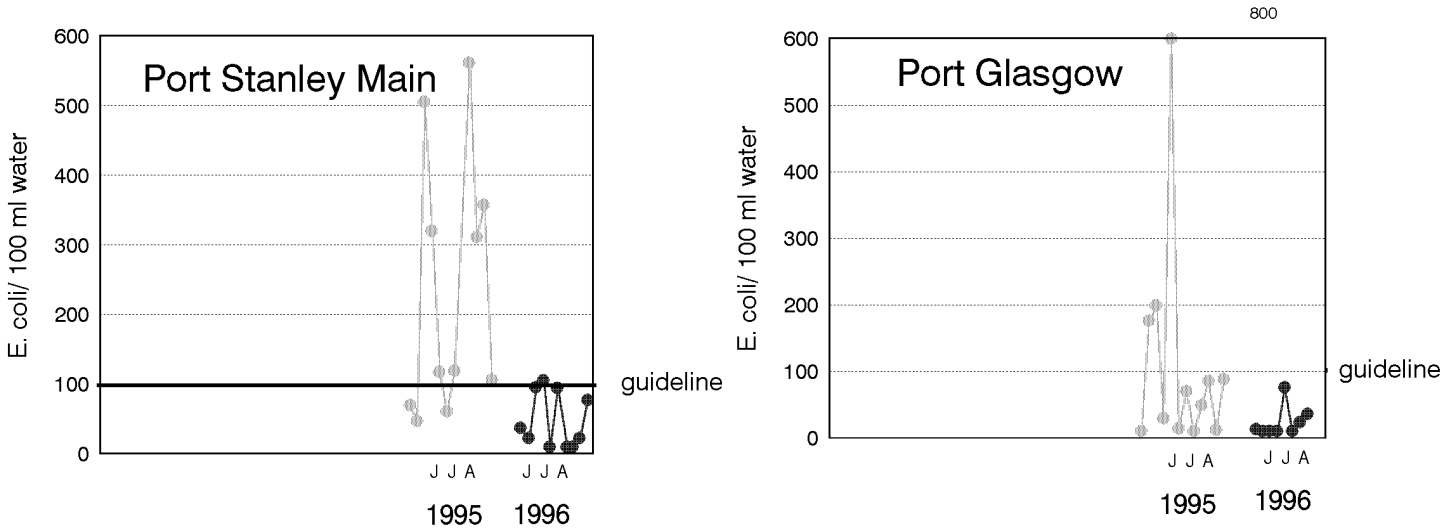

Figure 12-8: Geometric Mean of E. coli Levels in Elgin-St Thomas beaches, Lake Erie

c:\sberry\indicato\figures\new\elgin2.prs

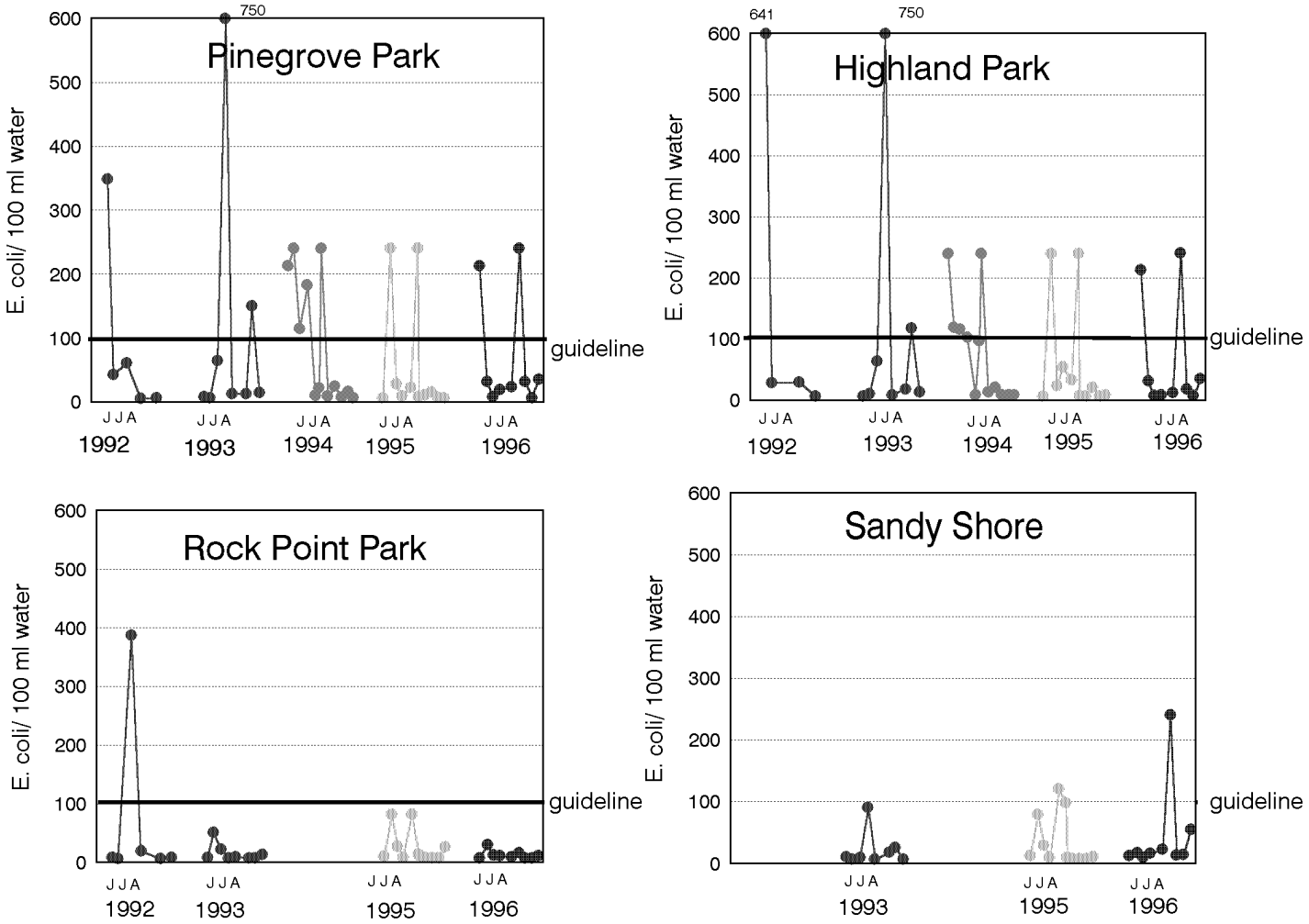

Figure 12-9: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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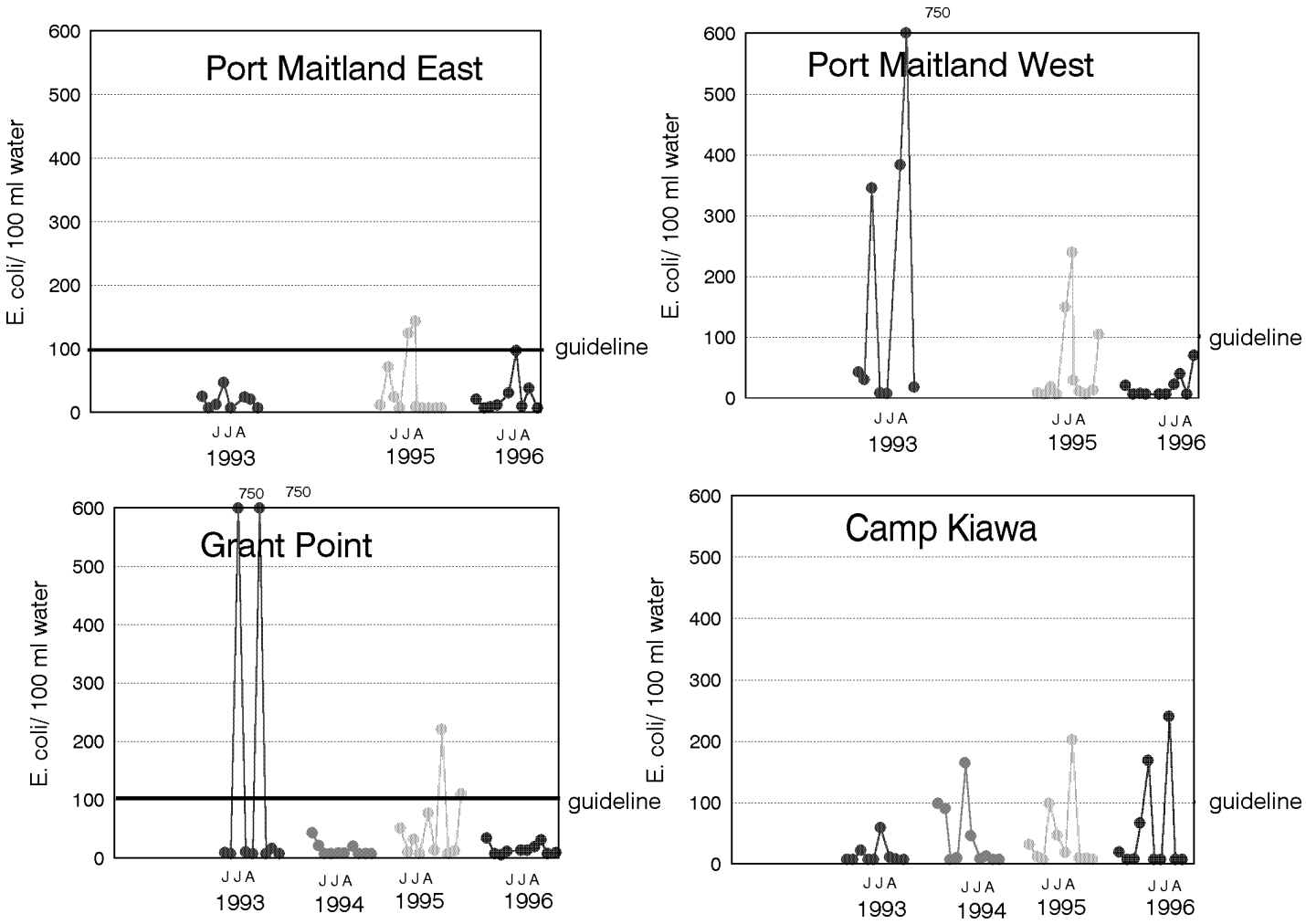

Figure12-10: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

c:\sberry\indicato\figures\new\hald2.prs

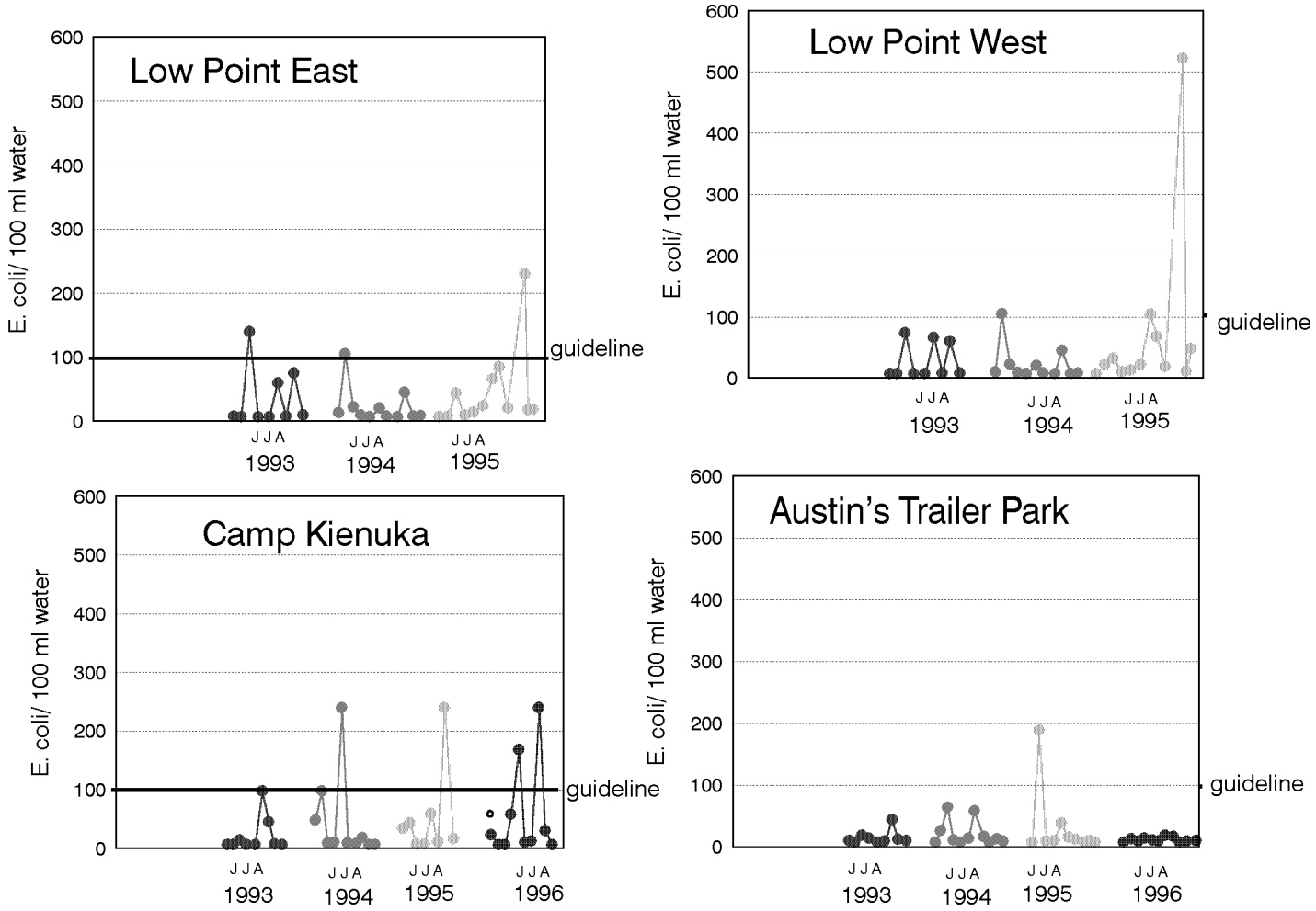

Figure 12-11: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

c:\sberry\indicato\figures\new\hald3.prs

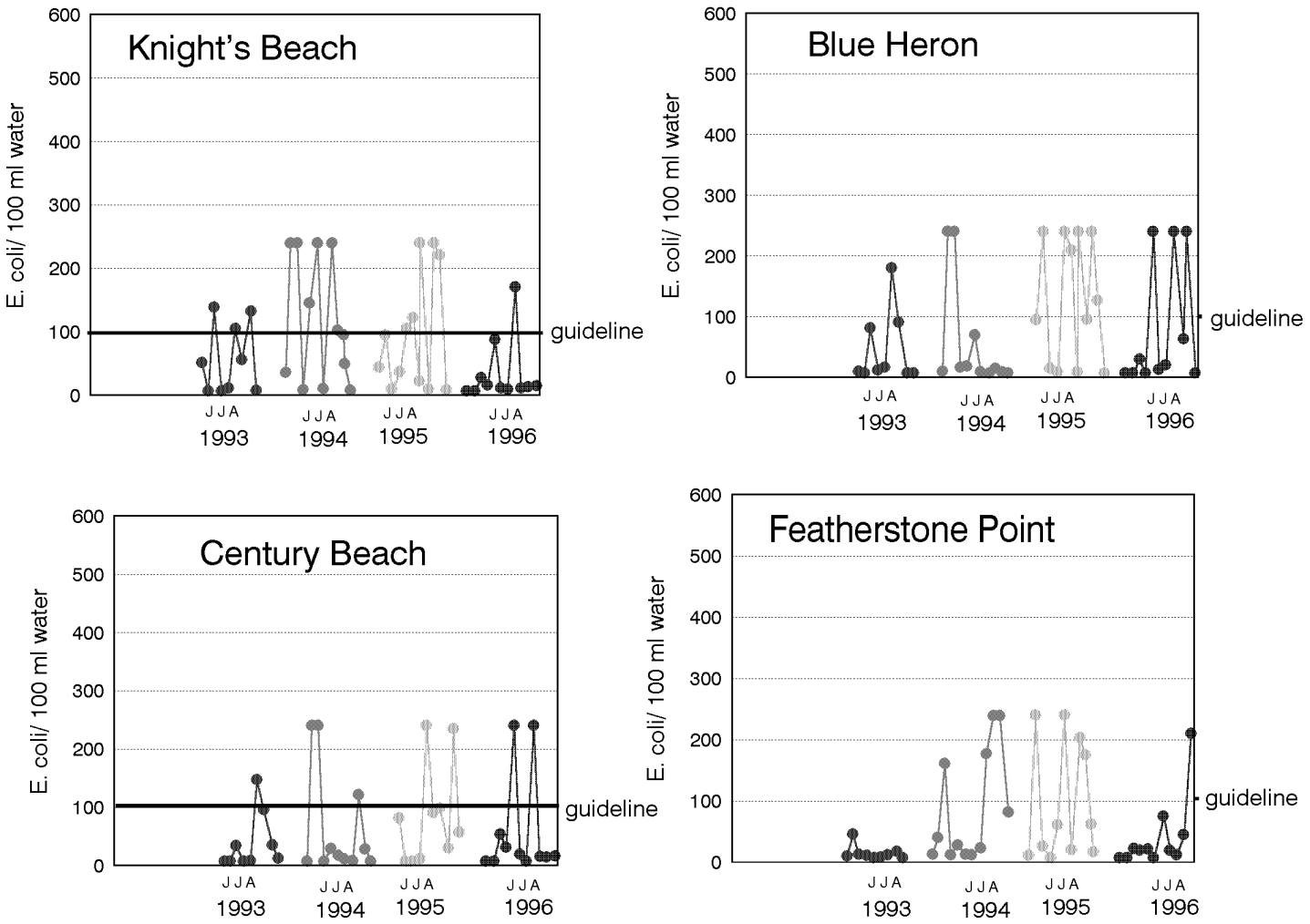

Figure 12-12: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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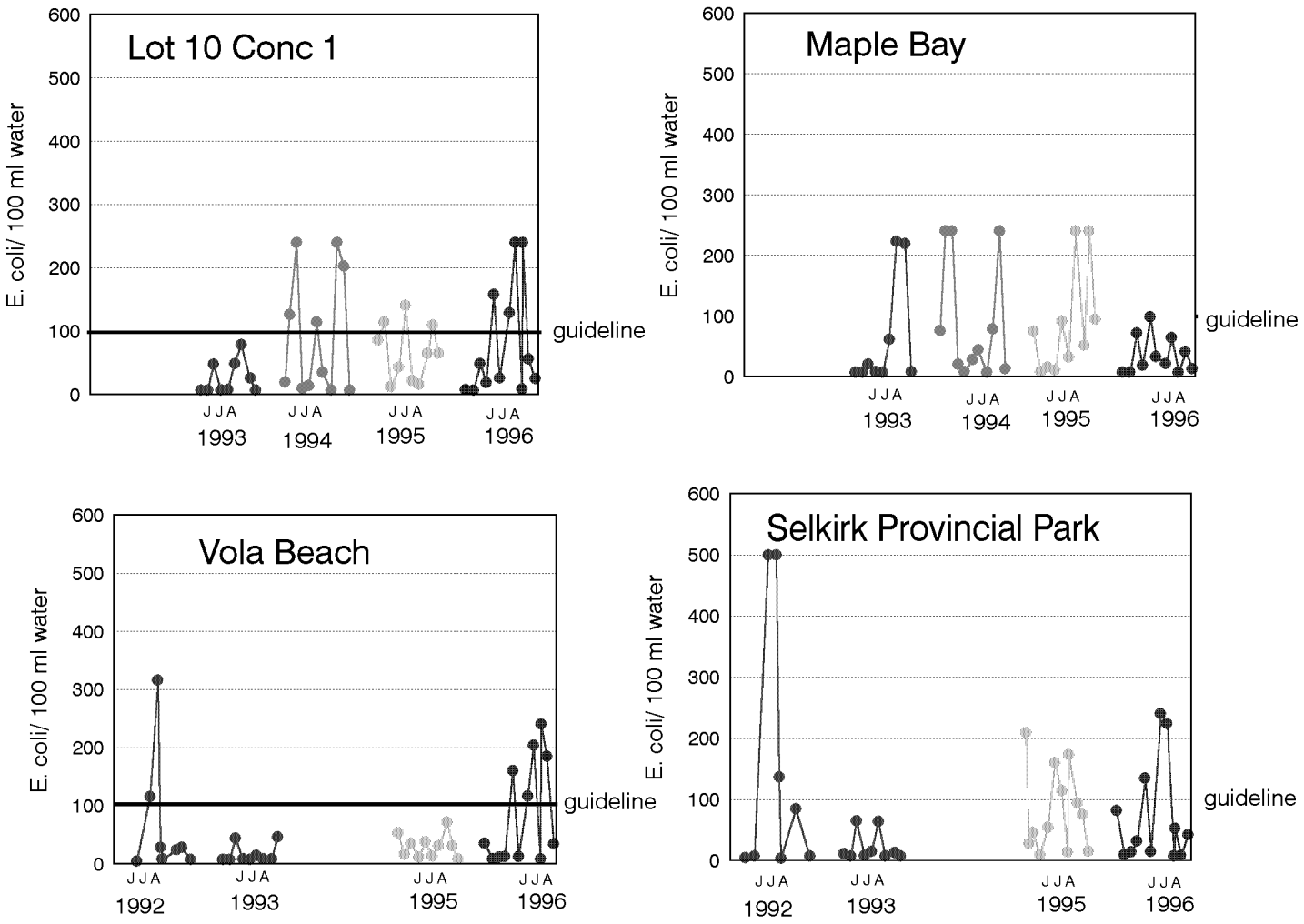

Figure 12-13: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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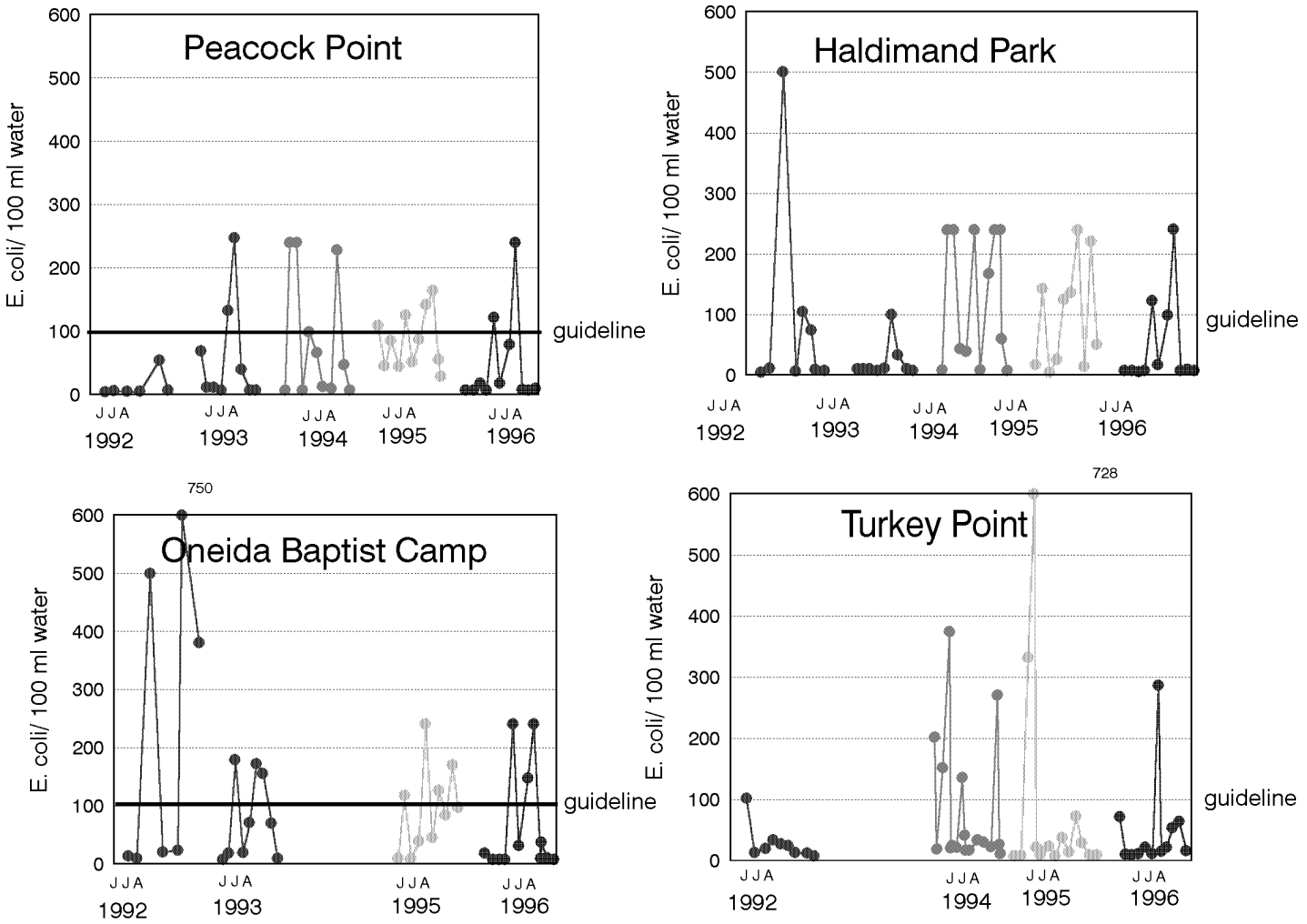

Figure 12-14: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

c:\sberry\indicato\figures\new\hald6.prs

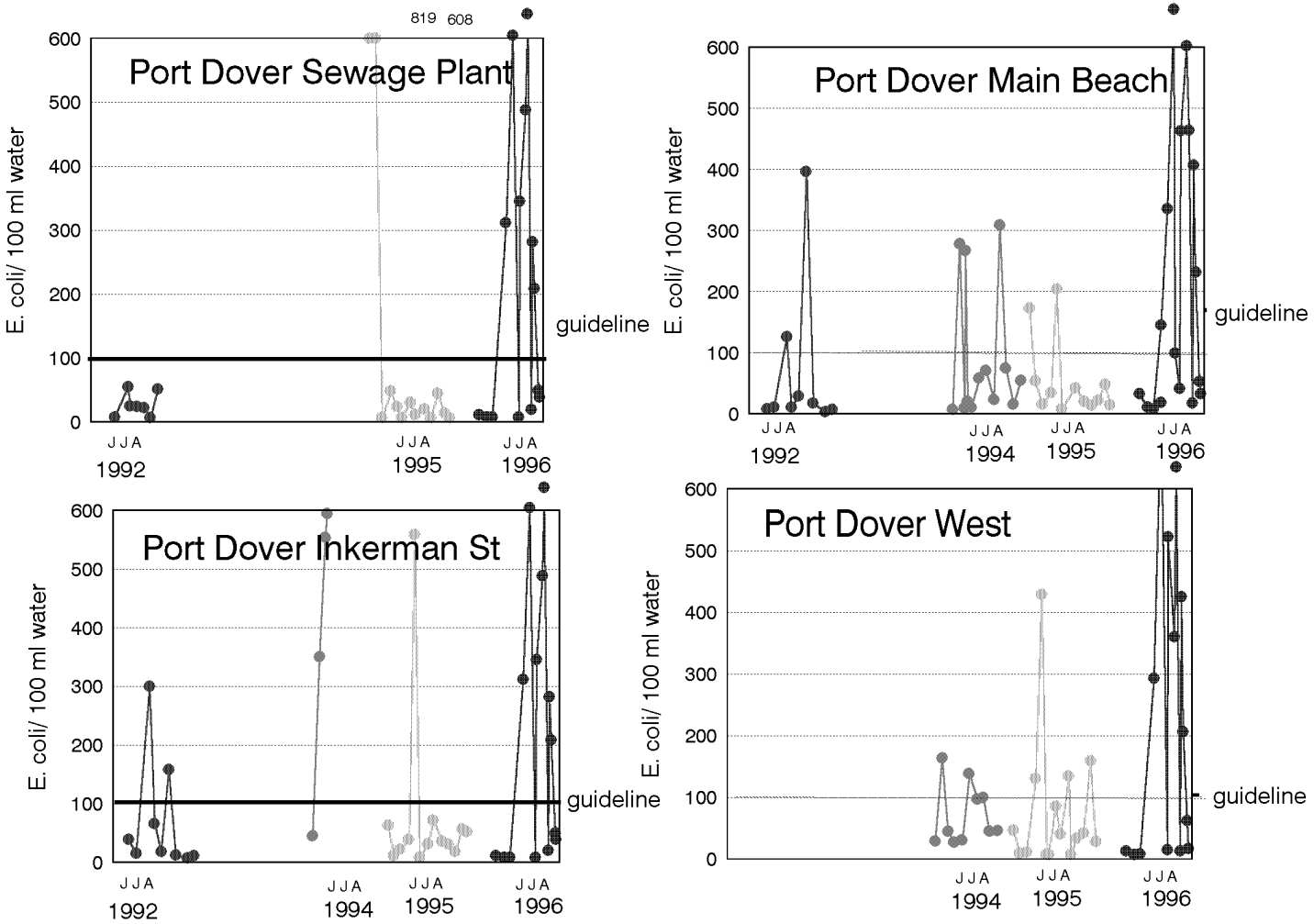

Figure 12-15: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

c:\sberry\indicato\figures\new\hald7.prs

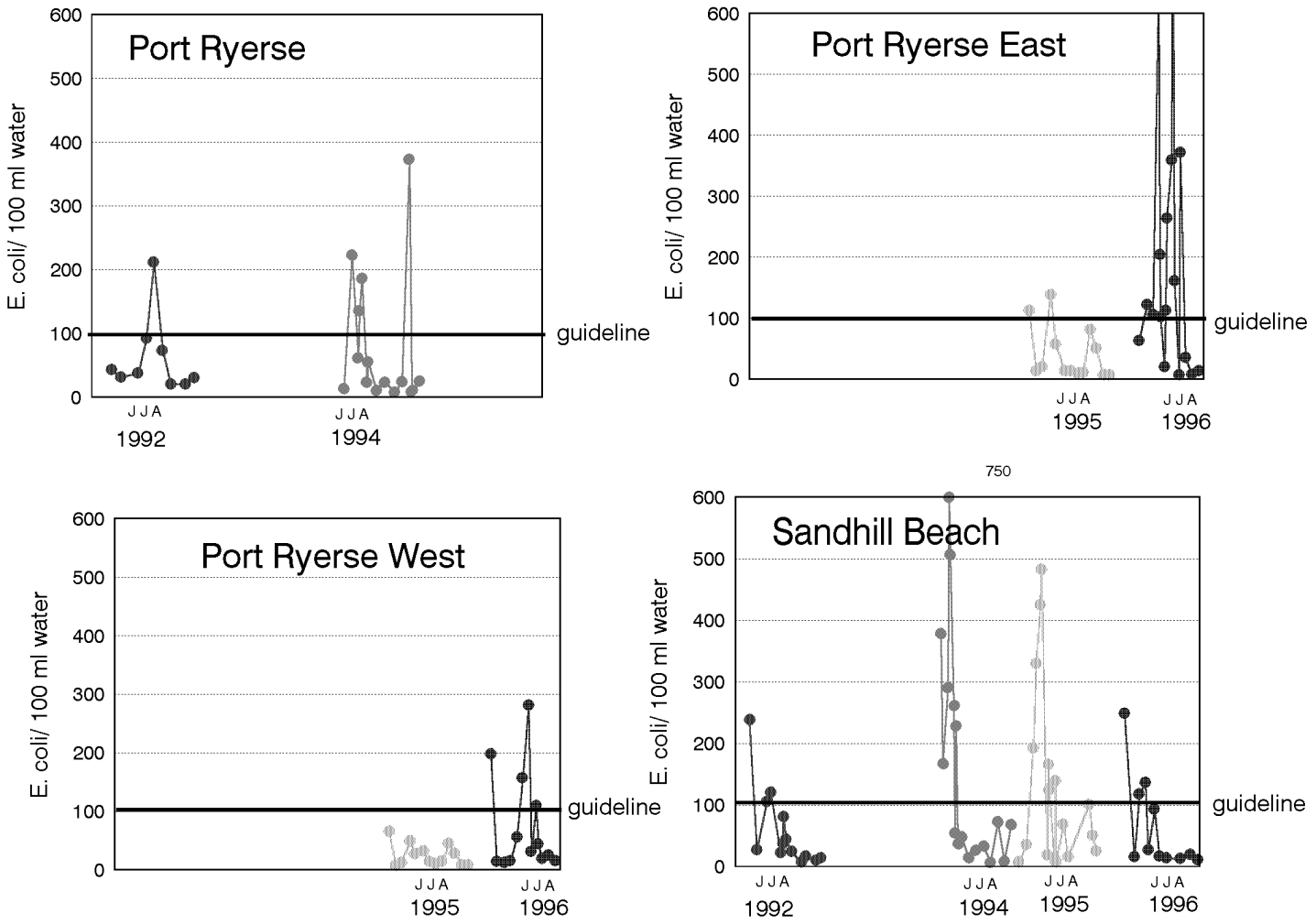

Figure 12-16: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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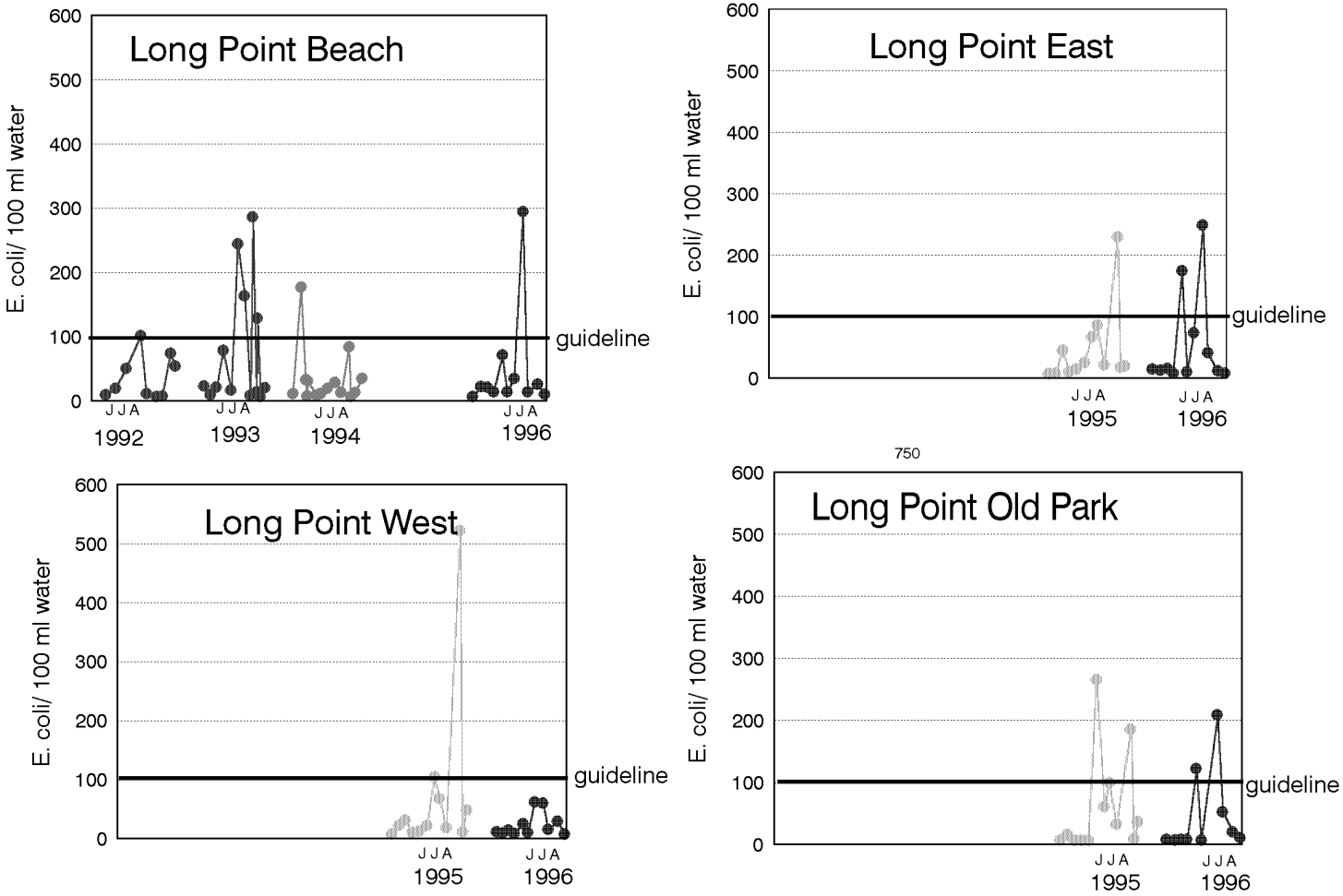

Figure 12-17: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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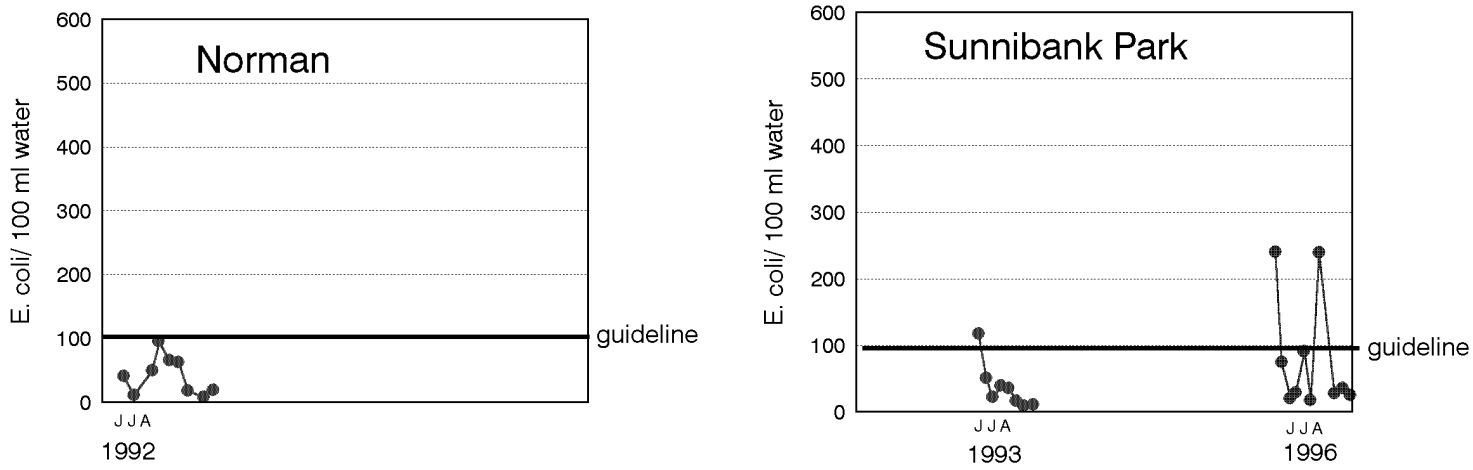

Figure 12-18: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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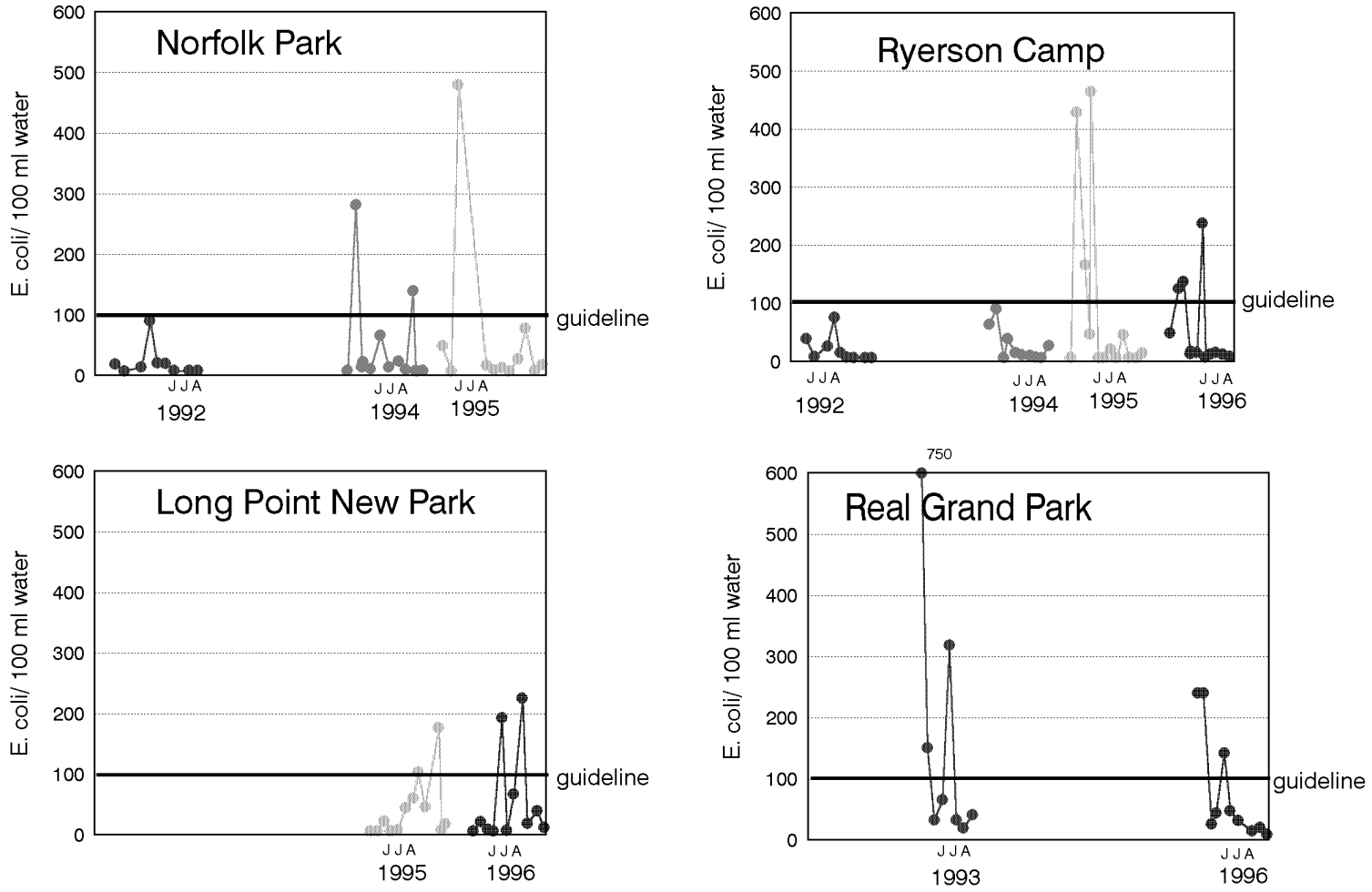

Figure 12-19: Geometric Mean of E. coli Levels in Haldimand-Norfolk beaches, Lake Erie

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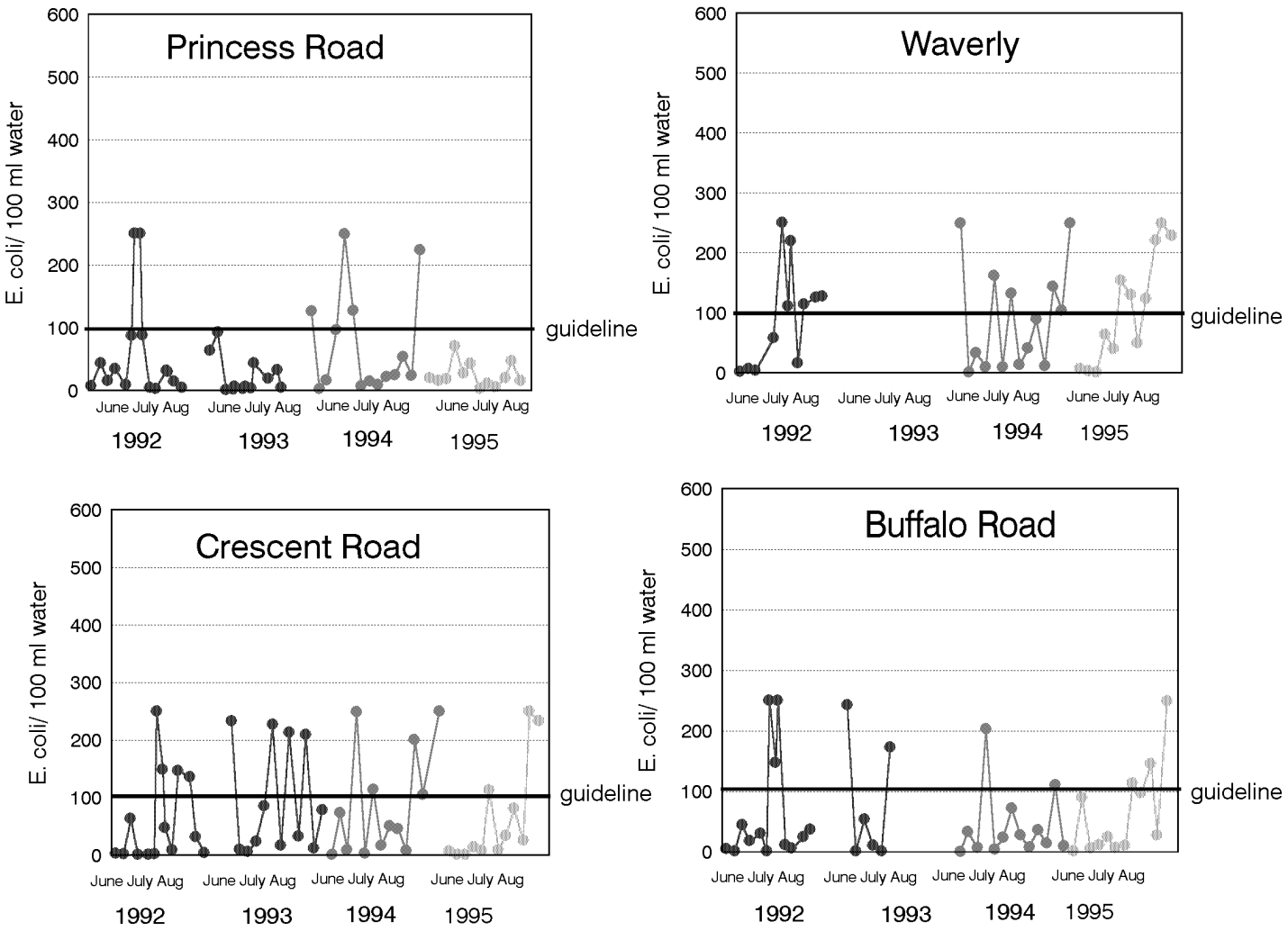

Figure 12-20 : Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

c:\sberry\indicato\figures\new\niagara2.prs

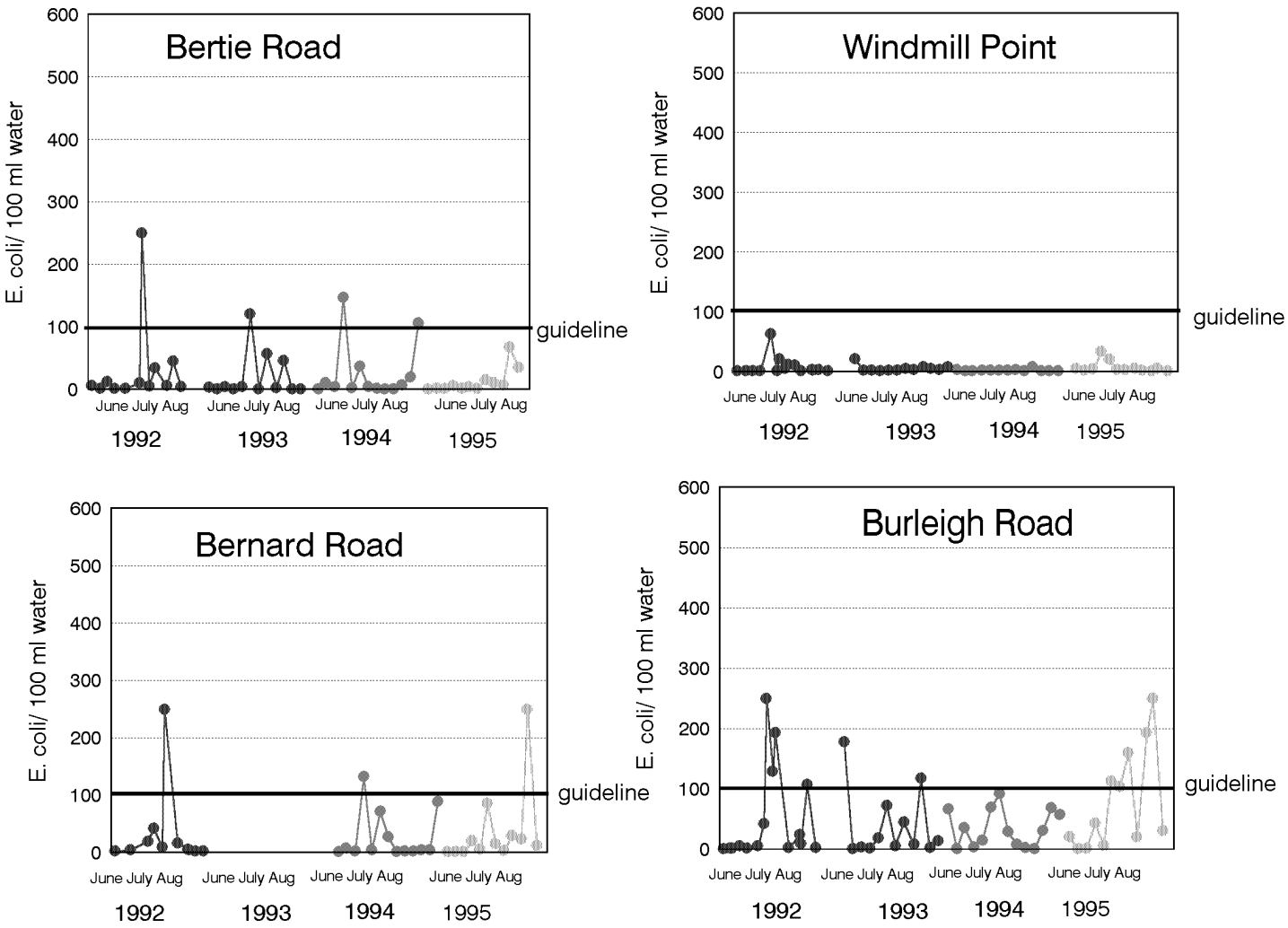

Figure 12-21: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

c:\sberry\indicato\figures\new\niagara3.prs

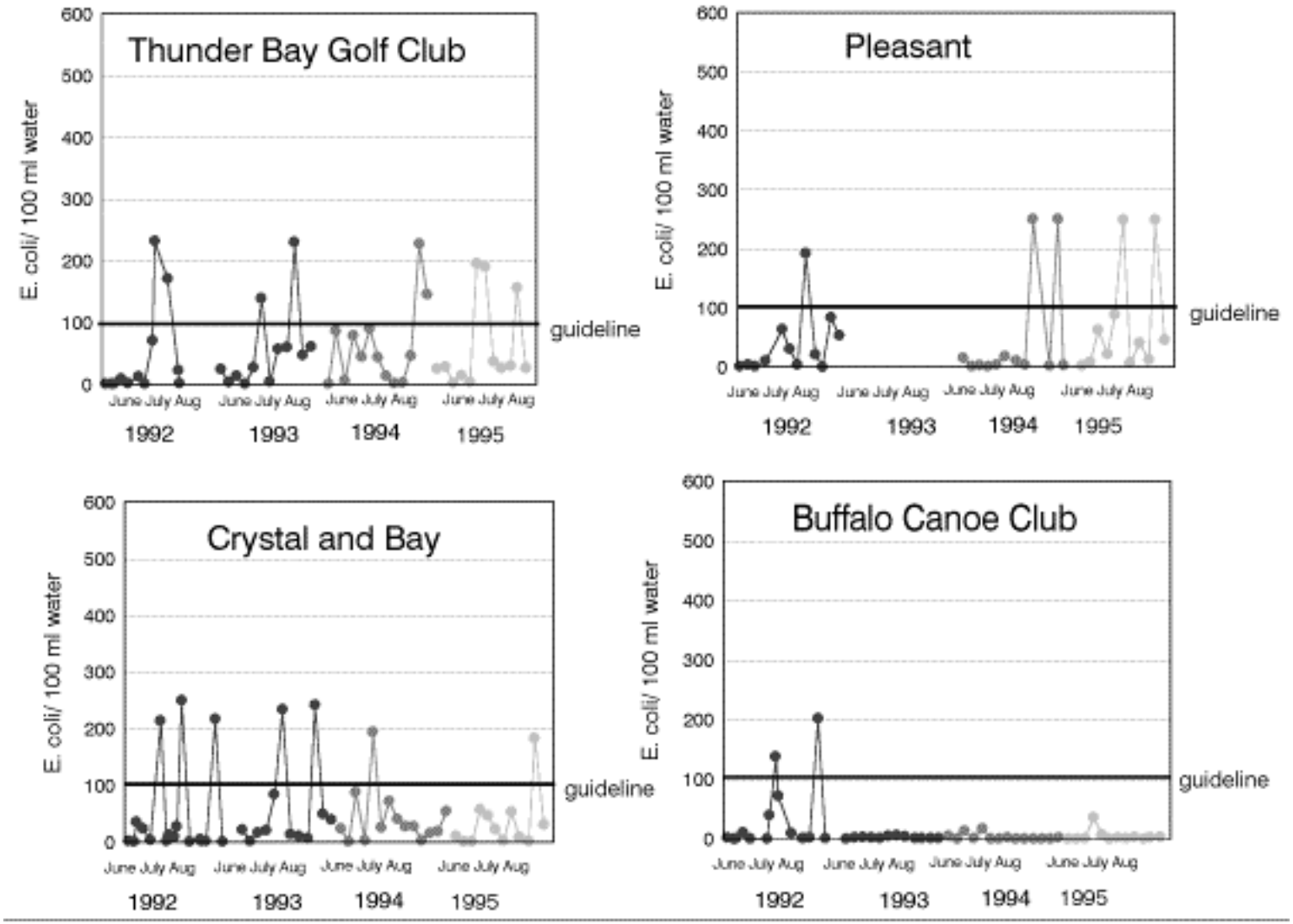

Figure 12-22: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

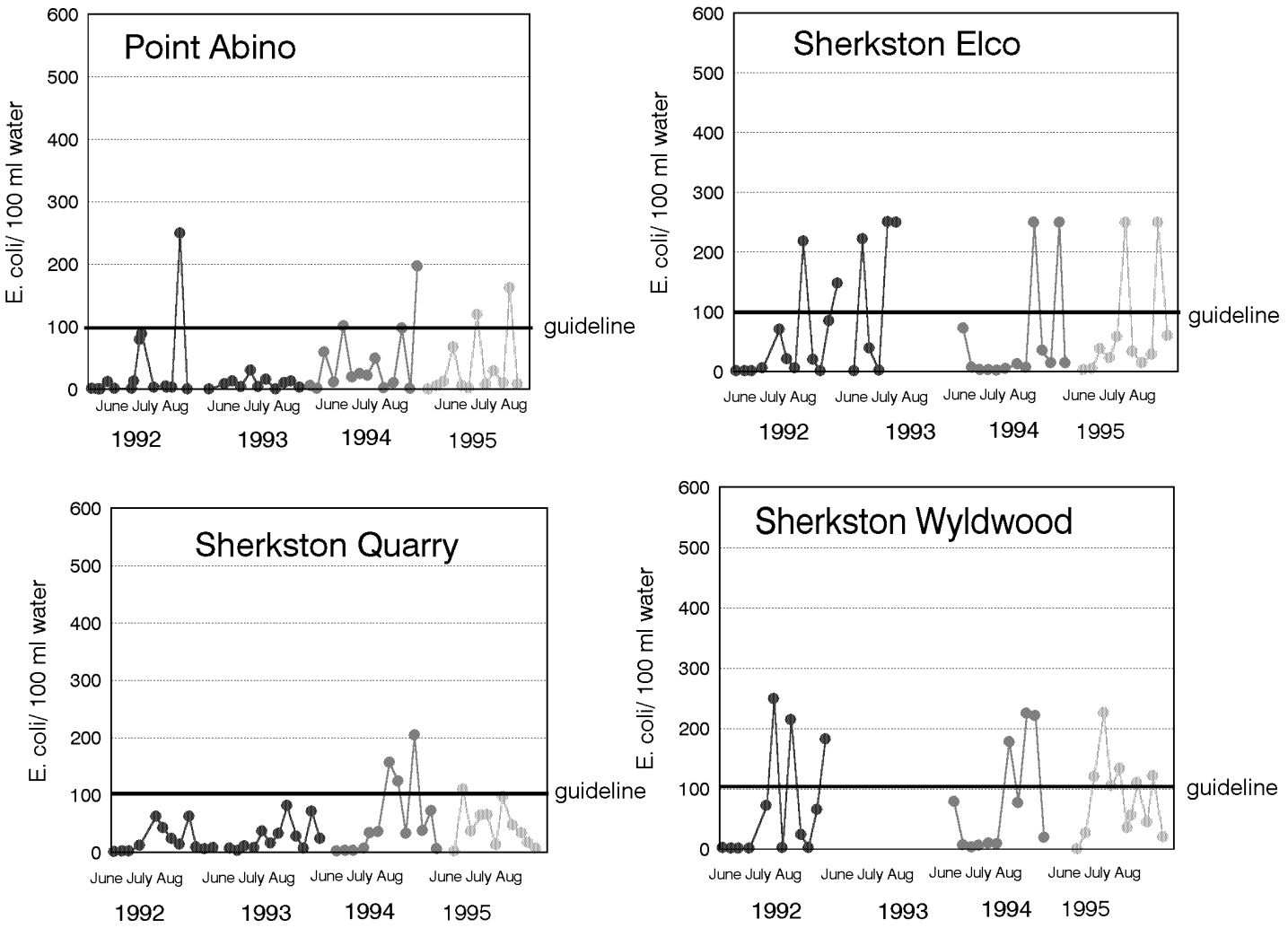

Figure 12-23: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

c:\sberry\indicato\figures\new\niagara5.prs

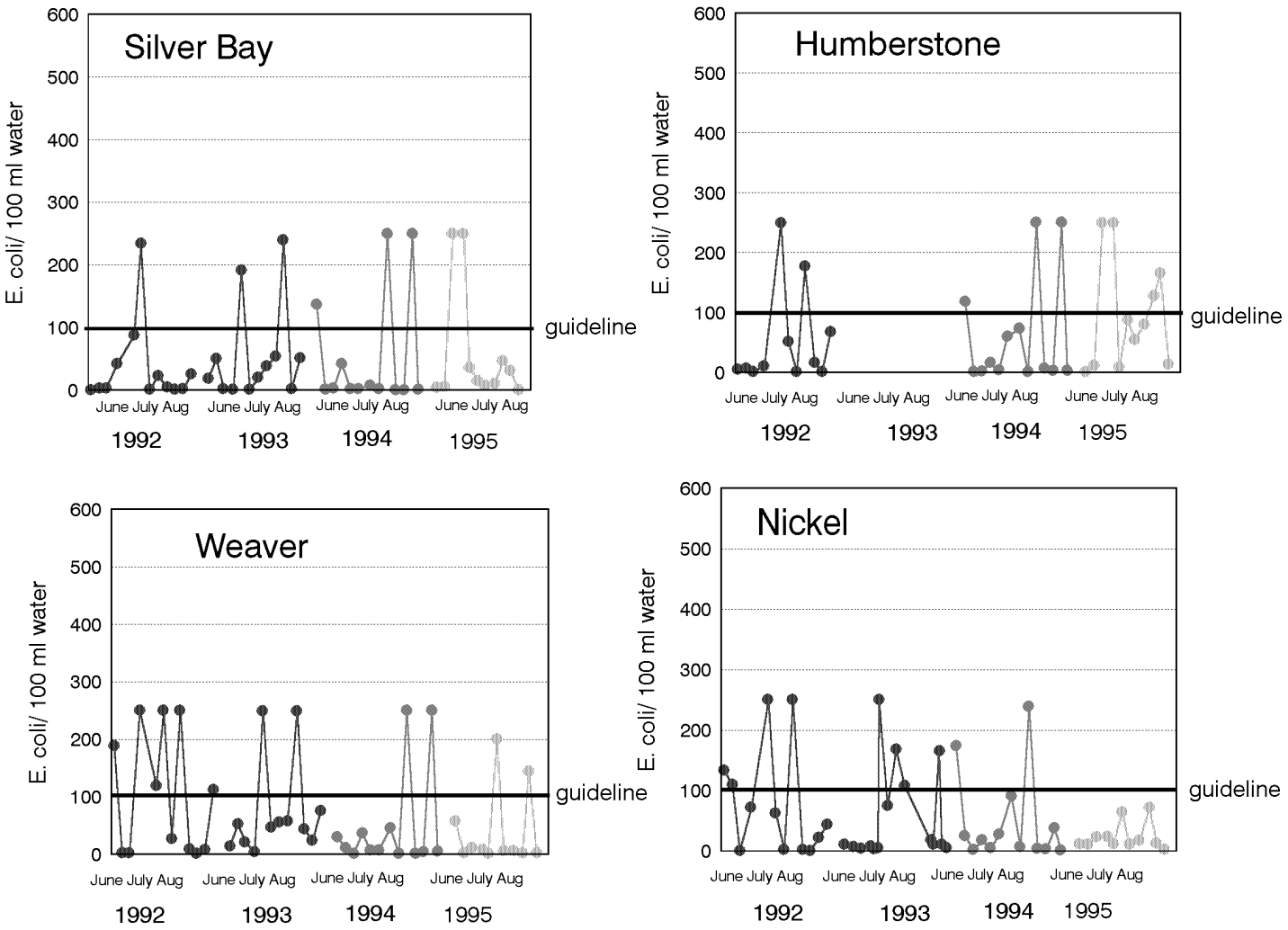

Figure 12-24: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

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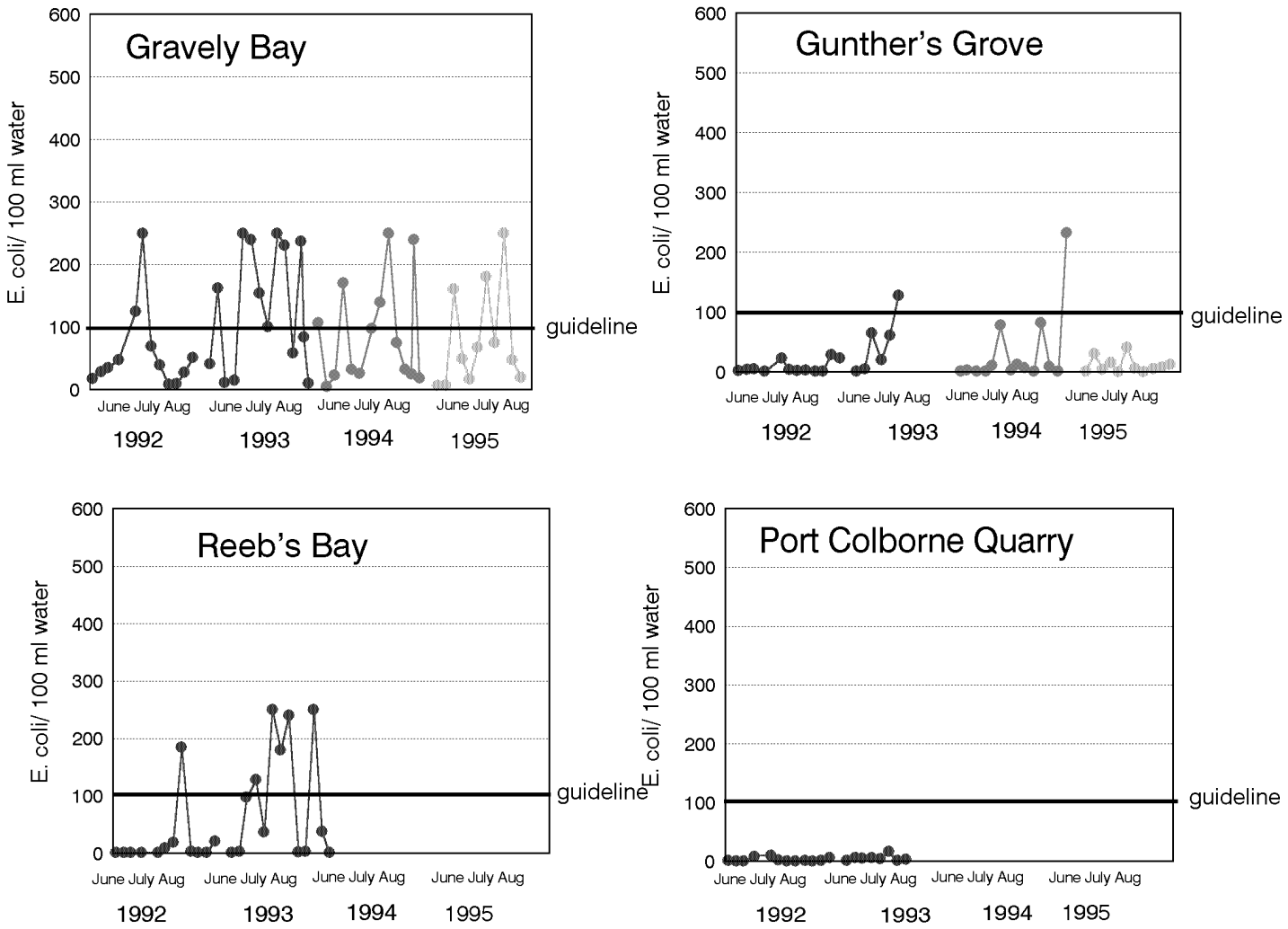

Figure 12-25: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

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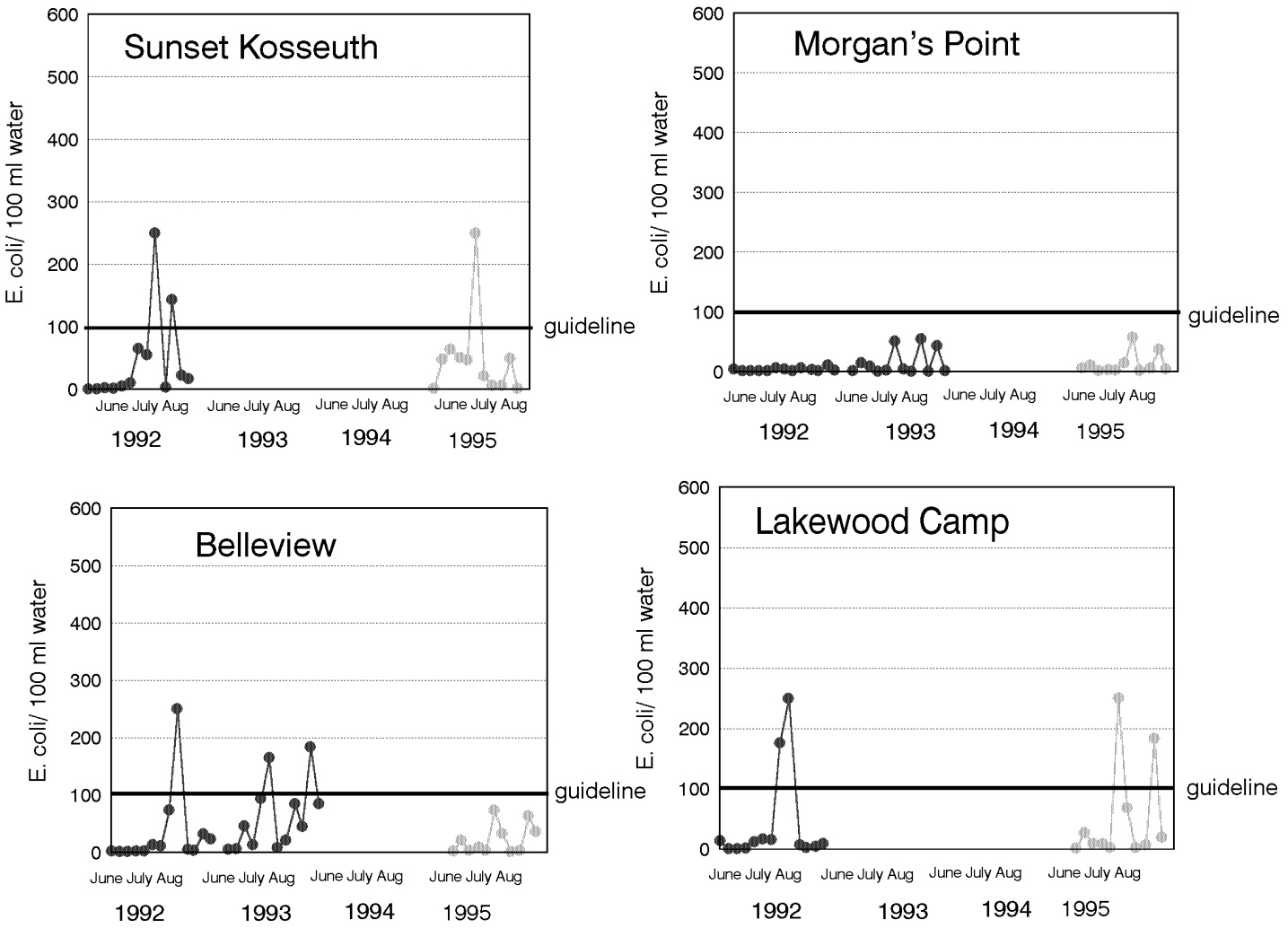

Figure 12-26: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

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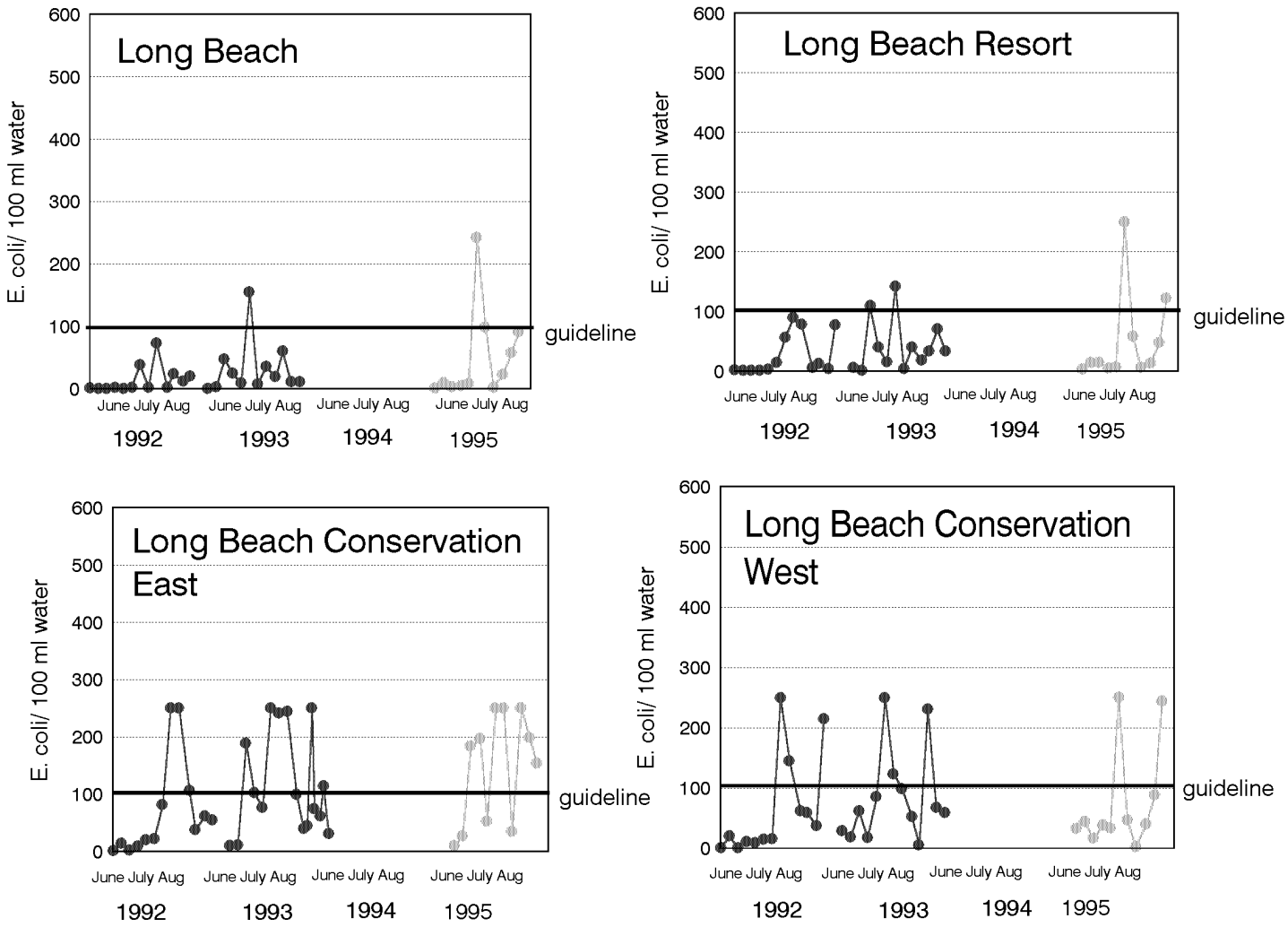

Figure 12-27: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

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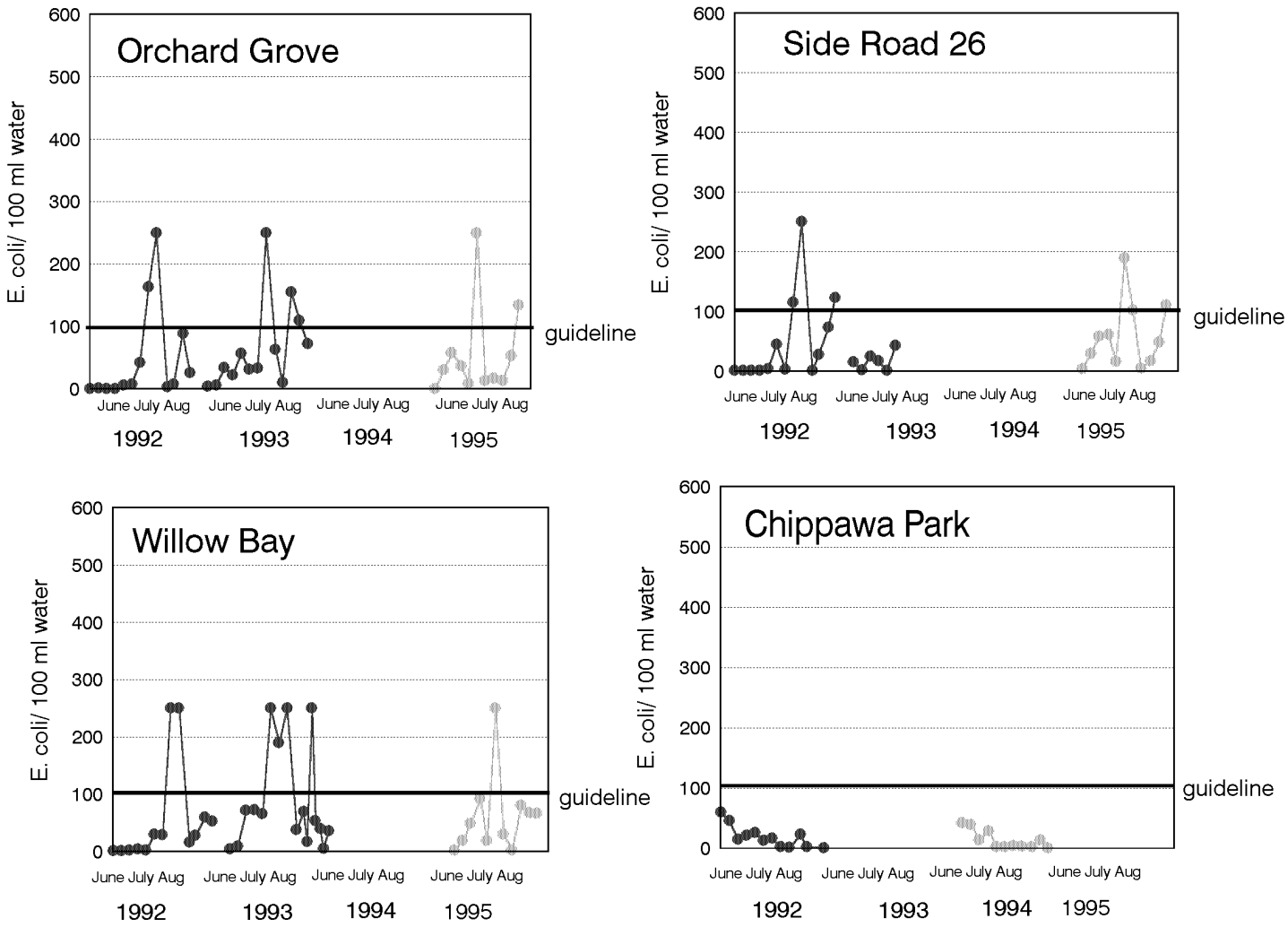

Figure 12-28: Geometric Mean of E. coli Levels in Niagara beaches, Lake Erie

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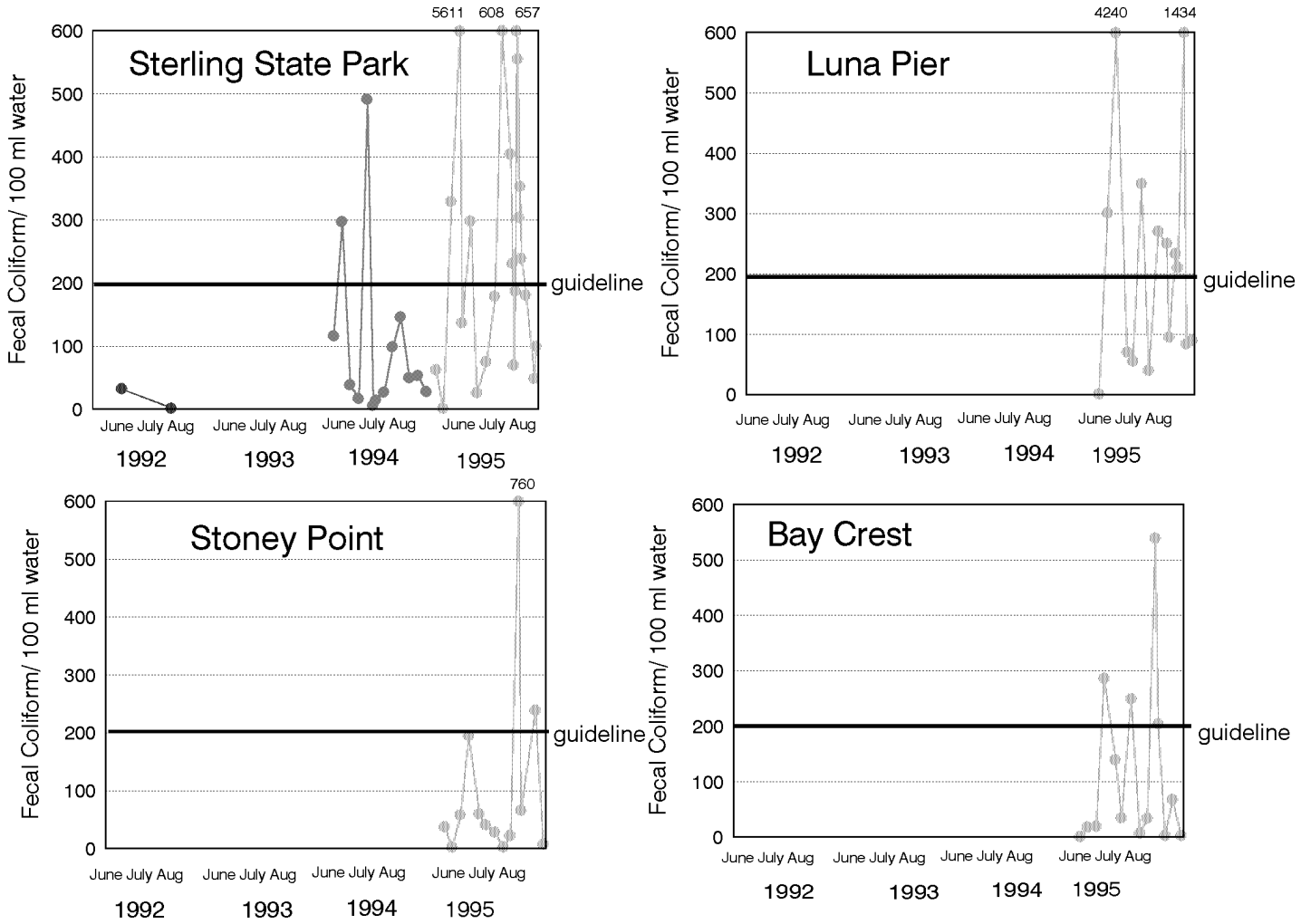

Figure 12-29: Geometric Mean of Fecal Coliform Levels in Monroe County, Michigan beaches, Lake Erie

c:\sberry\indicato\erie\monroe1.prs

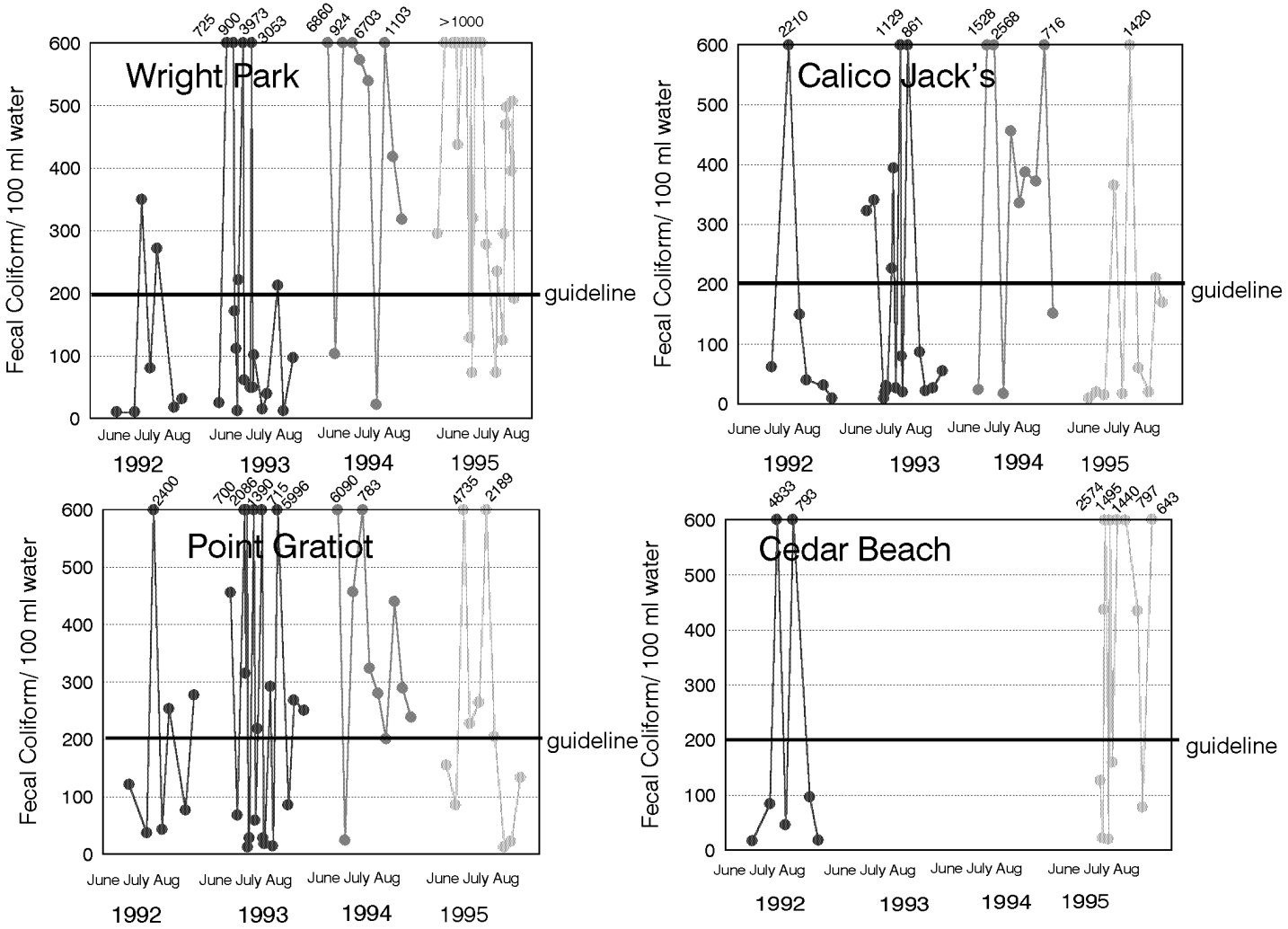

Figure 12-30: Geometric Mean of Fecal Coliform Levels in New York State beaches, Lake Erie

c:\sberry\indicato\erie\newyork1.prs

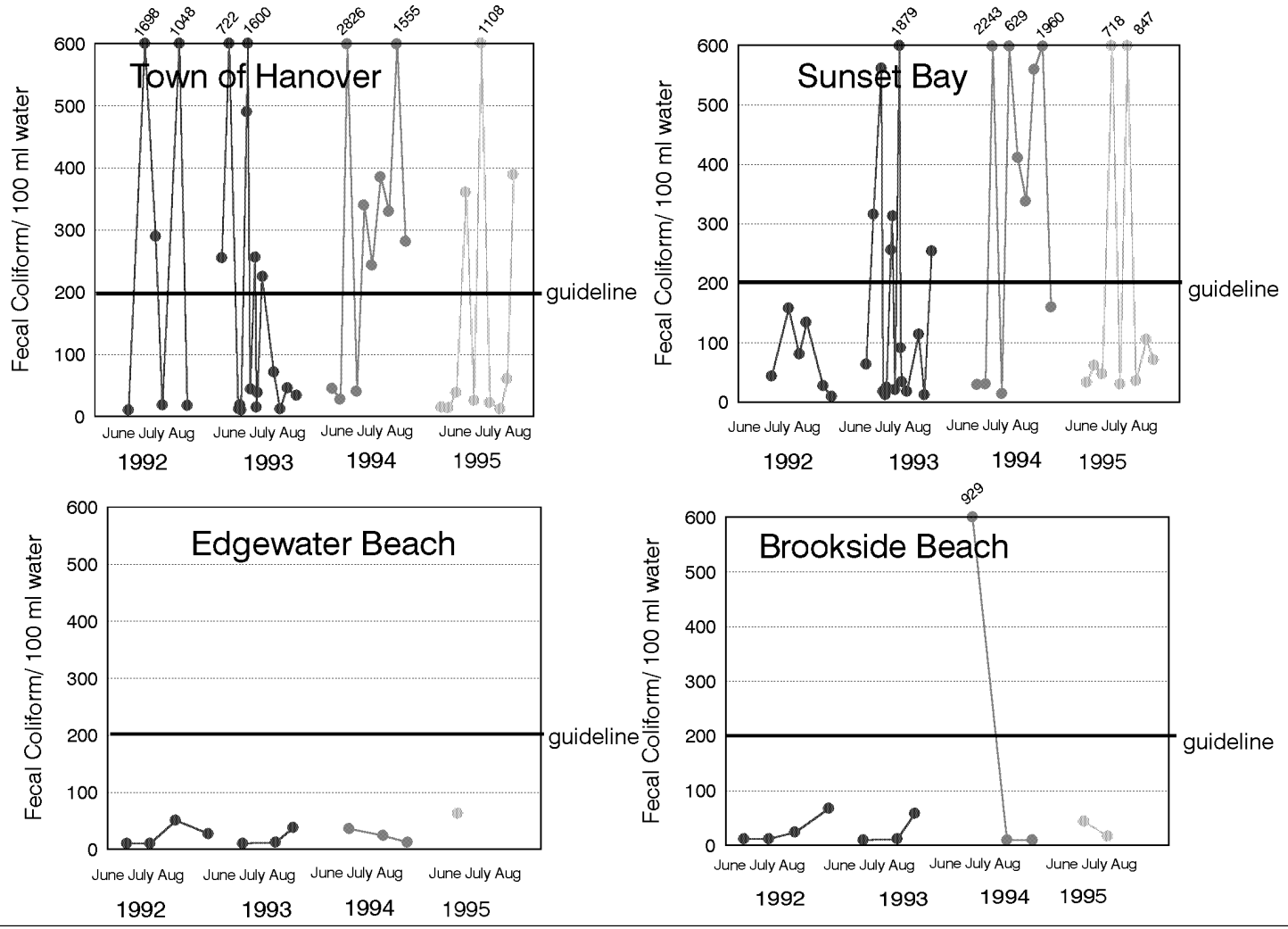

Figure 12-31: Geometric Mean of Fecal Coliform Levels in New York State beaches, Lake Erie

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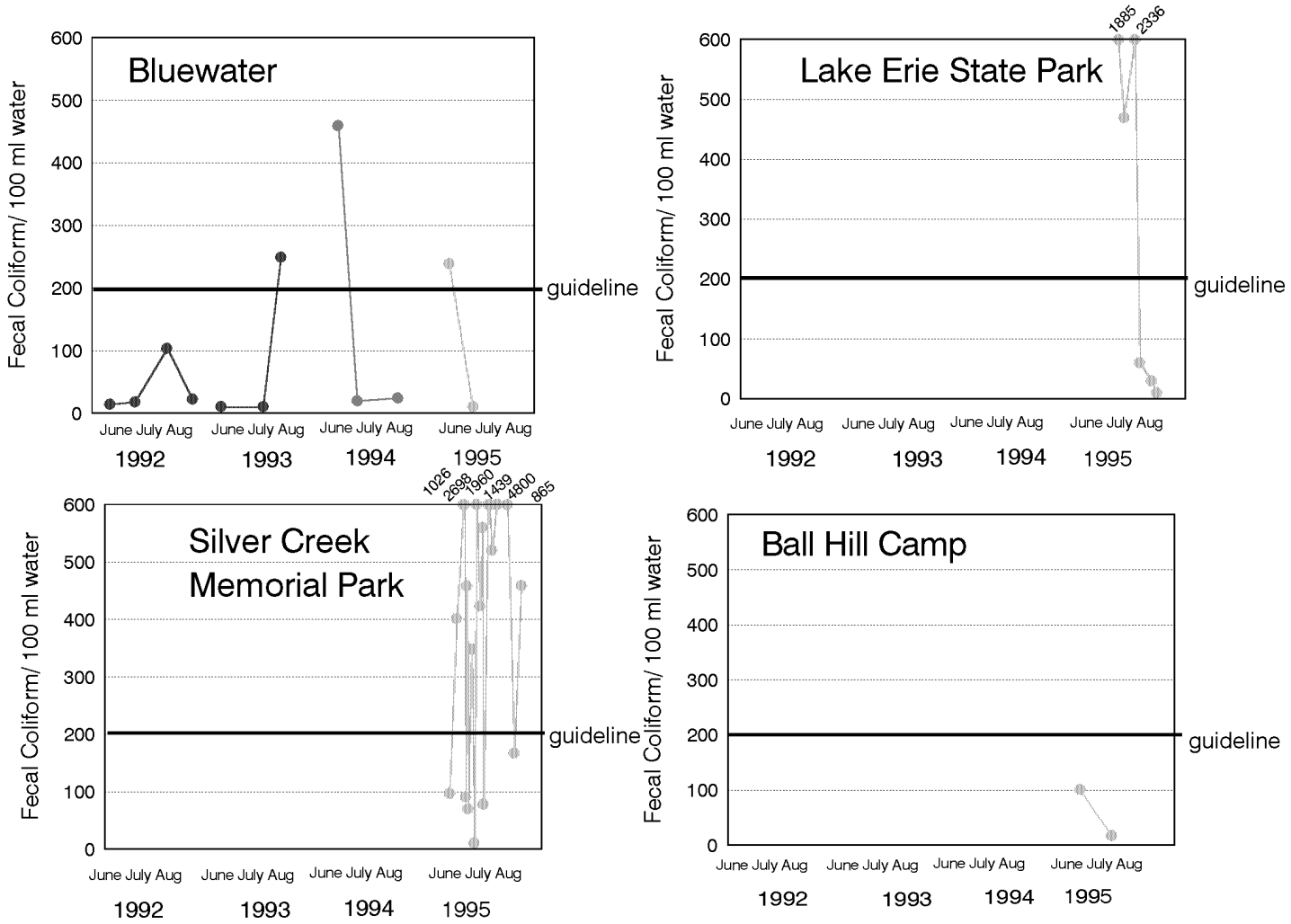


Figure 12-32: Geometric Mean of Fecal Coliform Levels in New York State beaches, Lake Erie

c:\sberry\indicato\erie\newyork3.prs

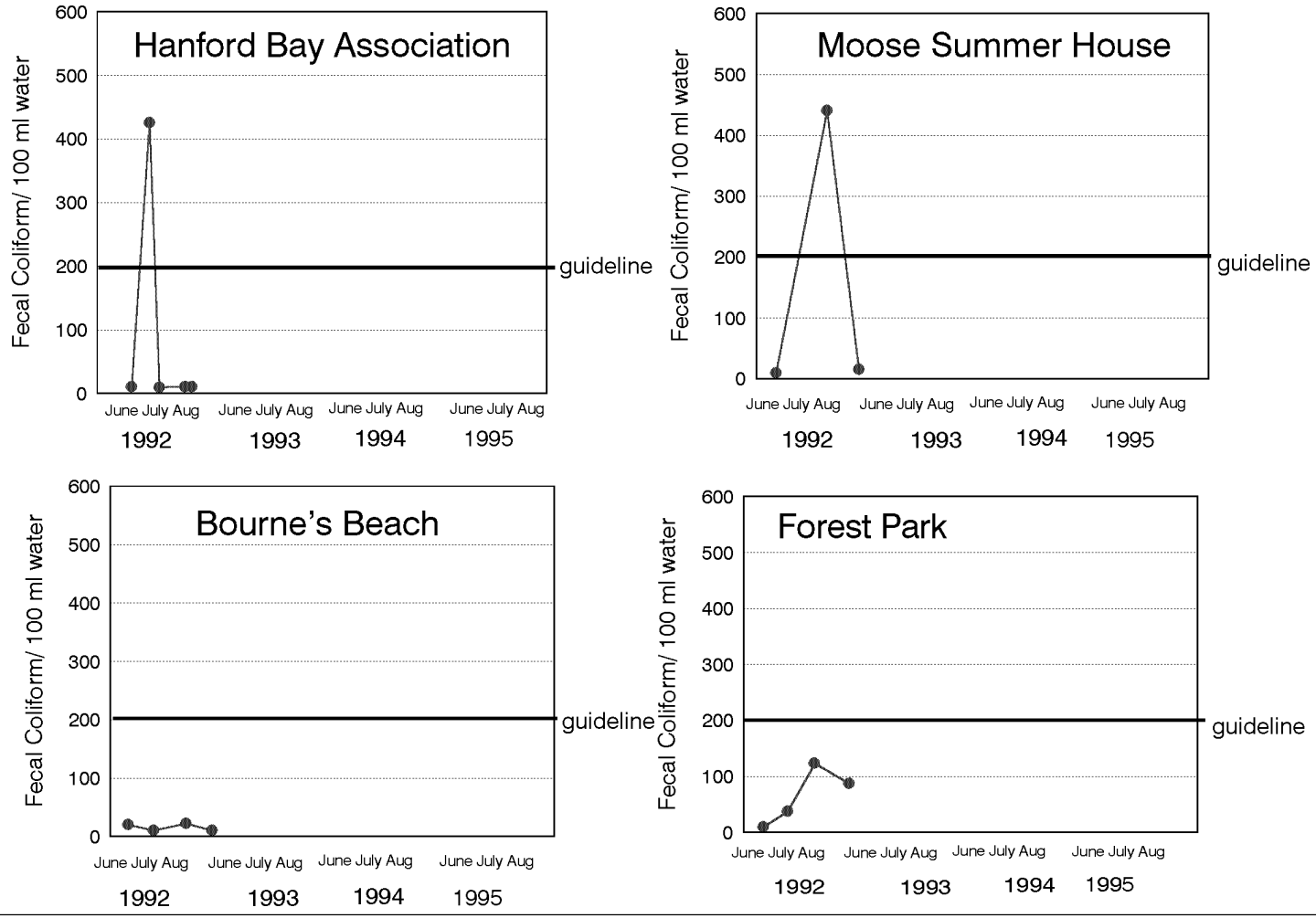


Figure 12-33: Geometric Mean of Fecal Coliform Levels in New York State beaches, Lake Erie

c:\sberry\indicato\erie\newyork4.prs

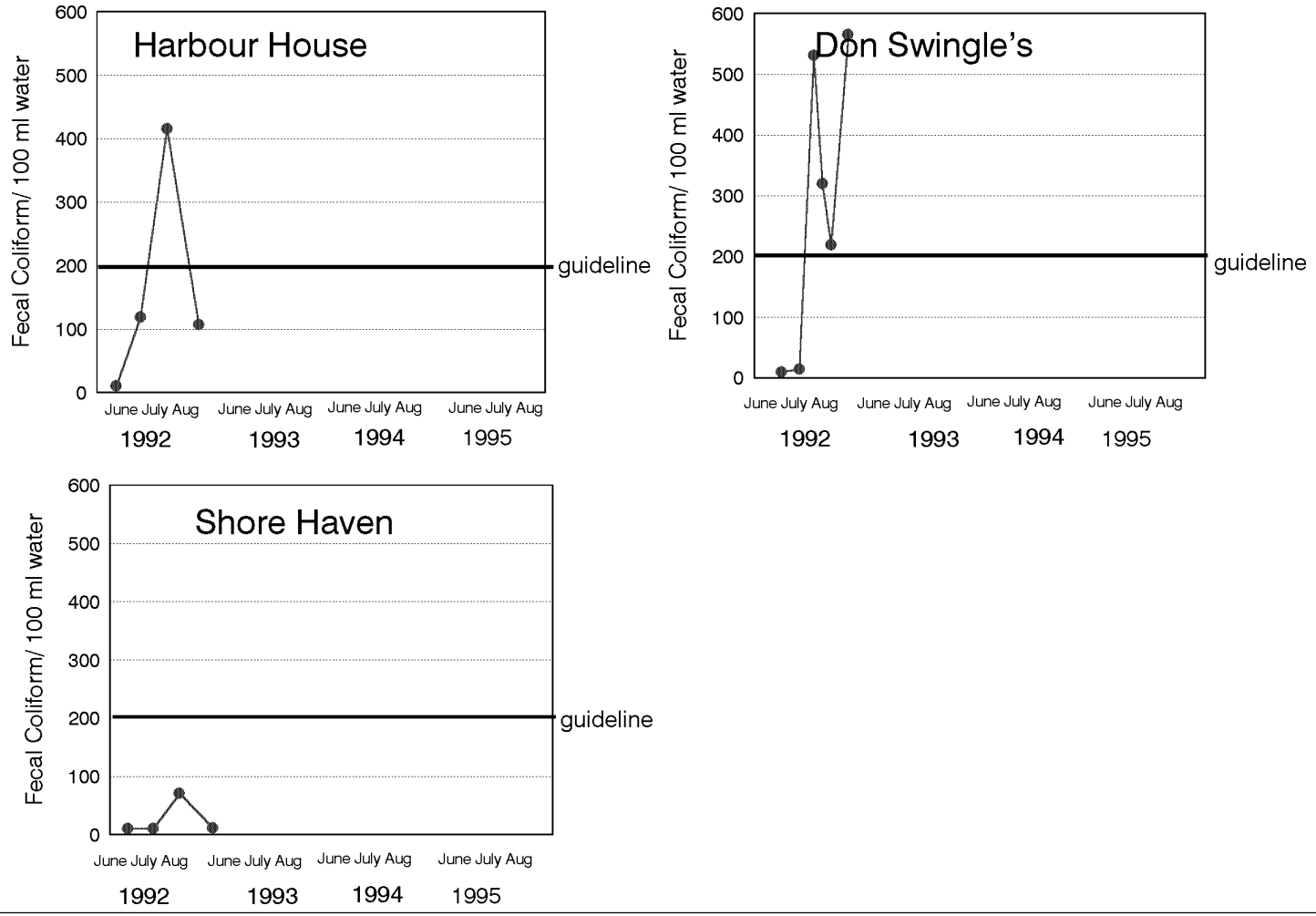


Figure 12-34: Geometric Mean of Fecal Coliform Levels in New York State beaches, Lake Erie

c:\sberry\indicato\erie\newyork5.prs

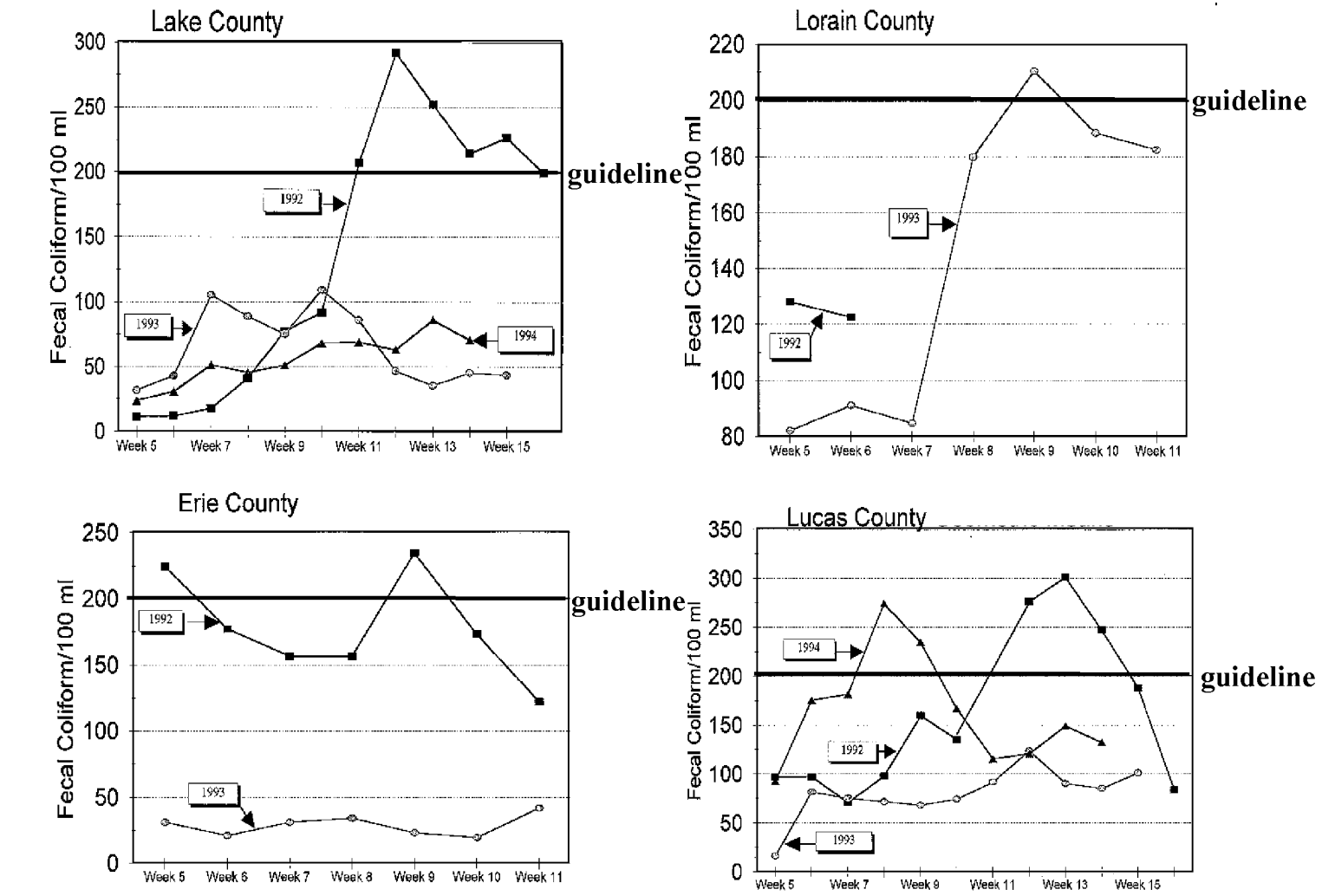


Figure 12-35: Geometric Means of Fecal Coliform in Ohio beaches, Lake Erie.

Week 1 corresponds to the first Tuesday after May 30.

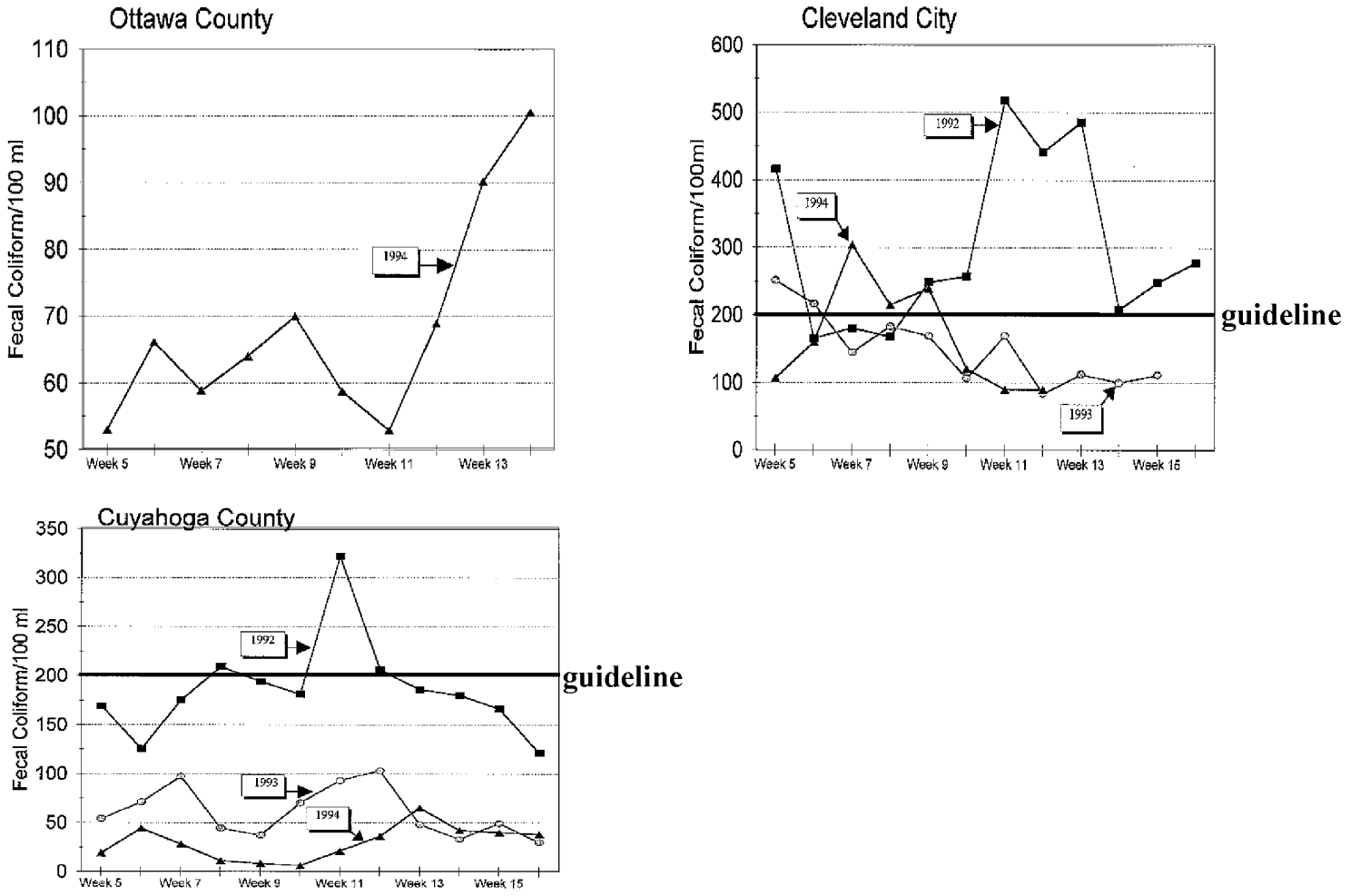


Figure 12-36: Geometric Means of Fecal Coliform in Ohio beaches, Lake Erie.

Week 1 corresponds to the first Tuesday after May 30.

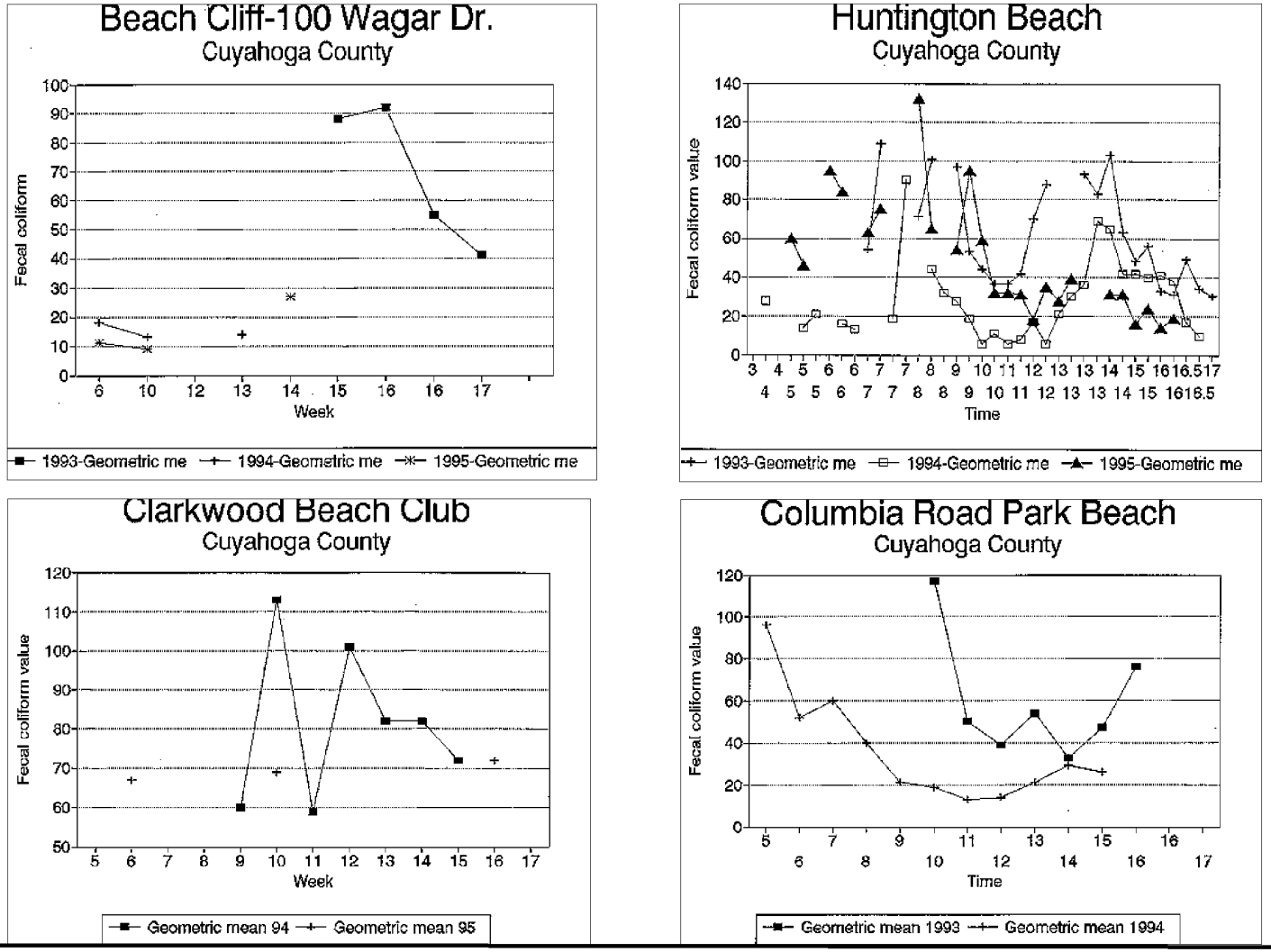
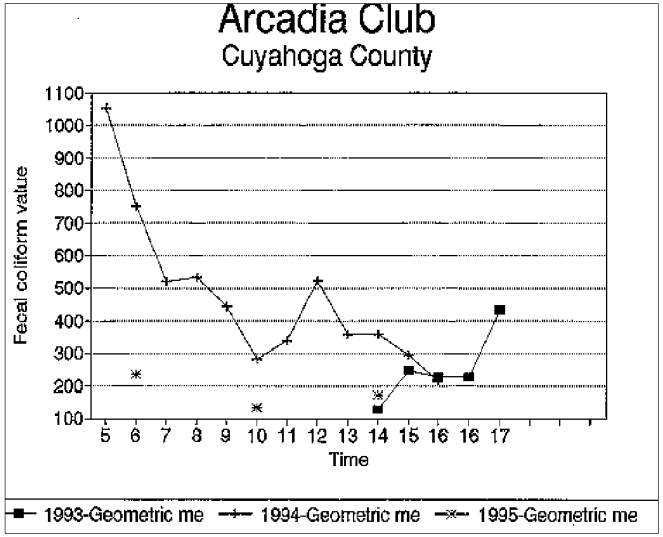
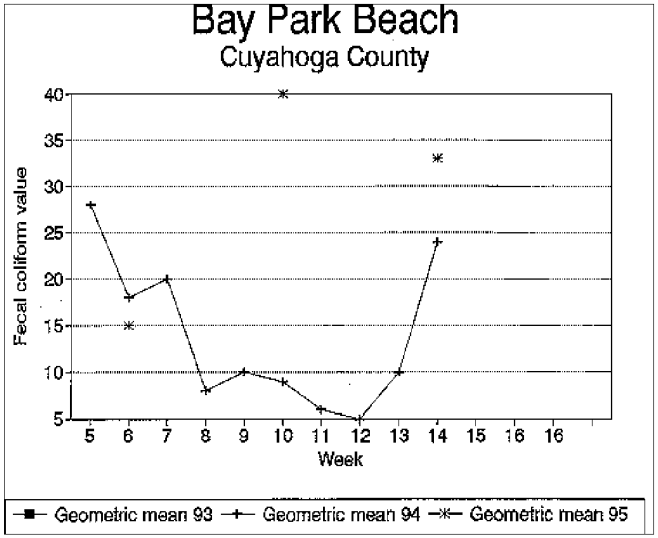


Figure 12-37: Geometric Mean of Fecal Coliform levels in Private Beaches, Cuyahoga County (Ohio), Lake Erie

Week 1 corresponds to the first Tuesday after May 30.





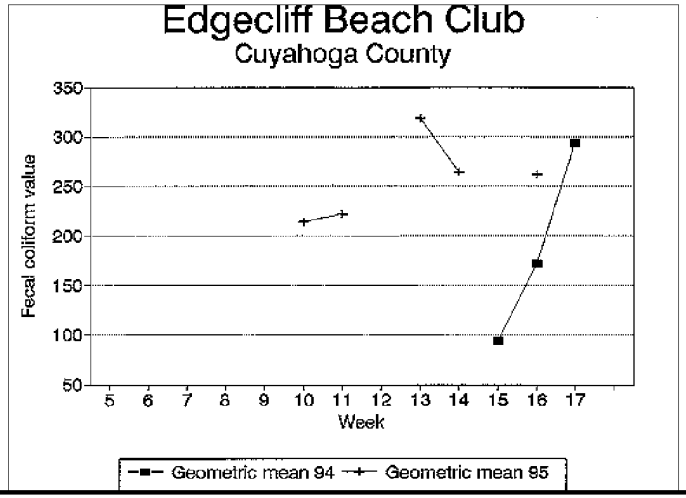


Figure 12-38: Geometric Mean of Fecal Coliform levels in Private Beaches, Cuyahoga County (Ohio), Lake Erie Week 1 corresponds to the first Tuesday after May 30.

Figure 12-39
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean Fecal Coliform Concentrations
1993

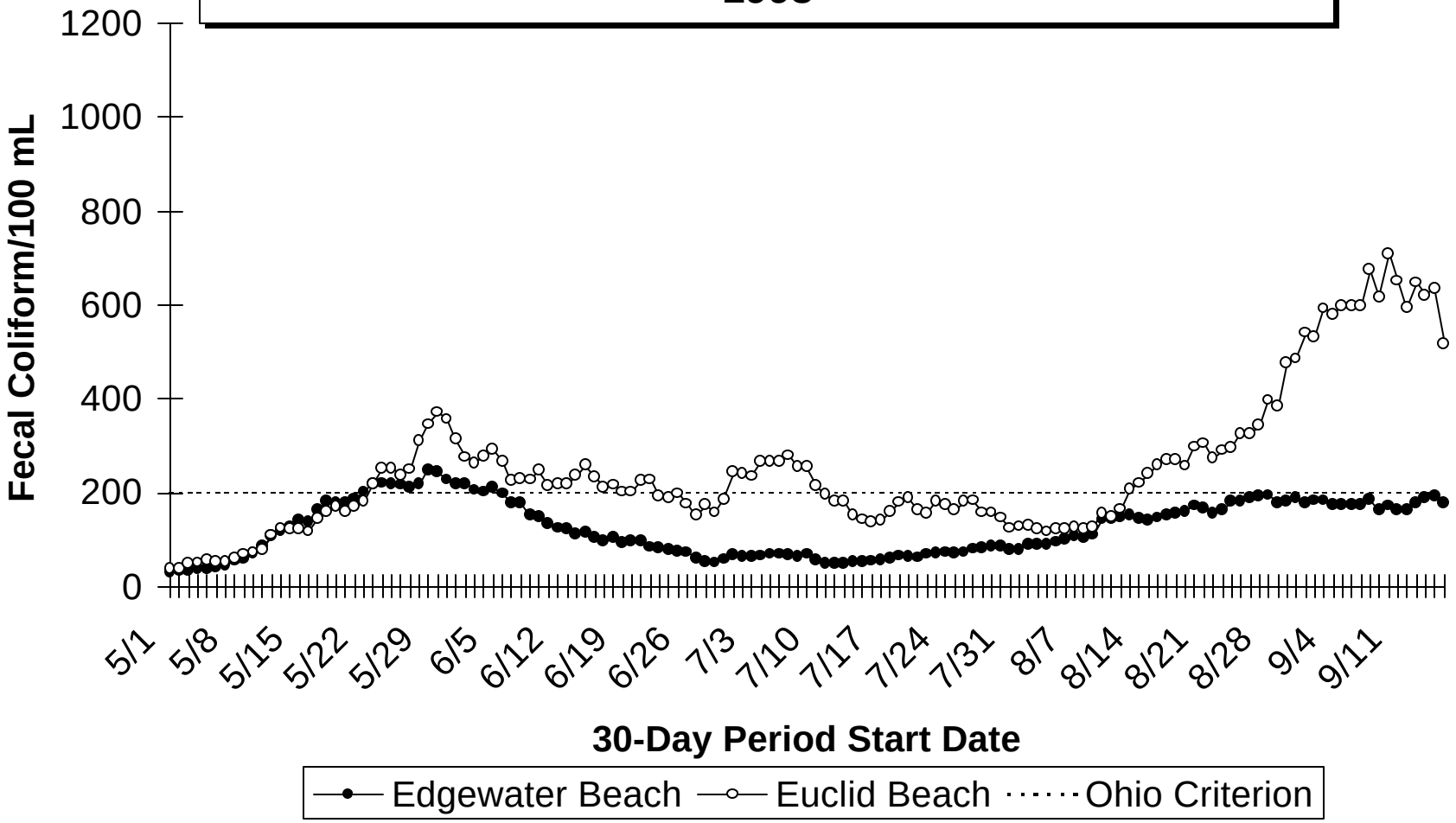


Figure 12-40
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean *E. coli* Concentrations
1993

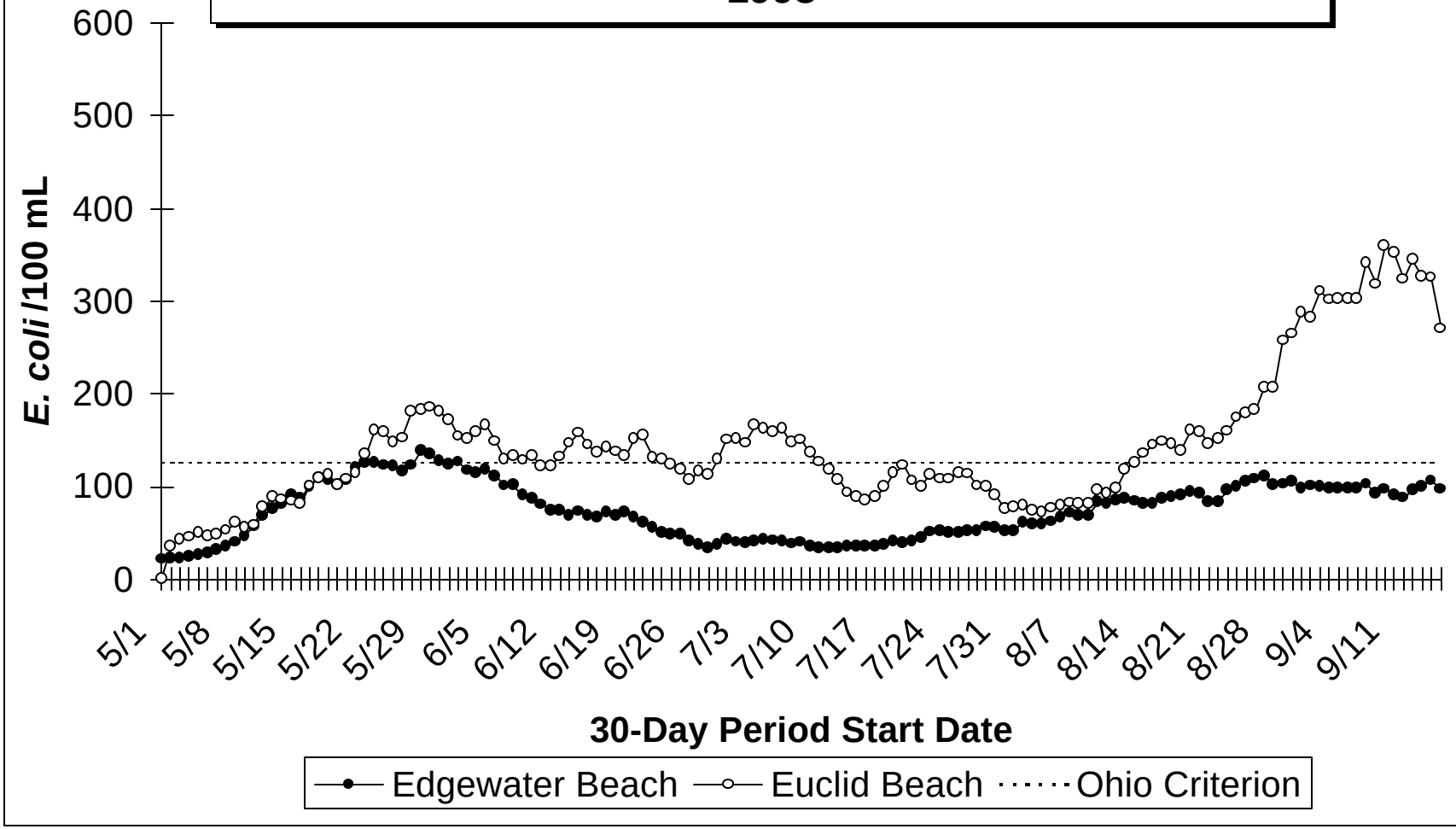


Figure 12-41
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of Fecal Coliform Conc. > 400/100 mL
1993

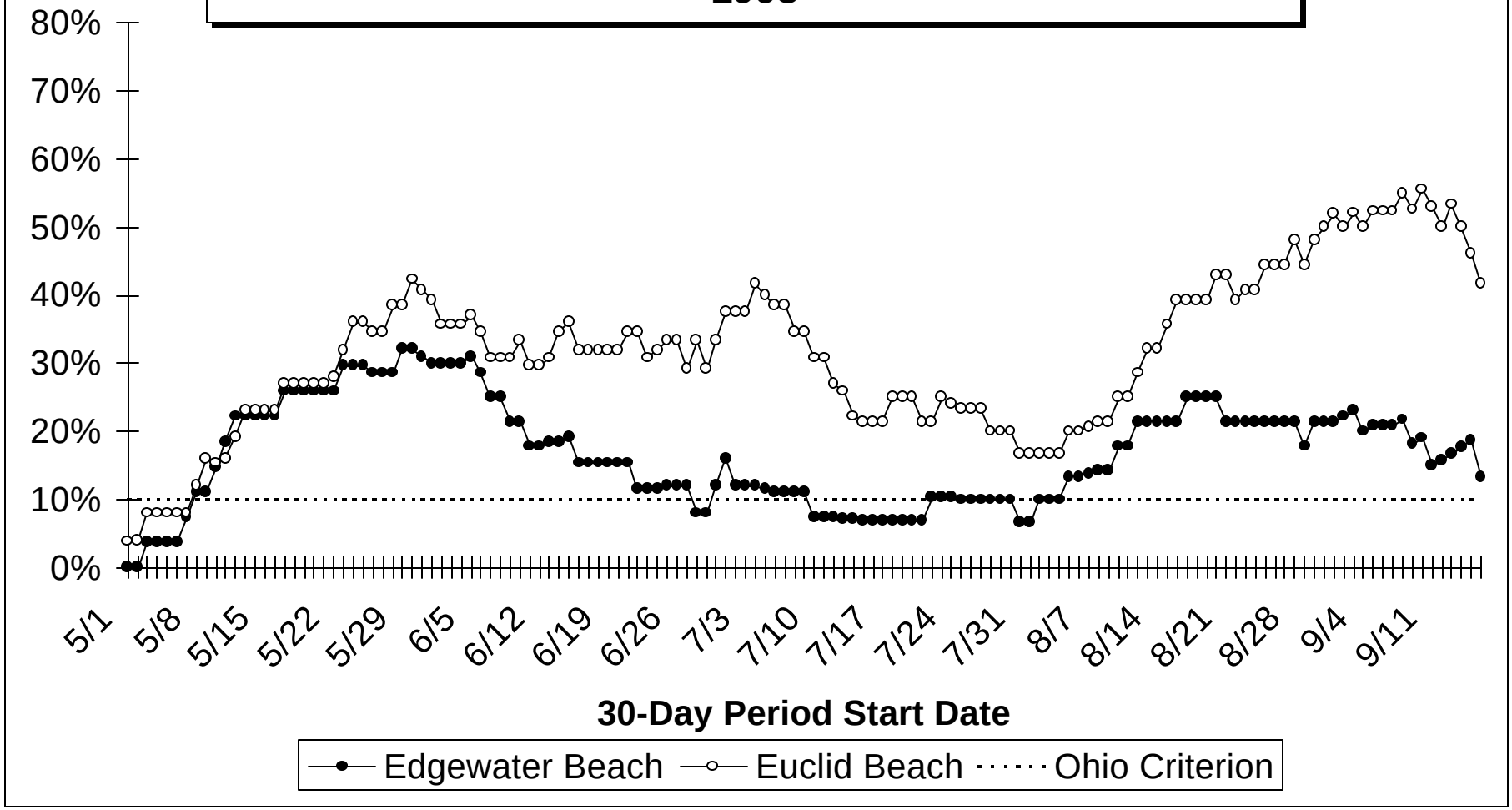


Figure 12-42
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of *E. coli* Concentrations > 235/100 mL
1993

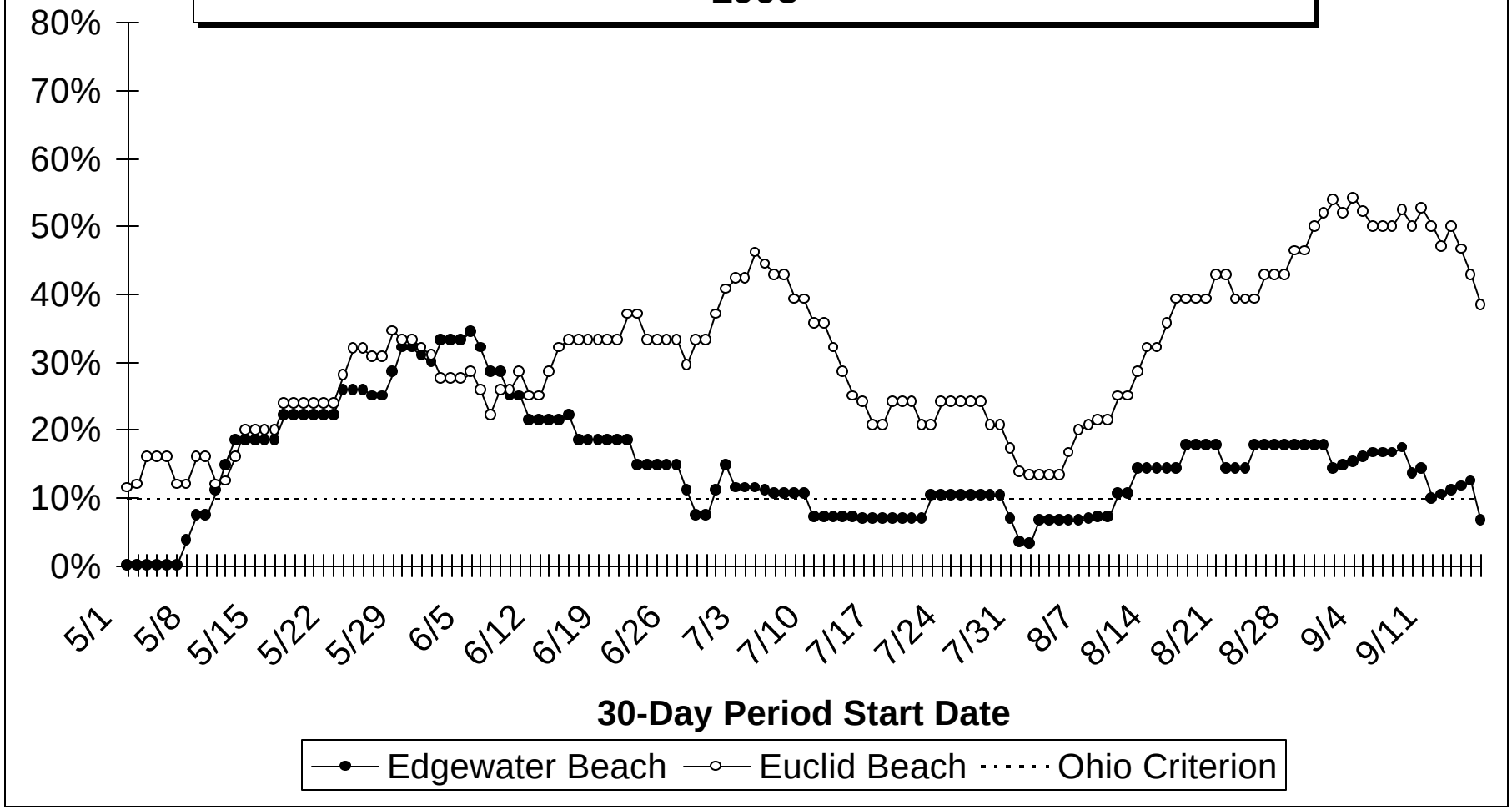


Figure 12-43
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean Fecal Coliform Concentrations
1994

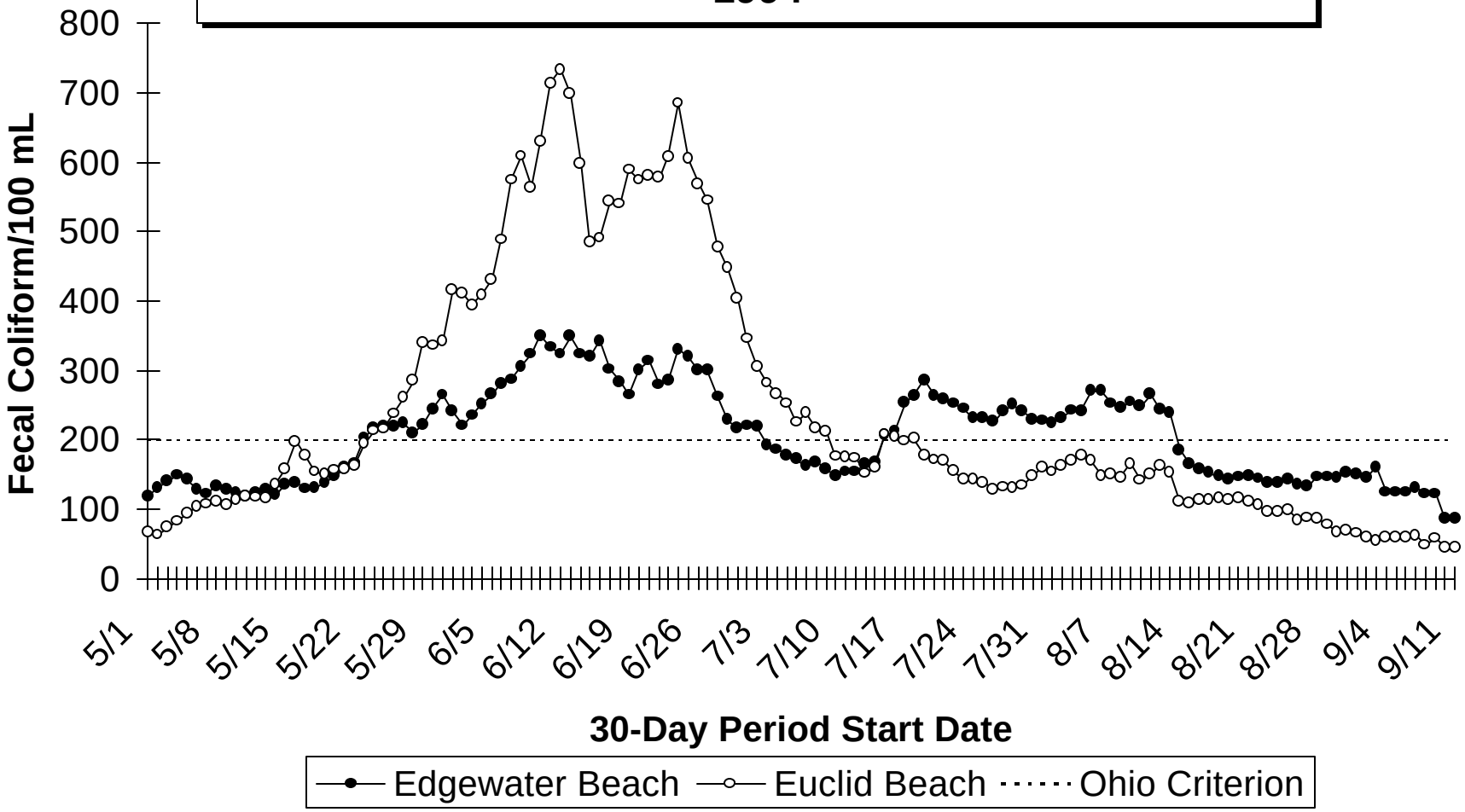


Figure 12-44
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean *E. coli* Concentrations
1994

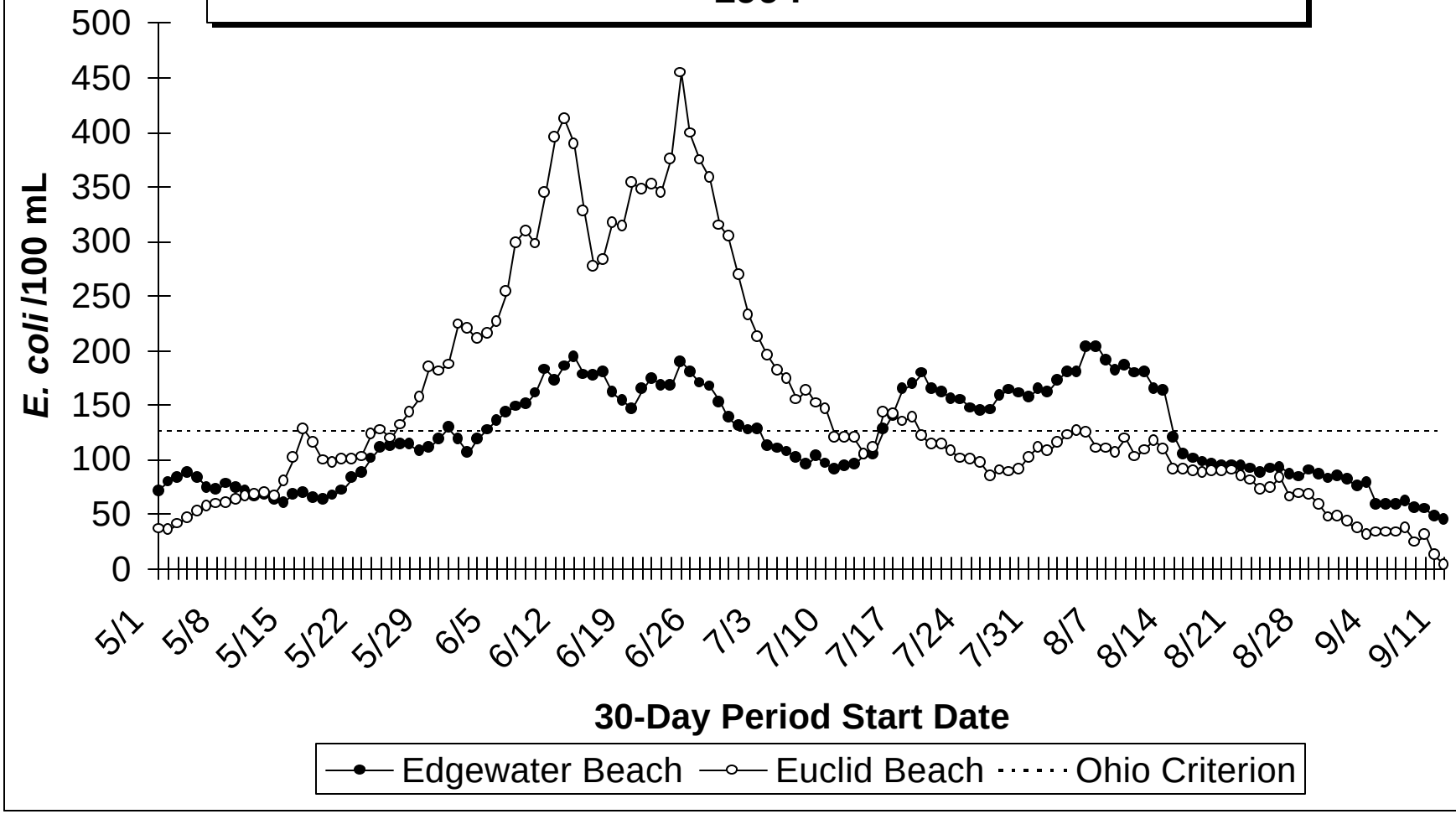


Figure 12-45
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of Fecal Coliform Conc. > 400/100 mL
1994

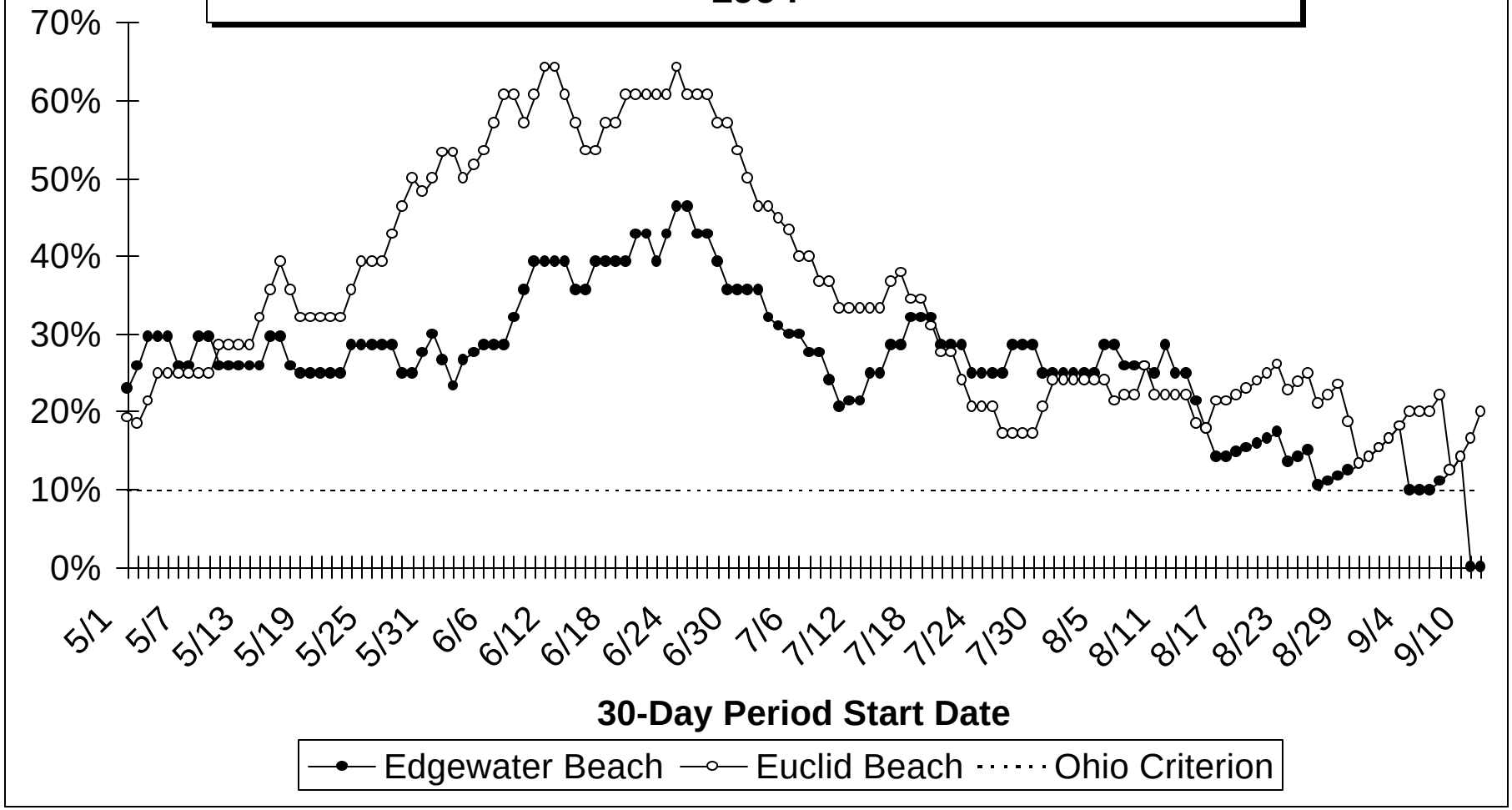


Figure12-46
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of *E. coli* Concentrations > 235/100 mL
1994

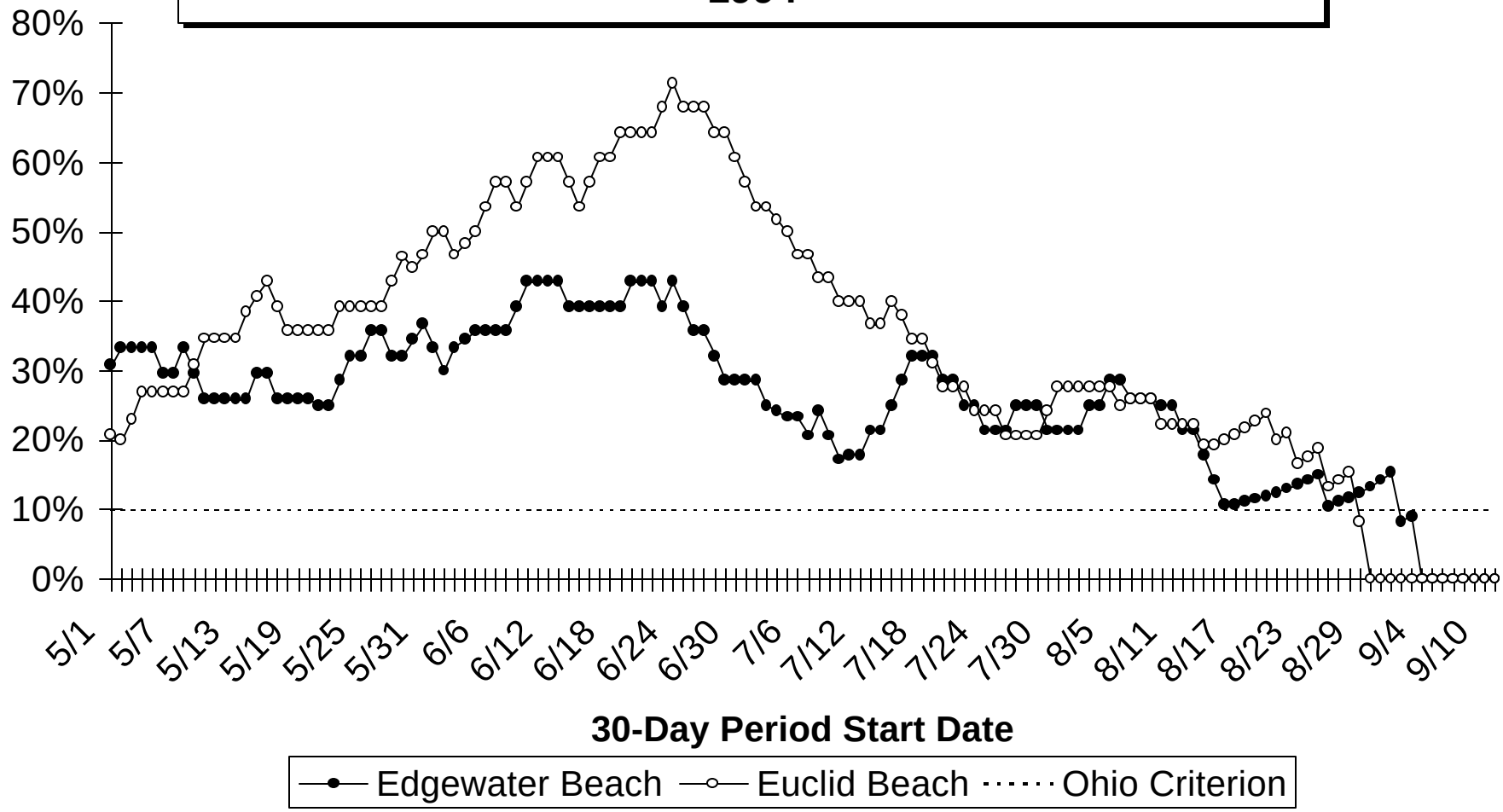


Figure 12-47
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean Fecal Coliform Concentrations
1995

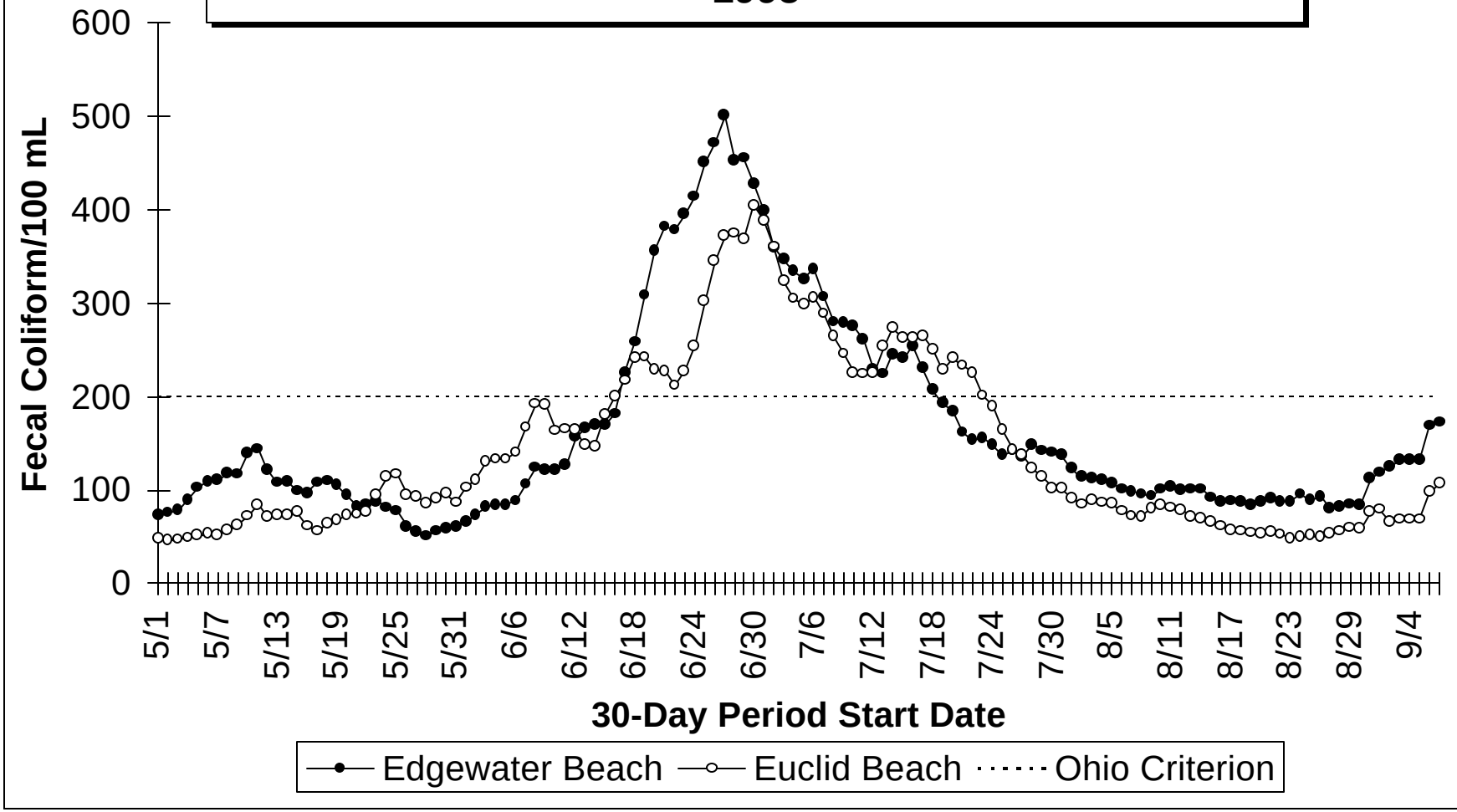


Figure 12-48
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of Fecal Coliform Conc. > 400/100 mL
1995

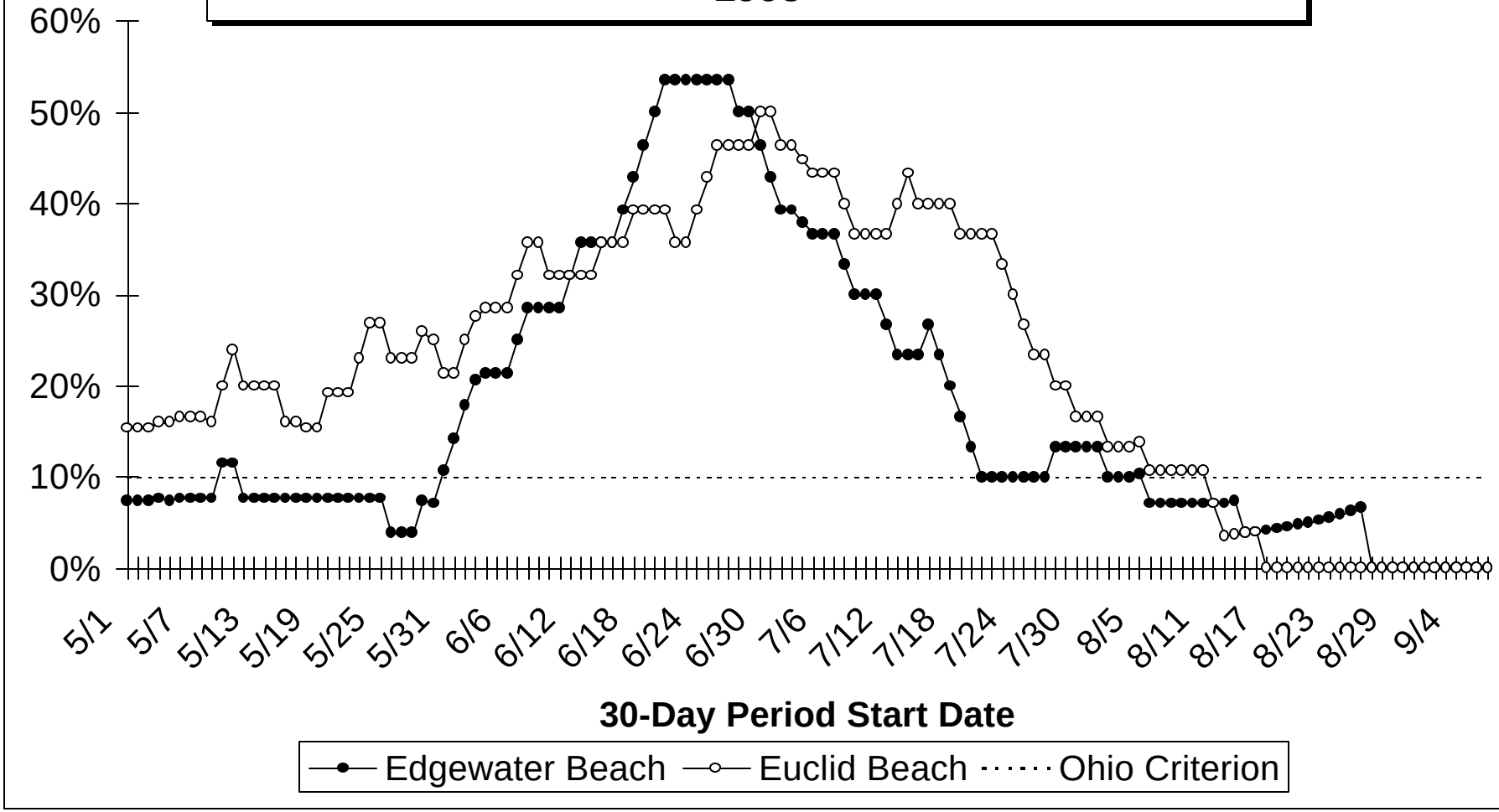


Figure 12-49
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean Fecal Coliform Concentrations
1996

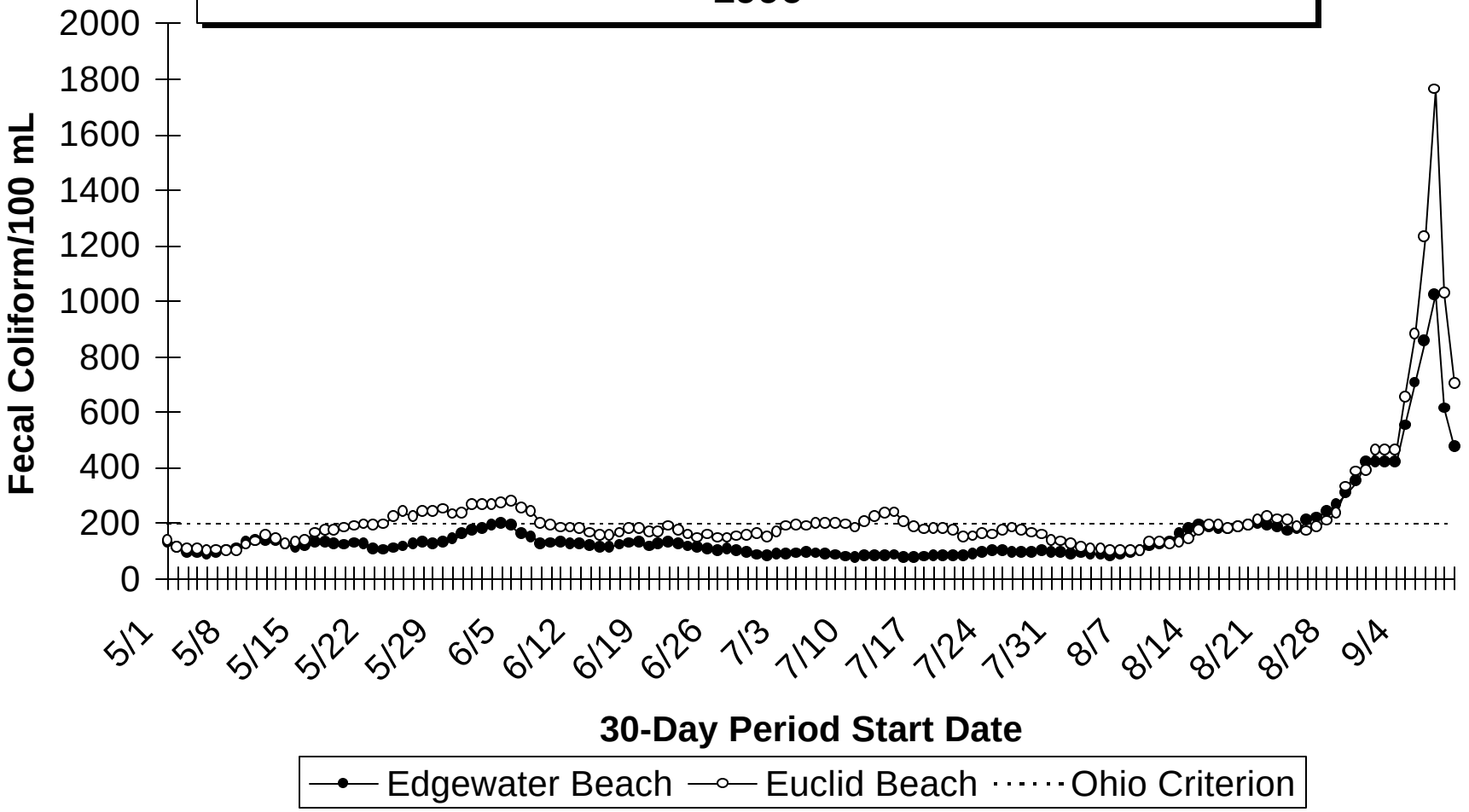


Figure 12-50
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Geometric Mean *E. coli* Concentrations
1996

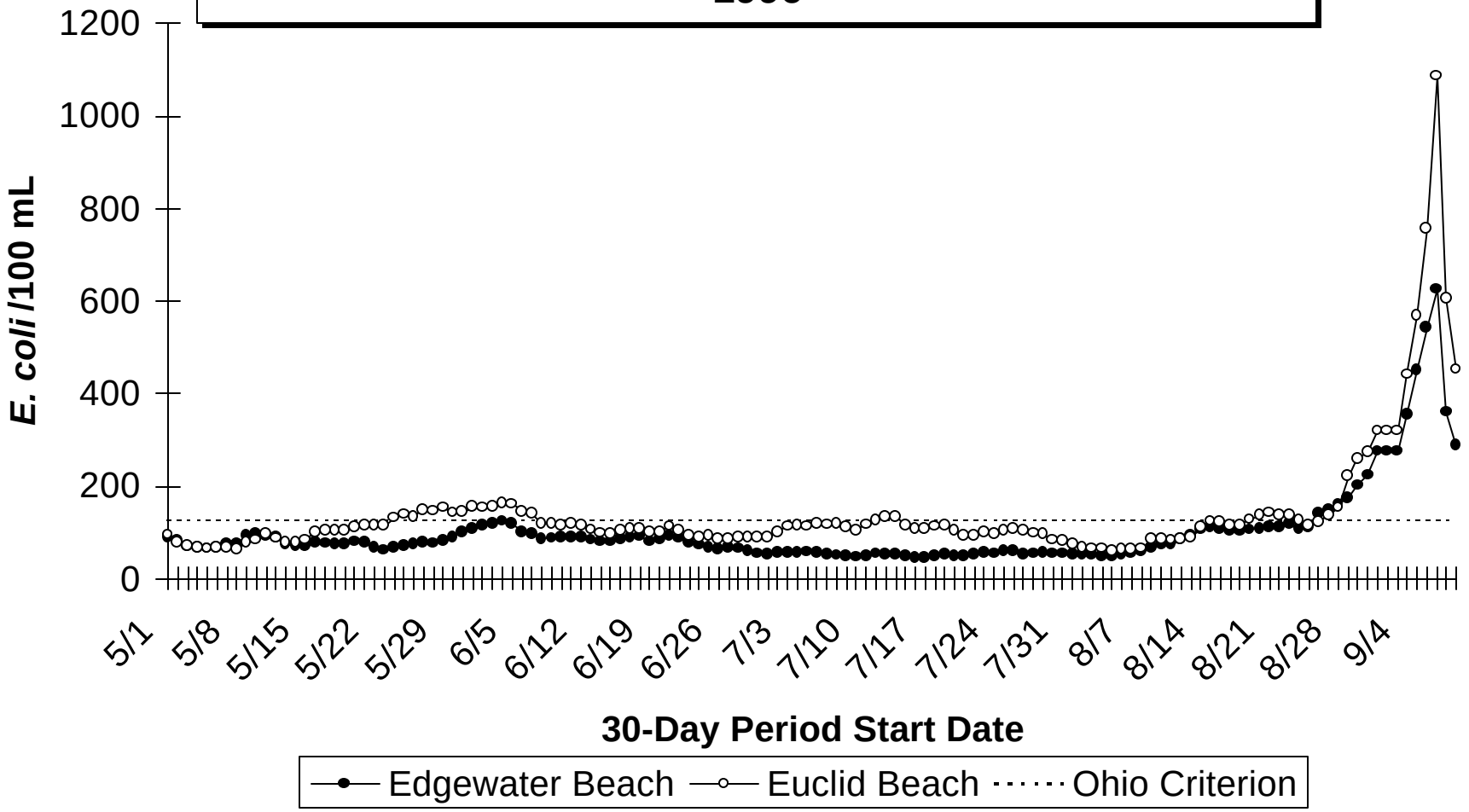


Figure 12-51
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of Fecal Coliform Conc. > 400/100 mL
1996

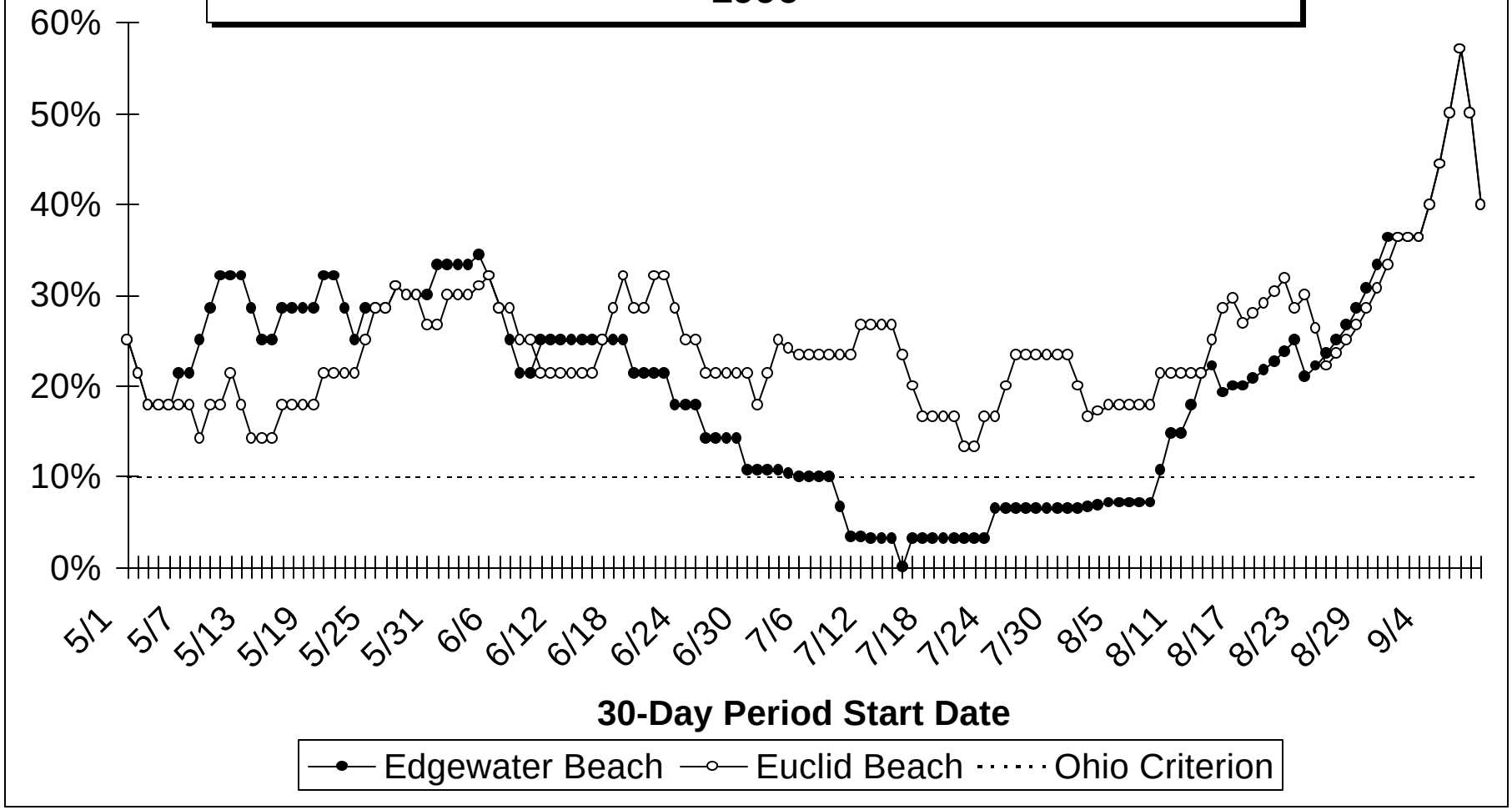
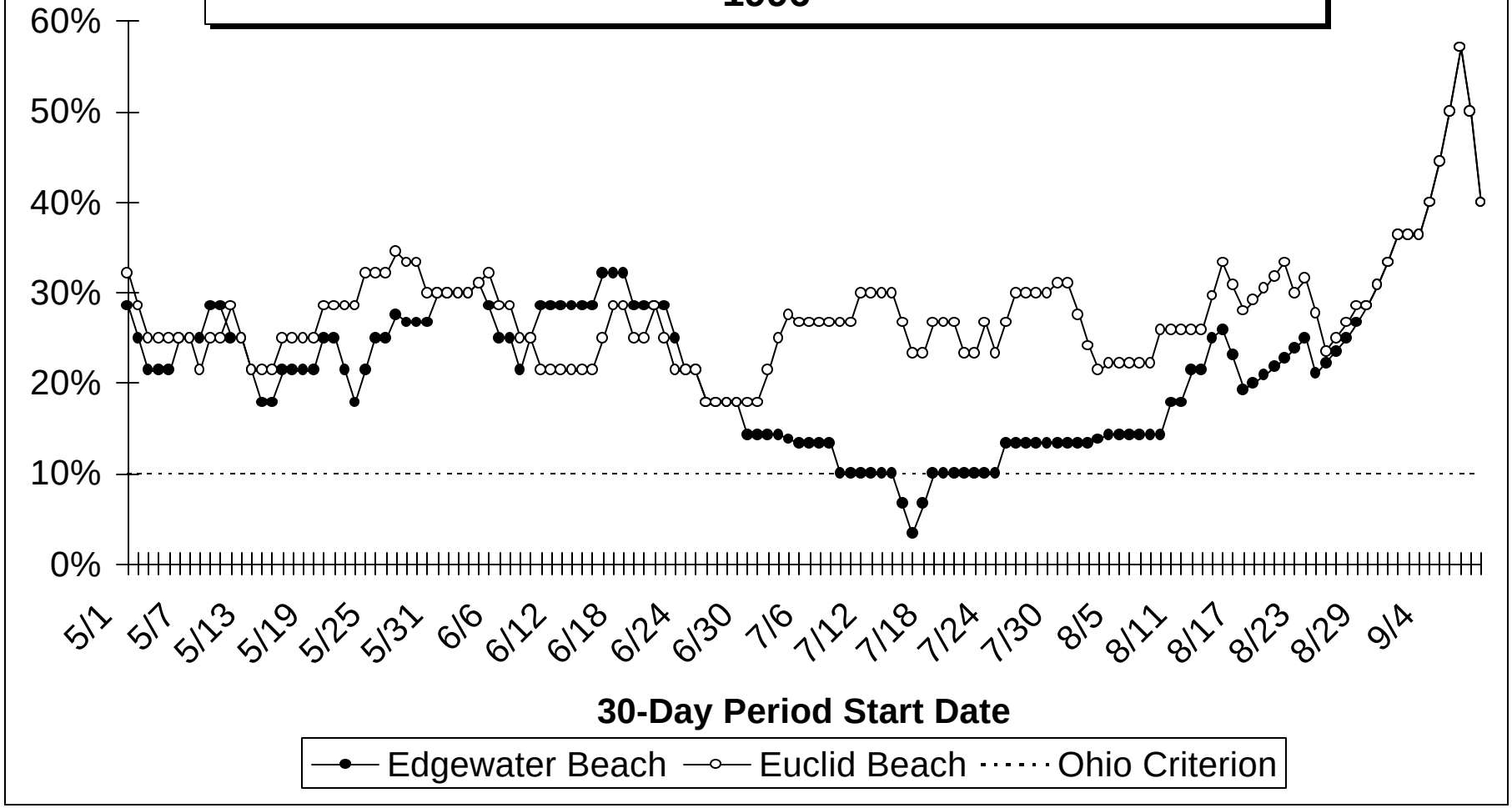



Figure 12-52
N.E. Ohio Regional Sewer District Lake Erie Beach Study
30-Day Percentage of *E. coli* Concentrations > 235/100 mL
1996