Water Quality Monitoring Report for the St. Joseph River Watershed Initiative

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EXECUTIVE SUMMARY

The St. Joseph River Watershed Initiative has maintained a water quality sampling program in the St. Joseph River Watershed since 1996. This report summarizes spatial and temporal trends of selected parameters throughout the watershed from 1999 to 2006. These parameters included: herbicides, bacteria, ammonia and total phosphorous, dissolved oxygen and turbidity. Additionally, concentrations of contaminants were compared to water quality criteria.

Median concentrations of herbicides were below water quality criteria for all years at all sites. Nettle Creek, Matthews Ditch, and Upper Cedar Creek sites had the highest median herbicide concentrations, while the East Branch and Garrett City Ditch had lowest median herbicide concentrations. Although median herbicide concentrations were below water quality criteria, individual samples throughout the watershed exceeded criteria for atrazine and alachlor. No obvious temporal trends were found for atrazine or metolachlor during 1999-2006, but an apparent decreasing trend was observed for cyanazine and alachlor. Additionally, cyanazine concentrations have fallen to near or below detectable limits over recent years at many sites.

Median concentrations of E. coli exceeded the full body contact recreation criterion for most sites over most of the years analyzed. However, median concentrations of E. coli from the West Branch site never exceeded this criterion. Garrett City Ditch had the highest E. coli concentrations, but this is largely due to extremely high concentrations in 2003. Since 2003, E. coli concentrations in Garrett City Ditch more closely resemble those at other sites in the watershed. No obvious temporal trends were observed for E. coli. from 1999-2006. At all sites water did not support recreational use in most years.

Phosphorus concentrations exceeded reference conditions at all sites in all years, but ammonia concentrations were always well below even the most sensitive chronic toxicity criterion. Water samples from Bear Creek, OH had the highest concentrations of both phosphorus and ammonia, while

the Diehl/Peckhart Ditch had the lowest concentrations of phosphorus and ammonia. No obvious temporal trends were observed for phosphorus or ammonia.

Median dissolved oxygen concentrations were well above water quality criteria. The West Branch and Lower Cedar Creek sites had the lowest dissolved oxygen concentrations, while Matthews Ditch and the Upper Cedar Creek sites had the highest dissolved oxygen concentrations. No obvious temporal trends were observed for dissolved oxygen from 1999-2006. Median turbidity values were above reference conditions for all sites in all years. East Branch had the highest median turbidity, while East Fork had the lowest median turbidity. A decreasing trend from upstream to downstream was found for turbidity in tributaries as they entered the St. Joseph River. Turbidity decreased from 2000 to 2004 at most sites, but increased in 2005 and 2006.

BACKGROUND

The St. Joseph River, fed by a 694,400-acre watershed that drains parts of six counties in Michigan, Ohio, and Indiana, serves as a source of domestic water for more than 200,000 residents in the City of Fort Wayne and surrounding area. The confluence of the St. Joseph and St. Mary's rivers in Fort Wayne forms the Maumee River that empties into the western basin of Lake Erie at Toledo, Ohio. The Maumee River Watershed is the largest in the Great Lakes basin.

In 1995, the City of Fort Wayne was cited by the Environmental Working Group in *Weed Killers by the Glass* for having unsafe levels of herbicides in drinking water. This prompted concerned stakeholders to organize the *Conference on the St. Joseph River* in 1996 that resulted in the formation of the St. Joseph River Watershed Initiative (SJRWI). The mission of the SJRWI is "*to improve water quality in the St. Joseph River Watershed by promoting economically and environmentally compatible land uses and practices"*. To support its' mission and goals, the SJRWI has managed an extensive water quality monitoring program in the St. Joseph River Watershed since 1996. This report summarizes the results of the water monitoring program from 1999-2006.

METHODS

Sampling Site Locations

Currently, the initiative samples 24 sites among 9 sub-watersheds throughout the St. Joseph River Basin (Figure 1). In the upper St. Joe Watershed, 8 sites among 3 sub-watersheds have been sampled over the history of the monitoring program (Figure 2). Another site (155) was added in 2007, but monitored only for field, physical, and chemical measurements. In the middle and lower St. Joe Watershed, 16 sites among 6 sub-watersheds have been sampled (Figure 3). A list of the sub-watersheds and site locations is presented in Table 1.

Figure 1. Sampling sites and subwatersheds in the St. Joseph River Watershed.

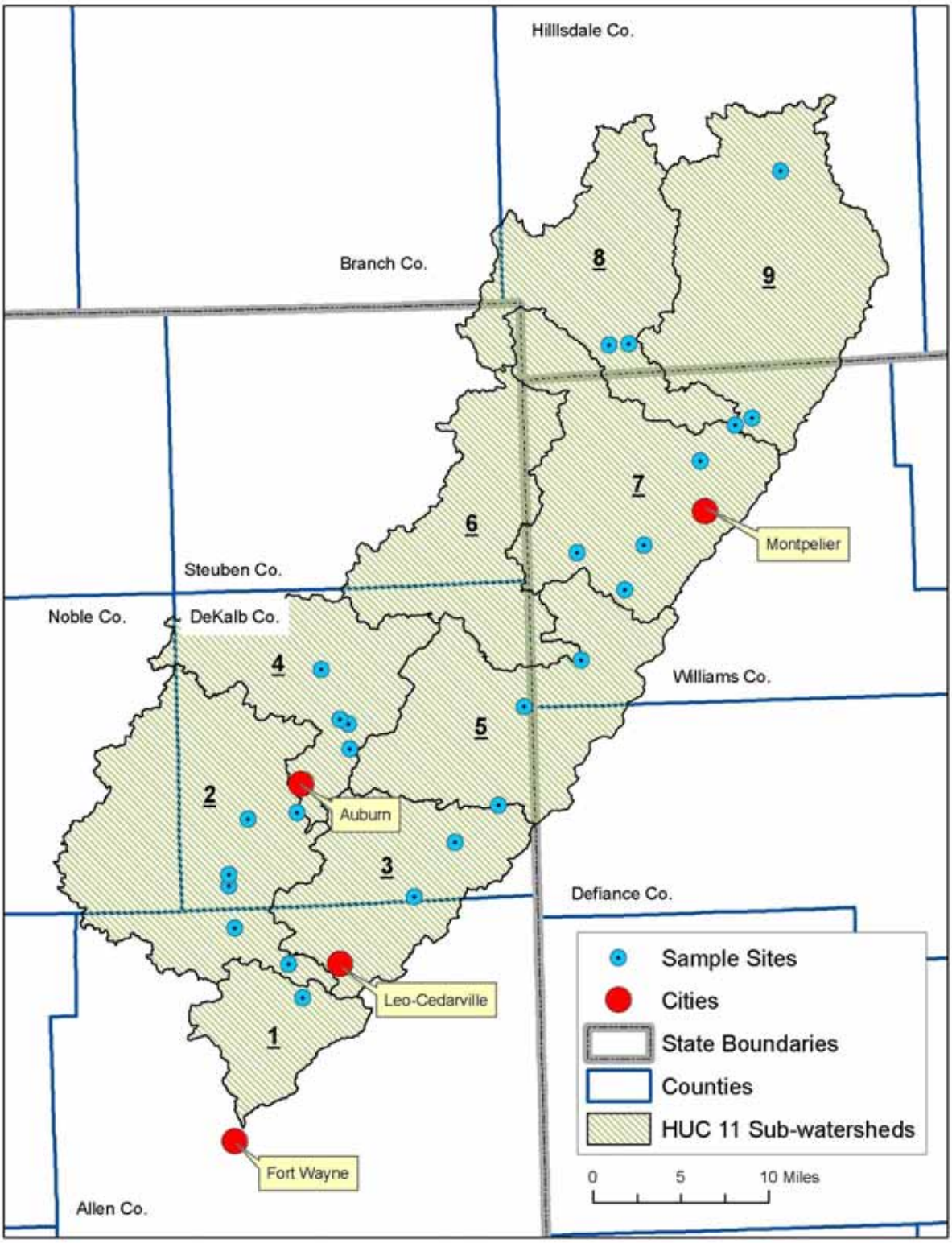


Figure 2. Sampling sites in the upper portion of the St. Joseph River Watershed.

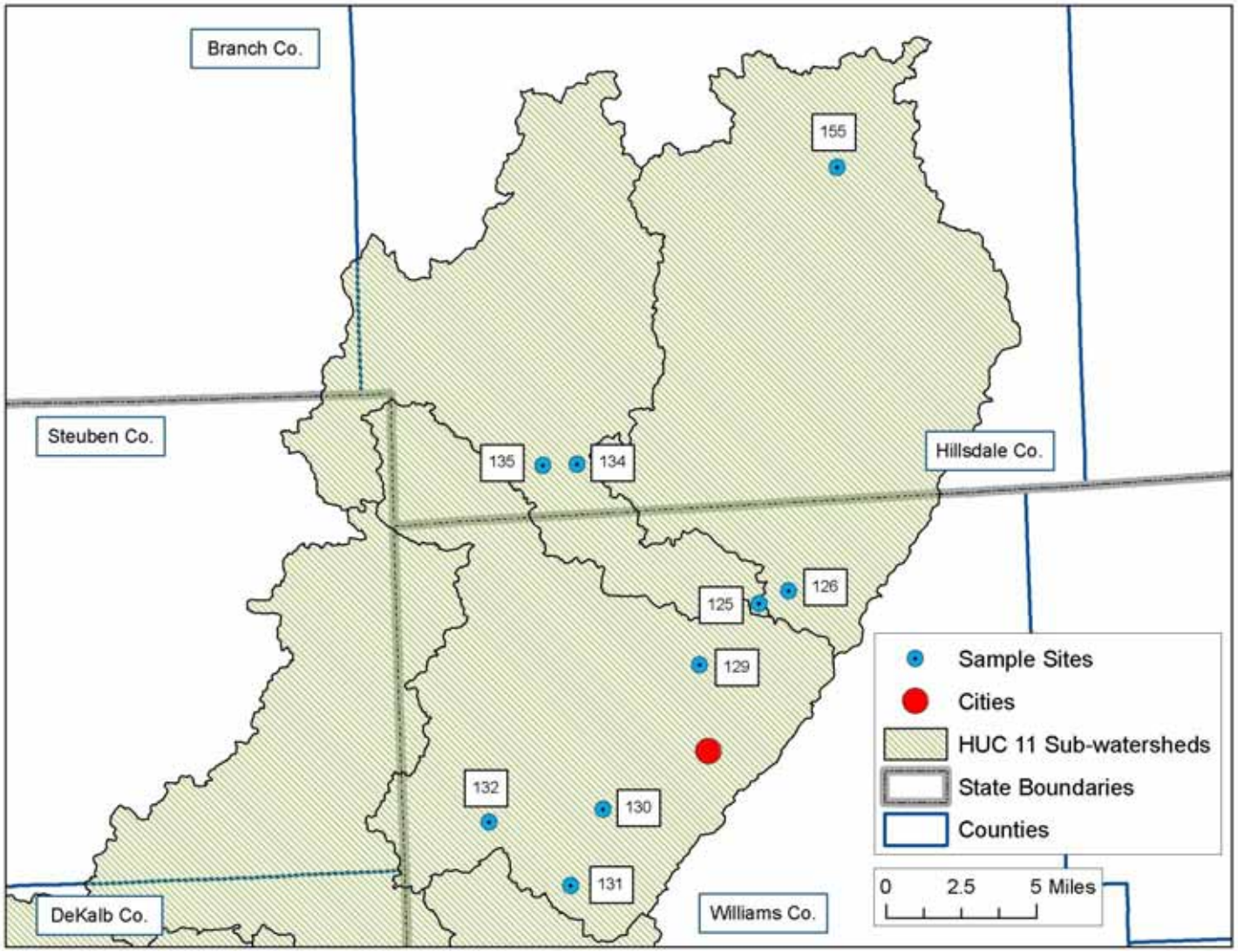
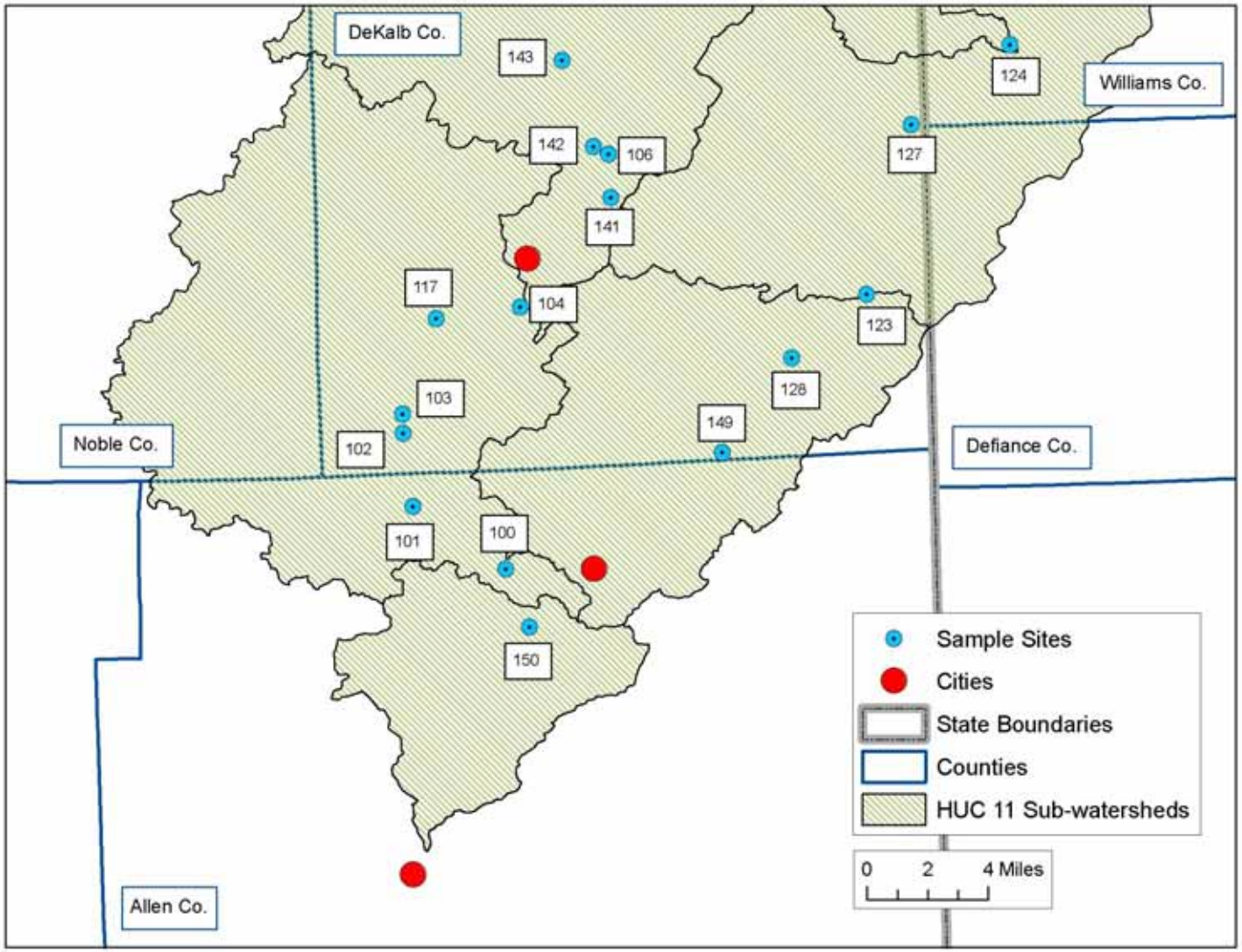


Figure 3. Sampling sites in the lower portion of the St. Joseph River Watershed.



Field Measurements and Sampling

Field measurements and water samples were collected from a marked point at the center of a bridge. Air temperature was measured with a hand-held thermometer, while wind speed and cloud cover are estimated using a subjective scale. The bridge-to-river distance is measured from the top of the bridge railing to the top of the water surface using a weighted measuring tape. Water depth was estimated as the difference between the bridge-to-river distance and the known distance from the bridge to the stream bed. The water sampling apparatus has a large, permanently-attached amber jar and a compartment for an additional small, sample bottle. The sampler is lowered into the stream just below the surface to fill both bottles. Care is taken to avoid disturbing sediments during sampling. When both jars are filled, the sampler is retrieved and the bottles are recapped. For herbicides, water is collected in a removable, 100-ml amber glass bottle. For nutrient analysis, 250 ml of water is placed in a plastic bottle containing 2mL of 9M sulfuric acid to achieve a pH less than 2. At all sites, 1 mL of sample water is pipetted into a sterile, plastic jar for bacteria analysis. Bottles with water for bacteria, herbicides, and nutrients are capped, labeled by site number and date, and placed into a cooler. Samples were surrounded by plastic ice packs in a cooler for transport to IPFW. All samples are stored in a refrigerator at 10^{o}C and transported to the analytical laboratory within 24 hours of collection. Water in the large, permanent amber sampling bottle was transferred to a jar and tested for physical and chemical parameters. For the years 2000-2002, temperature, dissolved oxygen, and turbidity were measured with a Horiba U-10 instrument. For the years 2003-2006, temperature, dissolved oxygen, turbidity, specific conductance, total dissolved solids, and pH were measured with a Hydrolab Quanta Instrument.

Table 1: Sampling site locations				
Site Name	**Site Number**	**Location**	**Sub-watershed**	**Nutrient Sample**
Cedar Creek	100	Tonkel Rd, Allen Co.	Lower Cedar Creek	+
Willow Creek	101	Coldwater Rd, Allen Co.	Lower Cedar Creek	
Black Creek	102	CR 7A, Dekalb Co.	Lower Cedar Creek	
Little Cedar Creek	103	CR 64, Dekalb Co.	Lower Cedar Creek	
Diehl/Peckhart Ditch	104	SR 427, Dekalb Co.	Lower Cedar Creek	+
Matson Ditch	106	CR 39, Dekalb Co.	Upper Cedar Creek	+
Garrett City Ditch	117	CR 15, Dekalb Co.	Upper Cedar Creek	
Shank Ditch	123	CR 75A, Dekalb Co.	Bear Creek	
Fish Creek	124	SR 49, Williams Co., Ohio	Fish Creek	
St. Joe - West	125	US 20, Williams Co., Ohio	West Branch	+
St. Joe - East	126	SR 15, Williams Co., Ohio	East Branch	
Big Run	127	CR 79, Dekalb Co.	Middle St. Joe	
Bear Creek – IN	128	SR 1, Dekalb Co.	Bear Creek	
Nettle Creek	129	SR 576, Williams Co., Ohio	Nettle Creek	
Eagle Creek	130	CR J, Williams Co., Ohio	Nettle Creek	
Bear Creek – OH	131	SR 34, Williams Co., Ohio	Nettle Creek	+
Matthews Ditch	132	CR 4, Williams Co., Ohio	Nettle Creek	
East Fork – West	134	Sampson Rd, Hillsdale Co., MI	West Branch	
West Fork – West	135	Sampson Rd, Hillsdale Co., MI	West Branch	
Walter Smith Ditch	141	CR 39, Dekalb Co.	Upper Cedar Creek	+
David Link Ditch	142	CR 37, Dekalb Co.	Upper Cedar Creek	
Dibbling Ditch	143	CR 18, Dekalb Co.	Upper Cedar Creek	
+ water samples are collected at these sites for nutrient analyses				

Table 2. List of measurements and analytical parameters			
Field Measurements	**Physical/Chemical Measurements**	**Herbicides and Bacteria**	**Nutrients**
Air Temperature	Water Temperature	Atrazine	Total Phosphorus
Cloud Cover	pH	Metolachlor	Ammonia
Wind	Specific Conductance	Alachlor	
Water Depth	Total Dissolved Solids	Cyanazine	
	Dissolved Oxygen	E. coli	
	Turbidity	Total Coliform	
		Heterotrophic Plate Count	

Laboratory Analysis

Herbicides and bacteria are analyzed by laboratory technicians at the Three Rivers Filtration Plant, City of Fort Wayne. Atrazine, Alachlor, and Metolachlor were quantified using immunoassay (ELISA) kits manufactured by Abraxis, Warminster, PA. Cyanazine is measured by immunoassay kits from Strategic Diagnostics, Inc., Newark, DE. Total coliform and *E. coli* were analyzed with Colilert Quanti-tray methods (USEPA- SM 9223). Heterotrophic plate counts were determined using the USEPA method, SM 9215 B. Ammonia and total phosphorous were analyzed by technicians at the Water Pollution Control Plant, City of Fort Wayne. Ammonia was analyzed using the ion selective electrode method (USEPA- 350.3). Total phosphorus was analyzed using an automated colorimetric method (USEPA- 365.4).

Data Analysis

Selection of Data for Analysis

This report presents the results of water quality monitoring for nine parameters at 22 sites during 1999-2006 (Table 3). Seven water quality parameters were measured at all sites, while total phosphorous and ammonia were measured at six sites. Data from weeks 15 to 39 (early April to late September) were used in this analysis because these weeks were consistently sampled among all sites and among the years presented. Additionally, this duration comprises the greatest intensity of land use activities that affect water quality.

Table 3. List of water quality parameters presented in this report.	
Parameter	**Years in Analysis**
Dissolved Oxygen	2000-2006
Turbidity	2000-2006
Herbicides	1999-2006
E. coli	1999-2006
Total Phosphorous	2002-2006
Ammonia	2002-2006

Box Plot Analysis

Raw data were exported from a Microsoft Access database to Microsoft Excel spreadsheets. Data were sorted by site and years and examined for potential errors. Data determined likely to be erroneous were deleted from the spreadsheet. Data from Excel spreadsheets were imported to Sigma Plot, Systat Software, Inc., for graphic analysis. Box plot analysis was used to compare the central tendency and distribution of water quality data among sites and among years. Sigma Plot box-plot analysis uses the frequency distribution of data points (Figure 4, step 1) to calculate the 10%, 25%, 50% (median), 75%, and 90% limits in the data frequency distribution (Figure 4, steps 2 and 3). Each box presents the median, percentiles and outliers for many data points in a single view. The box plot was used to compare water quality data among sites over many years and to compare data among years within sites. Each graph reports the number of samples and the number of sites sampled for calculation of the box plots (Figure 5).

Figure 4. Explanation of the creation of box plots for presenting water quality parameters.

East Branch	
Date	Atrazine
05/01/06	0.66
05/08/06	0.42
05/15/06	0.78
05/22/06	1.23
05/29/06	1.65
06/06/06	0.96
06/13/06	0.77
06/20/06	1.13
06/27/06	1.67
07/04/06	0.67
07/11/06	0.55
07/18/06	0.32
07/25/06	1.98
08/01/06	0.92
08/08/06	0.32
08/15/06	0.12

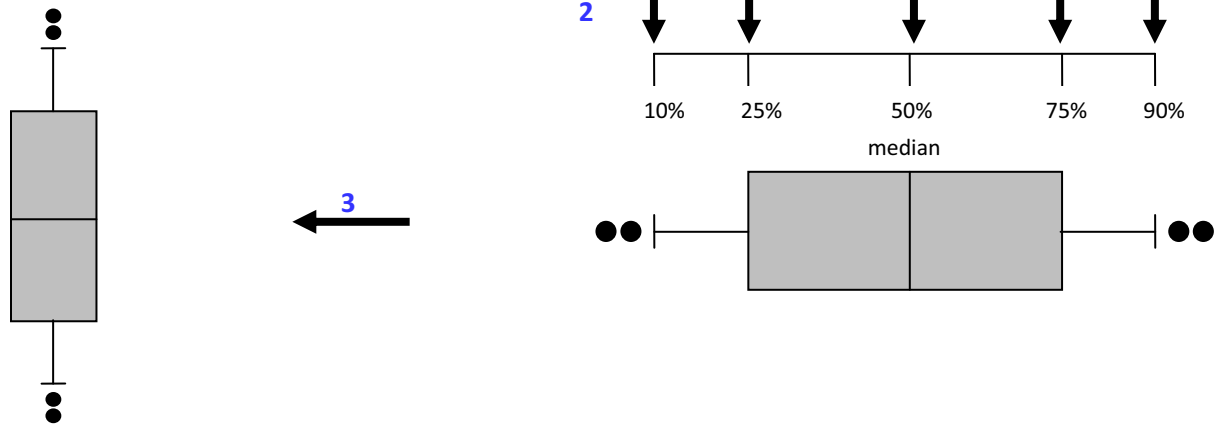
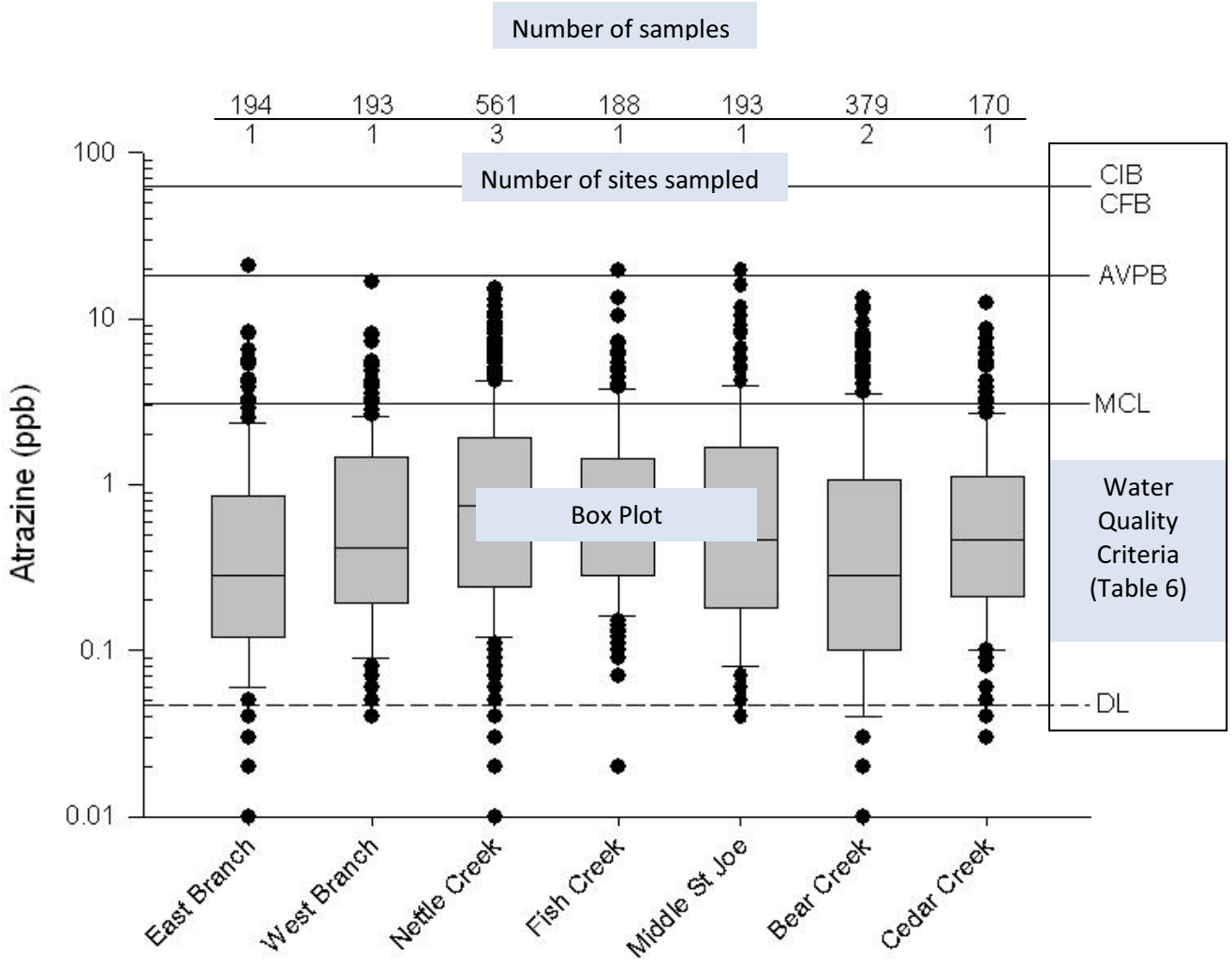


Figure 5. Example of a box plot for presentation of water quality data. Each box plot presents the number of samples, the number of sites sampled, and water quality criteria.



Spatial Comparisons

For all parameters except total phosphorous and ammonia, sites were grouped into two sets based on their proximity to the St. Joseph River. Confluence sites were sampled just upstream of the St. Joseph River and were identified by sub-watershed name (Table 4). If multiple confluence sites were sampled within a sub-watershed, the data were pooled. Data from collection sites in the Nettle Creek and Bear Creek sub-watersheds were pooled in this manner. In all graphs the confluence sites were arranged left to right in the order that they enter the St. Joseph River, from upstream to downstream.

Headwater sites were sampled in streams and ditches well upstream from the confluence with the St. Joseph River. Data were pooled from multiple sites with similar land use characteristics within the Upper Cedar Creek and Lower Cedar Creek sub-watersheds. In all graphs the headwater sites were grouped by proximity and similarity of land use. The East Fork, West Fork and Lower Cedar Creek sites are streams whose channels are mostly unmodified and where there is minimal agricultural, domestic, and industrial land use. The Upper Cedar Creek sites and Matthews Ditch comprise agricultural ditches. Garrett City Ditch and the Diehl/Peckhart Ditch, in the Upper Cedar Creek sub-watershed, are influenced by land uses that differ from these other two groups.

Temporal Comparisons

Comparisons of water quality parameters among years were made by creating annual box plots over the duration of sample years for each site or site group. For most sites and site groups, annual data for all water quality parameters were available from 1999-2006 (Tables 4 & 5). For other sites, water quality data have been collected for only a few to several years.

Table 4. List of years analyzed for each parameter at each site or site group.

Site/Site Group	Years in Analysis			
	Dissolved Oxygen	Turbidity	Herbicides	E. coli
Confluence Sites				
East Branch	2000-2006	2000-2006	1999-2006	1999-2006
West Branch	2000-2006	2000-2006	1999-2006	1999-2006
Nettle Creek	2000-2006	2000-2006	1999-2006	1999-2006
Fish Creek	2000-2006	2000-2006	1999-2006	1999-2006
Middle St. Joseph	2000-2006	2000-2006	1999-2006	1999-2006
Bear Creek	2000-2006	2000-2006	1999-2006	1999-2006
Cedar Creek	2000-2006	2000-2006	1999-2006	1999-2006
Headwater Sites				
East Fork	2000-2006	2000-2006	1999-2006	1999-2006
West Fork	2000-2006	2000-2006	1999-2006	1999-2006
Lower Cedar Creek	2004-2006	2004-2006	2004-2006	2004-2006
Garrett City Ditch	2003-2006	2003-2006	2003-2006	2003-2006
Diehl/Peckhart Ditch	2000-2006	2000-2006	1999-2006	1999-2006
Upper Cedar Creek	2002-2006	2002-2006	2002-2006	2002-2006
Matthews Ditch	2000-2006	2000-2006	1999-2006	1999-2006

Table 5. List of years that sites were analyzed for nutrients.

Site/Site Group	Years in Analysis	
	Total Phosphorus	Ammonia
Nutrient Sites		
St. Joe West Branch	2002-2006	2002-2006
Bear Creek OH	2002-2006	2002-2006
Cedar Creek	2002-2006	2002-2006
Diehl/Peckhart Ditch	2002-2006	2002-2006
Walter Smith Ditch	2002-2006	2002-2006
Matson Ditch	2002-2006	2002-2006

Comparisons to Water Quality Criteria and Reference Condition

Water quality criteria or reference condition values are presented in all graphs. For water parameters that have criteria or reference condition values, the percent of samples exceeding the criteria or reference were calculated. For many herbicides, maximum contaminant levels (MCL) for drinking water (Table 6) have been established by the USEPA (USEPA-SAFE). Concentrations of herbicides must be below the MCL before being delivered for human consumption. Similarly, maximum allowable concentrations (MAC) have been established for herbicides by Health Canada (HC). If there are not enough data to support a MAC, an interim maximum acceptable concentration (IMAC) is established to protect human health. For the purpose of this report, MCLs were presented for pollutants, if available. In the absence of an MCL, MACs or IMACs were reported.

Water quality criteria and toxicity benchmarks to protect aquatic life have been established for herbicides and ammonia (Table 7). Chronic toxicity benchmarks are intended to protect aquatic organisms from adverse effects over a lifetime of contact with a contaminant, while acute toxicity benchmarks are intended to protect aquatic organisms from a single high dose of a contaminant. Toxicity benchmarks have been established for vascular plants (rooted plants), nonvascular plants (algae), invertebrates (such as insects), and fish. For some herbicides, a chronic toxicity benchmark has been established to protect the entire aquatic community from adverse effects.

Several water quality criteria to protect human health from exposure to *E. coli* have been established based on different levels of body contact with water (Table 6). These levels are based on the likelihood of illness resulting from a specific level of contact with water that is contaminated with *E. coli* (USEPA 1986a). The Indiana Department of Environmental Management (IDEM) uses USEPA criteria for *E. coli* to assess whether designated uses for recreational waters are being met. IDEM qualifies bodies of water as not supporting recreational use if (1) more than 10% of samples exceed the USEPA

infrequent full body contact (IBC) recreation criteria of 576 CFU/100 mL, or (2) more than one sample exceeds the recreational use support (RUS) criterion of 2,400 CFU/100mL.

Water quality criteria to protect aquatic life have been established for dissolved oxygen (Table 7). The USEPA has multiple criteria to protect aquatic life based on the presence of certain life stages of organisms (USEPA 1986b). The early life stage criterion is the most sensitive for dissolved oxygen and was used for this report. The Indiana Department of Environmental Management (IDEM) classifies bodies of water with dissolved oxygen below 4 mg/L as impaired for aquatic life.

Water quality criteria to protect aquatic life have been established for total phosphorus and ammonia (Table 7). IDEM classifies bodies of water with concentrations of total phosphorous greater than 0.3 mg/L as being impaired for aquatic life. The USEPA has established acute and chronic toxicity criteria for ammonia (USEPA 2006). These criteria are calculated for specific bodies of water based on average temperature and pH. We calculated a site-specific criteria for ammonia, using a median temperature of 20°C and median pH of 7.87 that was calculated from six sites over a five-year period.

Reference conditions, established by the USEPA, are determined by ecoregions to provide standards for assessment of water quality by tribes and states (USEPA 2000). Reference conditions for total phosphorus and turbidity were used to assess the quality of St. Joseph Watershed water for these contaminants (Table 7). We used reference condition values at the 25^{th} percentile from Aggregate Nutrient Ecoregion VI for turbidity and from Subecoregion 55 for phosphorous (UEPA 2000).

Table 6. Water quality criteria to protect human health.

Water Parameter	Criterion	Value	Notes	Citation
Atrazine	Maximum contaminant level	3 ppb	MCL	1
Metolachlor	Interim maximum allowable concentration	50 ppb	IMAC	2
Alachlor	Maximum contaminant level	2 ppb	MCL	1
Cyanazine	Interim maximum allowable concentration	10 ppb	IMAC	2
E. coli	Frequent full body contact recreation	235 CFU/100mL	FBC	3
	Moderate full body contact recreation	298 CFU/100mL	MBC	3
	Lightly used full body contact recreation	409 CFU/100mL	LBC	3
	Infrequent full body contact recreation	576 CFU/100mL	IBC	3
	Recreational use support	2400 CFU/100mL	RUS	4

1 Drinking Water Contaminants (USEPA-SAFE)
2 Guidelines for Canadian Drinking Water Quality (HC)
3 USEPA 1986a
4 Criteria for Use Support Assessment for 303d Listing (IDEM)

Table 7. Water quality criteria to protect freshwater life and reference conditions.

Water Parameter	Criterion	Value	Notes	Citation
Dissolved Oxygen	Other aquatic life stage criteria	3 mg/L	OSC	5
	Impaired aquatic life use	4 mg/L	IAL	4
	Early aquatic life stage criteria	5 mg/L	ESC	5
Turbidity	Reference conditions- ecoregion IV	9.89 NTU	Ref	6
Atrazine	Acute toxicity vascular plant	18 ppb	AVPB	7
	Acute toxicity nonvascular plant	32 ppb	ANVPB	
	Chronic toxicity invertebrate	62 ppb	CIB	
	Acute toxicity invertebrate	360 ppb	AIB	
	Chronic toxicity fish	62 ppb	CFB	
	Acute toxicity fish	2650 ppb	AFB	
Metolachlor	Chronic toxicity fish	780 ppb	CFB	7
	Acute toxicity fish	1950 ppb	AFB	
	Acute toxicity invertebrates	12550 ppb	AIB	
Alachlor	Acute toxicity nonvascular plant	1.64 ppb	ANVPB	7
	Chronic toxicity invertebrate	110 ppb	CIB	
	Acute toxicity invertebrate	1600 ppb	AIB	
	Chronic toxicity fish	187 ppb	CFB	
	Acute toxicity fish	900 ppb	AFB	
Total Phosphorous	Reference conditions- ecoregion 55	0.0625 mg/L	Ref	6
	Impaired aquatic life use	0.3000 mg/L	IAL	4
Ammonia	Chronic fish toxicity	1.94 mg/L	CFT	8

4 Criteria for Use Support Assessment for 303d Listing (IDEM)
5 USEPA 1986b
6 USEPA 2000
7 Aquatic Life Benchmark (USEPA-OPP)
8 Calculated using a median temperature of 20°C and median pH of 7.87 (USEPA 2006)

RESULTS

Atrazine

Spatial Comparisons

Among confluence sites (Figure 6), Nettle Creek and Fish Creek sub-watersheds had the highest median concentrations (0.74 ppb and 0.66 ppb, respectively) of atrazine, while East Branch and Bear Creek sub-watersheds had the lowest median atrazine concentrations (0.28 ppb). Among headwater sites (Figure 6), Matthews Ditch and the Upper Cedar Creek sites had the highest median atrazine concentrations (0.61 ppb and 0.54 ppb, respectively), while Garrett City Ditch had the lowest median atrazine concentration (0.12 ppb). Maximum atrazine concentrations occurred in 6 of the 11 sites sampled in 1999 and in 5 of the 14 sites sampled in 2004.

Temporal Comparisons

Concentrations of atrazine varied among years at all sites and there were no obvious trends during 1999-2006. However, the lowest median concentration of atrazine occurred in 1999 for 8 of 11 sites. Additionally, the highest median concentration of atrazine occurred in 2000 for 9 of 11 sites. Median atrazine concentrations in Garrett City Ditch decreased from 0.23 ppb in 2003 to 0.09 ppb in 2006. Although this trend was detected over only four years, changes in application and/or land use practices may have contributed to this decline.

Comparison to Water Quality Criteria

Although the median concentrations of atrazine were well below the MCL for drinking water at all sites (Figures 7, 8), water samples regularly exceeded the MCL at most sites and in most years (Table 8). Between 1999-2006, Nettle Creek had the highest percent of samples among confluence sites that exceeded the MCL for atrazine (17%). During these years, East Branch, West Branch, and Cedar Creek confluence sites had the lowest percent of samples that exceeded the MCL for atrazine (9%). From 1999-2006 Matthews Ditch had the highest percent of samples among headwater sites that exceeded

the MCL for atrazine (16%). During these years, Lower Cedar Creek sites had the lowest percent of samples that exceeded the MCL for atrazine (5%).

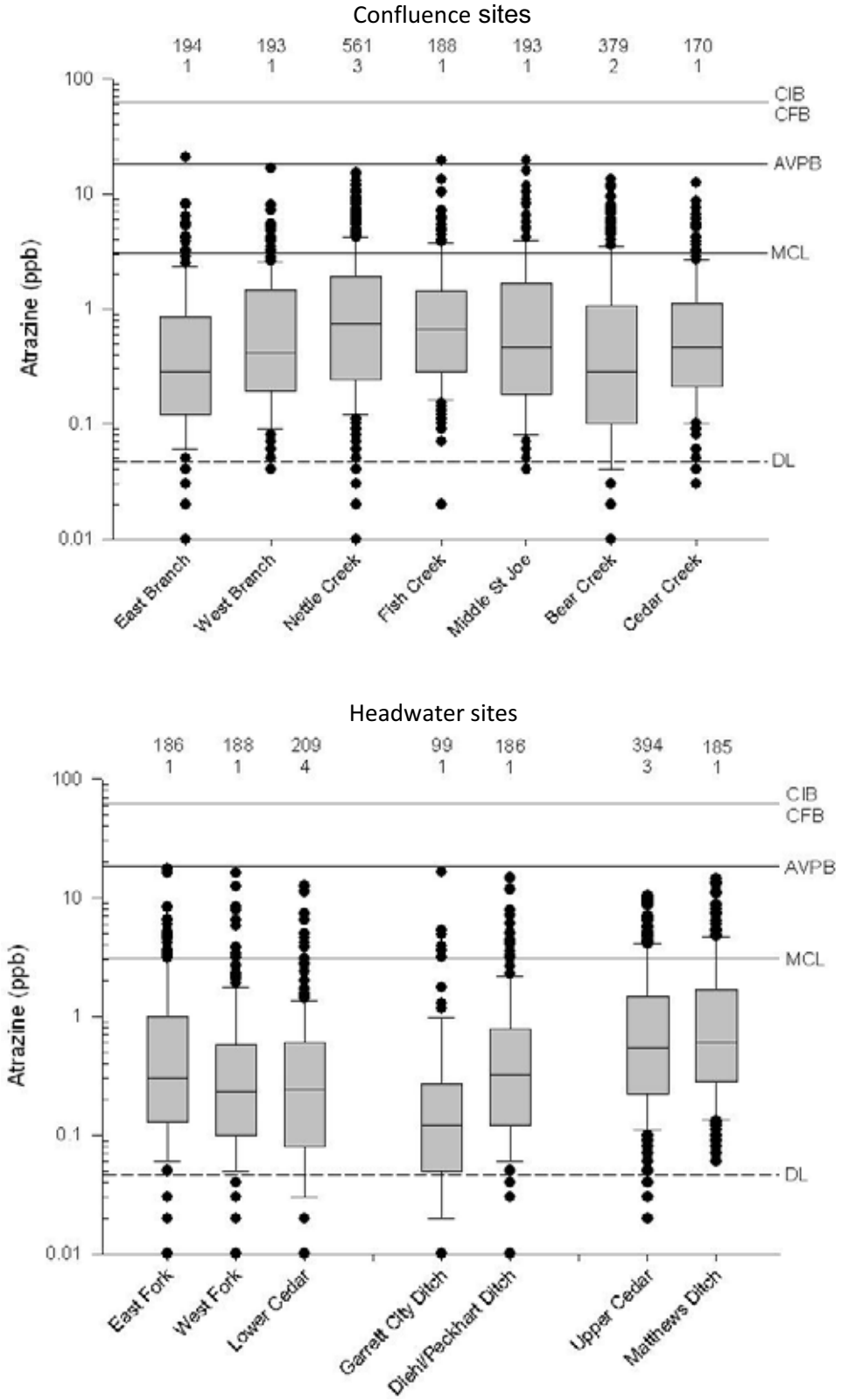
During 1999-2006, the greatest percent of samples that exceeded the MCL for atrazine occurred during 2000 (9-35%). During these years, the least percent of samples that exceeded the MCL for atrazine occurred during 2005 (0-8%), when water samples exceeded the MCL for atrazine at only 5 of 14 sites. During 1999-2006, concentrations of atrazine exceeded the vascular plant acute chronic toxicity criterion only twice (East Branch and Fish Creek) and never exceeded chronic toxicity criteria for fish and macroinvertebrates (Figures 6, 7).

Table 8. Percent of samples that exceeded the MCL for atrazine in drinking water

Site	1999	2000	2001	2002	2003	2004	2005	2006	Total years
Confluence Sites									
East Branch	13	22	8	4	4	12	0	8	9
West Branch	17	22	4	9	4	0	8	8	9
Nettle Creek	21	35	8	9	12	15	5	28	17
Fish Creek	21	35	4	4	12	16	5	9	13
Middle St Joe	21	22	16	4	8	24	0	4	12
Bear Creek	18	20	14	2	12	18	5	13	13
Cedar Creek	14	14	4	5	14	9	0	10	9
Headwater Sites									
East Fork	8	26	16	13	13	0	0	4	10
West Fork	13	9	8	5	0	8	0	4	6
Lower Cedar	ND	ND	ND	ND	ND	11	0	5	5
Garrett City	ND	ND	ND	ND	12	8	0	4	6
Diehl/Peckhart	17	17	4	5	8	12	0	5	9
Upper Cedar	ND	ND	ND	28	8	17	5	12	13
Matthews Ditch	21	26	12	22	16	16	0	13	16

ND= no data

Figure 6. Atrazine concentrations among 14 sites for 1999-2006

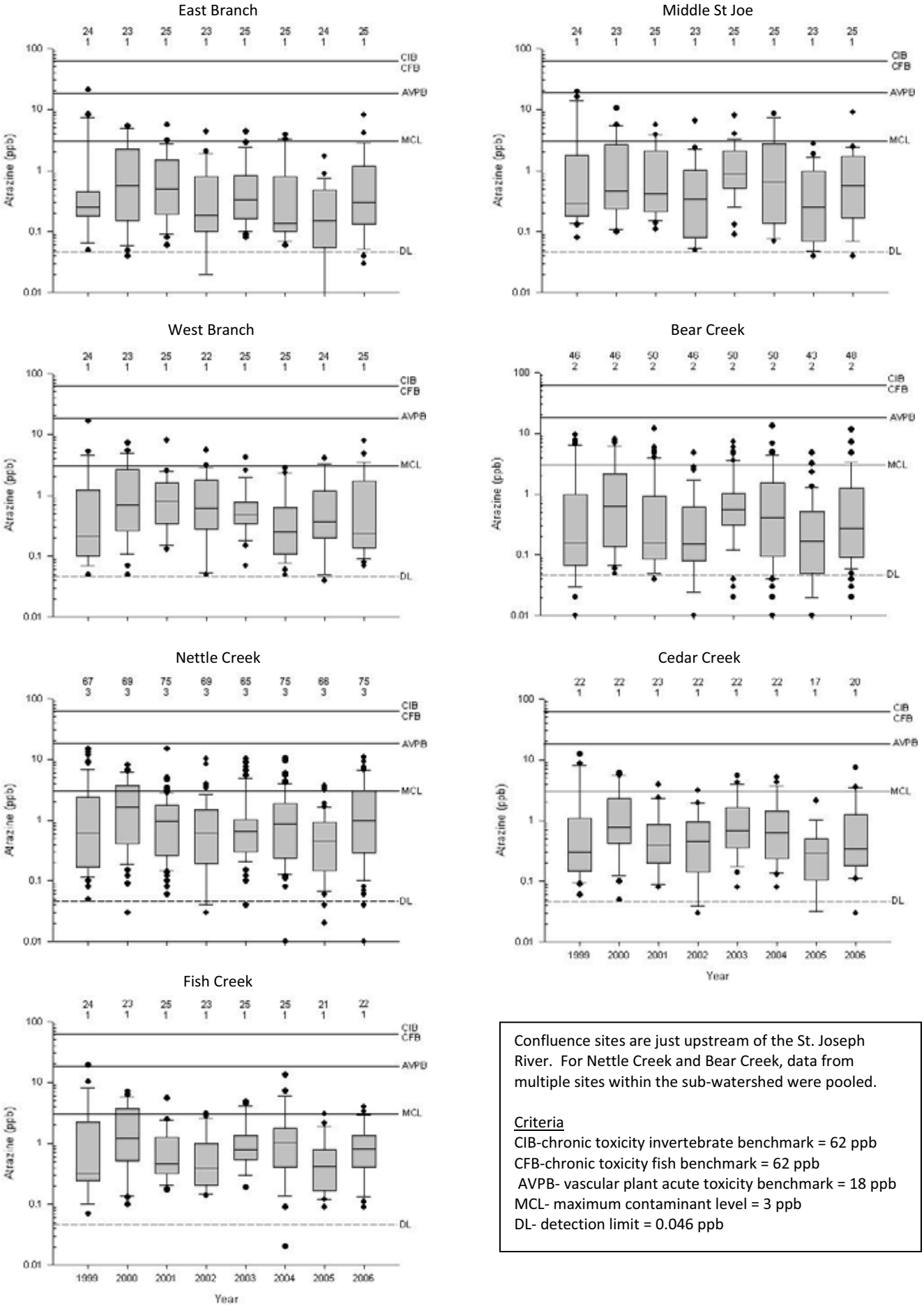


Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

Criteria

CIB-chronic toxicity invertebrate benchmark = 62 ppb; CFB-chronic toxicity fish benchmark = 62 ppb; AVPB- vascular plant acute toxicity benchmark = 18 ppb; MCL- maximum contaminant level = 3 ppb; DL- detection limit = 0.046 ppb

Figure 7. Atrazine concentrations at confluence sites from 1999-2006

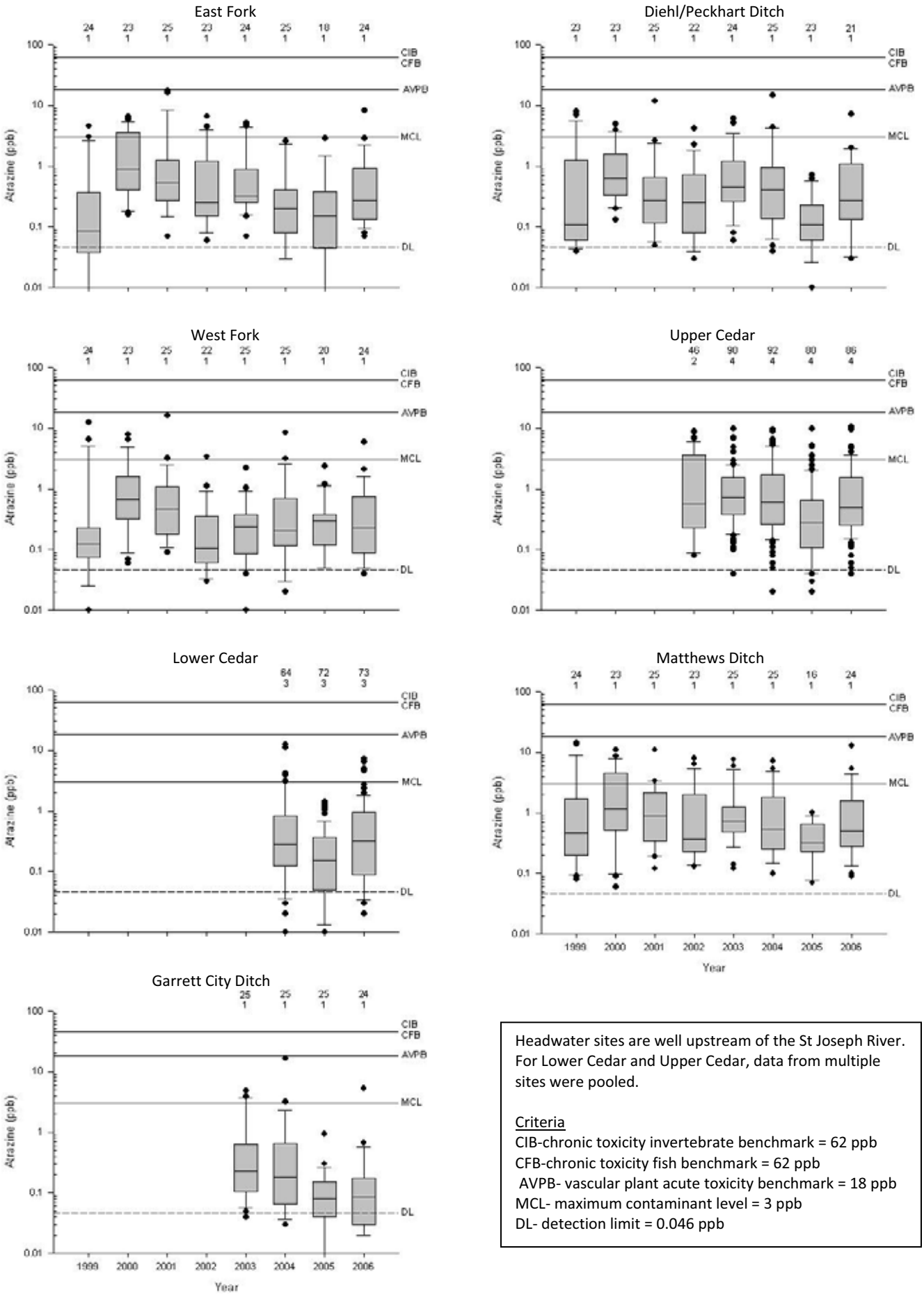


Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

Criteria

CIB-chronic toxicity invertebrate benchmark = 62 ppb
CFB-chronic toxicity fish benchmark = 62 ppb
AVPB- vascular plant acute toxicity benchmark = 18 ppb
MCL- maximum contaminant level = 3 ppb
DL- detection limit = 0.046 ppb

Figure 8. Atrazine concentrations at headwater sites from 1999-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria

CIB-chronic toxicity invertebrate benchmark = 62 ppb
CFB-chronic toxicity fish benchmark = 62 ppb
AVPB- vascular plant acute toxicity benchmark = 18 ppb
MCL- maximum contaminant level = 3 ppb
DL- detection limit = 0.046 ppb

Alachlor

Spatial Comparisons

Among confluence sites (Figure 8), Middle St. Joe and Nettle Creek sub-watersheds had the highest median concentrations of alachlor (0.17 ppb and 0.14 ppb, respectively), while the East Branch sub-watershed had the lowest median alachlor concentration (0.07 ppb). Among headwater sites (Figure 9), the Upper Cedar Creek sites and Matthews Ditch had the highest median alachlor concentrations (0.20 ppb and 0.18 ppb, respectively), while Garrett City Ditch and West Fork had the lowest median alachlor concentration (0.05 ppb).

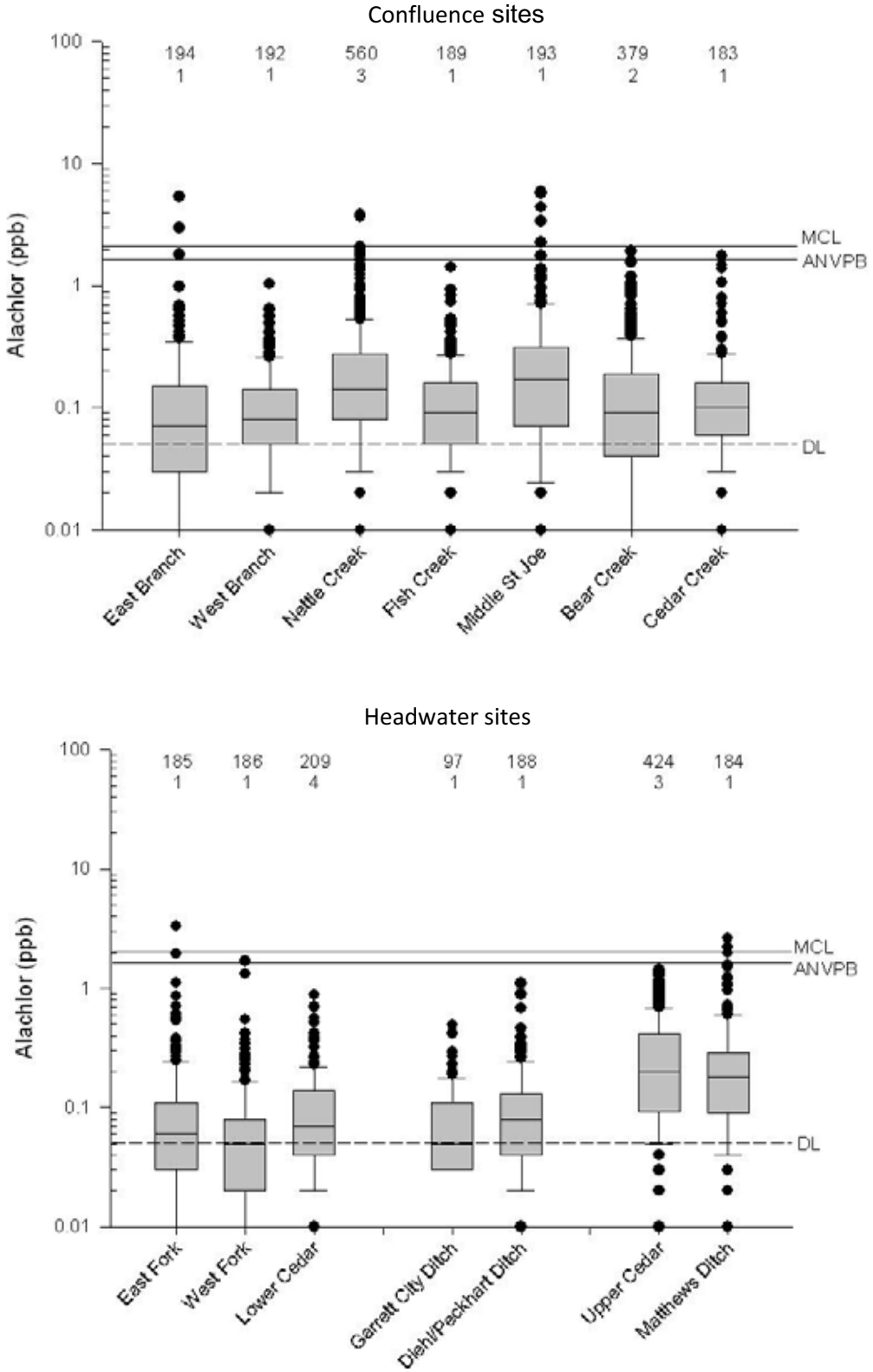
Temporal Comparisons

Concentrations of alachlor varied among years at all sites but there seemed to be a general decreasing trend from 1999-2006 at all sites (Figures 10, 11). The highest median concentration of alachlor occurred in 2000 and the lowest median concentration of alachlor occurred in 2006 for 10 of 14 sites. At the four remaining sites, the lowest median concentration of alachlor occurred in 2005 and each showed a slight increase in 2006.

Comparison to Water Quality Criteria

Concentrations of alachlor at all sites occasionally exceeded water quality criteria (Figures 10, 11). The percent of samples that exceeded the criteria for alachlor ranged from 0 to 3%, with concentrations at six sites never exceeding either criterion. Among confluence sites, the Middle St. Joe had the highest maximum alachlor concentration (5.85 ppb) and the highest percent of samples that exceeded criteria (3%). Among headwater sites, the East Fork had the highest maximum alachlor concentration (3.33 ppb). Exceedances of both criterion occurred in 1999, with the exception of one exceedance of the ANVPB that occurred in Cedar Creek in 2006.

Figure 9. Alachlor concentrations among 14 sites for 1999-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

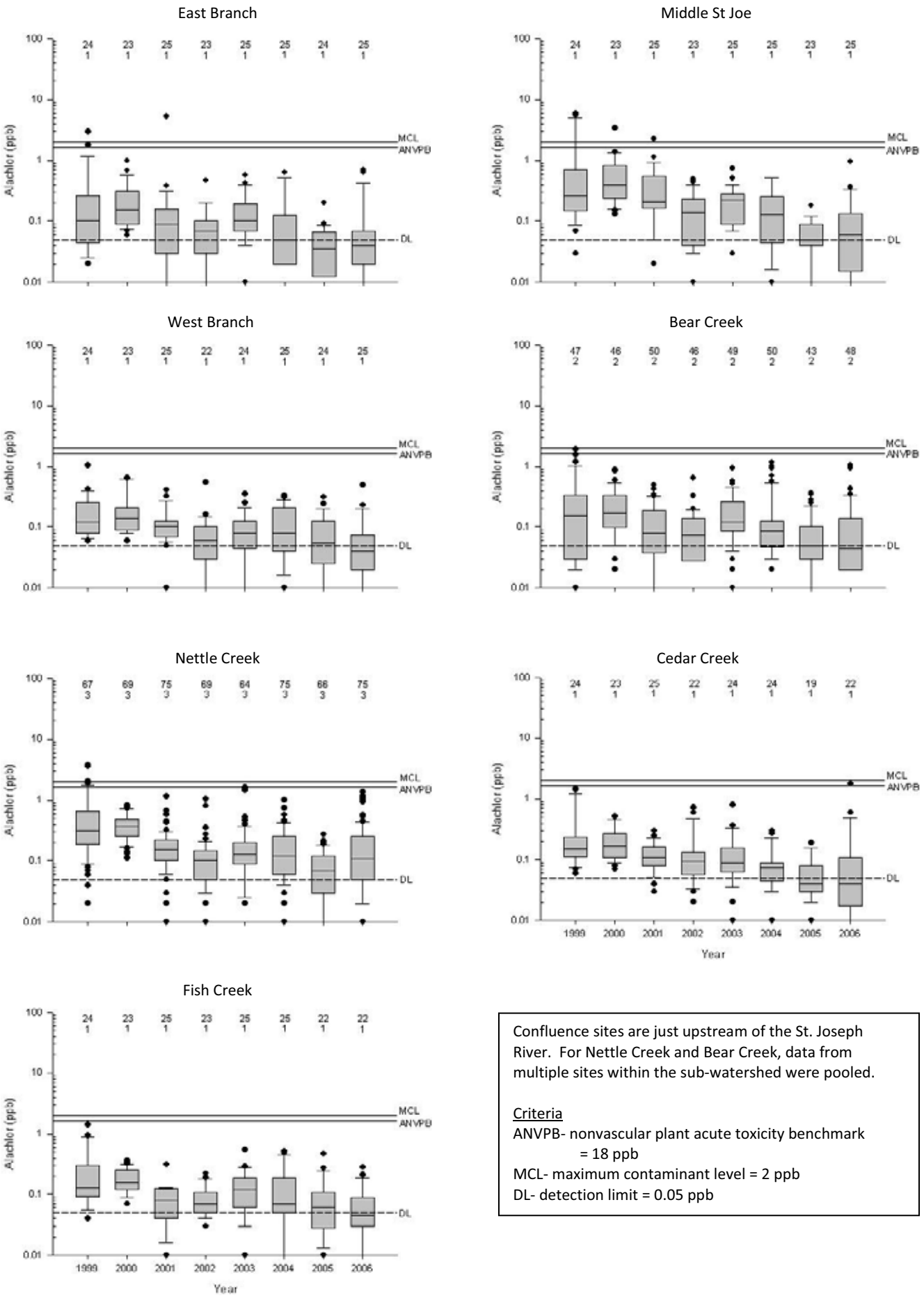
Criteria

ANVPB- nonvascular plant acute toxicity benchmark = 1.64 ppb

MCL- maximum contaminant level = 2 ppb

DL- detection limit = 0.05 ppb

Figure 10. Alachlor concentrations at confluence sites from 1999-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

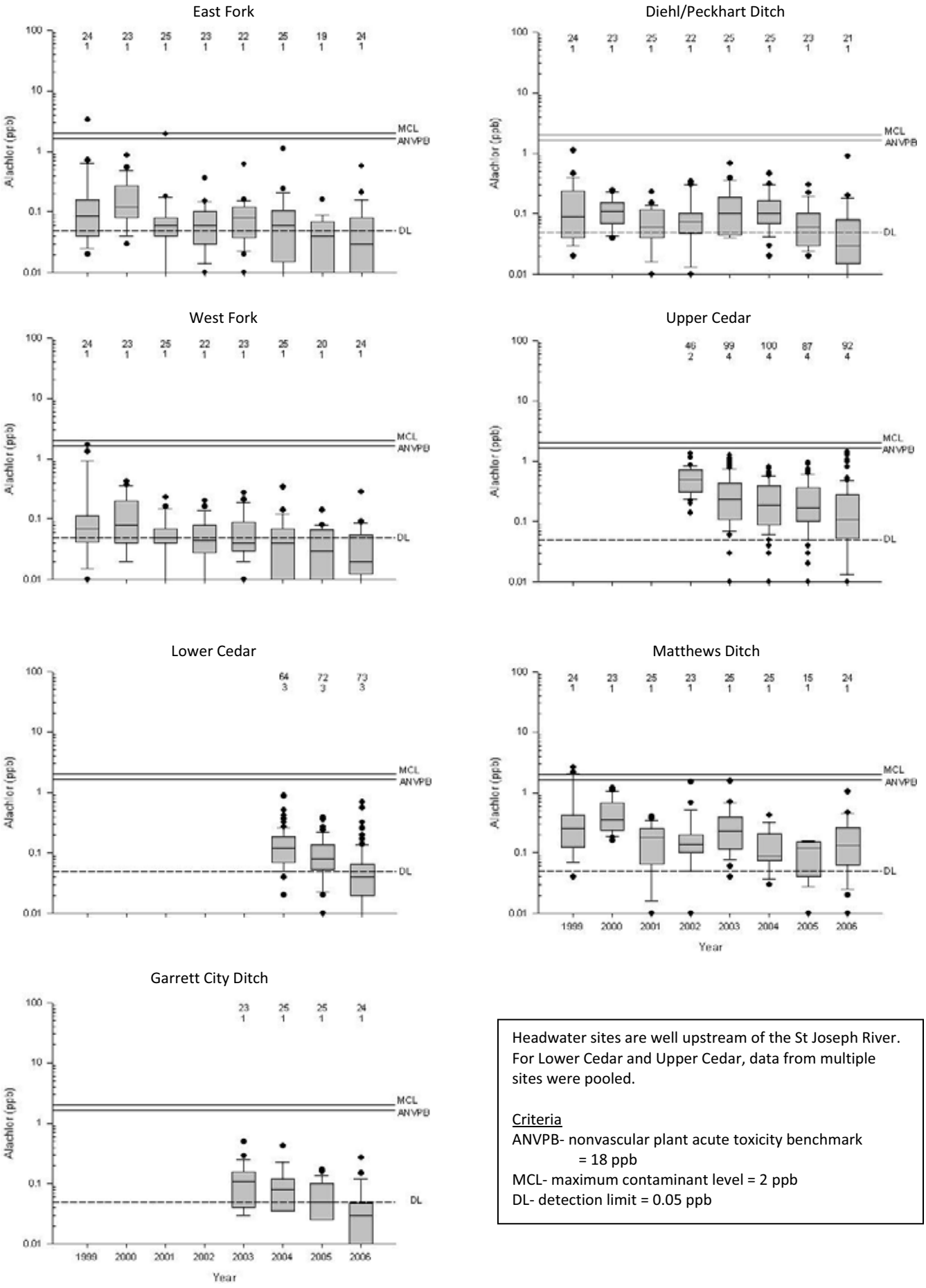
Criteria

ANVPB- nonvascular plant acute toxicity benchmark = 18 ppb

MCL- maximum contaminant level = 2 ppb

DL- detection limit = 0.05 ppb

Figure 11. Alachlor concentrations at headwater sites from 1999-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria

ANVPB- nonvascular plant acute toxicity benchmark = 18 ppb

MCL- maximum contaminant level = 2 ppb

DL- detection limit = 0.05 ppb

Cyanazine

Spatial Comparisons

Among confluence sites (Figure 12), Nettle Creek and West Branch sub-watersheds had the highest median concentration (0.06 ppb) of cyanazine, however concentrations varied only from 0.04-0.06 ppb among all confluence sites. Among headwater sites (Figure 12), Matthews Ditch, East Fork, and Upper Cedar Creek sites had the highest median cyanazine concentrations (0.05-0.07 ppb). The median concentrations of cyanazine in the Lower Cedar Creek sites and Diehl/Peckhart Ditch were below detectable limits for cyanazine. Among confluence sites, Nettle Creek had the highest maximum concentration of cyanazine (7.76 ppb). Among headwater sites, Matthews Ditch had the highest maximum concentration of cyanazine (7.30 ppb).

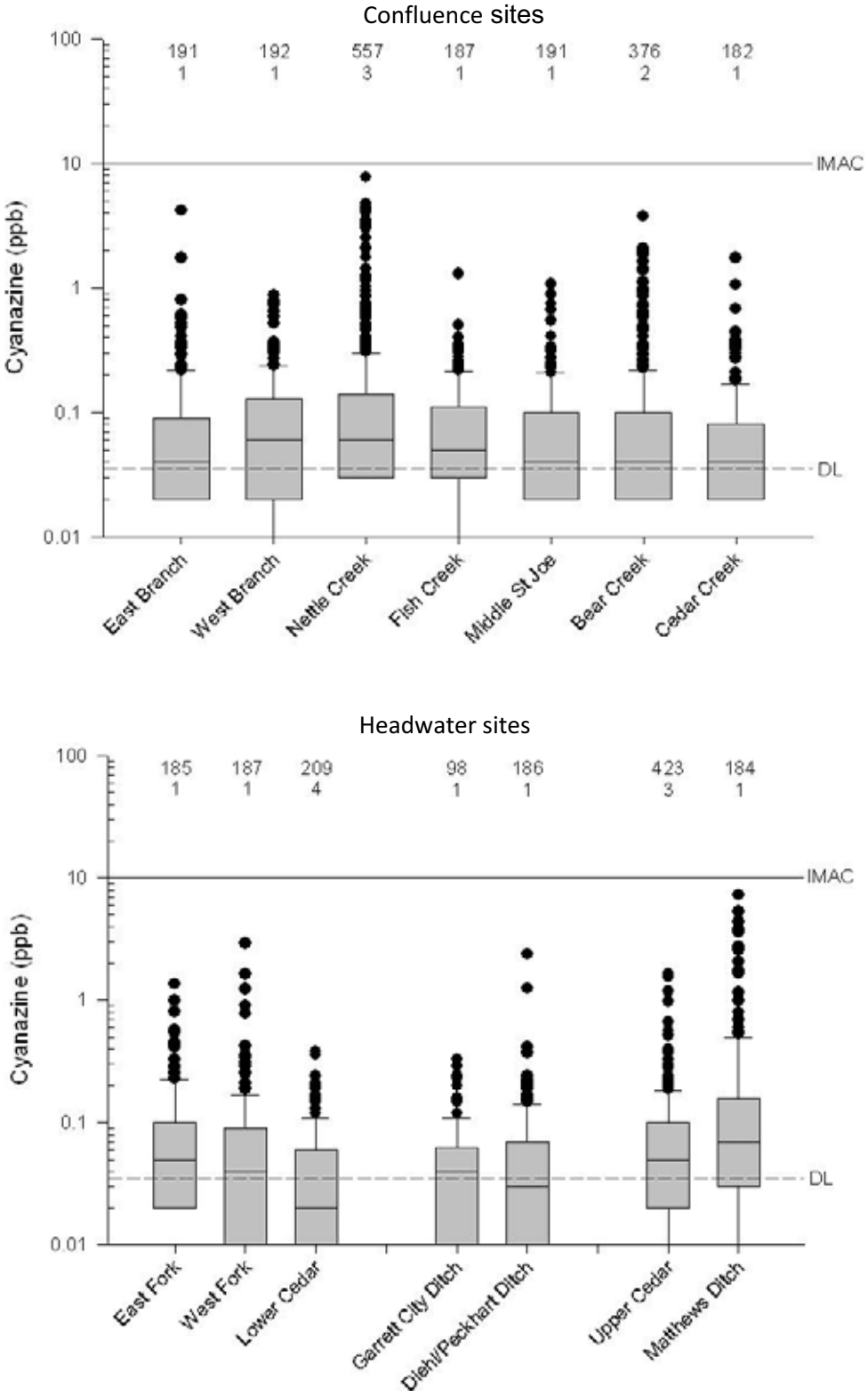
Temporal Comparisons

Concentrations of cyanazine varied among years at all sites but, there seemed to be a decreasing trend from 2000-2006 at most sites (Figures 13, 14). The highest median concentration of cyanazine occurred in 2000 at 9 of 11 sites. Additionally, median concentrations of cyanazine decreased to detectable limits and below in 2006 for 5 of 14 sites. At the nine remaining sites, the lowest median concentration of cyanazine occurred in 2005 and each showed a slight increase in 2006. Over the seven-year period, the highest maximum cyanazine concentrations occurred in 1999.

Comparison to Water Quality Criteria

The concentrations of cyanazine never exceeded the Interim Maximum Acceptable Concentration (IMAC) for drinking water at any site (Figures 13, 14). There are no aquatic life criteria for cyanazine.

Figure 12. Cyanazine concentrations among 14 sites for 1999-2006



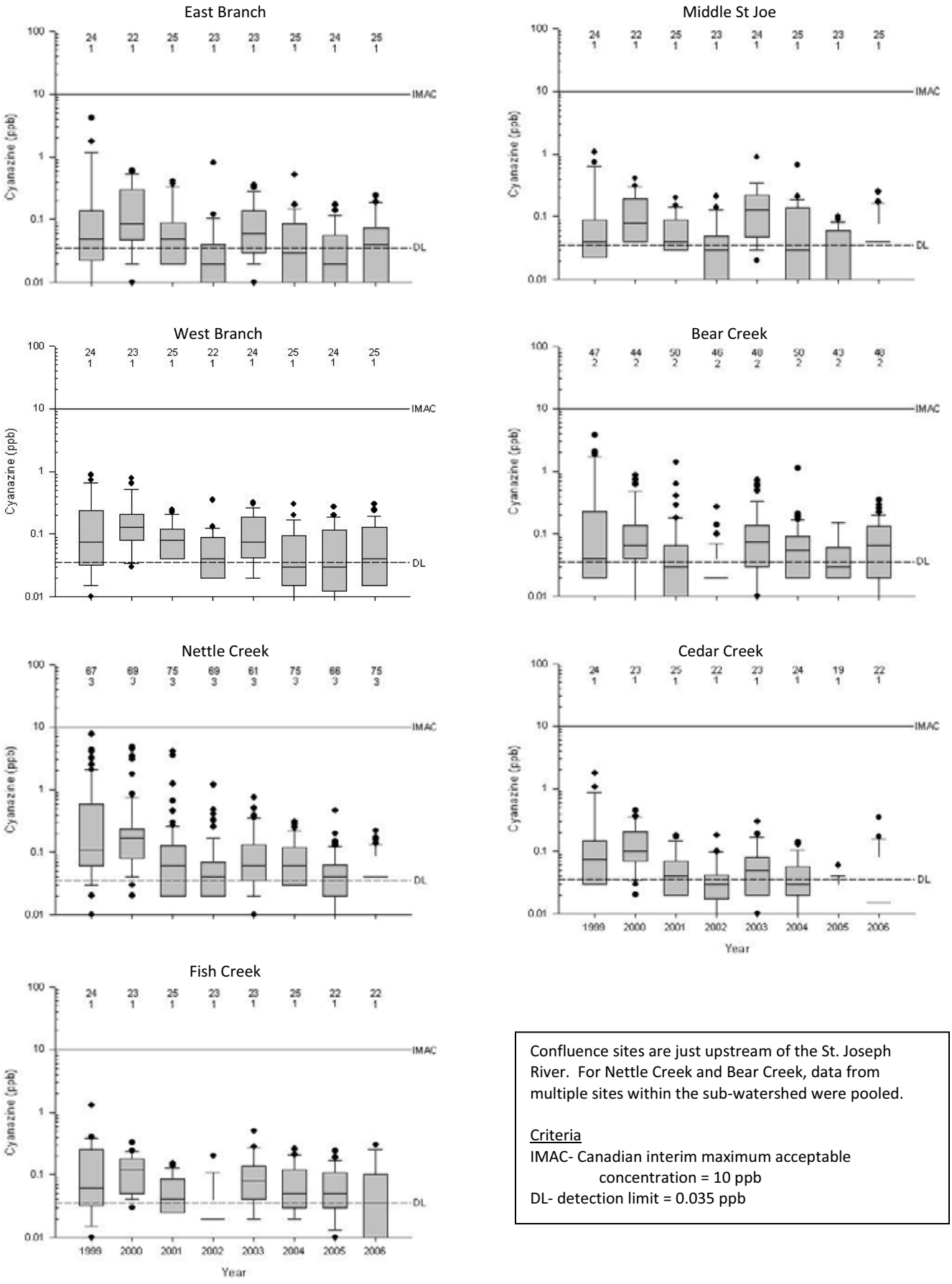
Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

Criteria

IMAC- Canadian interim maximum acceptable concentration = 10 ppb

DL- detection limit = 0.035 ppb

Figure 13. Cyanazine concentrations at confluence sites from 1999-2006



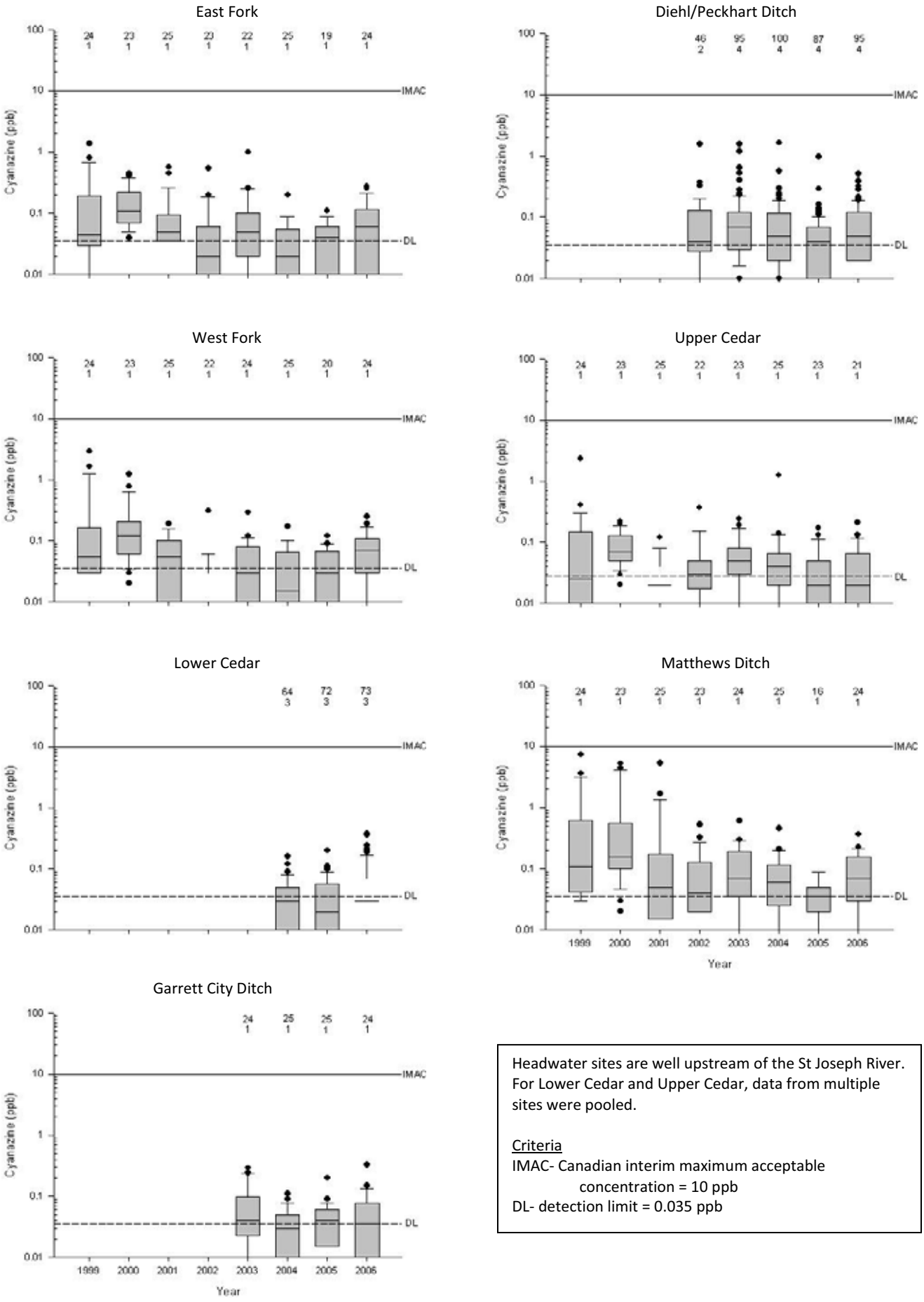
Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

Criteria

IMAC- Canadian interim maximum acceptable concentration = 10 ppb

DL- detection limit = 0.035 ppb

Figure 14. Cyanazine concentrations at headwater sites from 1999-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria

IMAC- Canadian interim maximum acceptable concentration = 10 ppb

DL- detection limit = 0.035 ppb

Metolachlor

Spatial Comparisons

Among confluence sites (Figure 15), the Nettle Creek and Middle St. Joe sub-watersheds had the highest median concentrations of metolachlor (0.22 ppb), while the East Branch sub-watershed had the lowest median concentration of metolachlor (0.07 ppb). Among headwater sites (Figure 15), Matthews Ditch and the Upper Cedar Creek sites had the highest median concentrations of metolachlor (0.37 ppb and 0.23 ppb, respectively), while the Lower Cedar sites and East Fork had the lowest median concentrations of metolachlor (0.05 ppb and 0.06 ppb, respectively). Among confluence sites, the Middle St. Joe and Nettle Creek had the highest maximum concentrations of metolachlor (16.3 ppb and 12.2 ppb, respectively).

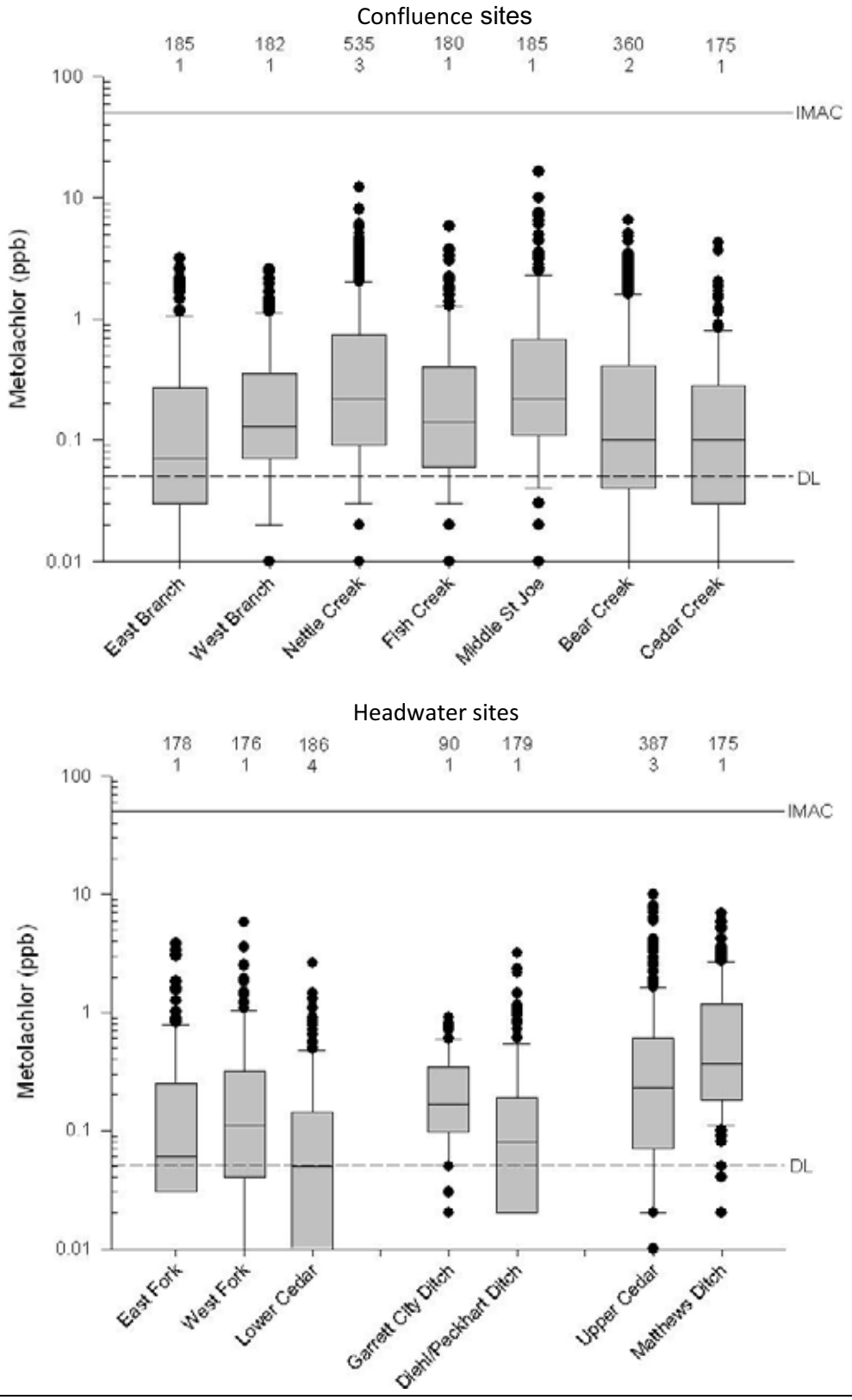
Temporal Comparisons

Concentrations of metolachlor varied among years at all sites and there were no obvious trends from 1999-2006 (Figures 16, 17). The highest median concentration of cyanazine occurred in 2000 for 7 of 11 sites. Median concentrations of metolachlor in the Cedar Creek sub-watershed were at detectable limits or below from 2004 to 2006. Concentrations of metolachlor in the Diehl/Peckhart Ditch and Lower Cedar Creek sites decreased to below detectable limits in during 2003-2006. Among headwater sites, the Upper Cedar Creek had the highest maximum concentration of metolachlor (9.83 ppb).

Comparison to Water Quality Criteria

Concentrations of metolachlor never exceeded the IMAC at any site (Figures 16, 17). The Chronic Aquatic Life Benchmarks for metolachlor range from 780 ppb (fish) to 12,550 ppb (invertebrates). The most sensitive benchmark (780 ppb) is almost 50 times greater than the highest concentration of metolachlor detected among all sites (16 ppb).

Figure 15. Metolachlor concentrations among 14 sites for 1999-2006



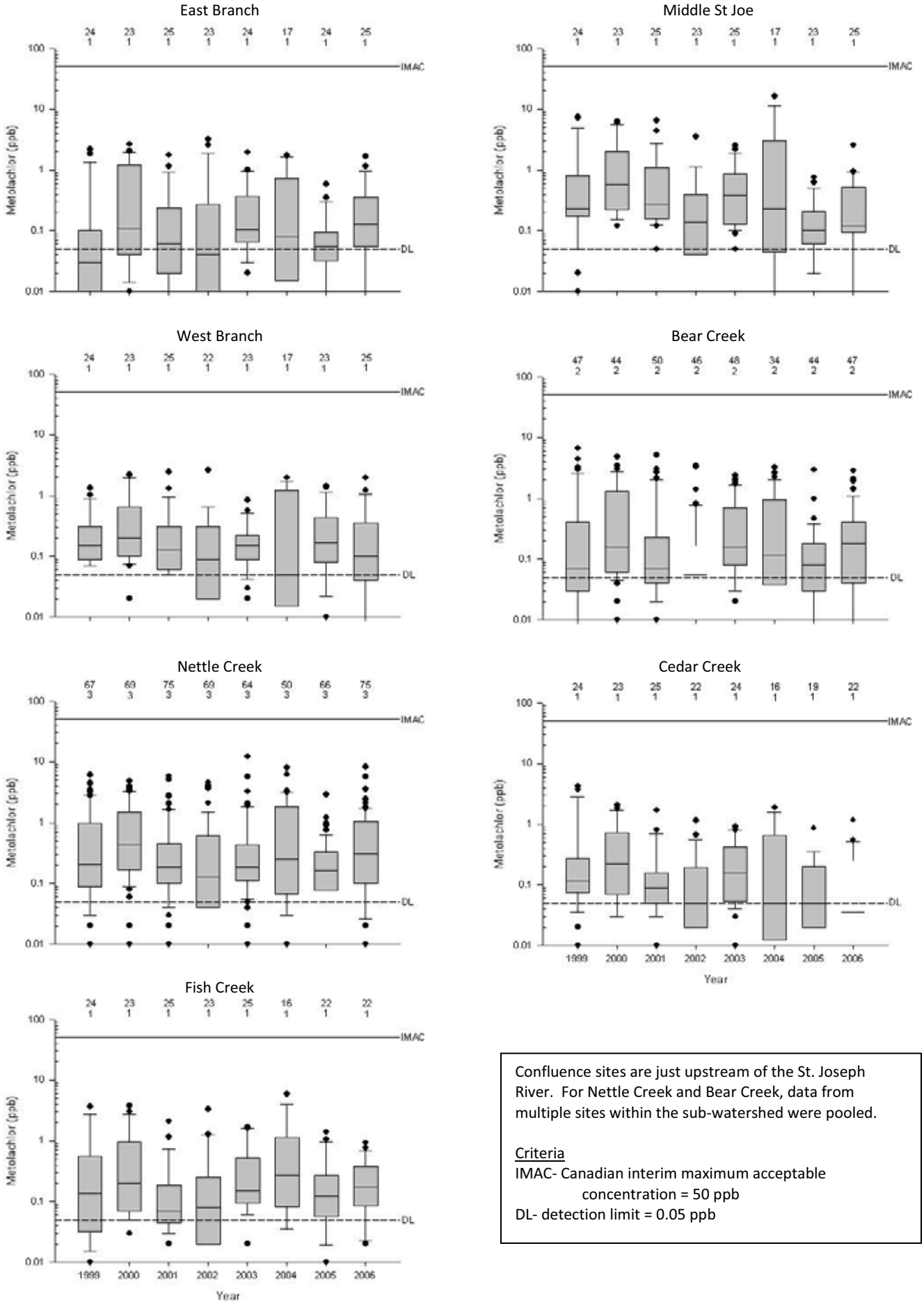
Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

Criteria

IMAC- Canadian interim maximum acceptable concentration = 50 ppb

DL- detection limit = 0.05 ppb

Figure 16. Metolachlor concentrations at confluence sites from 1999-2006



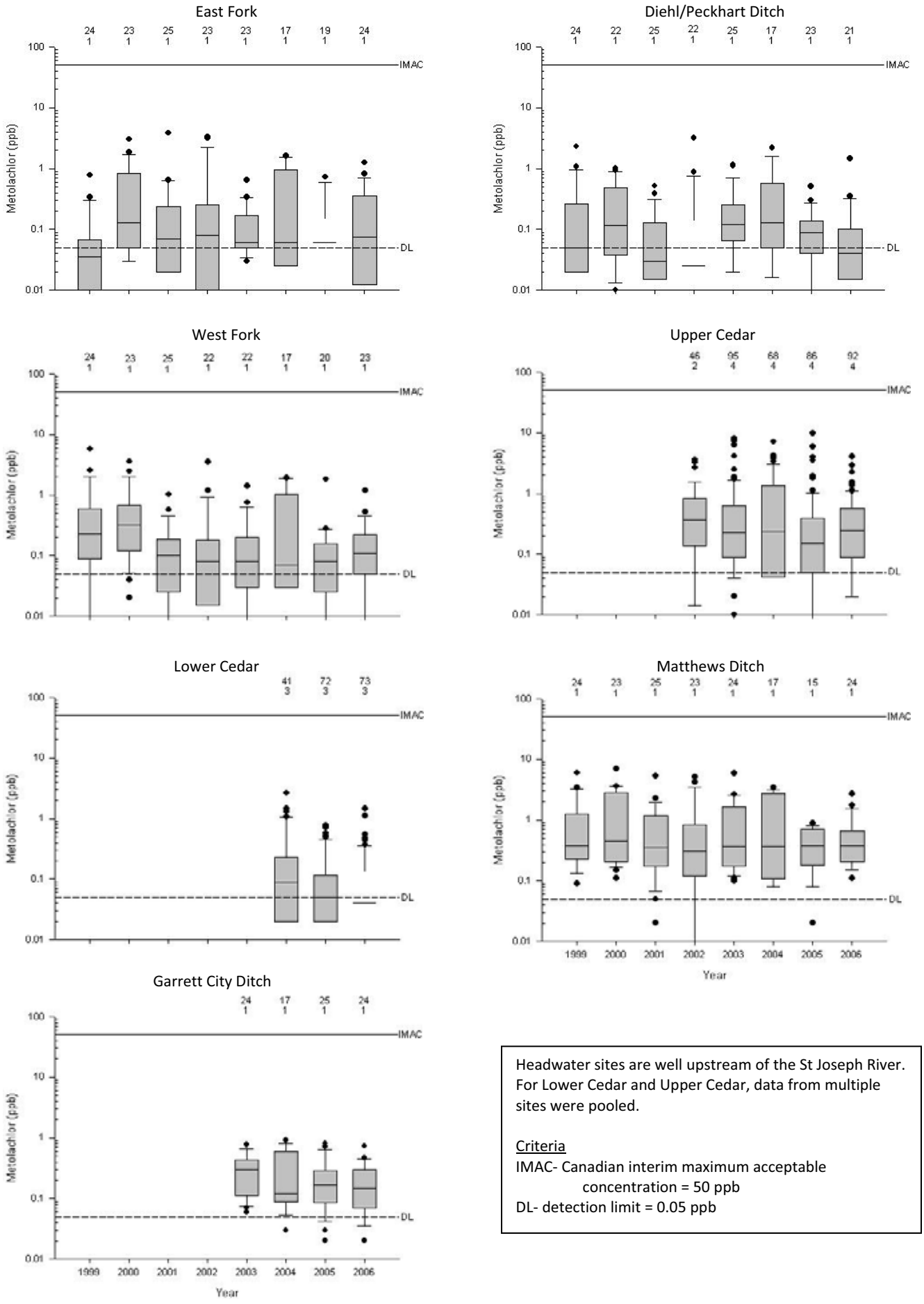
Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

Criteria

IMAC- Canadian interim maximum acceptable concentration = 50 ppb

DL- detection limit = 0.05 ppb

Figure 17. Metolachlor concentrations at headwater sites from 1999-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria

IMAC- Canadian interim maximum acceptable concentration = 50 ppb

DL- detection limit = 0.05 ppb

E. coli

Spatial Comparisons

Among confluence sites (Figure 18), the Middle St. Joe sub-watershed had the highest median concentration of *E. coli* (530 CFU/100mL), while theWest Branch, Fish Creek, and Cedar Creek sub-watersheds had the lowest median concentration of *E. coli* (200 CFU/100mL). Among headwater sites (Figure 18), Garrett City Ditch had the highest median concentration of *E. coli* (870 CFU/100mL), while the East Fork and West Fork sites had the lowest median concentrations of *E. coli* (200 CFU/100mL).

Temporal Comparisons

Concentrations of *E. coli* varied among years at all sites and there were no consistent trends from 1999-2006 among sites (Figures 19, 20).

Comparison to Water Quality Criteria

At all sites, about 50% or more of samples had concentrations of E. coli that were above the maximum criteria for frequent full body contact (FBC, Figures 19, 20). If more than one sample in a season exceeds 2,400 CFU/100mL, the water body does not support recreational use (RUS). Water samples regularly exceeded the RUS criterion (Table 9). Among confluence sites, Nettle Creek had the highest number of samples that exceeded the RUS for E. coli (47), while the West Branch had the lowest number of samples that exceeded the RUS for E. coli (4). Among headwater sites, the Upper Cedar Creek sites had the highest number of samples that exceeded the RUS for E. coli (53), while the East Fork had the lowest number of samples that exceeded the RUS for E. coli (11). During 1999-2006, the greatest number of samples that exceeded the RUS occurred in 2003 (90). During these years, the least number of samples that exceeded the RUS for E. coli occurred in 1999 (8), when samples at 6 of 11 sites never exceeded the RUS for E. coli in 1999.

The criterion for infrequent full body contact for E. coli (IBC) is used to assess the ability of the water to support recreational use. If more than 10% of total samples exceed the IBC (576 cfu/100ml),

then a water body does not support recreational use. Based on this criterion, most sites sampled in the St. Joseph River Watershed did not support recreational use in most of the years from 1999-2006 (Table 10). Confluence sites that supported recreation use over the seven years, included the West Branch (2001 and 2005), Fish Creek (2004 and 2005), and Cedar Creek (2001 and 2005). The only headwater site that supported recreational use was the East Fork during 2001 and 2002. Among confluence sites the Middle St. Joe had the highest percent of samples that exceeded the IBC (48%), while the West Branch had the lowest percent of samples that exceeded the IBC (14%). Among headwater sites, Garrett City Ditch had the highest percent of samples that exceeded the IBC (62%), while East Fork had the lowest percent of samples that exceeded the IBC (18%).

Table 9. Number of samples that exceeded the criteria for recreational use support for E. coli

Site	1999	2000	2001	2002	2003	2004	2005	2006	Total years
Confluence Sites									
East Branch	2	3	0	1	3	0	1	4	14
West Branch	0	1	0	1	0	1	1	0	4
Nettle Creek	0	7	5	4	11	8	1	11	47
Fish Creek	0	2	0	1	3	1	0	4	11
Middle St Joe	3	5	3	2	8	3	2	7	33
Bear Creek	0	4	1	0	7	2	1	4	19
Cedar Creek	1	4	0	1	6	1	1	1	15
Headwater Sites									
East Fork	1	3	1	0	2	1	0	3	11
West Fork	1	3	1	1	3	0	1	4	14
Lower Cedar	ND	ND	ND	ND	ND	3	1	11	15
Garrett City Ditch	ND	ND	ND	ND	15	2	4	4	25
Diehl/Peckhart Ditch	0	2	2	1	4	3	1	3	16
Upper Cedar	ND	ND	ND	0	22	7	5	19	53
Matthews Ditch	0	2	2	1	6	2	0	5	18

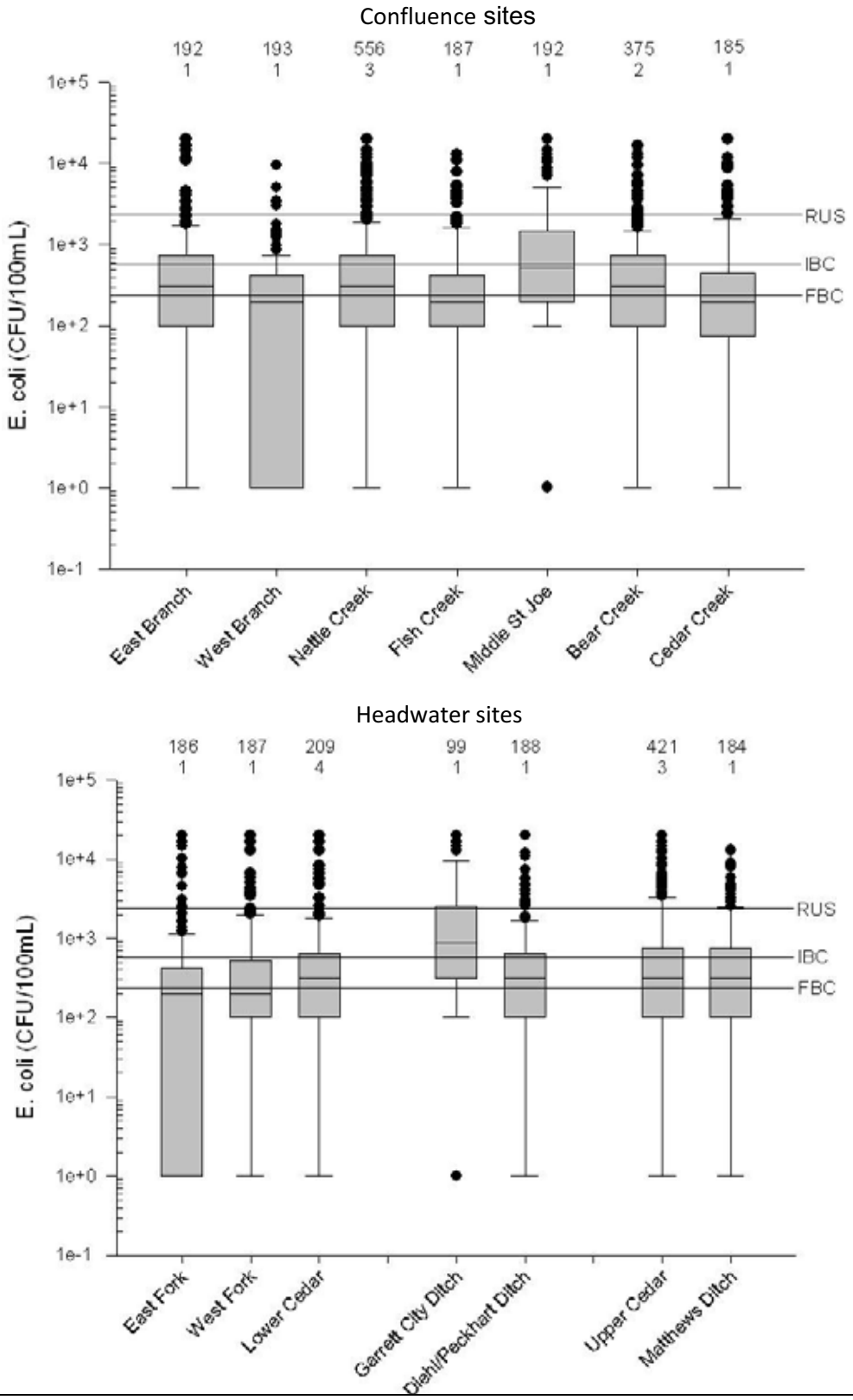
ND= no data

Table 10. Percent of samples that exceeded the criteria for infrequent full body contact for E coli

Site	1999	2000	2001	2002	2003	2004	2005	2006	Total years
Confluence Sites									
East Branch	13	39	28	18	36	36	13	36	28
West Branch	17	22	8	14	12	12	4	24	14
Nettle Creek	19	36	27	25	33	48	18	39	31
Fish Creek	21	35	16	14	28	8	0	18	18
Middle St Joe	42	61	56	36	56	52	26	56	48
Bear Creek	44	70	60	63	57	71	56	65	31
Cedar Creek	17	39	4	23	32	17	10	27	21
Headwater Sites									
East Fork	13	22	8	9	24	25	16	25	18
West Fork	13	26	12	23	40	21	25	29	24
Lower Cedar	ND	ND	ND	ND	ND	26	17	47	30
Garrett City Ditch	ND	ND	ND	ND	80	48	68	50	62
Diehl/Peckhart Ditch	25	35	16	27	32	28	30	33	28
Upper Cedar	ND	ND	ND	21	35	31	17	43	31
Matthews Ditch	17	30	16	27	48	40	13	42	30

ND= no data

Figure 18. E. coli concentrations among 14 sites for 1999-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

Criteria

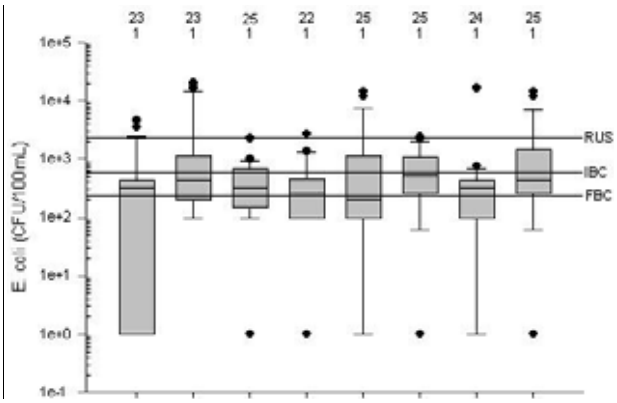
FBC- frequent full body contact = 235 CFU/100 mL

IBC- infrequent full body contact = 576 CFU/100 mL

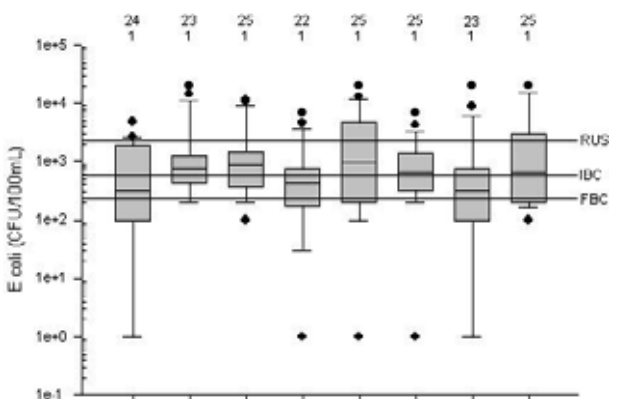
RUS- recreational use support = 2400 CFU/100 mL

Figure 19. E. coli concentrations at confluence sites from 1999-2006

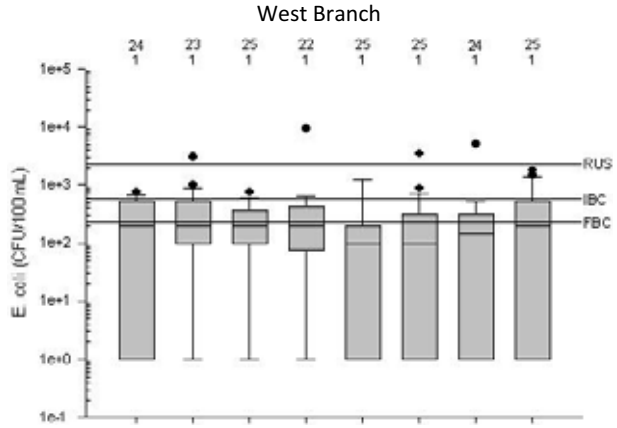
East Branch



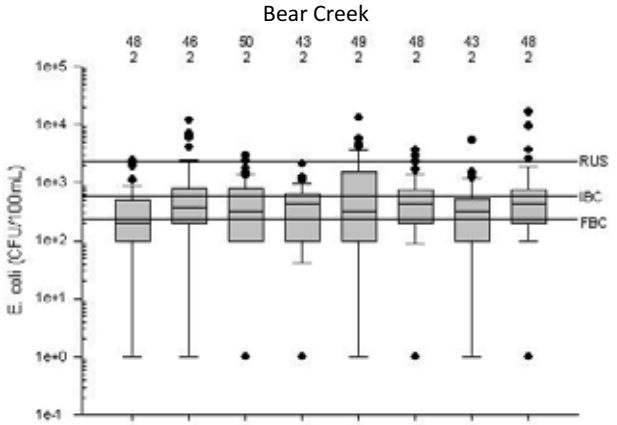
Middle St Joe



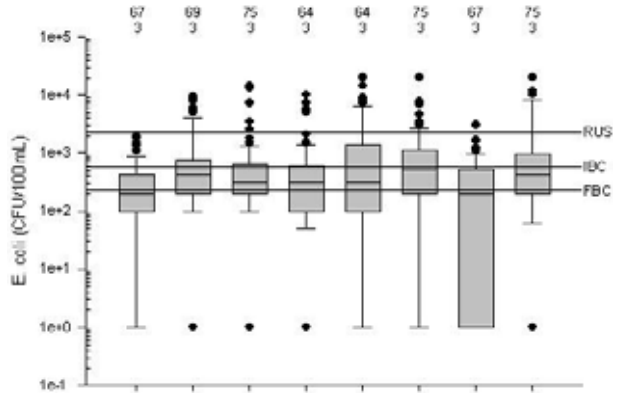
West Branch



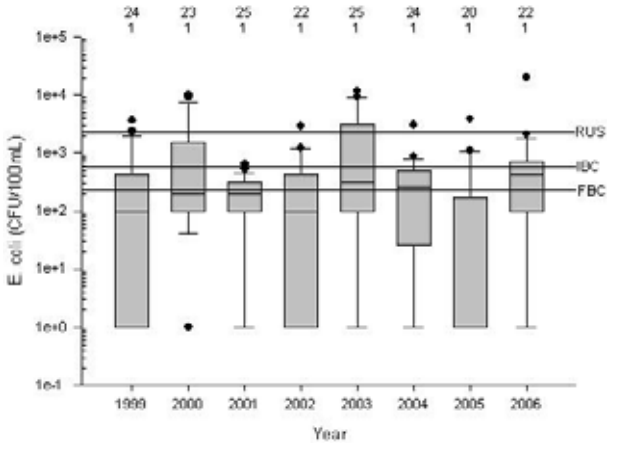
Bear Creek



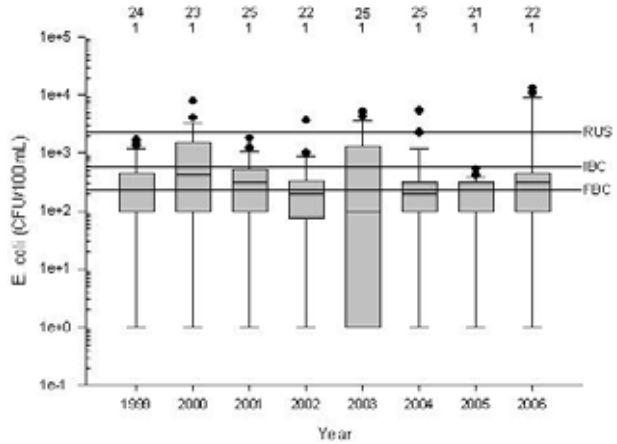
Nettle Creek



Cedar Creek



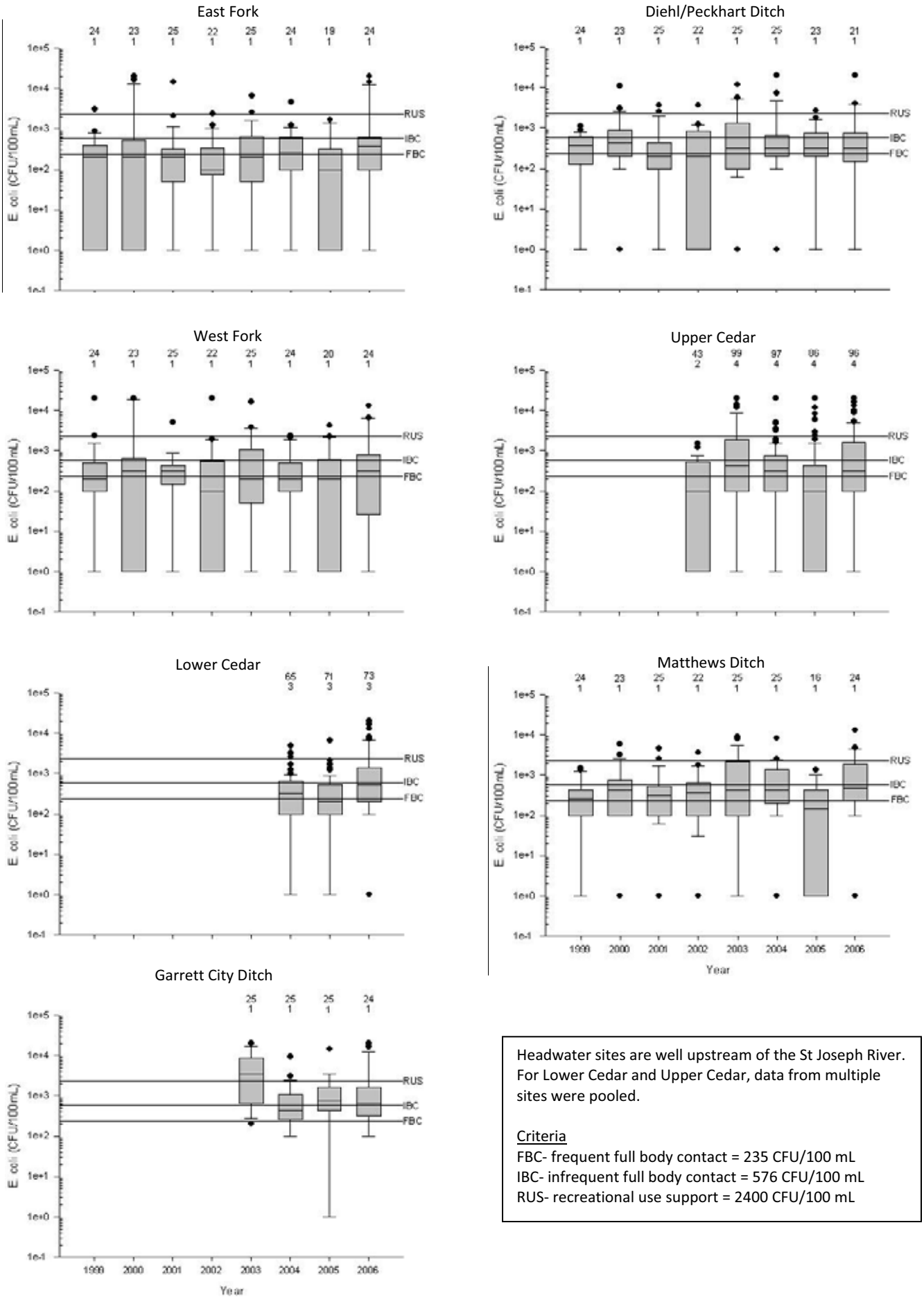
Fish Creek



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

Criteria
FBC- frequent full body contact = 235 CFU/100 mL
IBC- infrequent full body contact = 576 CFU/100 mL
RUS- recreational use support = 2400 CFU/100 mL

Figure 20. E. coli concentrations at headwater sites from 1999-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria

FBC- frequent full body contact = 235 CFU/100 mL
IBC- infrequent full body contact = 576 CFU/100 mL
RUS- recreational use support = 2400 CFU/100 mL

Phosphorus

Spatial Comparisons

Of the sites regularly tested for nutrients (Figure 21), the Bear Creek OH and Walter Smith Ditch sites had the highest median concentrations of total phosphorous (0.145 mg/L and 0.135 mg/L, respectively), while the Diehl/Peckhart and Matson Ditches had the lowest median total phosphorus concentrations (0.08 mg/L and 0.082 mg/L, respectively). Walter Smith Ditch also had the highest maximum total phosphorus concentration (2.12 mg/L).

Temporal Comparisons

Concentrations of total phosphorus varied among years at all sites and there were no obvious trends from 1999-2006 among sites (Figure 22). However, the lowest median concentration of total phosphorus occurred in 2002 at 4 of 6 sites. Additionally, the highest median concentration of total phosphorus occurred in 2003 for 3 of 6 sites. Median total phosphorus concentrations in the Walter Smith Ditch decreased from 2003 to 2006, but this trend was not detected for any other site.

Comparison to Water Quality Criteria

Concentrations of total phosphorus exceeded the IAL at most sites and in most years (Figure 22; Table 11). Walter Smith DItch had the highest percent of samples that exceeded the IAL for total phosphorus (30%), while the West Branch had the lowest percent of samples that exceeded the IAL for total phosphorus (4%). During 2002-2006, the greatest number of samples that exceeded the IAL for total phosphorous occurred in 2003 (9-38%). During these years, the least number of samples that exceeded the IAL for total phosphorous occurred in 2004 and 2005, when only 2 of 6 sites exceeded the criterion.

Median concentrations of total phosphorus were above the reference conditions at all sites among all years (Table 12). Bear Creek OH and Walter Smith Ditch had the highest percent of samples that exceeded the reference conditions for 2002-2006 (81% and 78%, respectively), while the Matson

Ditch had the lowest percent of samples that exceeded reference conditions. The greatest number of samples that exceeded the reference conditions occurred in 2004 (73-100%.

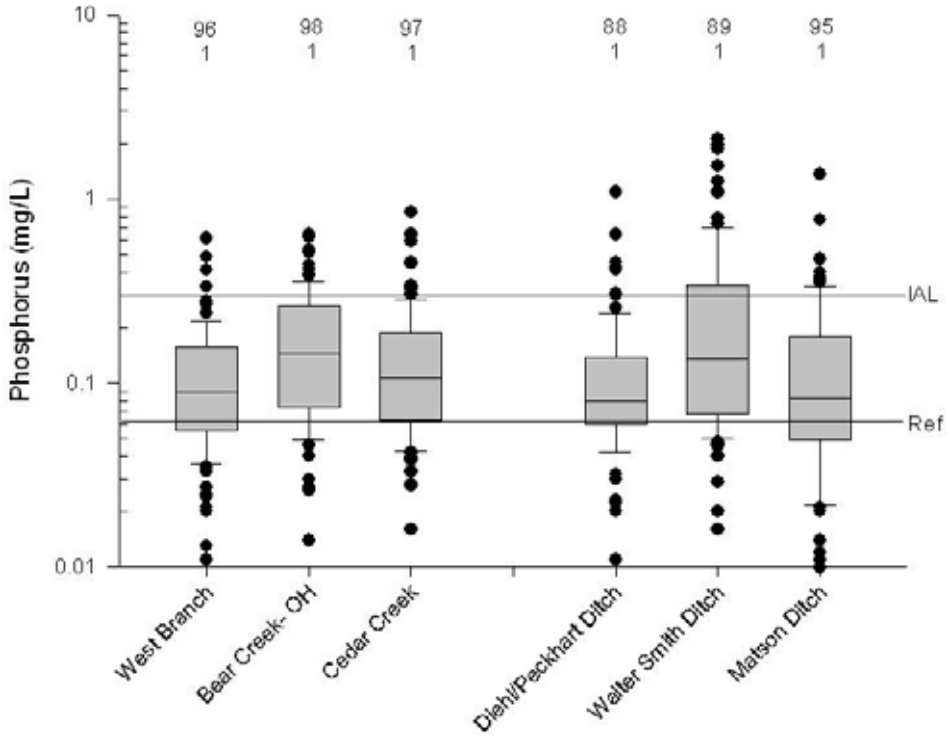
Table 11. Percent of samples that exceeded criteria for impaired aquatic life use for phosphorus

Site	2002	2003	2004	2005	2006	2002-2006
Nutrient Sites						
West Branch	0	9	0	0	8	4
Bear Creek OH	35	17	7	0	9	14
Cedar Creek	9	17	0	0	14	9
Diehl/Peckhart Ditch	0	26	0	0	0	7
Walter Smith Ditch	39	38	47	21	10	30
Matson Ditch	6	18	0	6	18	11

Table 12. Percent of samples that exceeded reference condition for phosphorus

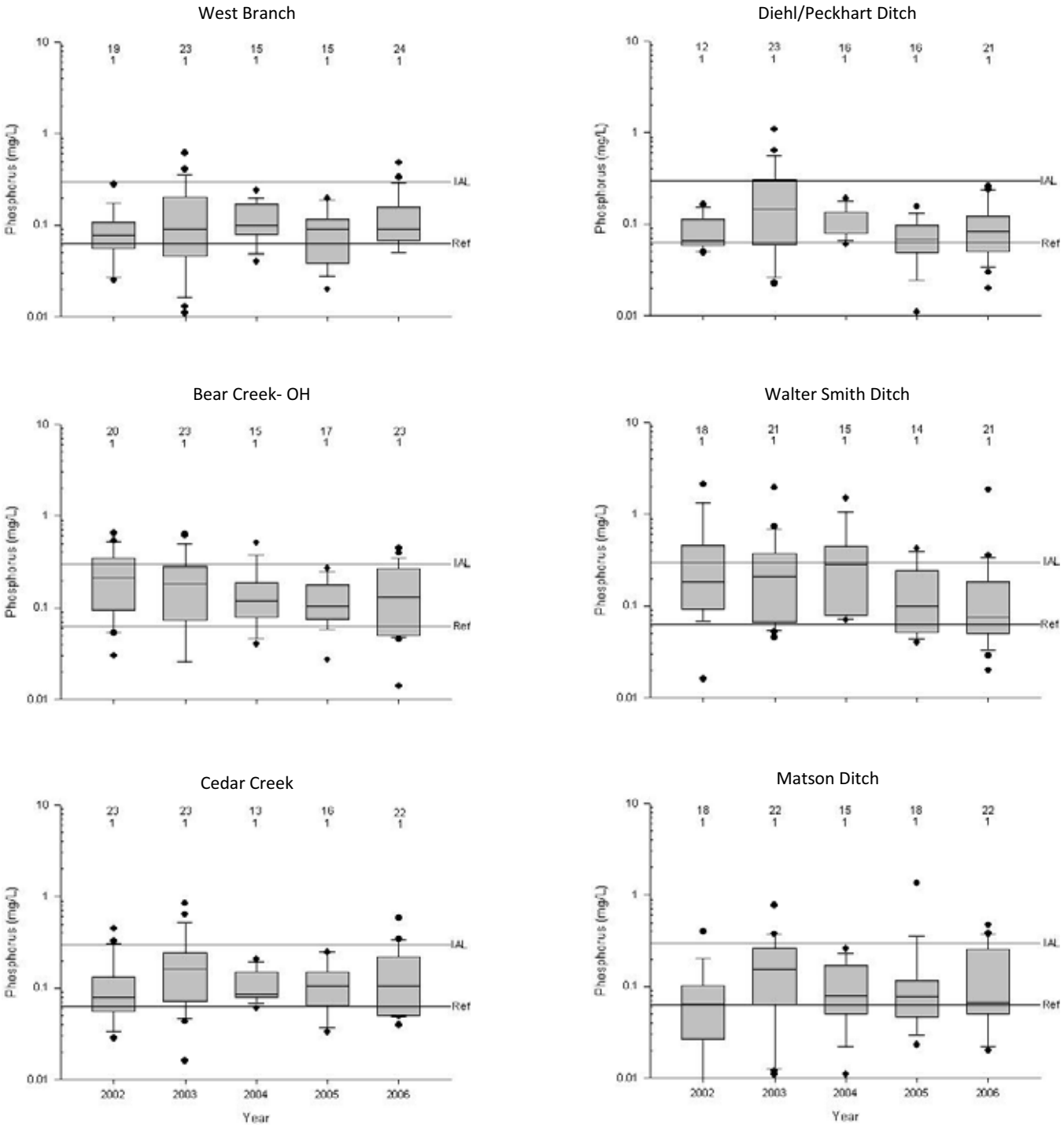
Site	2002	2003	2004	2005	2006	2002-2006
Nutrient Sites						
West Branch	63	65	87	60	79	71
Bear Creek OH	85	78	87	94	65	81
Cedar Creek	70	83	92	75	64	75
Diehl/Peckhart Ditch	58	70	94	56	62	68
Walter Smith Ditch	94	81	100	64	52	78
Matson Ditch	50	77	73	56	50	61

Figure 21. Total phosphorus concentrations 2002-2006



Criteria
Ref- reference condition = 0.0625 mg/L
IAL- impaired aquatic life use = 0.3 mg/L

Figure 22. Total phosphorus concentrations at nutrient sites from 2002-2006



Criteria
Ref- reference condition = 0.0625 mg/L
IAL- impaired aquatic life use = 0.3 mg/L

Ammonia

Spatial Comparisons

Among the sites sampled for nutrients (Figure 23), Bear Creek OH had the highest median concentration of ammonia (0.0855 mg/L), while the Diehl/Peckhart Ditch had the lowest median concentration of ammonia (0.0422 mg/L).

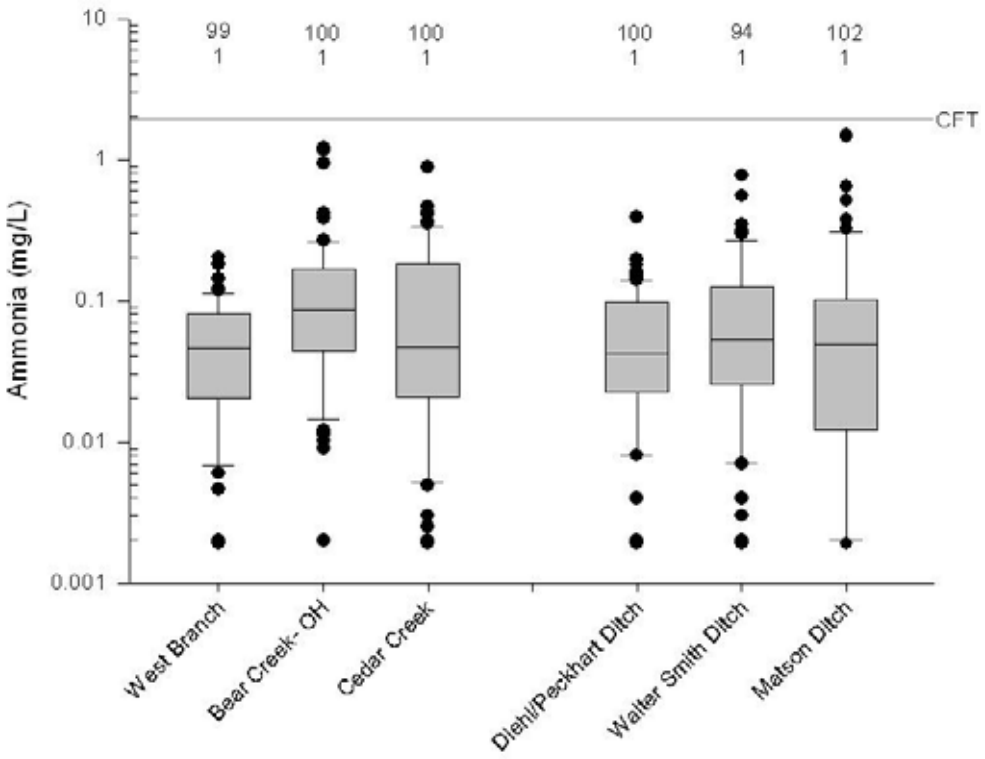
Temporal Comparisons

Concentrations of ammonia varied among years at all sites and there were no trends from 2002-2005 among sites (Figure 24). The highest median concentration of ammonia occurred in 2003 for 4 of 6 sites. Additionally, the lowest median concentrations of ammonia occurred in 2004 for 3 of 6 sites.

Comparison to Water Quality Criteria

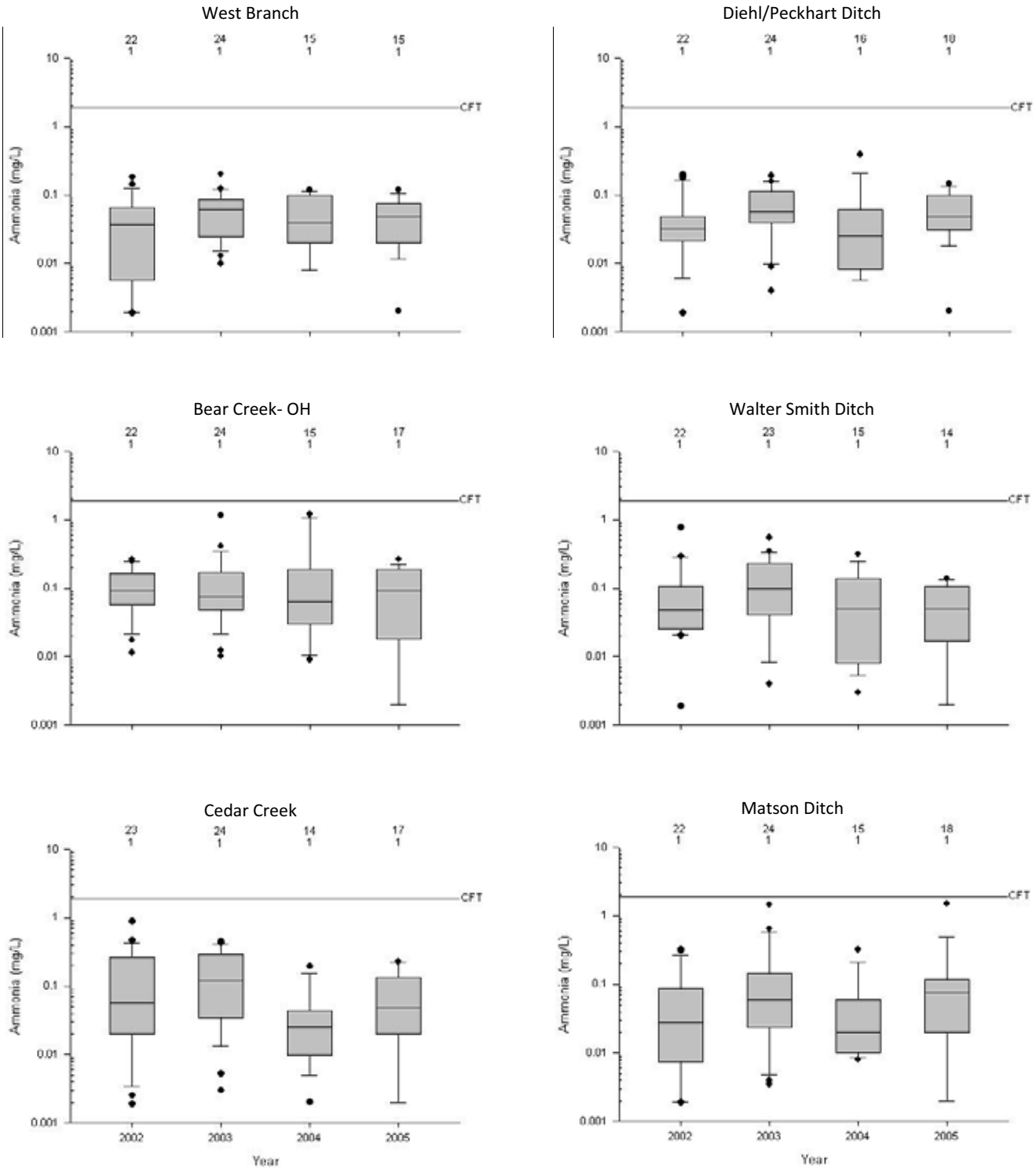
No water samples at any site exceeded the chronic fish toxicity criterion (CFT) for ammonia (Figure 24). The highest maximum ammonia concentrations were found at the Matson Ditch and Bear Creek OH (1.49 mg/L and 1.21 mg/L, respectively).

Figure 23. Ammonia concentrations 2002-2006



Criteria
CFT- chronic fish toxicity = 1.94 mg/L

Figure 24. Ammonia concentrations at nutrient sites from 2002-2005



Ammonia Criteria
CFT- chronic fish toxicity = 1.94 mg/L

Dissolved oxygen

Spatial Comparisons

There was little variation in median concentrations of dissolved oxygen among confluence sites (Figure 25). The West Branch sub-watershed had the lowest median concentration of dissolved oxygen (7.05 mg/L), while the Bear Creek sub-watershed had the highest median concentration of dissolved oxygen (7.61 mg/L). Greater variation in dissolved oxygen was detected among headwater sites (Figure 25). The Lower Cedar Creek sites had the lowest median concentration of dissolved oxygen (7.3 mg/L), while Matthews Ditch and the Upper Cedar Creek sites had the highest median concentration dissolved oxygen (9.1 mg/L and 9.18 mg/L, respectively).

Temporal Comparisons

Concentrations of dissolved oxygen varied among years at all sites and there were no trends from 2000-2006 (Figures 26, 27). However, the lowest median concentration of dissolved oxygen occurred in 2001 for 10 of 11 sites. Additionally, the highest median concentration of dissolved oxygen occurred in 2000 for 8 of 12 sites. Median dissolved oxygen concentrations decreased in Garrett City Ditch between 2004 and 2006 and decreased in the Upper Cedar Creek sites from 2002-2006.

Comparison to Water Quality Criteria

Although the median concentrations of dissolved oxygen were well above the early life stage criteria (ESC) at all sites (Figures 26, 27), water samples regularly fell below the ESC at all sites and in most years (Table 13). Among confluence sites, the West Branch had the highest percent of samples below the ESC for dissolved oxygen (14%), while the Bear Creek and Cedar Creek confluence sites had the lowest percent of samples below the ESC for dissolved oxygen (7%). Among headwater sites, Garrett City Ditch had the highest percent of samples that fell below the ESC for dissolved oxygen (14%), while East Fork had the lowest percent of samples below the ESC for dissolved oxygen (3%). The

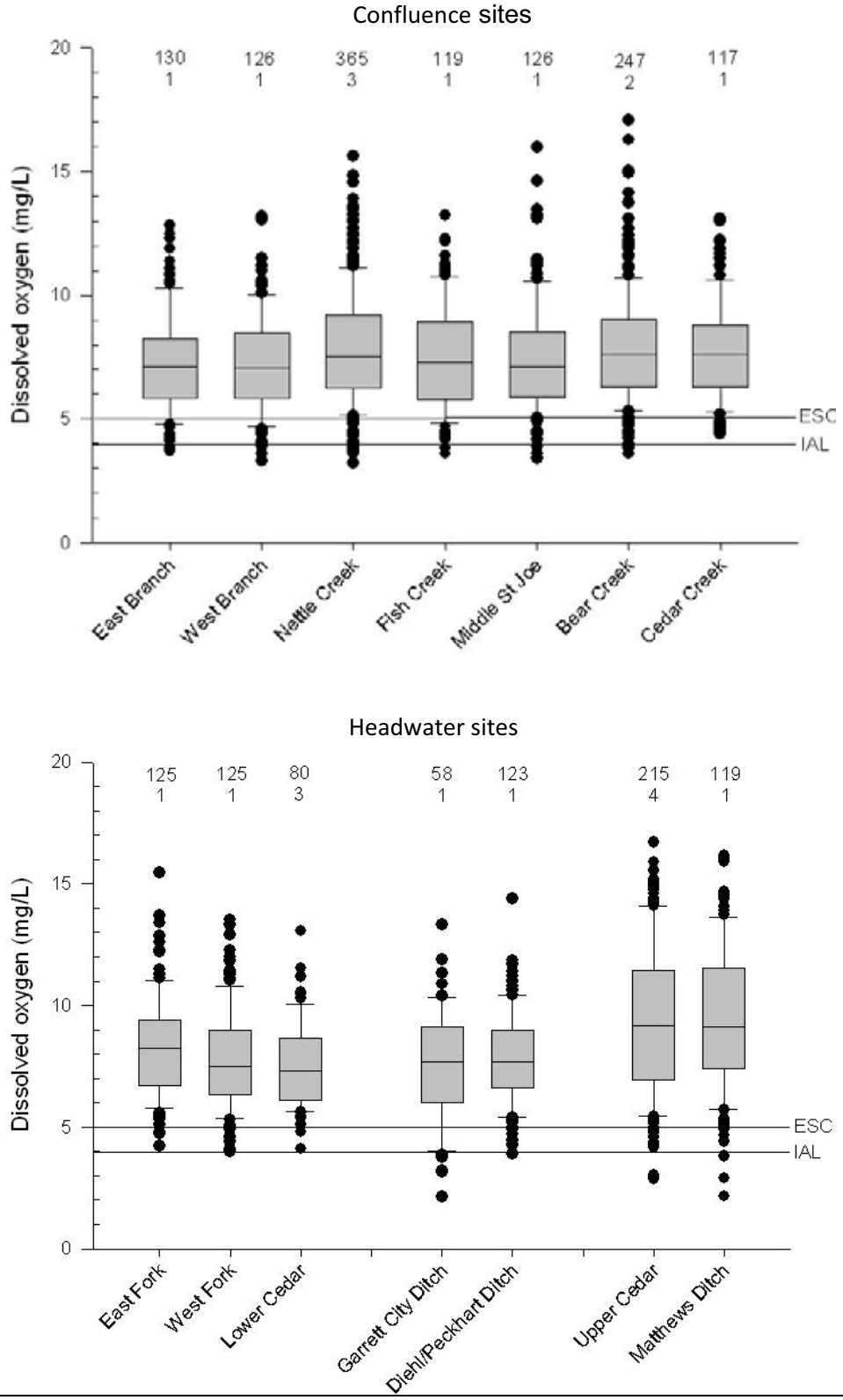
greatest percent of samples below the ESC for dissolved oxygen occurred in 2001 (9-38%) and 2003 (4-28%). The least percent of samples below the ESC occurred in 2000, 2002, 2004, and 2005 (0-5%).

Table 13. Percent of samples that were below the criteria to protect early life stages for DO

Site	2000	2001	2002	2003	2004	2005	2006	Total years
Confluence Sites								
East Branch	0	33	0	24	0	0	0	11
West Branch	0	38	5	28	0	0	9	14
Nettle Creek	0	29	0	13	0	0	3	8
Fish Creek	4	33	0	20	0	ND	0	12
Middle St Joe	0	38	0	8	0	0	0	9
Bear Creek	2	24	0	8	0	0	5	7
Cedar Creek	0	25	0	8	ND	ND	0	7
Headwater Sites								
East Fork	0	13	0	4	0	ND	0	3
West Fork	0	29	0	4	0	0	0	6
Lower Cedar	ND	ND	ND	ND	0	4	3	3
Garrett City Ditch	ND	ND	ND	20	0	0	23	14
Diehl/Peckhart Ditch	0	26	0	8	ND	ND	0	7
Upper Cedar	ND	ND	0	13	0	ND	5	7
Matthews Ditch	0	9	0	17	0	ND	0	5

ND= no data

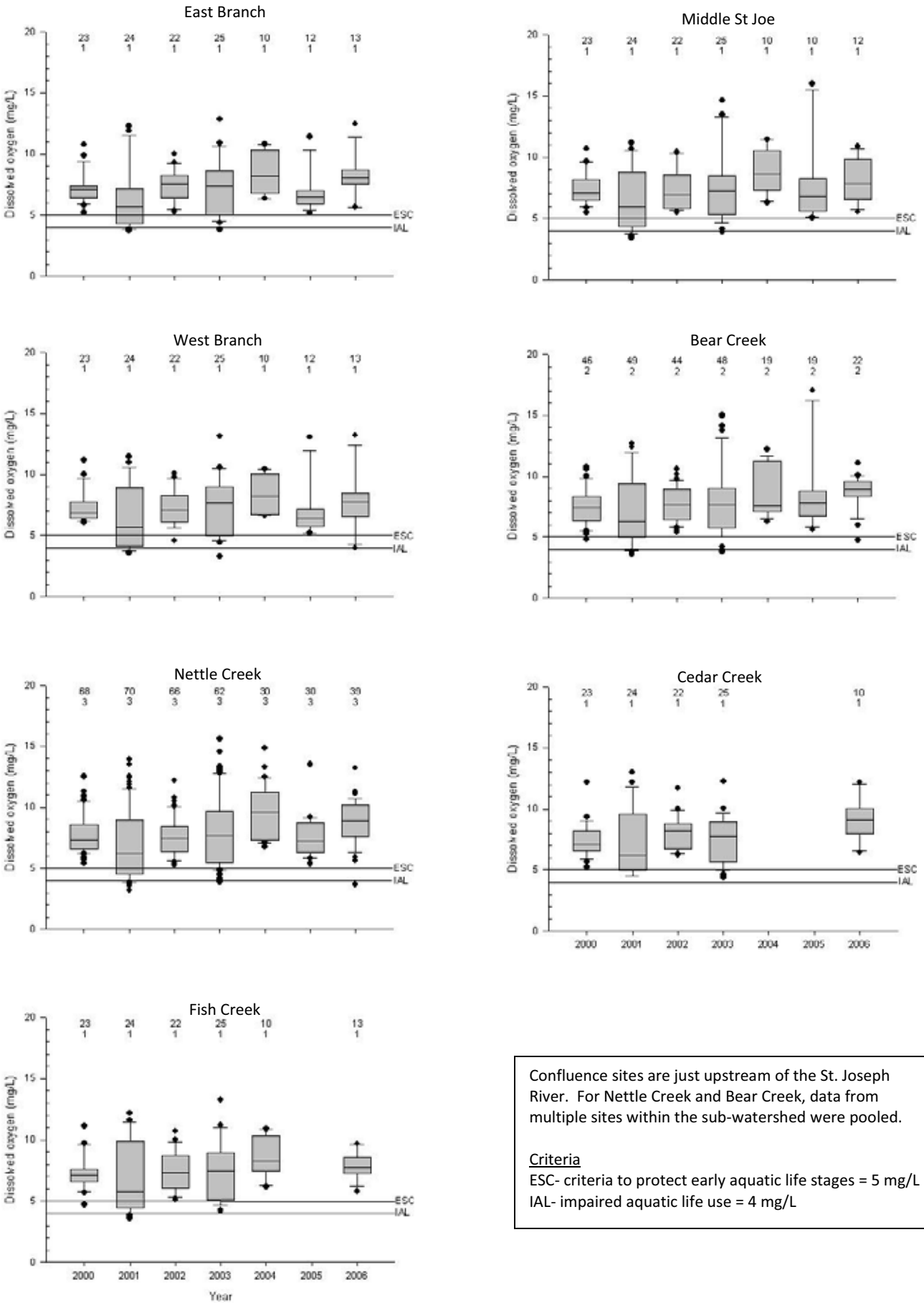
Figure 25. Dissolved oxygen concentrations among 14 sites for 1999-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

Criteria
ESC- criteria to protect early aquatic life stages = 5 mg/L
IAL- impaired aquatic life use = 4 mg/L

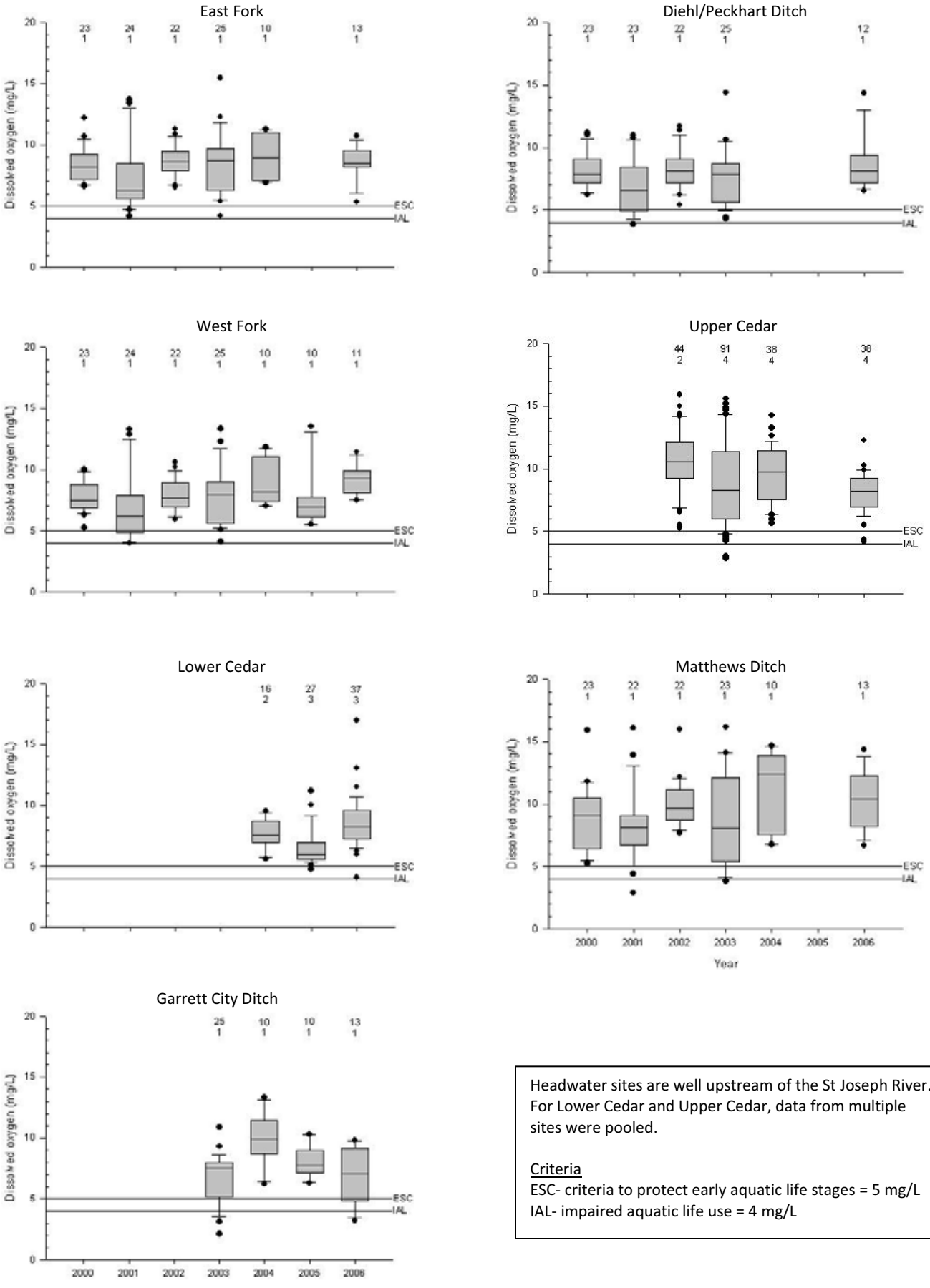
Figure 26. Dissolved oxygen concentrations at confluence sites from 1999-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

Criteria
ESC- criteria to protect early aquatic life stages = 5 mg/L
IAL- impaired aquatic life use = 4 mg/L

Figure 27. Dissolved oxygen concentrations at headwater sites from 1999-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria

ESC- criteria to protect early aquatic life stages = 5 mg/L

IAL- impaired aquatic life use = 4 mg/L

Turbidity

Spatial Comparisons

Among confluence sites, a spatial pattern was detected for turbidity (Figure 28). As the sub-watersheds entered the St. Joseph River in an upstream-downstream direction, there appeared to be a decrease in turbidity. The East Branch confluence site had the highest median turbidity (66.6 NTU), while the Bear Creek confluence site had the lowest median turbidity (32.4 NTU). Among headwater sites, the West Fork and the Lower Cedar Creek sites had the highest median turbidity (36 NTU and 34.7 NTU, respectively), while the East Fork had the lowest median turbidity (20.35 NTU).

Temporal Comparisons

A pattern in turbidity was detected for most sites. Turbidity seemed to decrease from 2000 to 2002, but spiked in 2005. The highest median turbidity occurred in 2000 for 5 of 11 sites, while the lowest median turbidity occurred in 2003 for 7 of 12 sites.

Comparison to Water Quality Criteria

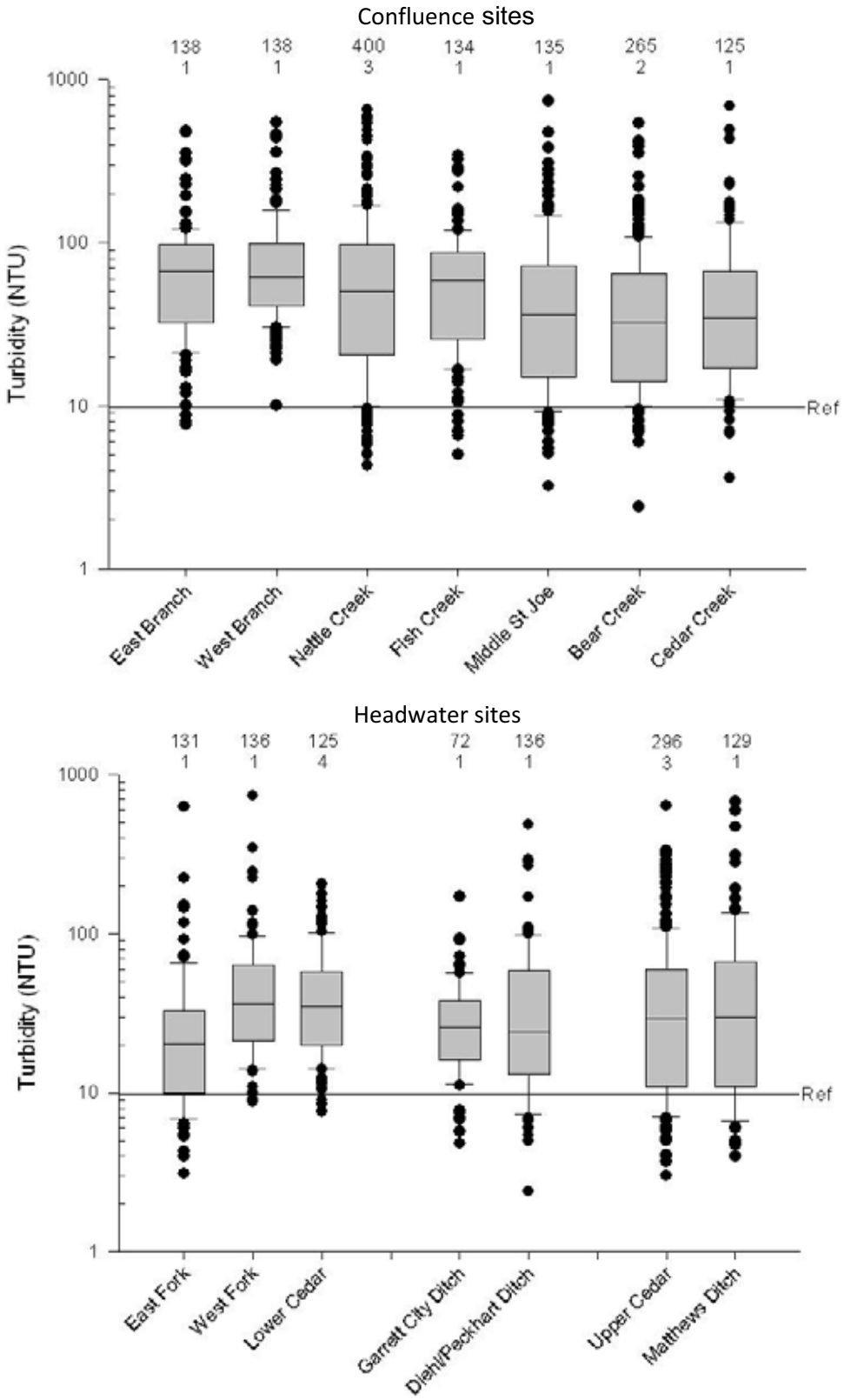
The median turbidity levels were well above the reference conditions at all sites (Figures 29, 30). Water samples were below the reference conditions only occasionally (Table 14). Among confluence sites, the West Branch had the highest percent of samples that exceeded th reference condition (100%), while Middle St Joe had the lowest percent of samples that exceeded the reference condition for turbidity (89%). Among headwater sites, the West Fork and the Lower Cedar sites had the highest percent of samples that exceeded the reference condition (98% and 97%, respectively), while Matthews Ditch, the Upper Cedar sites and East Fork had the lowest percent of samples that exceeded the reference condition for turbidity (79%, 79% and 80%). The greatest percent of samples that exceede the reference condition for turbidity occurred during 2006 (84-100%), while the least percent of samples that exceeded reference conditions occurred in 2002 (44-100%)s.

Table 14. Percent of samples that were above the reference conditions for turbidity

Site	2000	2001	2002	2003	2004	2005	2006	Total years
Confluence Sites								
East Branch	100	100	94	96	90	100	100	98
West Branch	100	100	100	100	100	100	100	100
Nettle Creek	94	96	91	80	80	95	100	92
Fish Creek	100	100	89	100	80	95	100	96
Middle St Joe	91	100	89	68	70	100	100	89
Bear Creek	98	96	73	85	94	100	100	92
Cedar Creek	100	100	94	92	ND	87	100	94
Headwater Sites								
East Fork	91	96	65	52	70	88	94	80
West Fork	100	100	100	96	90	95	100	98
Lower Cedar	ND	ND	ND	ND	100	96	98	97
Garrett City Ditch	ND	ND	ND	75	100	100	100	92
Diehl/Peckhart Ditch	87	100	56	76	ND	95	100	84
Upper Cedar	ND	ND	44	60	65	95	84	79
Matthews Ditch	91	83	95	63	60	67	87	79

ND= no data

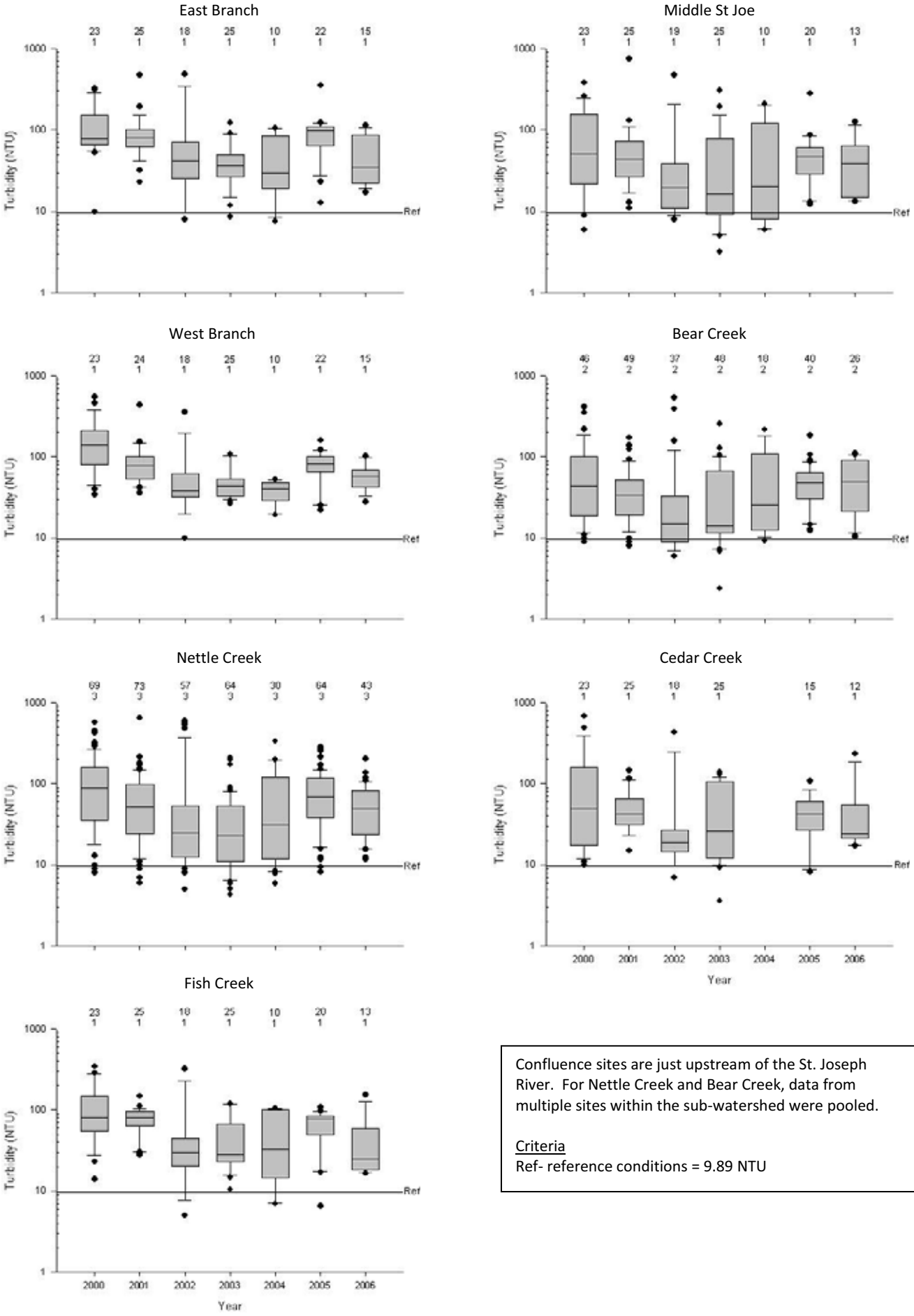
Figure 28. Turbidity among 14 sites for 2000-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple confluence sites were pooled. Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, multiple sites were pooled.

Criteria
Ref- reference conditions = 9.89 NTU

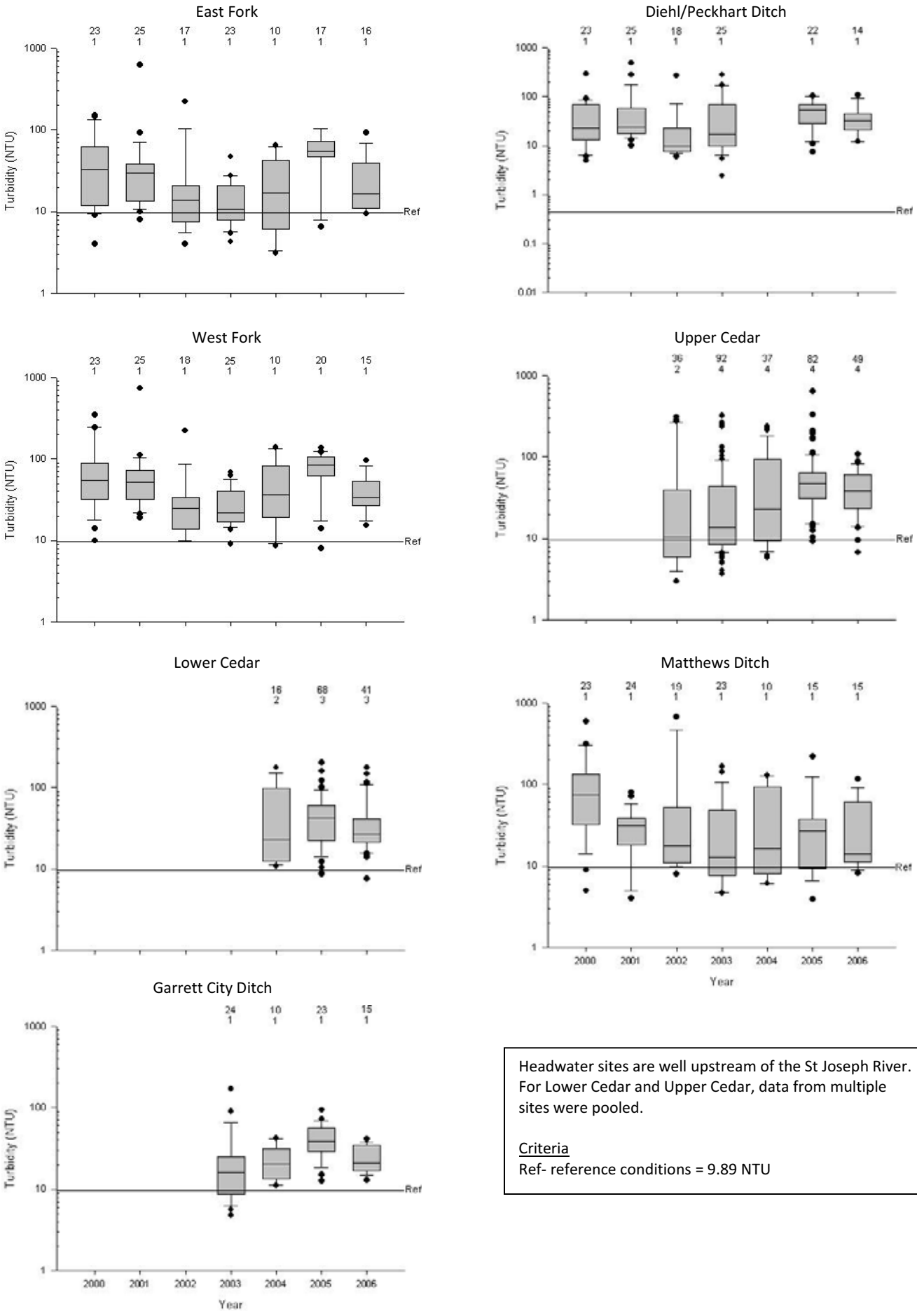
Figure 29. Turbidity at confluence sites from 2000-2006



Confluence sites are just upstream of the St. Joseph River. For Nettle Creek and Bear Creek, data from multiple sites within the sub-watershed were pooled.

Criteria
Ref- reference conditions = 9.89 NTU

Figure 30. Turbidity at headwater sites from 2000-2006



Headwater sites are well upstream of the St Joseph River. For Lower Cedar and Upper Cedar, data from multiple sites were pooled.

Criteria
Ref- reference conditions = 9.89 NTU

REFERENCES

Health Canada (HC). 2007. Guidelines for Canadian Drinking Water Quality- Summary Table. Federal-Provincial-Territorial Committee on Drinking Water. http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/chemical-chimiques_e.html#4

Indiana Department of Environmental Management (IDEM). 2007. Indiana's Water Quality Assessment and 303(d) Listing Methodology for Waterbody Impairments and Total Maximum Daily Load Development for the 2008 Cycle. Office of Water Quality. Indianapolis, IN. (http://www.in.gov/idem/programs/water/303d/index.html)

U. S. Environmental Protection Agency (USEPA). 1986a. Ambient Water Quality Criteria for Bacteria. Washington, D.C.: U. S. Environmental Protection Agency. EPA440/5-84-002. http://www.epa.gov/waterscience/criteria/library/ambientwqc/bacteria1986.pdf

U.S. Environmental Protection Agency (USEPA). 2000. Ambient Water Quality Criteria Recommendations. Washington, D.C.: U. S. Environmental Protection Agency. EPA822-B-00-017. http://epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_6.pdf

U. S. Environmental Protection Agency (USEPA). Analytical Methods Approved for Drinking Water Compliance Monitoring Listed by Contaminant. http://www.epa.gov/OGWDW/methods/compmon.html

U. S. Environmental Protection Agency (USEPA-OPP). Aquatic Life Benchmark Table. http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm

U. S. Environmental Protection Agency (USEPA-SAFE). Drinking Water Contaminants. http://www.epa.gov/safewater/contaminants/index.html

U.S. Environmental Protection Agency (USEPA). 2006. National Recommended Water Quality Criteria. Washington, DC. U. S. Environmental Protection Agency. http://www.epa.gov/waterscience/criteria/wqcriteria.html

U.S. Environmental Protection Agency (USEPA). 1986b. Quality Criteria for Water. Washington, DC. U. S. Environmental Protection Agency. EPA440/5-86-001 **.** http://www.epa.gov/waterscience/criteria/goldbook.pdf