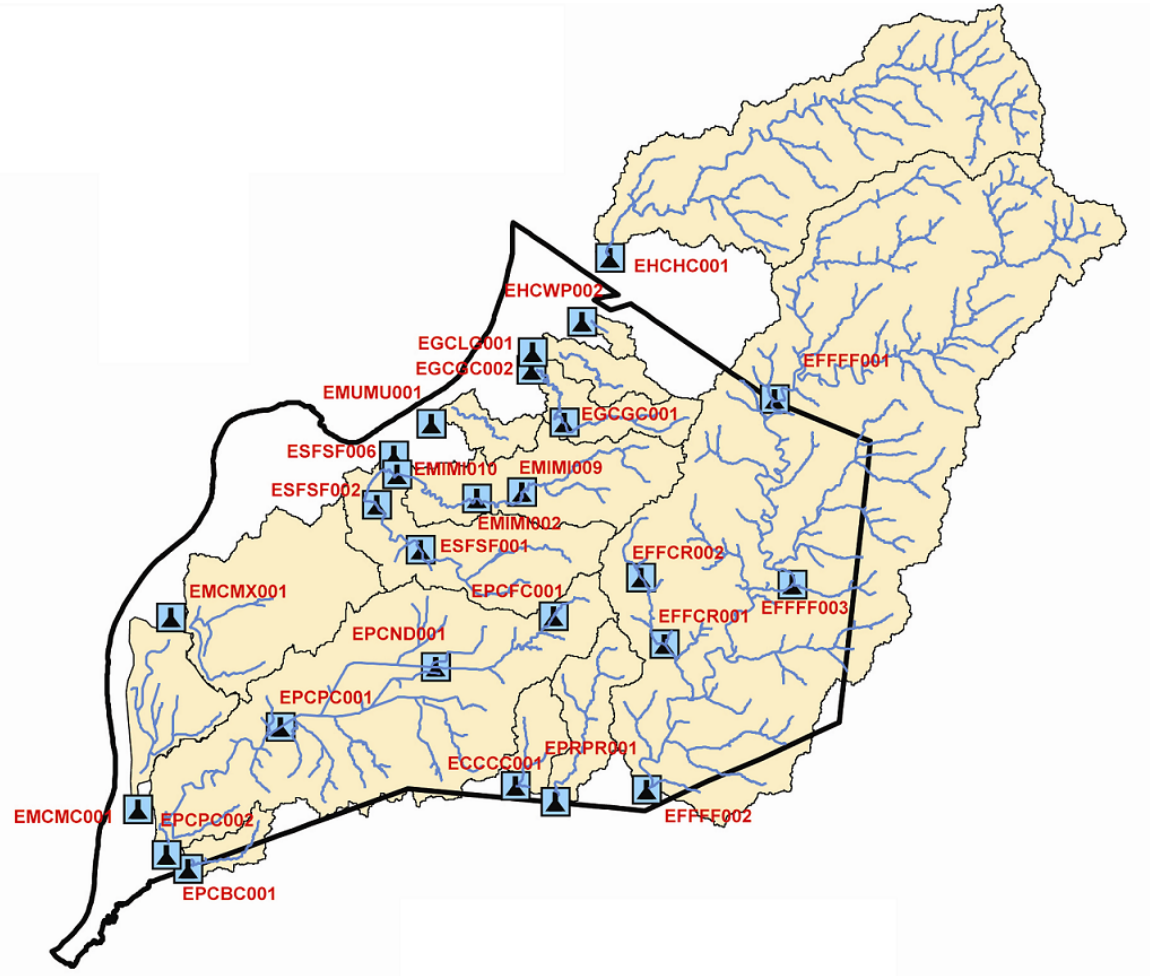
Water Quality in Jefferson County, Kentucky

A Watershed Synthesis Report, 2000-2007



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Disclaimer:

Data presented in this report are subject to further revision and can be different in the next phase comprehensive report.

Table of Contents

Chapter 1 Project Overview
Assessing water quality of streams in Jefferson County (KY) with biological and chemical data

1.1 Introduction

In 1988, the Louisville Metropolitan Sewer District (LMSD) and the United States Geological Survey (USGS) began a sampling and monitoring program to collect physical, chemical and biological samples from the surface waters in the Louisville Metro Area (LMA) and surrounding areas. The USGS conducts stream flow monitoring and Louisville MSD conducts water quality sampling and biological monitoring. The Long Term Monitoring Network (LTMN) developed by MSD consists of 28 sites (Table 1-1, Figure 1-1, Figure 1-2), 25 of which are located at USGS continuous streamflow gauging stations. MSD collects continuous water quality data of each LTMN site by deploying data sondes which collect and store water temperature, dissolved oxygen, pH, and conductivity.

This report provides analysis on water quality trends of LTMN sites based on the laboratory-analyzed parameters and biological data collected during the years of 2000-2007. The analysis begins with the watershed landuse patterns for each LTMN site as a template (or master) parameter influencing the stream ecosystems and biological communities. The next level analysis deals with the composition of biological communities to assist the determination of stream water quality: diatom, macroinvertebrates, and fish biotic integrity indices. Then sonde-acquired data are used to provide summary of DO, pH, and conductivity and to estimate stream community metabolism (gross primary production and community respiration) for each LTMN site. Finally, laboratory-analyzed water quality (mainly water chemistry) data are presented.

Each chapter of this report deals with a separate major watershed monitored by MSD through the LTMN. The watersheds included are, in the order of the report: Mill Creek (Chapter 2), Cedar Creek in Jefferson County (Chapter 3), Cedar Creek in Bullitt County (Chapter 4), Floyds Creek (Chapter 5), Goose Creek (Chapter 6), Harrods Creek (Chapter 7), Middle Fork Beargrass Creek (Chapter 8), Muddy Fork Beargrass Creek (Chapter 9), Pennsylvania Run (Chapter 10), Pond Creek (Chapter 11), South Fork Beargrass Creek (Chapter 12), and Otter Creek (Chapter 13).

1.2 Land Use/Cover Characterization

Land use/cover (LUC) at each Long Term Monitoring Network (LTMN) site was calculated from Kentucky's 2005 LUC update (KDGI 2007). LUC was quantified as the % composition of each LUC type at three spatial scales (Figure 1-3) including the entire watershed, a 100 meter buffer around whole-length of the stream in the watershed, and a 100 meter buffer around the stream that extended 1 kilometer upstream (reach-scale) of each LTMN sampling site. Definitions for land use classes are listed below (adapted from Homer *et al.* 2004):

1. **Open Water** - All areas of open water, generally with less than 25 percent cover of vegetation or soil.

2. **Developed, Open Space** - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units,

parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

3. **Developed, Low Intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49 percent of total cover. These areas most commonly include single-family housing units.

4. **Developed, Medium Intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50–79 percent of the total cover. These areas most commonly include single-family housing units.

5. **Developed, High Intensity** - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

6. **Barren Land** (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

7. **Deciduous Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

8. **Evergreen Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

9. **Mixed Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

10. **Shrub/Scrub** - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

11. **Grassland/Herbaceous** - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

12. **Pasture/Hay** - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

13. **Cultivated Crops** - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

14. **Woody Wetlands** - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

15. **Emergent Herbaceous Wetlands** - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

1.3 Biological Data

Biological assemblages (fish, macroinvertebrates, and diatoms) are have been sampled in alternating years. Here, we describe these stream organisms and the methods used to evaluate the 'quality' or biotic integrity of these stream assemblages. Assessing the living organisms of streams and surface waters offers many advantages over other monitoring methods. First, these organisms have been found to consistently respond to a wide variety of disturbances. Additionally, they integrate disturbances and stressors throughout time because they are constantly exposed during their lifespan. In contrast, other estimates of water quality such as chemical analyses provide only "a snapshot in time" that is only representative of the exact moment the water sample was taken.

Diatoms are unicellular, microscopic algae. They have an intricate siliceous valve or shell, the morphology of which is the basis of their taxonomy. Diatoms are readily identifiable to species level and are easily preserved and prepared for enumeration. Many diatom species are cosmopolitan. Also, many diatom taxa have been identified from a range of sites throughout the world. Diatom samples were collected from artificial substrates placed in 28 LTMN streams during the years 2000 – 2003, and 2005 as a means of characterizing water quality of those streams. Not all streams were sampled during all years. In most cases, a total of 33 samples were collected from each stream within the Network. In general, samples were collected every three days over a continuous nine or fifteen-day growth period. A total of nine samples were collected from most streams during 2001 - 02, while five samples were collected from most streams during 2003. Finally, ten samples were collected from most streams during 2005. Diatom assemblage data from sample year 2000 were not included in the analyses as these samples were not collected during one continuous growth cycle but rather spanned the entire summer. A total of 860 diatom samples were collected in conjunction with this project. Diatom enumeration was performed for all samples collected. Following computation of six (6) component diatom metrics for each sample, further analyses were performed to determine the overall diatom bioassessment index (DBI) for each sample as per Kentucky Division of Water (KDOW) protocols. Specific diatom metrics are described in the next section.

Macroinvertebrate assemblages are composed primarily of the larval stages of many insects along with many other non-insect organisms including snails, crayfish, worms, etc. These organisms have been found to be very good indicators of stream impairment from multiple types of disturbance. As a result, they are one of the most studied aspects of streams and other surface waters. For the purpose of this analysis the KDOW defines a macroinvertebrate as:

> "organisms large enough to be seen by the unaided eye, can be retained by a U.S. Standard No. 30 sieve (28 mesh/inch, 600 µm (0.6mm) openings) and live at least part of their life cycle within or upon available substrates of a waterbody."

Macroinvertebrate collections detailed in this report were collected in 2000, 2004, and 2005. Macroinvertebrate sampling consisted of four composited 0.25m^2 samples collected from riffle habitats at each site using a kicknet, and composited into a single semi-quantitative riffle sample. In addition, a qualitative multi-habitat sample was collected from each site. For the multi-habitat sample, various habitats within the stream reach are systematically sampled and composited into a single qualitative sample. Invertebrates in both the semi-quantitative riffle and qualitative multi-habitat samples were identified to the lowest determinable taxonomic level, typically genus and species, and counted for abundance. This data was then used to calculate the Kentucky macroinvertebrate biotic index (MBI). The MBI is a multi-metric index computed by averaging the scores of six percentile-based component metrics including total taxa richness, EPT richness, %EPT, a modified Hilsenhoff biotic index, %Chironomids and Oligochaetes, and %Clinger. Only the semi-quantitative riffle sample was used to quantify the %EPT, %CO, %Clinger, and mHBI. Taxa richness and EPT Richness were determined by summing all taxa found in both the semi-quantitative riffle sample and the qualitative multi-habitat sample. Macroinvertebrate metrics are described in the next section.

Fish collections were completed using a combination of seining and electrofishing at each site using Kentucky Division of Water (KDOW) standard protocols. Fish were identified to species in the field and enumerated to calculate the Kentucky Index of Biotic Integrity (IBI). The IBI was calculated as the average of six percentile-based metric scores including native species richness, darter, madtom, sculpin richness, intolerant species richness, simple lithophilic spawning richness, %Insectivorous, and %Tolerant Individuals.

As previously mentioned for all three assemblages (Diatoms, Macroinvertebrates, and Fish), several different measures (i.e. metrics) of the structure of the assemblage are determined from sampling, identifying, and counting the number of individuals in each taxa (i.e. species). These metrics are then combined to create a final assessment value for each assemblage that ranges from 0-100. In general the higher the value the ‘better’ the assemblage structure (i.e. higher biotic integrity). The overall metrics for each assemblage are the Diatom Bioassessment Index (DBI), the Macroinvertebrate Bioassessment Index (MBI), and the Index of Biotic Integrity (IBI) for fish assemblages. First we describe the individual metrics computed for each assemblage, and then we describe the calculation and rating criteria for the overall DBI, MBI and IBI.

Diatom Metric Descriptions (adapted from KDOW protocols)

1.) Total Number of Diatom Taxa (TR): Total number of diatom taxa (TR) is an estimate of diatom species richness or more simply, an estimate of the number of different species of diatoms in a sample. In general, high species richness is associated with overall good water quality and is expected to decrease as water quality is impaired. However, slight levels of nutrient enrichment may increase species richness in naturally unproductive, nutrient-poor streams.

2.) Pollution Tolerance Index (PTI): The Pollution Tolerance Index (PTI) is based on the decimal fraction of diatoms in each of four (4) pollution tolerance groups. These groups range in value from 1 (most tolerant) to 4 (most sensitive). These group point values were derived from extensive research with respect to the ecology of these organisms. This index number will range from 1.000 (all most-tolerant diatoms) to 4.000 (all most-sensitive diatoms). In general, as the level of pollution in a system increases, the PTI decreases.

3.) Siltation Index (%NNS): The siltation index is the sum of all relative abundances of species in the genera *Navicula, Nitzschia,* and *Surirella*. These genera are highly motile and highly adapted to living on loose and shifting substrates (e.g., silt or sand). The computed siltation index metric will yield values ranging from 0.0 to 100.0% and increases as the level of sedimentation decreases.

4.) Shannon Diversity Index (SDI): The Shannon diversity index incorporates elements of both species richness (who is there) and evenness (how are they distributed). It generally ranges from less than 1.00 to greater than 4.00. This index is sensitive to changes in water quality and, in general, higher values are indicative of good water quality.

5.) Fragilaria Group Richness (FGR): The total number of taxa represented in the sample from the genera *Fragilaria* and *Synedra* reflects high water quality. As water pollution increases, the FGR is expected to decrease. The development of this index will continue as the taxonomy of these groups is currently being refined.

6.) Cymbella Group Richness (CGR): The total number of taxa represented in the sample from the genus *Cymbella* reflects high water quality. As water pollution increases, the CGR is expected to decrease. The development of this index will continue as the taxonomy of this group is currently being refined.

Macroinvertebrate Metric Descriptions (adapted from KDOW protocols)

1.) Taxa Richness. This refers to the total number of distinct taxa (i.e. species) present in the composited sample. In general, increasing taxa richness reflects increasing water quality, habitat diversity and/or habitat suitability.

2.)Ephemeroptera, Plecoptera, Trichoptera Richness (EPT). This is the total number of distinct taxa (both semi-quantitative and qualitative samples combined) within the generally pollution sensitive insect orders of Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies) in the sample. This index value will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

3.) Modified Hilsenhoff Biotic Index (mHBI). The HBI was developed to summarize the overall pollution tolerance of the macroinvertebrate community. Each macroinvertebrate taxa is given a pollution tolerance value ranging from 0 (Intolerant) to 10 (very tolerant). The abundance of each taxa and its associated tolerance value is then used to calculate the tolerance of the collective taxa together in the assemblage. This assemblage level tolerance is still expressed on a scale from 0 (Intolerant) to 10 (very tolerant).

4.) Modified Percent EPT Abundance (m%EPT). This metric measures the abundance of the generally pollution-sensitive insect orders of Ephemeroptera, Plecoptera and Trichoptera.

5.) Percent Ephemeroptera (%Ephem). The relative abundance of mayflies is calculated to show impacts of metals and high conductivity associated with mining and oil well impacts. Ephemeroptera abundance normally declines in the presence of brine and metal contamination.

6.) Percent Chironomidae+Oligochaeta (%CO). This metric measures the relative abundance of the generally pollution tolerant midges and Oligochaete worms. Increasing abundance of these groups suggests decreasing water quality conditions.

7.) Percent Primary Clingers (%Clingers). This habit metric measures the relative abundance of those organisms that need hard, silt-free substrates to "cling" to.

Fish Metric Descriptions (adapted from KDOW protocols)

1. **Native Species Richness (NAT)**: This is the total number of native species present in a sample. Exotic species, those introduced to the area by mumans either purposefully or accidentally, were excluded since they were a direct indication of anthropogenic impairment.

2. **Darter, Madtom, and Sculpin Richness (DMS)**: This is the total number of the species present in a sample within the tribe Etheostomatini (darters), the genus *Noturus* (madtoms), and the genus *Cottus* (sculpins). These groups, relatively, are intolerant or sensitive to pollution.

3. **Intolerant Species Richness (INT)**: This is the total number of intolerant species present in a sample. Members of this metric were believed to represent the first species to disappear after impairment and the last to re-establish after restoration.

4. **Simple Lithophilic Spawning Species Richness (SL)**: This metric is the total number of simple lithophilic spawning species and represents species that require relatively clean gravel and exhibit simple spawning behavior.

5. **Relative Abundance of Insectivorous Individuals (%INSCT)**: This metric is the relative abundance of insectivorous (i.e. fish that eat insects and other small invertebrates) individuals excluding tolerant individuals.

6. **Relative Abundance of Tolerant Individuals (%TOL)**: This metric represents a proportion of individuals that are pollution tolerant and increase in abundance with impairment.

7. **Relative Abundance of Facultative Headwater Individuals (%FHW)**: The metric was designed to detect the abundance of species that were atypical of headwater streams (e.g., *Lepomis* spp.) or typically exhibit low abundance in small streams (e.g., *Campostoma* spp.), but tend to increase in abundance with impairment (negative response).

Individually, the above component metrics for each assemblage provide valuable information with respect to the water quality of a particular reach of stream. As previously mentioned, the individual scores for each metric above is used to calculate an overall assessment score for each assemblage (i.e. the DBI, MBI and IBI). To accomplish this, each individual metric for each assemblage described above is given a calculated score (range 0 ('low biotic integrity or water qualtiy') –100 ('high biotic integrity or water quality')) that is based on the sites percentile-rank compared to reference or optimal conditions. For each assemblage, the percentile-rank for each metric calculated for that assemblage is averaged to create the DBI, MBI and IBI.

Additionally, a qualitative assessment evaluation (i.e. excellent, good, fair, or poor) can be assigned to the overall DBI, MBI, and IBI that is based on the metric score and the region of the state that the sample was taken. For this qualitative rating, Kentucky is divided into four distinct bioregions (Figure 1-3). Each bioregion has specific overall DBI, MBI, and IBI value ranges used to describe stream water quality. The bioregions of interest in the current project were the Bluegrass and Pennyroyal. The Bluegrass bioregion is bounded roughly by the Appalachian Mountains to the east, the Ohio River to the north, and a line drawn between the cities of Louisville, Bardstown, and Danville, Kentucky to the west and south. The Pennyroyal bioregion shares its northern border with the bluegrass bioregion. It is bounded to the east by the Appalachian Mountains and to the south by the Tennessee border. Portions of the western border extend to the Ohio River.

A total of 24 streams in the current project were located within the Bluegrass bioregion. These included seven sites on three tributaries of Beargrass Creek, three sites on Floyds Fork and Goose Creek, two sites on Mill Creek, Chenoweth Run, and Harrods Creek, and one site on each of Penn Run, Northern Ditch, Fern Creek, Cedar Creek (Jefferson County) and Cedar Creek (Bullitt County). In contrast, only one site on Otter Creek and Brier Creek, and two sites on Pond Creek were located within the Pennyroyal bioregion.

Interpretation of DBI, MBI, and IBI with Respect to Water Quality

As previously mentioned, the Kentucky Division of Water (KDOW) has developed a single word description of water quality for each stream or reach of stream based on that stream's diatom, macroinvertebrate, and fish assemblage composition. Water quality or health of the stream may be variously described as poor to excellent (Table 1-2). The range of DBI, MBI, and IBI values that corresponds with a particular description of water quality from the aforementioned categories is shown in Table 1-2 within the two bioregions (Figure 1-4) sampled in this study.

1.4 Sonde data

Each LTMN site has a water quality sonde unit that measures and records water temperature, dissolved oxygen, pH and conductivity with 15 minute interval. The data is retrieved from the sonde and consolidated into a cumulative database file for each LTMN location. These database files were transferred from MSD to UofL for further analyses for daily statistics and estimation of gross primary production and community respiration.

1.4.1 Dissolved oxygen, pH, and conductivity

Portions of sonde data were initially extracted for each season. For spring (April), summer (July), and fall (October) seasons, sonde data for 5-7 day-long 'base-flow' periods were extracted. The definition of 'base-flow' is that the selected data period was preceded by at least 5 'dry' (precipitation-free) days. Thus, the selected periods for each year were slightly different depending on the rainy periods for each year. Sonde data from winter was extracted from a 10-day period in the middle of January regardless of flow condition due to the wet nature of the season. Those LTMN locations that did not contain any reliable data during the designated periods due to malfunction of the sonde or fouling of probes were not included in this analysis.

Daily mean, maximum, and minimum of the four parameters (water temperature, dissolved oxygen, pH, and conductivity) were calculated from the seasonal data sets described above. Thus there were 5-10 daily summary estimates for each season of each year. These daily summary values (mean, min, and max) were then averaged for each year and presented as seasonal mean, minimum, and maximum estimates for each year.

1.4.2 Primary productivity and community respiration

Primary productivity is defined as the rate at which inorganic carbon is converted to an organic form by photosynthesizing organisms and thus represents the conversion of solar energy to reduced chemical energy. Some of this fixed energy is lost through plant respiration (autotrphoc respiration); the portion stored in the plant biomass is net primary productivity (NPP); and the total (respired plus stored) is gross primary production (GPP). Chlorophyll-bearing plants (phytoplankton, periphyton, and macrophytes) in aquatic ecosystems serve as primary producers. Photosynthesis results in the formation of a wide range of organic compounds, release of oxygen, and depletion of carbon dioxide (CO_2) in the surrounding waters.

The basic reactions in algal photosynthesis involve uptake of inorganic carbon and release of oxygen, summarized by the relationship:

$$CO_2 + H_2O \rightarrow (CH_2O)_x + O_2$$

Thus, primary productivity can be determined by measuring the changes in oxygen (O_2) and CO_2 concentrations. The rate of change in stream DO (ΔDO) at a given time interval is represented by photosynthetic rate (P), respiration (R), reaeration (E), and accrual from groundwater inflow and surface runoff (A):

$$\Delta DO = P - R \pm E + A$$

Primary productivity of the periphyton community in a stream or river ecosystem can be related to changes in dissolved oxygen (DO). These changes are the integrated effects of photosynthesis, affected by light levels and turbidity, that is carried out during the photoperiod by stream plankton, periphyton, and the submerged portions of macrophytes. Productivity is calculated on the assumption that one atom of carbon is assimilated for each molecule of oxygen released.

Respiration results from metabolism of plant communities, aquatic animals, and attached and free-floating microbial heterotrophs. Respiration by microbes, fish and benthic fauna is difficult to quantify directly and usually is not separated from periphyton respiration, thus reported as the community respiration (CR).

Water depth, turbulence, and water temperature all influence the process of reaeration (*E*), the exchange of oxygen between the water surface and atmosphere. Oxygen also can enter by accrual of groundwater and surface change. Daily fluctuations in photosynthetic production of oxygen are imposed on the relatively steady demand of respiratory activity. However, this latter process may fluctuate greatly in streams receiving a significant load of organic wastes, particularly under intermittent loads such as oxygen demand from urban stormwater runoff. Respiration rates also may vary diurnally under certain conditions, but the factors involved are not well understood. The influence of groundwater and surface runoff on the stream DO concentration can be ignored when the stream segment does not have considerable groundwater inputs and DO data is obtained during ‘dry’ period.

Sonde data of dissolved oxygen and water temperature during three seasons (spring, summer, and fall) obtained above were used to estimate gross primary production (**GPP**) and community respiration (**CR**) in LTMN sites. The procedure measures the time-variable oxygen concentrations in a stream over a 24-hr period. Compensations are made for oxygen changes due to physical factors (mainly reaeration) and the rate of oxygen change due to biological activity that is separated into components due to respiration and primary production. The metabolic rates are the sum of the activity of the entire stream community, thus community metabolism and community respiration.

Community metabolism (GPP and CR) was calculated using the open-system single-station diel oxygen curve method (Odum 1956; Bott 1996; APHA et al. 1998). The method assumes that the change in dissolved oxygen in stream water (ΔDO) is related to photosynthesis (P), respiration (R), and gas exchange (E) with the atmosphere as long as accrual from surface and groundwater inputs is negligible (Bott 1996).

Metabolic measurements were calculated as the net difference in dissolved oxygen changes at 15-minute intervals after correcting for reaeration (E) during the same time interval. The reaeration coefficient was estimated using the nighttime regression method, which measures the oxygen exchange between the water and atmosphere by regressing the rate of change of DO after sunset during a series of time invals on mean deficit during each interval (Kosinski 1984). The net oxygen exchange with the water due to reaeration (E) during each time interval was calculated by multiplying the saturation deficit or surplus by the reaeration coefficient for the half-hour interval. The dissolved oxygen deficit or surplus ($DO_{deficit}$) was calculated as the difference between the $DO_{saturation}$ (saturation DO concentration at the water temperature) and the measured DO of the stream water. In the case of oxygen surplus (supersaturation), ΔDO would be increased, while the under-saturation (deficit) required ΔDO to be more negative to obtain the exchange corrected oxygen change. The corrected rate of oxygen change (per 15 min) was then plotted against the time of measurement.

Using the corrected rates of dissolved oxygen change, community respiration (CR) and gross primary production (GPP) were calculated. Initially, nighttime respiration was calculated as the mean of respiration values obtained during the night. The mean respiration rates for 2-hour pre-dawn and post-dusk periods were calculated and extrapolated to the daytime period. The daily community respiration (CR_{24}) was the time-integrated summation of the nighttime respiration and the extrapolated daytime respiration. Using the extrapolated respiration values through the daytime as a baseline, GPP was calculated as the sum of positive deviations in corrected DO change over the daylight hours. The area-specific metabolic rate was calculated by multiplying the average water depth (m) to the corrected rate of oxygen change (mg O_2/m^3/15 min) and summing across all intervals within the 24 hr period, which resulted in daily metabolic rate (g O_2/m^2/day). Daily GPP and CR estimates was averaged for each season and year and presented in this report.

Streams can be described energetically either **autotrophic** or **heterotrophic** depending on the relative magnitude of primary productivity and community respiration. This indicates whether the stream community is depending on the organic matter produced (photosynthetically) within the stream (algal primary production) or outside of the stream ecosystem. In this report, the absolute ratio of GPP:CR were compared to describe if the stream was autotrophic or heterotrophic. Most streams with riparian influence receive energetic supports from the riparian vegetation as organic matter generated from the riparian vegetation, such as leaves and tree branches, enters the stream channel and support various biological activities.

1.5 Stream water chemistry

Water samples have been collected by MSD personnel in all LTMN sites for laboratory analyses of water quality parameters. LTMN locations within three Beargrass Creek watersheds and Mill Creek watershed have been collected throughout the 2000-2007 period, while only fecal coliform counts have been continuously monitored at other LTMN sites. MSD had begun to sample all LTMN sites for water chemistry parameters since 2006.

The current report deals with 10 selected laboratory-analyzed water quality parameters: ammonia (NH_3)-nitrogen, nitrate (NO_3)-nitrogen, total kjeldahl nitrogen, ortho(PO_4)-phosphorus, total phosphorus, chloride (Cl), biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), and fecal coliform counts.

Nitrogen and phosphorus are important chemical elements influencing the metabolic activities of stream algae and microbes, and their concentrations in stream water can be used as indicators of stream pollution by various anthropogenic inputs, such fertilizer, sewage discharge, and overland stormflow. Chloride is biologically inert (non-reactive) chemical in aquatic ecosystems, but it could also be used as an indicator for anthropogenic pollution sources. The chloride concentration is higher in wastewater than in raw water because sodium chloride is a common article of diet and passes unchanged through the digestive system. Also it is the main component of the winter ‘road salt’.

TDS and TSS constitute the total solids, which is the material residue left after evaporation from water sample. TSS is the portion retained by a filter and TDS is the portion that passes through the filter. Solids may affects water quality adversely in a number of ways as waters with high dissolved solids generally are of inferior palatability and may induce an unfavorable physiological reaction in the transient consumer. They are also important in the control of biological and physical wastewater treatment processes and for assessing compliance with regulatory agency wastewater effluent limitations.

Fecal coliform bacteria is originated from warm-blooded animals, thus it can provide information on the sources of contamination such as sewage overflow.

Laboratory-analyzed water quality data were separated to either ‘dry’ or ‘wet’ samples depending on the precipitation amounts preceding the sampling. A water quality sample was considered as ‘wet’ when it met one (1) of the following three (3) criteria:

R24≥0.1: more than 0.1 inch of precipitation within 24 hour period prior to the sample
R48≥0.25: more than 0.25 inch of precipitation within 48 hour period prior to the sample
R72≥0.5: more than 0.5 inch of precipitation within 72 hour period prior to the sample

Many water chemistry data were recorded as below their respective minimum detection limits (<MDL). In such case, a half (1/2) of the MDL value was given as a data value. Some water chemistry data were excluded from the current analysis due to the suspected errors during sample transfer (chain of custody) and/or data entry. For example, a chloride sample (AB47856) was recorded as below the detection limit when a sample (AB47857) taken during the same day had 44 mg/L. This might be a case of sample mislabeled or error during data entry, thus was excluded from analysis.

Data were further divided into each individual year during 2000-2007. Summary statistics of the water quality data for each category (dry or wet) and for each year, annual mean, standard deviation (SD), and number of samples for the calendar year (count), were calculated.

1.6 References

APHA, AWWA, and WPCF. 1998. *Standard Methods for the Examination of Water Wastewater*. 20th ed. American Public Health Association, Washington, DC.

Bott, T. L. 1996. Primary productivity and community respiration. Pages 533-556 *in* F. R. Hauer and G. A. Lamberti (editors). *Methods in Stream Ecology*. Academic Press, New York.

Homer C, Huang C, Yang L, Wylie B, Coan M (2004) Development of a 2001 national land-cover database for the United States. Photogrammetric Engineering and Remote Sensing 70:829-840

Kentucky Division of Geographic Information (KDGI) (2007) Kentucky Land Cover Change Detection 2001/2005 - Anderson Level II (FGDC) / ky_lcc_0501 (ISO). Available from http://kygeonet.ky.gov/metadataexplorer/full_metadata.jsp?docId=%7B65E31366-1A04-4BE4-8128-0324E6C672F0%7D (accessed September 2008)

Kentucky Division of Water. 2008. Methods for assessing biological integrity of surface waters in Kentucky. Revision 3.

Kosinski, R.J. 1984. A comparison of the accuracy and precision of several open-water oxygen productivity techniques. Hydrobiologia 119: 139-148.

Table 1.1 MSD Long-Term Monitoring Network (LTMN) locations.

Location Code	Site Description	USGS Gauging Station
ECBCB001	Cedar Creek @ SR 1442	Yes
ECCCC001	Cedar Creek@ Thixton Rd	Yes
EFFCR001	Chenoweth Run #1 @ Gelhaus Ln	Yes
EFFCR002	Chenoweth Run #1 @ Ruckriegel Pkwy	Yes
EFFFF001	Floyd's Fork @ Ash Ave.	No
EFFFF002	Floyd's Fork @ Bardstown Rd	Yes
EFFFF003	Floyds Fork @ Old Taylorsville Rd	Yes
EGCGC001	Goose Creek @ Old Westport Rd	Yes
EGCGC002	Goose Creek @ US Hwy 42	Yes
EGCLG001	Little Goose Creek @ US Hwy 42	Yes
EHCHC001	Harrods Creek @Covered Bridge Rd	Yes
EHCWP002	Wolf Pen Branch @ 8200 Wolf Pen Branch Rd 2	No
EMCMC001	Mill Creek @ Orell Rd	Yes
*EMCMX001	Mill Creek Cutoff @ Old Cane Run Rd	Yes
EMIMI002	Middle Fork Beargrass Creek @ Old Cannons Lane	Yes
EMIMI009	Middle Fork Beargrass Creek @ Browns Lane	No
EMIMI010	Middle Fork Beargrass Creek @ Lexington Rd 2	Yes
EMUMU001	Muddy Fork Beargrass Creek @ Mockingbird Valley Rd	Yes
EOCOC001	Otter Creek @ Otter Creek Park	Yes
EPCBC001	Brier Creek @ Bear Camp Rd	Yes
EPCFC001	Fern Creek @ Old Bardstown Rd	Yes
EPCND001	Northern Ditch @ Preston Hwy	Yes
EPCPC001	Pond Creek @ Manslick Rd	Yes
EPCPC002	Pond Creek @ Pendleton Rd	Yes
EPRPR001	Penn Run @ Mt. Washington Rd	Yes
ESFSF001	South Fork Beargrass Creek @ Trevillian Way	Yes
ESFSF002	South Fork Beargrass Creek @ Schiller Ave Ramp	Yes
ESFSF006	South Fork Beargrass Creek @ Brownsboro Rd	No

* This is currently off-line due to low flow.

Table 1-2 Bioregion-specific description of stream water quality based on overall mean diatom bioassessment index scores. Scores are presented as ranges of values.

Assemblage	Water Quality Rating	Bluegrass Bioregion	Pennyroyal Region
Diatom	Excellent	≥ 53	≥ 67
	Good	46-52	55-66
	Fair	39-45	50-54
	Poor	< 39	< 50
Macroinvertebrate	Excellent	≥ 70	≥ 81
	Good	61-69	72-80
	Fair	41-60	49-71
	Poor	21-40	25-48
	Very Poor	0-20	0-24
Fish	Excellent	≥ 52	≥ 67
	Good	47-51	53-66
	Fair	31-46	35-52
	Poor	16-30	17-34
	Very Poor	0-15	0-16

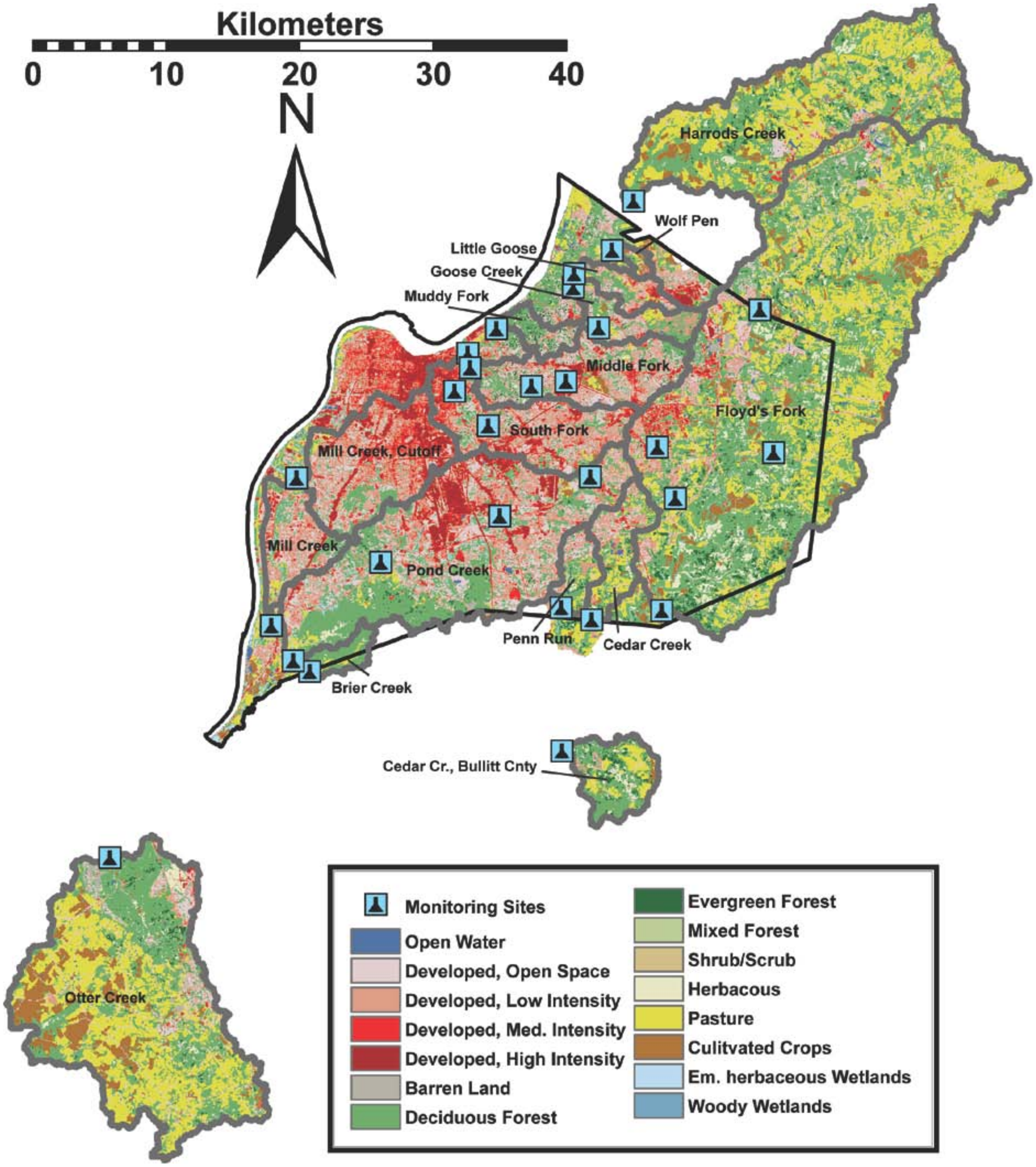

Figure 1-1 Landuse patterns of 12 watersheds monitored by MSD Long-Term Monitoring Network.

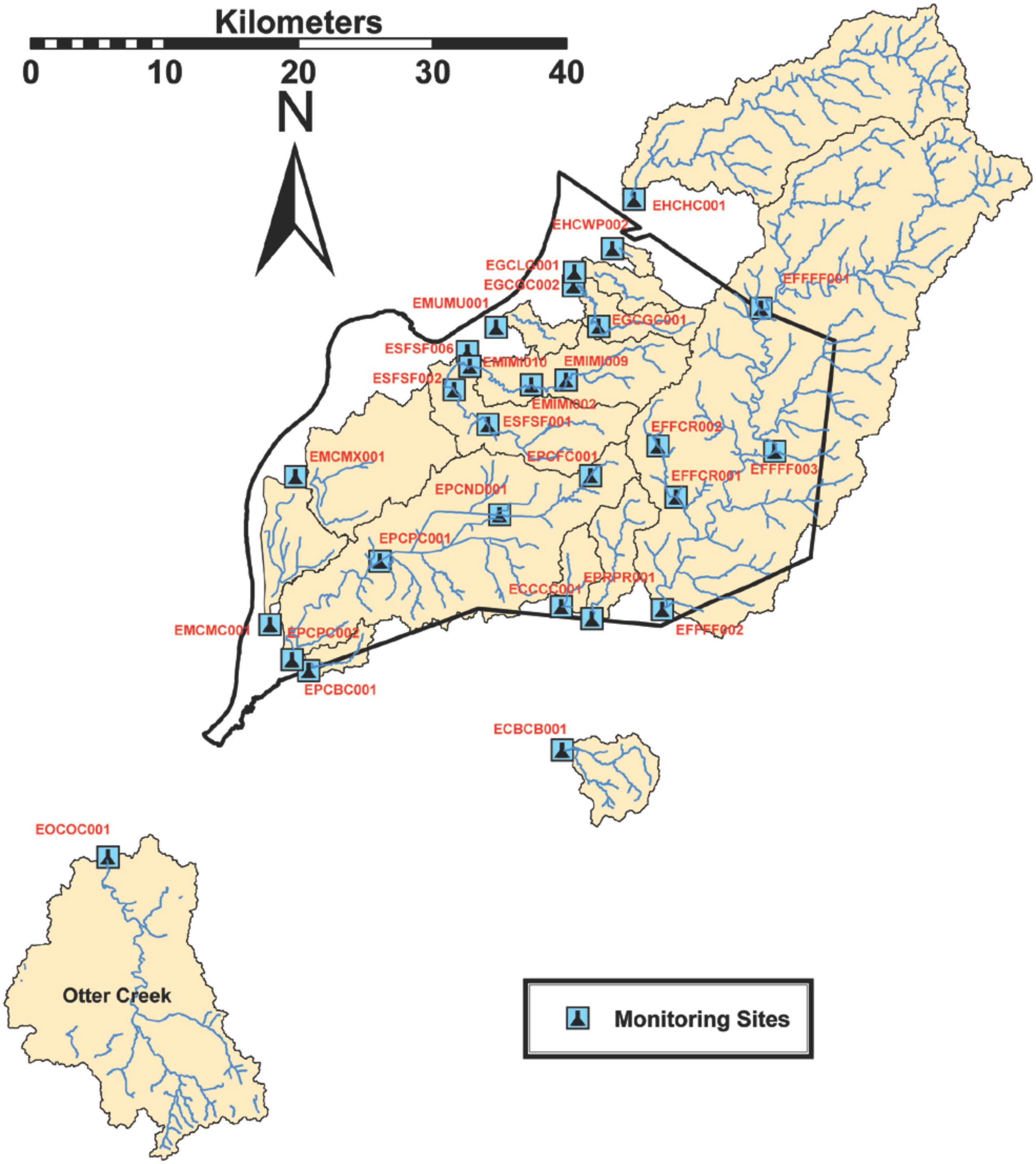

Figure 1-2 Stream networks and LTMN locations operated by MSD.

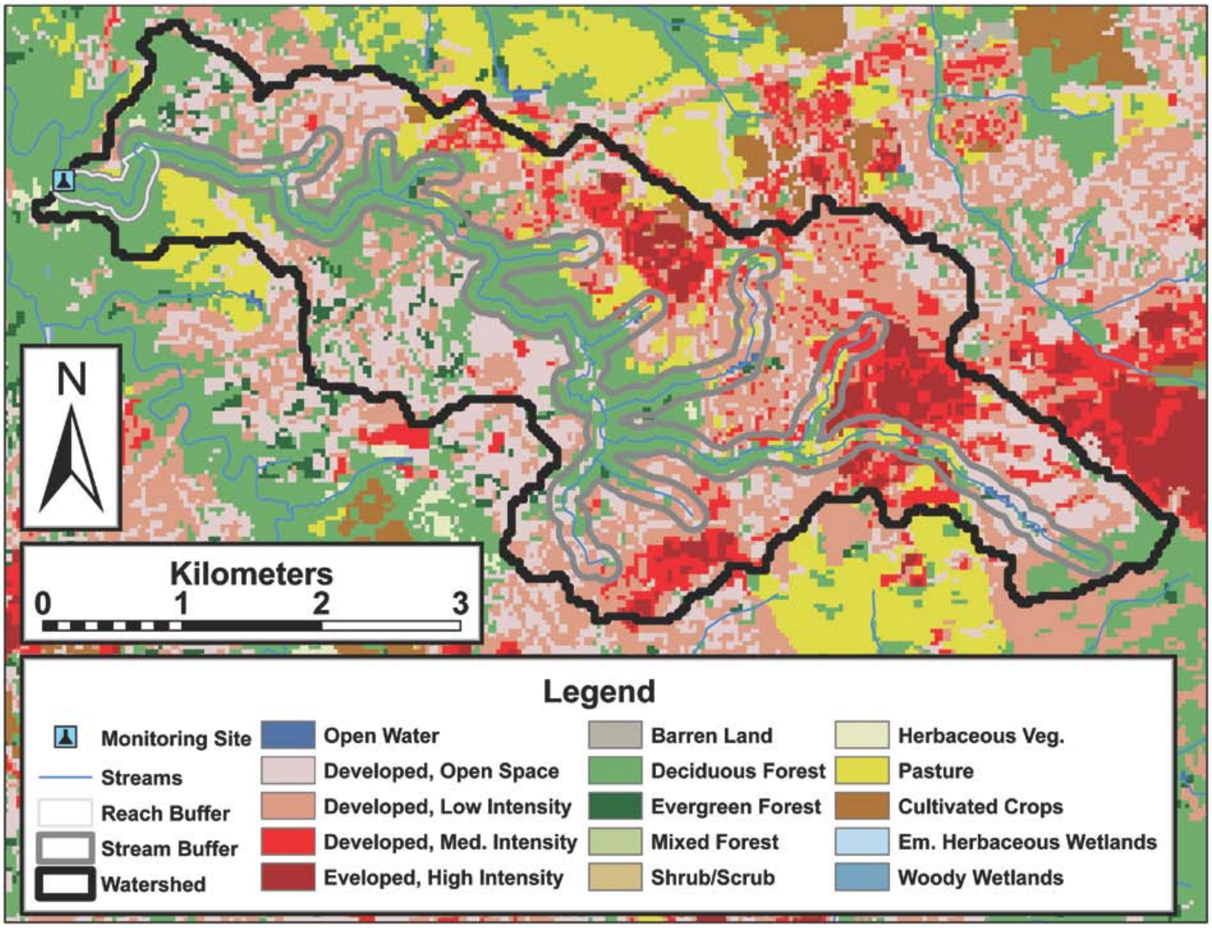

Figure 1-3 Landuse patterns of Little Goose Creek watershed showing delineations at 3 different scales: black line for the whole watershed, grey line for the whole-stream scale riparian buffer zone, and white line for the 1000-meter reach-scale riparian buffer zone.

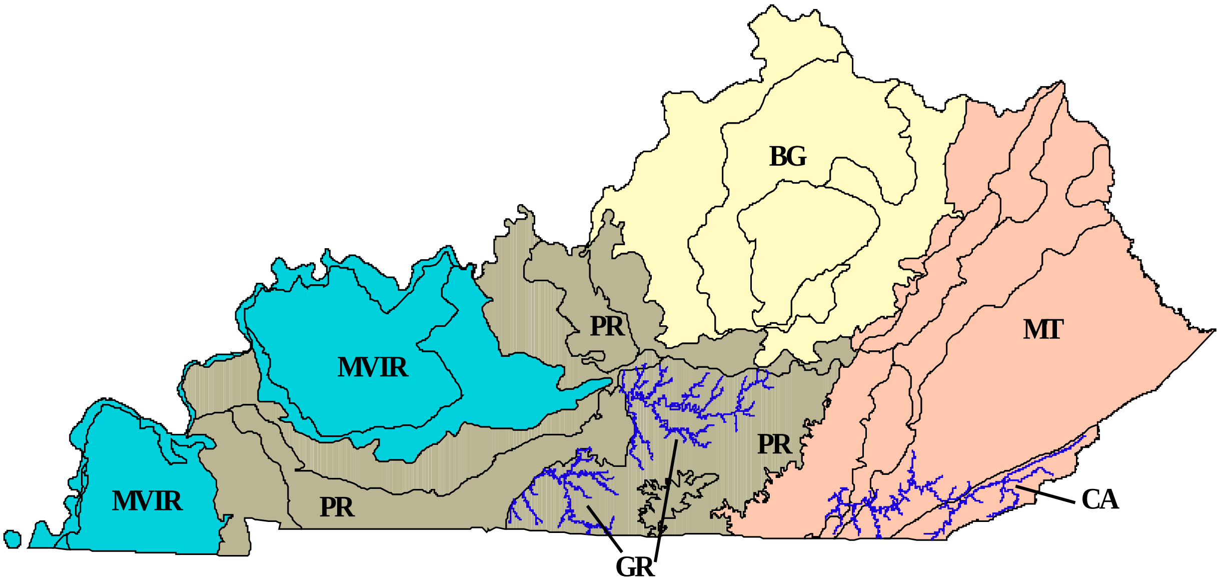

Figure 1-4 Bioregions of Kentucky 9BG= Bluegrass, CA= Cumberland above the Falls, GR= Green River, MT= Mountain, MVIR= Mississippi Valley-Interior River, PR= Pennyroyal) (KDoW 2002).

Chapter 2 Mill Creek Watershed

2.1 Watershed Physical Characteristics

The Mill Creek watershed is essentially divided into two sub-watersheds. The upstream portion of the Mill Creek watershed originates in the Shively and Parkwood areas, flowing from various directions before merging into the Mill Creek Cutoff , which directly flows into the Ohio River. There is one LTMN location on the Mill Creek Cutoff (EMCMX001). The main stem portion of Mill Creek starts just south of the Mill Creek Cutoff, flowing southwest before entering into the Ohio River. There is one LTMN location in the main stem portion of the Mill Creek watershed at Orell Road (EMCMC001).

The Mill Creek watershed is highly urbanized with impervious surfaces comprising 21% of the total watershed area and containing 68% developed and 21% forested areas (EMCMC001; Table 2-1). Such intense urbanization trend is pronounced in the areas closer to the stream channels as evidenced by 58% of developed land along the stream riparian buffer area. Landuse parameters showed much higher degree of urbanization at the EMCMX001 location, with 38% of impervious surfaces and 86% of developed areas with only 13% of forests (Table 2-1).

2.2 Biological Data

2.2.1 Diatom

EMCMC001: The overall water quality of Mill Creek at Orell Road (EMCMC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Good’ (Table 2-2). The overall mean score of 47 reflects the lower range of ‘Good’ scores. In general, water quality of Mill Creek at Orell Road seems to be improving over time. Specifically, during the 2001 sampling season, all nine sample dates characterized water quality as ‘Fair’ (mean DBI = 42,). In contrast, during subsequent sampling years, the mean overall water quality was characterized as ‘Good’ as 71% of samples scored in the ‘Good’ range (mean DBI = 49).

The taxa richness (TR) yearly mean score increased from year 2001 (32) to 2002 (48), but decreased during 2005 (40) (Table 2-2). These data suggest that species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality. The pollution tolerance index (PTI) yearly mean score increased from year 2001 (64) to 2003 (77), but decreased during 2005 (69) (Table 2-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution sensitive. In general, an increase in the PTI suggests an improvement in water quality.

The siltation index (%NNS) yearly mean score increased from year 2001 (55) to 2003 (74), but decreased during 2005 (64) (Table 2-2). These data suggest that species composition shifted away from those species adapted to living on silts and shifting sediments. In general, an increase in %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score changed little from year 2001 (90) to 2005 (91), but was generally indicative of good water quality (Table 2-2). Likewise, Fragilaria group richness (FGR) yearly mean score was largely constant throughout the study. Cymbella group richness (CGR) yearly mean score increased from year 2001 (4) to 2003 (29), but decreased during 2005 (6) (Table 2-2). These data suggest that the number of species observed from within the Cymbella group generally increased as the study progressed. The taxa within this group are widely considered to be indicators of good water quality. Also, these taxa tend to be pollution sensitive and may have contributed to the increase seen in the PTI.

EMCMX001: The overall water quality of Mill Creek Cutoff at Old Cane Run Road (EMCMX001) based on 12 diatom samples collected over two years (2001 – 02) may be characterized as 'Fair' (Table 2-2). The overall mean score of 41 reflects the lower range of 'Fair' scores. In general, water quality of Mill Creek Cutoff at Old Cane Run Road seems to be declining over time (Table 2-2). Specifically, during the 2001 sampling season overall water quality was categorized as 'Fair" (mean DBI = 45). One sample characterized water quality as 'Poor', three were characterized as 'Fair', and five were characterized as 'Good'. In contrast, only three samples were collected during 2002, all were scored as 'Poor' (mean DBI = 29). It is worth noting, MSD personnel were unable to sample after this time, as the creek had dried.

The taxa richness (TR) yearly mean score decreased from year 2001 (33) to 2002 (29) (Table 2-2). These data suggest that species were lost as the study progressed. In general, a decrease in the TR suggests a decline in water quality. The pollution tolerance index (PTI) yearly mean score decreased from year 2001 (67) to 2002 (49) (Table 2-2). These data suggest that species composition shifted in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality.

The siltation index (%NNS) yearly mean score decreased significantly from year 2001 (61) to 2002 (19) (Table 2-2). These data suggest that species composition shifted markedly toward those species adapted to living on silts and shifting sediments. This is significant in that many species within the *Navicula* and *Nitzschia* genera are pollution tolerant and an increase in their numbers may have adversely affected the PTI. In general, a decrease in %NNS suggests a decline in water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (86) to 2002 (75) (Table 2-2). These data suggest that species composition and distribution changed somewhat throughout the study period. The decrease in TR likely adversely affected the SDI.

The Fragilaria group richness (FGR) yearly mean score decreased dramatically from year 2001 (23) to 2002 (0) (Table 2-2). These data suggest that species within the Fragilaria group were lost as the study progressed. Taxa within this group are widely considered to be indicators of good water quality. A decrease with respect to this metric suggests site water quality may be deteriorating rapidly, especially given the complete loss of these taxa during 2002.

The cymbella group richness (CGR) yearly mean score was unchanged throughout the study (3) (Table 2-2). Taxa within this group are widely considered to be indicators of good water quality but were absent from 67% of samples from this site. This low metric value suggests site water quality is deteriorating.

2.2.2 Macroinvertebrates

The macroinvertebrate communities within the Mill Creek watershed were rated as 'fair' in Mill Creek at Orell Rd (EMCMC001) location and 'poor'–'very poor' in the Mill Creek Cutoff at Old Cane Run Rd (EMCMX001) location from surveys conducted during the year 2000 – 2005 (Table 2-3). In EMCMC001, total MBI scores decreased from 52.2 in 2000 to 41.8 in 2005. This decrease seems to be related primarily to a decrease in Taxa Richness and the m%EPT metrics used to calculate the overall MBI score. Taxa richness decreased by 21 taxa during 2000-2005, and the m%EPT decreased by 33% during this time. The decrease in taxa richness between 2000 and 2005 is primarily due to the loss of several Chironomidae taxa where it decreased by 14 taxa. A sharp decrease in the abundance of the mayfly species *Baetis intercalaris* resulted in the decrease in m%EPT from 2000 (76 individuals) to 2005 (12 individuals).

The Overall MBI scores at EMCMX001 have been more consistent over the three sampling dates (Table 2-3). The composited metrics used to calculate the MBI are overall consistently lower in EMCMX001 than EMCMC001, indicating it is a more highly degraded system.

2.2.3 Fish

The Fish IBI scores in the two LTMN sites were very low during 3 sampling efforts in the years 2002, 2003, and 2005 (Table 2-4). Fish IBI scores were almost constant throughout these years with ‘fair’ to ‘poor’ scores at EMCMC001 as it was during the earlier sampling periods (years 1999 and 2000). At this location, none of the component metric scores were higher than 50 percentile in all sampling dates. On the other hand, the fish community in EMCMX001 location was somewhat improved from ‘very poor’ (1999, 2000, and 2002) to ‘poor’ (2003) to ‘fair’ (2005) during the same period. Increased scores for the native fish species richness (NAT) was the main factor in higher fish IBI scores in 2003 and 2005 samples in EMCMX001 location.

2.3 Hydrolab Data

2.3.1 Stream metabolism

Stream metabolism estimates from EMCMC001 indicated the heterotrophic nature of the stream ecosystem, with community respiration exceeding primary productivity (Table 2-5). Gross primary production was generally higher during spring (0.34-1.56 g O_2/m^2/day) than summer (0.17-0.53 g O_2/m^2/day) and fall measurements (0.18-0.74 g O_2/m^2/day). Community respiration was consistently higher during fall (1.24-3.42 g O_2/m^2/day) than spring (1.31-2.31 g O_2/m^2/day) and summer (1.40-2.10 g O_2/m^2/day) periods. Inter-annual variation of metabolism parameters was not evident during the measurement years (2000 to 2007). There were several years and seasons where the DO and water temperature data were not available or reliable to estimate metabolism, thus lacking data on GPP and CR.

2.3.2 Dissolved Oxygen, pH, and conductivity

Daily average DO was highest during winter followed by spring, and summer and fall showed the similar averages in Mill Creek (EMCMC001) (Table 2-6). Daily mean DO was mostly above 5 mg/L except for several occasions in summer and fall. Daily mean pH values were above 7 most seasons except spring and fall 2005. Seasonal pattern was not clear for pH values. Mean conductivity values were in the order of summer, winter, spring and fall. Year-to-year variation was during winter, which might reflect the different intensity and magnitude of winter storms and road salt treatments.

2.4 Laboratory Data

2.4.1 Mill Creek at Orell Road

The EMCMC001 location clearly showed decreasing trend in overall inorganic nitrogen constituents during the report period (2000-2007) (Table 2-7, Figure 2-1). Annual average ammonia nitrogen concentration decreased from 0.3 mg/l (2000 and 2001) to mostly below the detection level beginning the year 2004. Ammonia nitrogen concentration during the previous decade (year 1991-1998) had a mean value of 0.078 mg/l (79 samples) (Jarrett and Saffran 1999). Nitrate nitrogen also had a similar decreasing trend, as its annual average decreased from around 0.5 mg/l (2000-2002) to less than 0.2 mg/l during 2007. This was much lower than the value reported during the preceding decade (0.636 mg/l).

Phosphorus parameters did not show any considerable trends during the report period. Ortho-phosphorus concentration was mostly below the MDL, while total phosphorus concentration did not change throughout. During 1991-1998, average ortho-phosphorus concentration, reported as the soluble reactive phosphorus, was 0.110 mg/l and average total phosphorus 0.157 mg/l.

Chloride concentration at this location also showed a generally decreasing trend during the report period. It was especially clear that chloride concentration was much lower during 2004 than 2001, although the small sample numbers during 2005-2007 would not reveal a clear trend. Chloride concentration during the 1991-1998 was 12.6 mg/l.

Fecal coliform count at this location was highly variable throughout the report period. Although the annual average values showed an increasing trend, the sampling periods during each year was different. The higher count values during the later years might have resulted from intensive sampling effort during the warmer months than the previous years.

2.4.2 Mill Creek Cutoff at Old Cane Road

The EMCMX001 location also showed decreasing nitrogen concentrations during the report period (Table 2-8, Figure 2-2). Annual average concentration of ammonia nitrogen fluctuated during 2000-2003 (0.11-0.27 mg/l), but it was below the MDL during the most of 2004 and 2005 (30 samples). Nitrate nitrogen showed clearly decreasing during 2001-2004 (0.74 mg/l to 0.36 mg/l), and remained at a somewhat stable concentrations during later years (2005-2007). Phosphorus parameters did not show any clear trends in annual average concentrations of ortho-phosphorus and total phosphorus. Chloride concentration at this location was also highly variable throughout the report period. Annual average values fecal coliform counts were also highly variable at this location as intra-annual variation is evident.

2.5 Watershed assessment based on the biological data

Overall, the EMCMC001 location could be classified as ‘fair-poor’ range, while EMCMX001 as ‘poor’ based on the combined biotic integrity indices of diatom, macroinvertebrates, and fish conducted in 2005. Three biotic indices had resulted in different water quality ratings in EMCMC001 during 2005: diatom with ‘good’, macroinvetebrates with ‘fair’, and fish with ‘poor’ ratings. Such differences in ratings were consistent throughout several measurements.

EMCMC001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	fair	good	good	—	**good**
MBI	fair	—	—	—	fair	**fair**
Fish KBI	fair	—	poor	poor	—	**poor**
EMCMX001						
DBI	—	fair	poor	—	—	—
MBI	very poor	—	—	—	poor	**very poor**
Fish KBI	very poor	—	very poor	poor	—	**fair**

Table 2-1 Land use/cover characteristics in Mill Creek watershed.

EMCMC001	Watershed (%)	Stream Buffer (%)	1000 m Reach Buffer (%)
Imperviousness	**21.20**	**15.40**	**0.60**
Open Water	0.25	0.45	0.00
Dev. Open Space	23.54	25.62	19.73
Dev. Low Intensity	32.50	24.48	0.45
Dev. Medium Intensity	9.10	5.88	0.00
Dev. High Intensity	3.35	1.84	0.00
Barren Land	1.40	0.66	0.00
Deciduous Forest	21.21	25.65	31.84
Evergreen Forest	0.02	0.00	0.00
Mixed Forest	0.00	0.00	0.00
Shrub/Scrub	0.03	0.05	0.00
Grassland/herbaceous	0.36	0.41	0.00
Pasture/Hay	4.43	7.33	17.04
Cropland	0.69	0.58	0.00
Woody Wetlands	2.95	6.64	30.94
Emergent Herbaceous Wetlands	0.15	0.41	0.00
EMCMX001			
Imperviousness	**37.79**	**21.69**	**13.14**
Open Water	0.06	0.37	0.00
Dev. Open Space	19.77	36.24	15.84
Dev. Low Intensity	31.04	28.32	38.01
Dev. Medium Intensity	21.55	10.02	10.41
Dev. High Intensity	13.36	4.05	0.00
Barren Land	0.12	0.23	0.00
Deciduous Forest	12.80	18.85	25.79
Evergreen Forest	0.12	0.04	0.00
Mixed Forest	0.01	0.00	0.00
Shrub/Scrub	0.01	0.00	0.00
Grassland/herbaceous	0.06	0.07	0.00
Pasture/Hay	0.83	0.80	9.95
Cropland	0.14	0.42	0.00
Woody Wetlands	0.14	0.56	0.00
Emergent Herbaceous Wetlands	0.01	0.05	0.00

Table 2-2 Diatom bioassessment index scores estimated in Mill Creek Watershed.

EMCMC001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	32	64	55	90	6	4	**42**	**FAIR**
2002	48	72	68	93	3	17	**50**	**GOOD**
2003	36	77	74	82	5	29	**51**	**GOOD**
Summer 05	42	66	58	97	5	5	**45**	**FAIR**
Fall 05	38	72	71	86	8	8	**47**	**GOOD**
2005 All	40	69	64	91	7	6	**46**	**GOOD**
Overall	**39**	**70**	**64**	**90**	**5**	**12**	**47**	**GOOD**
EMCMX001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	33	67	61	86	23	3	45	**FAIR**
2002	29	49	19	75	0	3	29	**POOR**
Overall	**32**	**62**	**50**	**83**	**17**	**3**	**41**	**FAIR**

Table 2-3 Macroinvertebrate biotic integrity scores in Mill Creek Watershed.

		EMCMC001		**EMCMX001**	
Year	Metric	Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness	55	74.32	24	32.43
	EPT Richness	8	26.67	3	10.0
	mHBI	7.11	41.94	8.26	25.25
	m%EPT	38	52.05	5	6.85
	%Clingers	42	56.76	5	6.76
	%Chir+Olig	39	61.62	60	40.40
	MBI	--------	52.2	--------	20.3
	Assessment	--------	**fair**	**--------**	**very poor**
2004	Taxa Richness	36	48.7	32	43.2
	EPT Richness	6	20	4	13
	mHBI	6.42	52	7.10	42.1
	m%EPT	12.9	17.7	1.9	2.6
	%Clingers	62.0	83.8	32.3	43.7
	%Chir+Olig	31.7	69.0	68.0	32.3
	MBI	--------	48.5	--------	29.5
	Assessment	--------	**fair**	**--------**	**poor**
2005	Taxa Richness	34	45.95	30	40.54
	EPT Richness	6	20.00	3	10.00
	mHBI	5.93	59.07	8.92	15.68
	m%EPT	4.92	6.74	0.69	0.94
	%Clingers	47.41	64.07	4.83	6.52
	%Chir+Olig	45.60	54.95	81.03	19.16
	MBI	--------	41.8	--------	15.5
	Assessment	--------	**fair**	**--------**	**very poor**

Table 2-4. Fish IBI scores and scores in the Mill Creek Watershed.

Site	EMCMC001	EMCMX001
1999-up	**very poor**	**very poor**
1999-dn	**very poor**	**very poor**
2000-up	**poor**	**very poor**
2000-dn	**fair**	**very poor**
2002	**poor**	**very poor**
Native	41	18
DMS	15	13
INT	15	13
WC	42	19
SL	15	13
%Insect_Ex_Tol	11	0
%OMNI	50	0
%TOL	50	0
IBI	30	10
2003	**poor**	**poor**
Native	39	36
DMS	16	13
INT	16	13
WC	52	29
SL	16	13
%Insect_Ex_Tol	11	9
%OMNI	50	37
%TOL	50	29
IBI	31	22
2005	**poor**	**fair**
NAT	34	35
DMS	15	12
INT	16	13
SL	16	14
%INSCT	50	100
%TOL	36	44
%FHW	0	0
KIBI	28	36

Table 2-5 Gross primary production and community respiration in Mill Creek at EMCMC001 location. Sonde data was not available for EMCMX001 location to estimate these.

	Spring		**Summer**		**Fall**	
Year	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)
2000	0.44	2.31	0.17	1.59	—	—
2001	—	—	0.53	2.04	0.24	1.40
2002	0.85	1.24	—	—	0.22	2.37
2003	0.41	1.93	0.29	1.32	0.38	3.09
2004	1.56	1.65	0.26	1.40	0.19	1.24
2005	—	—	—	—	—	—
2006	—	—	0.45	1.64	0.18	2.80
2007	0.34	1.31	0.29	2.10	0.74	3.42

Table 2-6. Daily water temperature, DO, pH, and conductivity in Mill Creek watershed at EMCMC001 location. Sonde data was not available for EMCMX001 location.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	14.2	11.9	16.4	6.32	5.00	7.84	7.47	7.26	7.63	377.8	322.7	393.1
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.5	10.1	15.0	9.67	8.34	11.84	—	—	—	458.0	439.3	476.8
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	14.0	10.9	17.1	9.58	6.48	12.79	8.16	7.76	8.56	416.7	387.0	436.6
2005	16.6	14.2	19.0	—	—	—	6.82	6.80	6.85	234.3	229.6	240.5
2006	16.2	13.5	19.3	—	—	—	7.08	7.01	7.15	—	—	—
2007	8.8	7.1	10.9	9.50	8.53	10.70	7.56	7.32	7.87	246.6	224.7	272.8
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	25.9	24.5	27.4	5.10	4.39	6.03	7.41	7.19	7.58	338.7	234.2	466.2
2001	24.7	23.2	26.4	6.18	3.76	11.30	7.76	7.65	7.94	624.4	488.5	673.5
2002	24.7	23.4	26.5	4.20	1.81	8.71	7.87	7.78	7.97	749.2	731.3	762.4
2003	25.0	23.8	26.3	6.11	5.10	7.71	7.36	7.24	7.60	313.7	280.3	359.1
2004	24.4	23.3	25.6	5.64	5.08	6.55	7.17	7.13	7.20	241.7	227.2	254.9
2005	24.3	22.7	26.7	—	—	—	7.78	7.68	7.90	784.8	768.5	795.5
2006	22.8	21.5	24.2	5.88	4.84	7.38	8.85	8.75	8.95	490.0	446.9	519.5
2007	25.2	23.6	26.9	5.38	3.07	8.09	7.54	7.42	7.92	493.1	485.8	524.4
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.9	13.7	16.6	7.65	6.54	14.61	7.96	7.72	8.17	300.8	183.7	367.7
2002	12.8	11.9	13.7	5.67	5.05	6.15	7.71	7.63	7.79	286.3	268.8	309.4
2003	15.0	13.3	16.8	2.11	1.17	5.09	7.22	7.12	7.33	218.0	200.1	240.3
2004	14.4	13.1	15.7	7.76	7.08	8.39	7.50	7.43	7.55	752.0	749.2	754.7
2005	15.8	14.8	17.0	—	—	—	6.98	6.93	7.05	583.0	572.3	593.2
2006	16.6	15.3	17.9	4.07	3.48	4.69	7.27	7.21	7.33	512.6	488.1	536.8
2007	22.1	20.2	24.3	3.16	1.40	5.72	7.61	7.48	7.80	483.1	467.8	494.9
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	0.0	-0.2	0.4	13.80	13.03	14.90	8.14	8.08	8.22	695.3	677.7	713.7
2004	1.8	1.0	2.7	—	—	—	7.29	7.15	7.41	170.1	165.0	174.5
2005	4.1	3.5	4.7	—	—	—	7.20	7.19	7.21	137.0	132.4	141.4
2006	6.4	5.3	7.6	—	—	—	7.35	7.27	7.42	244.2	191.0	288.7
2007	5.2	4.6	7.1	10.17	9.68	10.47	7.49	7.31	7.63	159.9	149.4	167.2

Table 2-7 Summary of selected water chemistry parameters in Mill Creek at EMCMC001.

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.27	0.37	0.07	0.21	0.03	0.03	0.03	0.05
	SD (Dry)	0.39	0.43	0.12	0.22	0.00	0.00	-	-
	Count (Dry)	13	20	17	15	12	2	1	1
	Mean (wet)	0.44	0.07	0.35	0.37	0.03	0.03	0.03	0.05
	SD (wet)	0.08	0.09	0.51	0.22	0.00	0.00	0.00	0.00
	Count (wet)	2	5	8	10	11	5	2	3
Nitrate-Nitrogen (mg/L)	Mean (Dry)	0.47	0.58	0.48	0.45	0.26	0.27	0.24	0.19
	SD (Dry)	0.23	0.40	0.19	0.21	0.19	0.07	-	-
	Count (Dry)	12	20	17	15	12	2	1	1
	Mean (wet)	0.60	0.59	0.49	0.57	0.29	0.27	0.32	0.17
	SD (wet)	0.18	0.16	0.13	0.13	0.11	0.19	0.22	0.20
	Count (wet)	3	5	8	10	11	5	2	3
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	0.84	0.88	-	0.59	0.72	0.72	0.68	0.87
	SD (Dry)	0.53	0.46	-	0.28	0.13	0.13	-	-
	Count (Dry)	5	6	0	2	10	2	1	1
	Mean (wet)	1.27	0.58	-	0.64	0.99	0.82	0.93	0.80
	SD (wet)	0.33	0.60	-	0.18	0.08	0.13	0.11	0.05
	Count (wet)	2	2	0	3	9	5	2	3
Ortho Phosphorus (mg/L)	Mean (Dry)	0.05	0.06	0.03	0.03	0.03	0.03	0.14	0.07
	SD (Dry)	0.08	0.12	0.00	0.00	0.01	0.00	-	-
	Count (Dry)	12	20	17	15	12	2	1	1
	Mean (wet)	0.03	0.03	0.03	0.07	0.07	0.03	0.17	0.03
	SD (wet)	0.00	0.00	0.00	0.13	0.07	0.02	0.21	0.00
	Count (wet)	3	5	8	10	11	5	2	3
Phosphorus (mg/L)	Mean (Dry)	0.16	0.13	0.09	0.09	0.06	-	0.02	0.03
	SD (Dry)	0.07	0.10	0.05	0.05	0.04	-	-	-
	Count (Dry)	13	19	17	15	12	0	1	1
	Mean (wet)	0.29	0.22	0.20	0.15	0.14	0.09	0.13	0.06
	SD (wet)	0.09	0.07	0.14	0.07	0.07	0.05	0.09	0.02
	Count (wet)	2	5	8	10	10	4	3	3
Chloride (mg/L)	Mean (Dry)	32.72	33.87	22.61	25.38	17.45	34.68	16.78	26.78
	SD (Dry)	17.62	30.33	13.07	18.44	10.34	14.97	-	-
	Count (Dry)	12	20	17	15	12	2	1	1
	Mean (wet)	27.86	21.71	16.57	21.38	16.58	29.39	11.66	16.98
	SD (wet)	27.30	13.01	10.79	17.27	19.77	29.56	7.84	9.58
	Count (wet)	3	5	8	10	11	5	2	3
BOD (mg/L)	Mean (Dry)	1.71	1.92	1.60	1.67	1.41	4.00	1.00	0.50
	SD (Dry)	0.75	1.32	0.98	1.19	1.55	1.41	-	-
	Count (Dry)	12	20	16	15	12	2	1	1
	Mean (wet)	9.67	2.29	5.50	2.70	3.78	2.24	2.25	1.17
	SD (wet)	9.87	0.88	4.88	1.89	1.88	0.83	2.47	0.76
	Count (wet)	3	5	8	10	11	5	2	3
TDS (mg/L)	Mean (Dry)	395.23	453.60	372.41	296.80	332.42	278.00	334.00	390.00
	SD (Dry)	80.90	101.61	134.43	65.99	161.28	113.14	-	-
	Count (Dry)	13	20	17	15	12	2	1	1
	Mean (wet)	248.67	407.20	396.50	281.30	217.64	259.60	224.00	242.67
	SD (wet)	179.44	141.64	101.22	115.92	129.56	101.16	135.76	107.45
	Count (wet)	3	5	8	10	11	5	2	3
TSS (mg/L)	Mean (Dry)	15.92	20.27	11.94	16.00	16.00	14.00	6.00	8.00
	SD (Dry)	14.89	27.66	12.53	7.99	15.37	9.90	-	-
	Count (Dry)	13	20	17	15	12	2	1	1
	Mean (wet)	52.67	17.20	27.75	24.20	88.45	18.20	49.00	32.33
	SD (wet)	32.33	22.42	38.66	21.38	90.05	8.61	28.28	16.74
	Count (wet)	3	5	8	10	11	5	2	3
Fecal Coliform (col/100 ml)	Mean (Dry)	102	71	150	288	180	186	3070	204
	SD (Dry)	136	95	168	532	434	318	10990	313
	Count (Dry)	35	27	28	27	32	25	14	23
	Mean (wet)	972	248	1116	292	865	1070	1224	1783
	SD (wet)	1498	232	1257	553	1253	1763	2348	2436
	Count (wet)	18	19	13	14	22	14	19	10

Table 2-8 Summary of selected water chemistry parameters in Mill Creek at EMCMX001.

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.41	0.11	0.17	0.28	0.03	0.03	0.03	0.05
	SD (Dry)	0.39	0.17	0.29	0.37	0.01	0.00	-	-
	Count (Dry)	10	10	11	12	12	4	1	1
	Mean (wet)	0.52	-	-	0.25	0.06	0.03	0.03	0.22
	SD (wet)	0.30	-	-	0.33	0.13	0.00	0.00	0.29
	Count (wet)	2	0	0	7	11	3	2	3
Nitrate-Nitrogen (mg/L)	Mean (Dry)	0.50	0.74	0.51	0.51	0.25	0.34	0.05	0.01
	SD (Dry)	0.22	0.36	0.18	0.34	0.21	0.11	-	-
	Count (Dry)	10	10	11	12	12	4	1	1
	Mean (wet)	0.44	-	-	0.52	0.48	0.57	0.49	0.57
	SD (wet)	0.21	-	-	0.16	0.15	0.04	0.20	0.21
	Count (wet)	2	0	0	7	11	3	2	3
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	1.32	0.69	-	0.28	0.88	0.59	0.62	0.68
	SD (Dry)	0.52	0.51	-	-	0.63	0.06	-	-
	Count (Dry)	4	4	0	1	10	4	1	1
	Mean (wet)	1.25	-	-	0.84	0.96	0.79	1.60	1.55
	SD (wet)	0.74	-	-	0.62	0.28	0.19	0.85	0.84
	Count (wet)	2	0	0	4	9	3	2	3
Ortho Phosphorus (mg/L)	Mean (Dry)	0.06	0.05	0.24	0.03	0.03	0.03	0.03	0.03
	SD (Dry)	0.09	0.08	0.63	0.00	0.00	0.00	-	-
	Count (Dry)	10	10	11	12	12	4	1	1
	Mean (wet)	0.18	-	-	0.13	0.10	0.03	0.19	0.04
	SD (wet)	0.22	-	-	0.18	0.09	0.00	0.13	0.03
	Count (wet)	2	0	0	7	11	3	2	3
Phosphorus (mg/L)	Mean (Dry)	0.11	0.14	0.17	0.08	0.03	0.09	0.02	0.04
	SD (Dry)	0.11	0.15	0.21	0.08	0.03	0.00	-	-
	Count (Dry)	10	10	11	11	9	2	1	1
	Mean (wet)	0.22	-	-	0.15	0.11	0.07	0.13	0.08
	SD (wet)	0.18	-	-	0.10	0.05	0.07	0.07	0.03
	Count (wet)	2	0	0	7	10	2	3	3
Chloride (mg/L)	Mean (Dry)	37.57	75.77	30.68	95.36	32.98	42.44	22.33	27.21
	SD (Dry)	20.95	132.85	30.02	218.87	9.15	8.65	-	-
	Count (Dry)	10	10	11	12	12	4	1	1
	Mean (wet)	19.02	-	-	31.95	34.22	54.46	19.28	22.82
	SD (wet)	9.17	-	-	32.53	39.64	49.75	18.78	6.92
	Count (wet)	2	0	0	7	11	3	2	3
BOD (mg/L)	Mean (Dry)	2.53	2.13	4.40	1.71	1.52	2.49	1.00	0.50
	SD (Dry)	1.37	1.63	5.73	1.54	1.25	0.57	-	-
	Count (Dry)	11	10	11	12	12	4	1	1
	Mean (wet)	2.00	-	-	3.86	3.86	1.17	5.50	6.67
	SD (wet)	-	-	-	1.95	1.79	0.76	0.71	5.13
	Count (wet)	1	0	0	7	11	3	2	3
TDS (mg/L)	Mean (Dry)	294.55	466.00	338.82	442.33	436.50	341.50	334.00	240.00
	SD (Dry)	191.56	180.47	115.61	388.85	85.88	105.23	-	-
	Count (Dry)	11	10	11	12	12	4	1	1
	Mean (wet)	206.00	-	-	333.86	292.36	310.67	165.00	290.67
	SD (wet)	76.37	-	-	150.66	186.88	94.96	108.89	172.62
	Count (wet)	2	0	0	7	11	3	2	3
TSS (mg/L)	Mean (Dry)	8.09	22.10	16.64	15.75	13.25	20.13	4.00	26.00
	SD (Dry)	6.24	21.18	19.28	7.86	11.03	9.70	-	-
	Count (Dry)	11	10	11	12	12	4	1	1
	Mean (wet)	80.00	-	-	39.71	38.64	18.33	59.50	143.33
	SD (wet)	98.99	-	-	32.54	29.97	4.51	50.20	194.72
	Count (wet)	2	0	0	7	11	3	2	3
Fecal Coliform (col/100 ml)	Mean (Dry)	188	475	1126	349	81	154	3320	78
	SD (Dry)	534	716	1504	844	91	325	13524	100
	Count (Dry)	35	24	23	24	32	27	18	21
	Mean (wet)	3020	-	-	2405	850	1044	2510	2286
	SD (wet)	6126	-	-	2862	968	1125	3079	3212
	Count (wet)	8	0	0	10	22	12	15	12

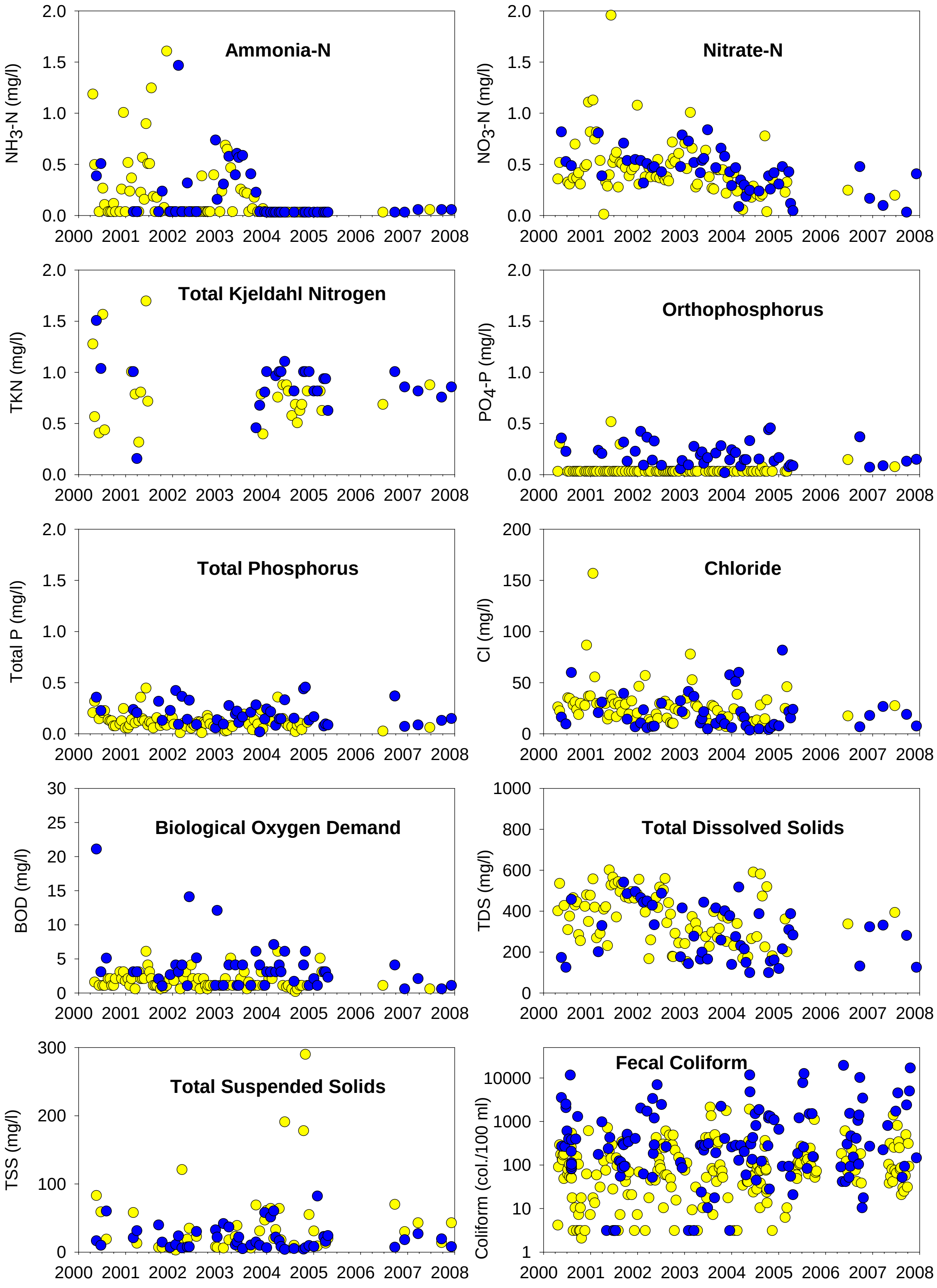

Figure 2-1 Major water chemistry parameters measured at EMCMC001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

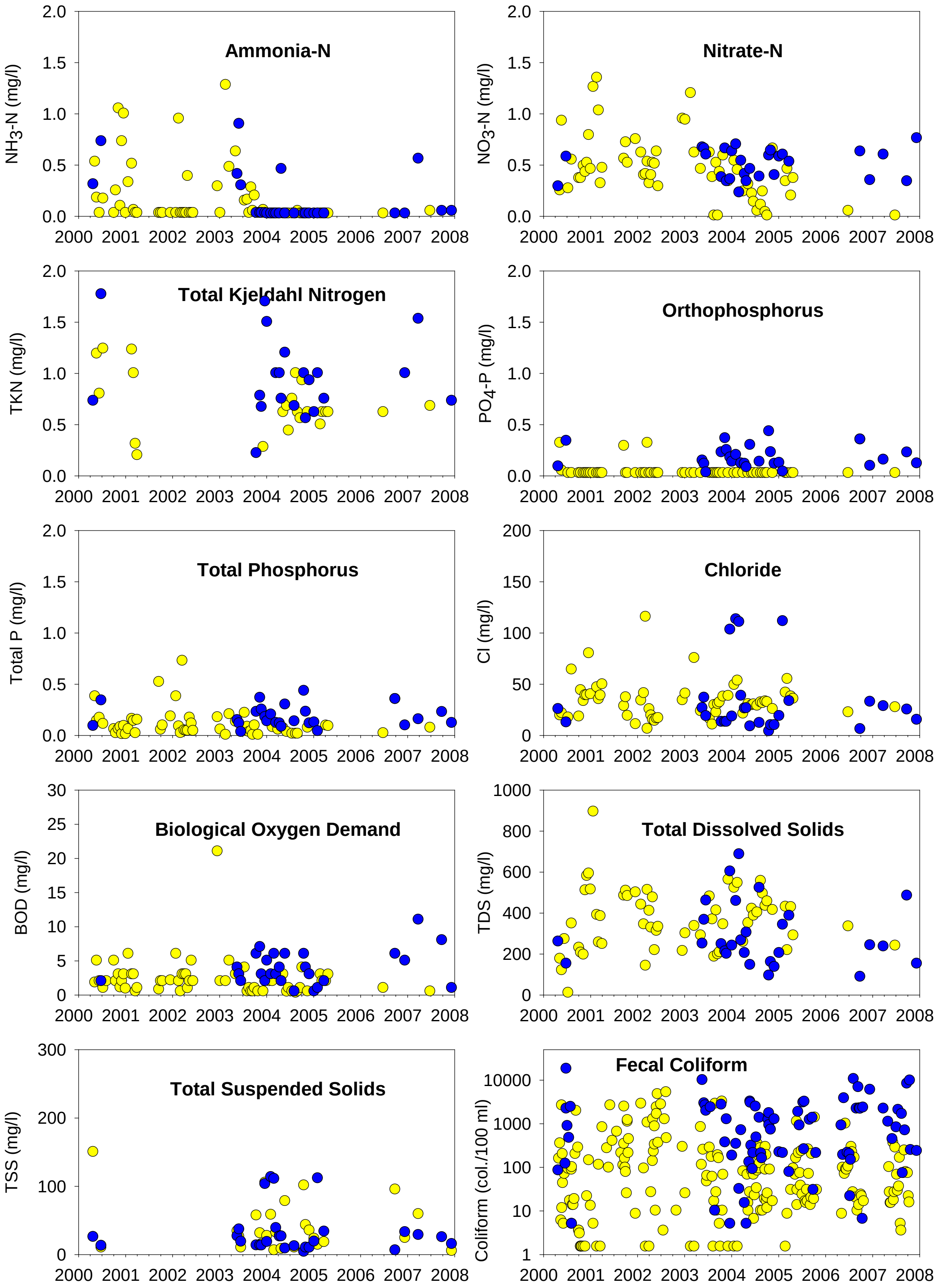

Figure 2-2 Major water chemistry parameters measured at EMCMX001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 3 Cedar Creek Watershed

3.1 Watershed Physical Characteristics

Cedar Creek in Jefferson County originates in the Fern Creek area and flows generally to the south. MSD maintains one LTMN location (ECCCC001 at Thixton Road) in the Cedar Creek watershed. Cedar Creek merges with Pennsylvania Run (Chapter 10) downstream of their respective LTMN locations (ECCCC001 and EPRPR001) as Cedar Creek, eventually flowing into Floyds Fork at downstream of Floyds Fork at Bardstown Road (EFFFF002) location.

The Cedar Creek watershed contains about 42% of developed areas and 32% of forests (Table 3-1). Average imperviousness of the watershed is about 10%. The riparian areas of the Cedar Creek is slightly less developed as its stream buffer contains less impervious surfaces (7% and <1% for overall and reach-scale, respectively) and developed areas than the whole watershed.

3.2 Biological Data

3.2.1 Diatom

The overall water quality of Cedar Creek at Thixton Lane (ECCCC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Fair’ (Table 3-2). The overall mean score of 44 reflects the upper range of ‘Fair’ scores. In general, water quality of Cedar Creek at Thixton Lane seems to be improving slightly over time (Table 3-2). Specifically, during the 2001 – 03 sampling seasons, approximately 70% of samples characterized mean overall water quality as ‘Fair’ (mean DBI = 43). In contrast, during the 2005 sampling season, approximately 70% of samples characterized mean overall water quality as ‘Good’ (mean DBI = 46).

The taxa richness (TR) yearly mean score decreased from year 2001 and 2002 (37) to 2003 (25), but increased during 2005 (40) (Table 3-2). These data suggest that species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality. The pollution tolerance index (PTI) yearly mean score increased from year 2001 (60) to 2003 (82), but decreased during 2005 (70) (Table 3-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution sensitive. In general, an increase in the PTI suggests an improvement in water quality.

The siltation index (%NNS) yearly mean score increased markedly from year 2001 (48) to 2003 (93), but decreased during 2005 (68) (Table 3-2). These data suggest that species composition shifted away from those species adapted to living on silts and shifting sediments. The data further suggest the dramatic increase in %NNS during 2003 may be related to that year’s PTI increase and TR decrease. Perhaps one or two pollution sensitive, non-*Navicula* or *Nitzschia*, species numerically dominated the community and competitively excluded other diatom taxa, thereby reducing TR while increasing the PTI and %NNS.

The Shannon diversity index (SDI) yearly mean score decreased markedly from year 2001 and 2002 (88) to 2003 (53), but increased during 2005 (85) (Table 3-2). As expected, these data mirrored the trends seen with TR. The precipitous drop in the SDI during 2003 is likely owing to the dominance of one or two species. The SDI rebound during 2005 coincides with the increase in TR. In general, the majority of SDI values were high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (16) to 2003 (3), but increased during 2005 (10) (Table 3-2). These data suggest that species within the Fragilaria group were lost as the study progressed. Taxa within this group are widely considered to be indicators of good water quality. A decrease with respect to this metric suggests site water quality may be deteriorating.

The cymbella group richness (CGR) yearly mean score increased from year 2001 and 2002 (7) to 2003 (11), but decreased during 2005 (5) (Table 3-2). These data suggest that species within the Cymbella group were lost as the study progressed. Taxa within this group are widely considered to be indicators of good water quality. A decrease with respect to this metric suggests site water quality may be deteriorating.

3.2.2 Macroinvertebrates

The macroinvertebrate communities at ECCCC001 were rated as ‘fair’ by the MBI in 2000 and 2004, but were rated as ‘poor’ in 2005. This can be attributed to the high numbers of chironomids and oligochaetes during 2005 samples, although the overall taxa richness was increasing during these years. Low MBI scores for ECCCC001 is primarily due to the low diversity and abundance of mayflies, stoneflies, and caddisflies, as it was evident from the low scores for the EPT Richness, %EPT metrics, and the %Ephemeroptera metrics.

3.2.3 Fish

It appears that the water quality at the ECCCC001 location is improving according to Fish IBI scores. It was ranging mainly in ‘fair’-‘poor’ range during 1999 and 2003, but it was ‘excellent’ during the 2005 sampling. Increased numbers of NAT (native fish richness), MDS (darter, madtom, sculpin), and %INSCT (insectivores excluding tolerant species) were the major metrics contributing such improvement in the KIBI scores.

3.3 Hydrolab Data

3.3.1 Stream metabolism

The stream metabolism estimates from ECCCC001 location showed the heterotrophic nature (GPP<CR) of this stream (Table 3-5). The heterotrophy (CR>GPP) was most pronounced during summer and fall, while GPP exceeded CR during spring measurements. Such fluctuation in stream energetic balance is mainly due to the higher GPP during spring (6.36-7.59 g O_2/m^2/day) than summer (0.83-3.25 g O_2/m^2/day) and fall (1.37-2.06 g O_2/m^2/day). CR estimates were higher during fall (4.68-10.27 g O_2/m^2/day) than spring (5.76-5.98 g O_2/m^2/day) and summer (3.30-6.80 g O_2/m^2/day).

3.3.2 Dissolved oxygen, pH, and conductivity

The daily average DO was very similar between spring (11.38-13.01 mg/L) and winter (8.67-11.80 mg/L) and they were higher than summer (0.70-7.12 mg/L) and fall (5.30-8.69 mg/L). Daily mean DO was mostly higher than 5 mg/L except summer 2004 and 2005. Daily pH was higher the 7, and there was no clear seasonal change in pH as it stayed between 7.5 and 8.5 throughout the years 2000-2007. Daily mean conductivity was highest in spring (571-644 µS/cm), followed by summer (485-980 µS/cm), winter and fall (Table 3-6).

3.4 Laboratory Data

Only fecal coliform data was collected in the Cedar Creek watershed before 2006. Fecal coliform concentration was much higher during ‘wet’ samples (843-5545 colonies/100 mL) than ‘dry’ samples (159-515 colonies/100 mL). Other water chemistry parameters (nitrogen, phosphorus, chloride, BOD, TDS, and TSS) showed higher average concentrations during ‘dry’ samples than ‘wet’ samples (Table 3-7, Figure 3-1).

3.5 Watershed assessment based on the biological data

The Cedar Creek at ECCCC001 location can be described as ‘good’ quality based on the biotic integrity indices measured during 2005. However, there are some discrepancies between different biotic indices; diatom and fish indices showed the ‘good-excellent’ water quality while macroinvertebrate index showing the ‘poor’, as shown below.

ECCCC001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	fair	fair	fair	—	**good**
MBI	fair	—	—	—	fair	**poor**
Fish KBI	fair	—	fair	poor	—	**excellent**

Table 3-1 Land use/cover characteristics of Cedar Creek watershed in Jefferson.

ECCCC001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	9.86	7.00	0.42
Open Water	0.85	0.38	0.00
Dev. Open Space	17.59	15.31	5.56
Dev. Low Intensity	19.56	13.78	30.56
Dev. Medium Intensity	4.16	3.37	0.00
Dev. High Intensity	0.97	0.74	0.00
Barren Land	0.62	0.43	0.00
Deciduous Forest	28.75	39.61	31.02
Evergreen Forest	2.87	3.54	0.00
Mixed Forest	0.19	0.17	0.00
Shrub/Scrub	0.01	0.01	0.00
Grassland/herbaceous	1.69	1.91	0.00
Pasture/Hay	20.84	18.41	32.87
Cropland	1.82	2.09	0.00
Woody Wetlands	0.05	0.19	0.00
Emergent Herbaceous Wetlands	0.02	0.06	0.00

Table 3-2 Diatom bioassessment index scores estimated in Cedar Creek in Jefferson County.

ECCCC001	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2001	37	60	48	88	16	7	**43**	**FAIR**
2002	37	66	56	88	4	7	**43**	**FAIR**
2003	25	82	93	53	3	11	**45**	**FAIR**
Summer 05	36	75	80	75	5	6	**46**	**GOOD**
Fall 05	44	65	56	94	15	3	**46**	**GOOD**
2005 All	40	70	68	85	10	5	**46**	**GOOD**
Overall	**36**	**68**	**63**	**82**	**9**	**7**	**44**	**FAIR**

Table 3-3 Macroinvertebrate biotic integrity scores in Cedar Creek in Jefferson County.

Year	**Metric**	**ECCCC001**	
		Raw Score	Metric Score
2000	Taxa Richness	27	50.94
	EPT Richness	7	21.21
	m%EPT	20	23.01
	mHBI	5.59	56.39
	%Chir. and Oli.	23	77.53
	%Clinger	34	45.03
	%Ephemeroptera	3	4.51
	MBI	--------	39.81
	Assessment	--------	**fair**
2004	Taxa Richness	35	47.3
	EPT Richness	9	30
	m%EPT	11.0	15.07
	mHBI	4.25	8.45
	%Chir. and Oli.	11.0	89.9
	%Clinger	24.8	33.51
	MBI	--------	49.87
	Assessment	--------	**fair**
2005	Taxa Richness	41	65.08
	EPT Richness	7	21.21
	m%EPT	4.82	5.55
	mHBI	6.07	50.28
	%Chir. and Oli.	38.60	61.82
	%Clinger	44.74	59.25
	%Ephemeroptera	0.88	1.32
	MBI	--------	37.79
	Assessment	--------	**fair**

Table 3-4 Fish IBI scores in Cedar Creek in Jefferson County.

Year	**ECCCC001**
1999-up	**poor**
1999-dn	**fair**
2000-up	**fair**
2000-dn	**fair**
2002	**fair**
Native	62
DMS	18
INT	30
WC	45
SL	43
%Insect_Ex_Tol	30
%OMNI	89
%TOL	94
IBI	**51**
2003	**poor**
Native	52
DMS	68
INT	38
WC	47
SL	34
%Insect_Ex_Tol	0
%OMNI	0
%TOL	0
IBI	**30**
2005	**excellent**
NAT	83
DMS	99
INT	51
SL	90
%INSCT	76
%TOL	89
%FHW	0
KIBI	**68**

Table 3-5 Gross primary production and community respiration in Cedar Creek in Jefferson County.

ECCCC001	**Spring**		**Summer**		**Fall**	
	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)
2000	—	—	1.75	5.33	—	—
2001	—	—	0.83	3.30	1.37	4.44
2002	—	—	0.99	4.38	2.06	10.27
2003	—	—	1.56	6.02	1.94	7.19
2004	—	—	2.42	7.17	1.50	6.29
2005	—	—	3.25	6.80	1.44	5.74
2006	7.59	5.76	—	—	1.75	4.68
2007	6.36	5.98	1.05	5.88	—	—

Table 3-6 Daily water temperature, DO, pH, and conductivity in Cedar Creek in Jefferson County at ECCCC001 location.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.7	11.3	16.5	12.41	6.98	19.61	8.50	8.01	9.08	571.4	544.7	595.1
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.7	10.6	14.7	13.01	9.48	17.44	8.58	8.21	8.95	622.0	596.2	640.3
2003	15.0	12.6	18.0	12.34	6.60	19.81	8.58	8.09	9.07	635.9	609.6	656.2
2004	13.4	10.9	16.8	11.56	5.98	20.00	8.20	7.59	8.90	620.8	520.8	663.6
2005	15.7	12.8	19.5	—	—	—	8.41	7.81	9.05	598.4	553.3	629.8
2006	14.6	12.0	17.1	11.38	7.28	18.16	8.38	7.88	8.92	586.3	565.1	604.9
2007	8.0	6.6	9.8	12.06	8.54	16.82	8.37	7.91	8.87	644.2	625.1	659.7
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	23.3	21.9	24.9	5.89	4.67	6.92	8.02	7.93	8.13	688.2	606.3	721.0
2001	22.2	19.9	25.4	7.12	6.09	7.98	7.79	7.72	7.87	—	—	—
2002	23.2	21.9	24.9	6.83	6.24	7.81	8.70	8.54	8.84	714.7	639.2	730.9
2003	22.9	21.8	24.3	5.78	4.81	7.01	7.53	7.38	7.77	552.5	453.2	616.7
2004	21.7	20.7	22.8	5.90	4.27	7.28	7.85	7.71	8.00	425.8	336.6	484.5
2005	23.4	22.0	24.6	4.89	1.43	6.44	7.69	7.31	7.89	971.8	958.3	980.0
2006	21.0	19.7	22.5	0.70	0.13	4.40	7.69	7.65	7.73	489.3	435.1	530.9
2007	23.1	21.5	25.0	5.8	5.1	6.8	7.8	7.7	7.9	789.0	780.9	799.4
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.1	12.1	16.34	8.54	7.40	9.54	7.38	7.25	7.51	596.2	398.0	697.3
2002	13.5	12.6	14.34	5.30	1.52	7.38	7.87	7.72	8.04	230.8	228.4	233.6
2003	15.3	14.0	16.65	7.22	5.90	9.20	7.80	7.69	7.96	642.6	594.9	648.7
2004	14.1	12.6	15.38	7.81	6.91	9.35	7.69	7.58	7.87	447.2	444.3	449.3
2005	15.2	13.8	18.37	7.63	6.73	8.81	7.51	7.46	7.60	483.5	200.5	533.4
2006	16.4	15.0	17.84	7.54	6.65	9.15	7.74	7.66	7.86	619.2	615.6	623.5
2007	—	—	—	—	—	—	—	—	—	—	—	—
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	5.4	4.0	7.1	10.81	7.75	15.71	8.39	8.06	8.85	755.2	594.0	785.9
2003	-1.9	-4.1	2.9	11.54	6.64	17.19	—	—	—	—	—	—
2004	4.4	3.5	5.3	—	—	—	7.97	7.83	8.12	385.6	341.5	394.6
2005	—	—	—	—	—	—	—	—	—	—	—	—
2006	8.5	7.2	9.7	8.67	7.21	10.08	7.82	7.65	8.01	487.1	403.6	544.5
2007	7.0	6.3	7.7	11.80	10.52	13.28	8.35	8.21	8.54	565.2	539.3	587.7

Table 3-7 Summary of selected water chemistry parameters in Cedar Creek in Jefferson County at ECCCC001 location.

	Year	2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	2.23	3.21	Total Kjeldahl Nitrogen (mg/L)	0.85	0.88
	SD (Dry)	0.00	0.00		0.75	2.50		0.06	0.32
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.03	0.05		1.80	2.51		0.87	0.61
	SD (wet)	-	0.00		-	0.62		-	0.10
	Count (wet)	1	2		1	2		1	2
Ortho Phosphorus (mg/L)	Mean (Dry)	0.47	0.66	Phosphorus (mg/L)	0.35	0.61	Chloride (mg/L)	31.08	71.94
	SD (Dry)	0.05	0.76		0.02	0.80		10.81	34.05
	Count (Dry)	2	2		3.00	2.00		2	2
	Mean (wet)	0.37	0.51		0.31	0.39		27.32	35.54
	SD (wet)	-	0.57		-	0.32		-	26.73
	Count (wet)	1	2		1	2		1.00	2.00
BOD (mg/L)	Mean (Dry)	0.50	0.75	TDS (mg/L)	440.00	593.00	TSS (mg/L)	9.00	11.50
	SD (Dry)	0.00	0.35		5.66	120.21		8.49	12.02
	Count (Dry)	2.00	2		2	2		2	2
	Mean (wet)	0.50	0.75		408.00	393.00		5.00	7.00
	SD (wet)	-	0.35		-	179.61		-	4.24
	Count (wet)	1	2		1	2		1	2

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	471	375	515	323	159	425	274	161
	SD (Dry)	1413	663	669	677	87	759	341	118
	Count (Dry)	23	30	29	24	14	23	16	26
	Mean (wet)	695	-	-	979	843	1516	5545	1410
	SD (wet)	1077	-	-	2215	832	2164	13562	2744
	Count (wet)	4	0	0	7	17	8	18	9

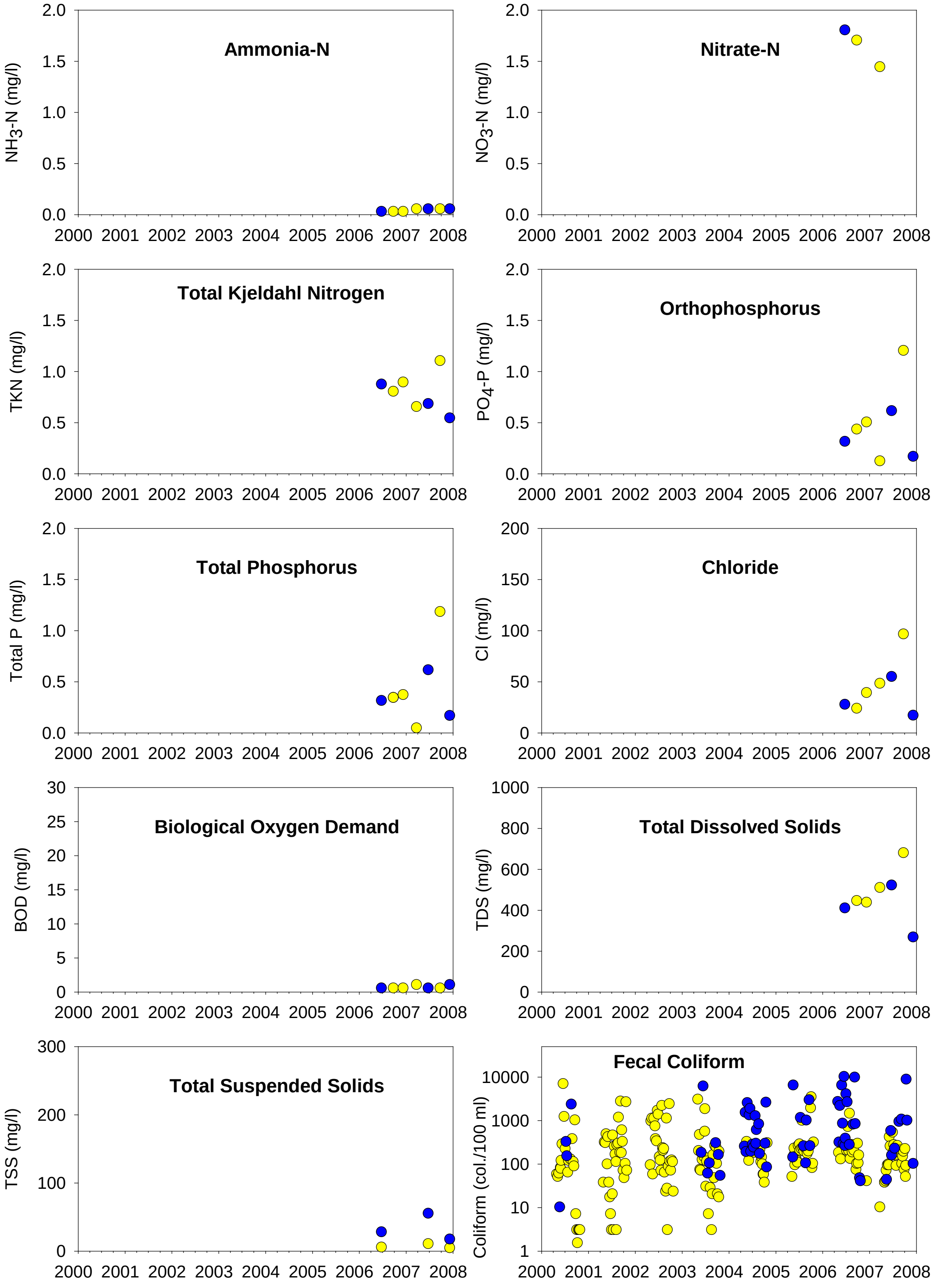

Figure 2-1 Major water chemistry parameters measured in Cedar Creek in Jefferson County at ECCCC001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 4 Cedar Creek in Bullitt County Watershed

4.1 Watershed Physical Characteristics

Cedar Creek in Bullitt County originates in Cedar Grove area (Bullitt County) and flows north before merging into the Salt River. This stream is not connected to Cedar Creek in Jefferson County (CC). MSD has maintained one LTMN location (ECBCB001 at State Hwy 1442) since 2002.

The Cedar Creek in Bullitt County is relatively undisturbed and the watershed mostly consists of forests (63%) and grasslands and pastures (29%) (Table 4-1). Impervious surface coverage of the watershed is minimal (0.2%). The watershed-level riparian buffer zone landuse of Cedar Creek also reflect the undisturbed nature of the watershed with a very low proportion of developed lands (7%) and low imperviousness. However, it contains very high proportion of grasslands (71%) within the riparian zone at the 1000 meter reach-scale from the LTMN location, implicating a possible influence of farming activities close to the stream. This watershed could be considered as a reference site for MSD's monitoring network streams due to such a low-intensity development.

4.2 Biological Data

4.2.1 Diatom

The overall water quality of Cedar Creek at Highway 1442 (Bullitt County, Kentucky) based on 24 diatom samples collected over three years (2002 – 03, 2005) may be characterized as 'Good' (Table 4-2). The overall mean score of 46 reflects the lower range of 'Good' scores. In general, water quality of Cedar Creek at Highway 1442 (Bullitt County) seems to be relatively constant over time (Table 4-2). Specifically, when considering all samples collectively, thirteen diatom samples characterized water quality as 'Fair' (Table 4-2), while ten samples characterized water quality as 'Good', and one sample characterized water quality as 'Excellent' (score = 55; Table 4-2).

The taxa richness (TR) yearly mean score changed little as the study progressed (Table 4-2). However, when compared to the other sites, overall mean taxa richness at this site was greatly reduced (Table 4-2). It is common for heavily shaded, nutrient-poor headwater streams, such as Cedar Creek, to be unable to support highly diverse communities as needed resources are usually lacking. This site's overall mean TR score (28) was the lowest of all sites surveyed in the current study (Table 4-2).

The pollution tolerance index (PTI) yearly mean score decreased from year 2002 (78) to 2005 (71) (Table 4-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. This site's overall mean PTI score (75) was among the highest observed in the current study (Table 4-2) and is considered indicative of good water quality.

The siltation index (%NNS) yearly mean score increased from year 2002 (77) to 2003 (91), but decreased during 2005 (77) (Table 4-2). These data are generally indicative of good water quality. It is not unusual for small streams, such as Cedar Creek, to be relatively free of silt as frequent storm events tend to flush silt from such systems. This site's overall mean %NNS score (80) was the highest observed in the current study.

The Shannon diversity index (SDI) yearly mean score decreased from year 2002 (66) to 2003 (54), but increased during 2005 (73) (Table 4-2). These data suggest that species distribution changed markedly throughout the study period since TR was largely constant. This site's overall mean SDI score (66) was the lowest observed in the current.

The fragilaria group richness (FGR) yearly mean score increased from year 2002 (4) to 2005 (11) (Table 4-2). These data suggest that new taxa within the Fragilaria group were observed as the study progressed. Taxa within this group are widely considered to be indicators of good water quality.

The cymbella group richness (CGR) yearly mean score decreased from year 2002 (20) to 2005 (15) (Table 4-2). These data suggest that species within the Cymbella group were lost as the study progressed. Taxa within this group are widely considered to be more reliable indicators of water quality than those within the Fragilaria group. This may explain why FGR trends suggest water quality is improving while CGR trends suggest site water quality is deteriorating.

4.2.2 Macroinvertebrates

The macroinvertebrate communities at ECBCB001 were rated as 'fair' in 2004 and 2005, while it was not sampled in 2000 (Table 4-3). The overall MBI score was almost 10 point higher in the 2005 samples than 2004 with much higher taxa richness, indicating a slight improvement in water quality at this site. Taxa richness and EPT richness were the 2 major metrics showed considerable improvements between 2004 and 2005. The lowest scores for component metrics were attained for EPT Richness, m%EPT, and %Clinger.

4.2.3 Fish

The water quality rating based on the fish IBI scores changed from 'good' (2002) to 'fair' (2003), then improved to 'excellent' (2005) at the ECBCB001 location (Table 4-4). The metric scores for proportion of insectivores species (%INSCT) varied a lot during this period (58 in 2002, 28 in 2003, and 100 in 2005), which reflected the changes in the overall fish IBI scores. Metric scores for the native species richness (NAT; 68-79) and simple lithophic spawning species (SL; 47-63) were consistently high at this location, while other indices varied year to year.

4.3 Hydrolab Data

4.3.1 Stream metabolism

The stream metabolism estimates from ECBCB001 location showed the heterotrophic nature (GPP<CR) of this stream (Table 4-5). The heterotrophy was most pronounced during summer and fall with GPP 3-4 times higher than CR. In general GPP was higher during spring (1.45-3.88 g O_2/m^2/day) and summer (1.82-2.79 g O_2/m^2/day) than fall (1.30-2.22 g O_2/m^2/day). CR was highest during fall (4.09-12.20 g O_2/m^2/day), followed by summer (5.06-9.51 g O_2/m^2/day) and spring (2.61-8.33 g O_2/m^2/day).

4.3.2 Dissolved oxygen, pH, and conductivity

The daily average DO was highest during spring (6.86-10.24 mg/L), followed by winter and fall, and lowest during summer (3.82-7.31 mg/L). Daily average DO was higher than 5 mg/L except on several occasions during summer and fall. There was no clear seasonal change in pH as it stayed between 7.3 and 8.3 throughout the year 2002-2007. Conductivity was also constant and did not reveal any seasonal variation, although it was slightly higher during winter than other seasons in ECBCB001 location (Table 4-6)

4.4 Laboratory Data

Fecal coliform concentration was much higher during ‘wet’ samples (160-15449 colonies/100 mL) than ‘dry’ samples (140-425 colonies/100 mL). Other water chemistry parameters, nitrogen, phosphorus, chloride, BOD, TDS, and TSS showed higher average concentrations during ‘dry’ samples than ‘wet’ samples (Table 4-7, Figure 4-1).

4.5 Watershed assessment based on the biological data

The Cedar Creek at ECBCB001 location can be described as overall ‘good’ quality stream based on three biotic integrity indices measured during 2005. Water quality ratings based on diatom and fish were higher than macroinvertebrate rating. Both diatom and fish indices resulted in either ‘good’ and ‘excellent’ water quality ratings during 2002-2005, while macroinvertebrate index resulted in ‘fair’ rating.

ECBCB001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	—	good	fair	—	**good**
MBI	—	—	—	—	fair	**fair**
Fish KBI	—	—	good	fair	—	**excellent**

Table 4-1 Land use/cover characteristics of the Cedar Creek in Bullitt County watershed at ECBCB001 location.

ECBCB001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	**0.20**	**0.24**	**0.14**
Open Water	0.11	0.07	0.00
Dev. Open Space	3.50	4.05	0.00
Dev. Low Intensity	1.98	2.78	0.00
Dev. Medium Intensity	0.07	0.13	0.00
Dev. High Intensity	0.00	0.00	0.00
Barren Land	0.25	0.31	4.48
Deciduous Forest	51.99	51.41	23.77
Evergreen Forest	9.95	9.50	0.90
Mixed Forest	0.66	0.55	0.00
Shrub/Scrub	0.14	0.24	0.00
Grassland/herbaceous	6.88	8.52	70.85
Pasture/Hay	21.71	20.03	0.00
Cropland	2.35	1.89	0.00
Woody Wetlands	0.41	0.51	0.00
Emergent Herbaceous Wetlands	0.01	0.00	0.00

Table 4-2 Diatom bioassessment index scores estimated in Cedar Creek in Bullitt County.

ECBCB001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2002	27	78	77	66	4	20	**46**	**GOOD**
2003	26	80	91	54	3	14	**45**	**FAIR**
Summer 05	31	72	82	69	13	18	**48**	**GOOD**
Fall 05	27	70	72	77	10	12	**45**	**FAIR**
2005 All	29	71	77	73	11	15	**46**	**GOOD**
Overall	**28**	**75**	**80**	**66**	**7**	**17**	**46**	**GOOD**

Table 4-3 Macroinvertebrate biotic integrity scores in Cedar Creek in Bullitt County.

Year	**Metric**	**ECBCB001**	
		Raw Score	Metric Score
2004	Taxa Richness	30	40.54
	EPT Richness	8	26.67
	m%EPT	11.1	15.21
	mHBI	3.15	99.42
	%Chir. and Oli.	0.9	100
	%Clinger	12.6	17.03
	MBI	--------	49.83
	Assessment	--------	**fair**
2005	Taxa Richness	50	67.57
	EPT Richness	17	56.67
	m%EPT	24.72	33.86
	mHBI	5.93	59.09
	%Chir. and Oli.	12.73	88.15
	%Clinger	35.58	48.08
	%Ephemeroptera	--------	--------
	MBI	--------	58.90
	Assessment	--------	**fair**

Table 4-4 Fish IBI scores in Cedar Creek in Bullitt County.

Year	**ECBCB001**
2002	**good**
Native	79
DMS	14
INT	14
WC	59
SL	63
%Insect_Ex_Tol	58
%OMNI	76
%TOL	63
IBI	**53**
2003	**fair**
Native	68
DMS	56
INT	26
WC	69
SL	47
%Insect_Ex_Tol	28
%OMNI	50
%TOL	50
IBI	**49**
2005	**excellent**
NAT	68
DMS	45
INT	14
SL	54
%INSCT	100
%TOL	59
%FHW	40
KIBI	57

Table 4-5 Gross primary production and community respiration in Cedar Creek in Bullitt County.

ECBCB001	**Spring**		**Summer**		**Fall**	
	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)
2002	—	—	1.82	9.51	2.16	9.38
2003	2.46	2.61	2.79	5.06	1.04	12.20
2004	3.88	3.75	—	—	—	—
2005	—	—	—	—	—	—
2006	1.92	7.34	2.40	9.62	1.30	4.09
2007	1.45	8.33	2.47	7.08	2.22	5.26

Table 4-6 Water temperature, DO, pH, and conductivity in Cedar Creek in Bullitt County at ECBCB001 location.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	14.5	11.2	18.3	10.24	8.60	12.38	7.69	7.44	8.00	438.2	428.5	445.4
2004	12.8	9.2	16.8	10.49	8.18	13.43	7.72	7.42	7.99	473.4	451.7	493.4
2005	14.9	11.3	18.8	—	—	—	7.30	7.24	7.38	340.4	331.3	347.1
2006	14.2	10.6	18.8	6.86	5.40	8.26	7.89	7.76	8.03	451.4	439.1	461.1
2007	7.3	5.4	9.5	7.74	6.78	8.81	8.25	8.18	8.30	476.1	466.8	483.1
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2002	24.0	21.9	26.8	3.82	2.16	5.56	7.49	7.39	7.59	522.4	509.6	533.2
2003	23.1	21.4	24.9	7.31	5.70	9.50	7.74	7.59	7.87	448.9	431.8	459.8
2004	21.8	20.2	23.4	—	—	—	7.63	7.53	7.73	450.4	434.7	465.9
2005	24.0	21.9	26.7	—	—	—	7.59	7.48	7.74	276.8	269.0	281.3
2006	21.8	18.9	24.7	4.59	3.28	6.27	7.83	7.65	8.04	253.2	235.7	260.1
2007	23.5	21.0	26.2	6.26	4.89	8.19	8.26	8.17	8.34	372.8	360.4	389.2
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2002	12.4	11.2	13.5	5.99	3.91	7.85	7.83	7.70	8.05	435.0	350.2	452.8
2003	13.8	12.3	15.2	3.82	2.79	4.81	7.58	7.37	7.71	478.0	463.8	497.5
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	—	—	—	—	—	—	—	—	—	—	—	—
2006	15.0	13.4	16.7	8.29	7.08	9.69	8.24	8.14	8.31	453.3	444.1	464.4
2007	20.6	19.1	22.1	6.91	5.26	8.76	7.82	7.74	7.90	461.3	455.6	467.8
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	2.0	1.0	3.0	6.72	6.03	7.63	8.15	7.90	8.36	591.8	566.9	613.2
2005	2.0	1.0	3.0	5.82	4.41	7.58	7.40	7.25	7.53	409.5	395.0	421.4
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	5.4	4.4	6.3	8.64	6.87	10.80	8.20	8.08	8.35	494.5	385.1	538.1

Table 4-7 Summary of selected water chemistry parameters in Cedar Creek in Bullitt County at ECBCB001 location.

	Year	2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.69	2.57	Total Kjeldahl Nitrogen (mg/L)	0.62	0.63
	SD (Dry)	-	0.00		-	3.55		-	0.52
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.08		0.25	1.12		0.65	0.53
	SD (wet)	0.00	0.04		0.21	1.38		0.15	0.05
	Count (wet)	2	2		2	2		2	2
Ortho Phosphorus (mg/L)	Mean (Dry)	0.44	0.62	Phosphorus (mg/L)	0.34	0.68	Chloride (mg/L)	23.32	51.75
	SD (Dry)	-	0.84		0.00	0.91		-	62.50
	Count (Dry)	1.00	2		2	2		1	2
	Mean (wet)	0.03	0.06		0.05	0.10		11.85	15.25
	SD (wet)	0.00	0.05		0.01	0.09		5.60	1.88
	Count (wet)	2	2		2	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	456.00	513.00	TSS (mg/L)	3.00	4.50
	SD (Dry)	-	1.06		-	224.86		-	3.54
	Count (Dry)	1.00	2		1	2		1	2
	Mean (wet)	0.50	3.00		306.00	305.00		7.00	14.50
	SD (wet)	0.00	1.41		25.46	26.87		2.83	12.02
	Count (wet)	2	2		2	2		2	2

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	-	-	-	181	167	425	140	161
	SD (Dry)	-	-	-	267	79	727	70	120
	Count (Dry)	0	0	0	15	14	23	15	25
	Mean (wet)	-	-	-	160	697	15449	2213	720
	SD (wet)	-	-	-	-	873	42250	3199	956
	Count (wet)	0	0	0	1	17	8	19	9

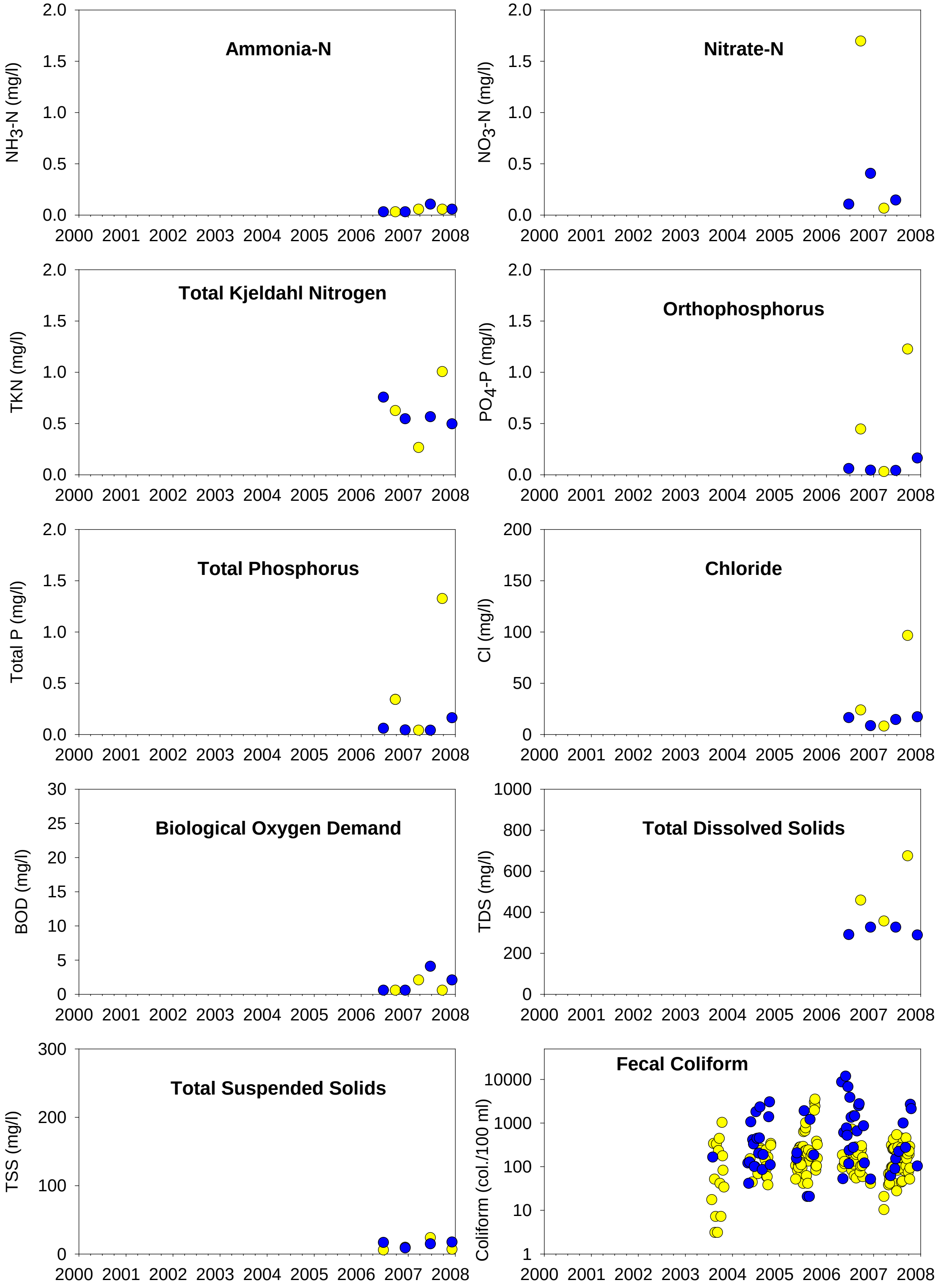

Figure 4-1 Major water chemistry parameters measured in Cedar Creek in Bullitt County at ECBCB001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 5 Floyds Fork Watershed

5.1 Watershed Physical Characteristics

Due to the longitudinal connectivity of LTMN locations in both Chenoweth Run and Floyds Fork watersheds, all data are presented following the order of upstream-downstream linkages; in Chenoweth Run (EFFCR002-EFFCR001), and in Floyds Fork (EFFFF001-EFFFF003-EFFFF002).

Chenoweth Run is a tributary of Floyds Fork, which originates in Middletown area and flows south and merging into Floyds Fork between the upstream (EFFFF003) and downstream (EFFFF002) locations. There are two LTMN locations in Chenoweth Run, an upstream location at Ruckriegel Parkway (EFFCR002) and a downstream location at Gelhaus Lane (EFFCR001).

The headwater portion of Chenoweth Run watershed is heavily developed, and it was evident from the landuse patterns with more than 77% of developed areas and 33% of impervious coverage at Ruckriegel Parkway location (EFFCR002) (Table 5-1). Riparian buffer zones, both in whole watershed and reach scale, also showed the similar level of high development with more than 30% of watershed imperviousness. Although the intensity of development is slightly lower at the downstream location at Gelhaus Lane (EFFCR001), high degree of urbanization is continued to the downstream. The watershed had more than half (55%) of developed lands with 21% of impervious surface coverage at this point. However, the riparian zone imperviousness (16.9% and 0.2% at watershed scale and reach scale, respectively) was much lower than the upstream location.

Floyds Fork originates in the Trimble County, Kentucky (East Fork), and flows west through Oldham County and enters into Jefferson County at Ash avenue (EFFFF001) location. EFFFF001 is the most upstream LTMN location in the main stem of Floyds Fork followed by the locations at Old Taylorsville (EFFFF003) and at Bardstown Road (EFFFF002).

The watershed has less than 10% of developed lands (with 1.4% impervious surface) as Floyds Fork entering into Jefferson County (Table 5-2). Riparian buffer zones also showed the similar landuse patterns (less than 10% developed lands) and impervious coverage (2% imperviousness) at the most upstream location (EFFFF001). The cumulative landuse patterns change slightly as it flows through more urbanized Jefferson County, and it has 15% of developed lands with 3.5% of impervious cover at the most downstream LTMN location (EFFFF002). At the most downstream location (EFFFF002), the reach-scale riparian buffer zone contains 16% of developed lands and 4.5% of impervious surface coverage.

5.2 Biological Data

5.2.1 Diatom

EFFCR002: the overall water quality of Chenoweth Run at Ruckriegel Parkway (EFFCR002) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Good’ (Table 5-3). The overall mean score of 51 reflects the mid/upper range of ‘Good’ scores. In general, these data suggest water quality of Chenoweth Run at Ruckriegel Parkway seems to be relatively constant over time (Table 5-3). Specifically, during the 2001 and 2002 sampling seasons, 61% of sample dates characterized water quality as ‘Good’ (mean DBI = 50). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as ‘Good’ as 60% of samples scored in the ‘Good’ range (mean DBI = 51).

The taxa richness (TR) yearly mean score revealed no real discernable pattern throughout the study period (Table 5-3). Small, yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. The pollution tolerance index (PTI) yearly mean score decreased from year 2001 (77) to 2003 (69) but increased during 2005 (77) (Table 5-3). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability. This site's overall mean PTI score (75) was among the highest observed in the current study (Table 5-3) and is considered indicative of good water quality.

The siltation index (%NNS) yearly mean score decreased from year 2001 (71) to 2002 (62) but increased during 2005 (79) (Table 5-3). These data suggest that species composition shifted slightly away from those species adapted to living on silts and shifting sediments. In general, an increase in %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score revealed no real discernable pattern throughout the study period (Table 5-3). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values throughout the study period were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 5-3). Small, yearly FGR fluctuations, as seen here, are well within the limits of expected yearly natural variability

The cymbella group richness (CGR) yearly mean score decreased from year 2001 (31) to 2003 (23) but increased during 2005 (27) (Table 5-3). These taxa are widely considered to be indicators of good water quality. This site's overall mean CGR score (27) was the highest observed in the current study and is considered indicative of good water quality.

EFFCR001: The overall water quality of Chenoweth Run at Gelhaus Lane (EFFCR001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Good' (Table 5-3). The overall mean score of 47 reflects the lower range of 'Good' scores. In general, these data suggest water quality of Chenoweth Run at Gelhaus Lane seems to be improving slightly over time (Table 5-3). Specifically, during the 2001 and 2002 sampling seasons, 56% of sample dates characterized water quality as 'Good' (mean DBI = 47). However, during subsequent sampling years (2003, 2005), mean overall water quality was characterized as 'Good' in 80% of samples analyzed (mean DBI = 48).

The taxa richness (TR) yearly mean score increased slightly from year 2001 (35) to 2005 (38) (Table 5-3). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score revealed no real discernable pattern throughout the study period with respect to those species identified as pollution tolerant or pollution sensitive (Table 5-3). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The siltation index (%NNS) yearly mean score decreased from year 2001 (68) to 2002 (59) but increased during 2005 (68) (Table 5-3). Small, yearly %NNS fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (95) to 2003 (89) but increased during 2005 (93) (Table 5-3). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values throughout the study period were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (13) to 2002 (3), but increased during 2005 (14) (Table 5-3). These data indicate that species within the Fragilaria group were lost during 2002, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 5-3). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of CGR values throughout the study period were moderate/high and indicative of good water quality.

EFFFF001: The overall water quality of Floyds Fork at Ash Avenue (EFFFF001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Fair’ (Table 5-4). The overall mean score of 43 reflects the mid/upper range of ‘Fair’ scores. In general, these data suggest water quality of Floyds Fork at Ash Avenue seems to be declining slightly over time (Table 5-4). Specifically, during the 2001 sampling season, seven of nine sample dates characterized water quality as ‘Good’ (mean DBI = 46). In contrast, during subsequent sampling years (2002 – 03, 2005), mean overall water quality was characterized as ‘Fair’ as 88% of samples scored in either the ‘Poor’ or ‘Fair’ range (mean DBI = 42).

The taxa richness (TR) yearly mean score increased from year 2001 (38) to 2005 (43) (Table 5-4). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score remained largely unchanged throughout the study period with respect to those species identified as pollution tolerant or pollution sensitive (Table 5-4). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The siltation index (%NNS) yearly mean score increased from year 2001 (46) to 2003 (61), but decreased sharply during 2005 (38) (Table 5-4). These data suggest that species composition shifted toward those species adapted to living on silts and shifting sediments. Further, these data suggest stream silt loads were likely substantial during 2001 and 2005 and likely a detriment to stream water quality.

The Shannon diversity index (SDI) yearly mean score remained largely unchanged throughout the study period (Table 5-4). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values were high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (20) to 2003 (3), but increased during 2005 (7) (Table 5-4). These data suggest that species within the Fragilaria group were lost as the study progressed. Taxa within this group are widely considered to be indicators of good water quality. A decrease with respect to this metric suggests site water quality may be deteriorating.

The cymbella group richness (CGR) yearly mean score decreased from year 2001 (18) to 2003 (0), but increased during 2005 (2) (Table 5-4). These data suggest that species within the

Cymbella group were lost as the study progressed. Taxa within this group are widely considered to be indicators of good water quality. A decrease with respect to this metric suggests site water quality may be deteriorating rapidly, especially given the complete loss of these taxa during 2003.

EFFFF003: the overall water quality of Floyds Fork at Old Taylorsville Road (EFFFF003) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Fair’ (Table 5-4). The overall mean score of 44 reflects the mid/upper range of ‘Fair’ scores. In general, these data suggest water quality of Floyds Fork at Old Taylorsville Road seems to be relatively constant over time (Table 5-4). Specifically, during the 2002 sampling season, 78% of sample dates characterized water quality as ‘Fair’ (mean DBI = 44). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as ‘Fair’ as 80% of samples scored in the ‘Fair’ range (mean DBI = 43).

The taxa richness (TR) yearly mean score increased from year 2001 (36) to 2005 (41) (Table 5-4). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score revealed no real discernable pattern throughout the study period with respect to those species identified as pollution tolerant or pollution sensitive (Table 5-4). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The siltation index (%NNS) yearly mean score increased from year 2001 (43) to 2003 (78), but decreased sharply during 2005 (39) (Table 5-4). These data suggest that species composition shifted away from then back toward those species adapted to living on silts and shifting sediments. Further, these data suggest stream silt loads were likely substantial during 2001 and 2005 and likely a detriment to stream water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (93) to 2003 (71), but increased during 2005 (96) (Table 5-4). These yearly SDI fluctuations, track well with the changes seen in TR and mirror those seen in %NNS and suggests a correlation among these parameters (Table 5-4). In general, the majority of SDI values during 2005 were high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 and 2002 (9) to 2003 (0), but increased during 2005 (11) (Table 5-4). These data indicate that species within the Fragilaria group were completely absent during 2003, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving.

The cymbella group richness (CGR) yearly mean score decreased from year 2001 (17) to 2003 (5), but increased during 2005 (9) (Table 5-4). These data suggest that species within the Cymbella group were lost as the study progressed. These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be deteriorating slightly.

EFFFF002: The overall water quality of Floyds Fork at Bardstown Road (EFFFF002) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Fair’ (Table 5-4). The overall mean score of 43 reflects the mid/upper range of ‘Fair’ scores. In general, these data suggest water quality of Floyds Fork at Bardstown Road seems to be relatively constant over time (Table 5-4). Specifically, during the 2001 and 2002 sampling seasons, 61% of sample dates characterized water quality as 'Fair' (mean DBI = 43). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as 'Fair' as 67% of samples scored in the 'Fair' range (mean DBI = 44).

The taxa richness (TR) yearly mean score increased from year 2001 (31) to 2005 (43) (Table 5-4). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score revealed no real discernable pattern throughout the study period with respect to those species identified as pollution tolerant or pollution sensitive (Table 5-4). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The siltation index (%NNS) yearly mean score decreased from year 2001 (63) to 2005 (40) (Table 5-4). These data suggest that species composition shifted toward those species adapted to living on silts and shifting sediments. Further, these data suggest stream silt loads were likely increasing throughout the study period and likely a detriment to stream water quality.

The Shannon diversity index (SDI) yearly mean score increased from year 2001 (81) to 2005 (98) (Table 5-4). These yearly SDI fluctuations, track well with the changes seen in TR and largely mirror those seen in %NNS and suggests a correlation among these parameters (Table 5-4). In general, the majority of SDI values throughout the study period were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (14) to 2002 (0), but increased during 2005 (18) (Table 5-4). These data indicate that species within the Fragilaria group were completely absent during 2002, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 5-4). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability.

5.2.2 Macroinvertebrates

The two LTMN sites along Chenoweth Run, EFFCR001 and EFFCR002, were rated as 'poor' and 'fair', respectively, in both 2000 and 2005 (Table 5-5). MBI scores during 2004 were slightly higher with 'fair' (EFFCR002) and 'good' (EFFCR001) than 2000 and 2005. Low scores for these two sites are due to the low EPT richness and %EPT scores. MBI scores are higher at the downstream site (EFFCR001) compared to the upstream site (EFFFFCR002), possibly reflecting the lower urban development intensity at this downstream portion of watershed.

The macroinvertebrates along the main stem of Floyd's Fork were rated as 'poor/fair' in 2000, and were rated as 'Good' in 2005 (Table 5-5). In 2004 samples, two sites (EFFFF002 and EFFFF003) scored 'excellent', but this was most likely due to an underrepresentation of chironomids and oligochaetes (lower %Chir. and Oli metric) in the sample, which ultimately inflated the MBI scores. This underrepresentation of chironomids and oligochaetes also might have affected the scores for the %Clinger and %EPT metrics as well. In 2005, all three sites along the Floyd's Fork main stem had very similar scores ('good') based on the overall MBI. These main stem sites had much higher overall taxa richness scores (51-65) than the tributary, Chenoweth Run, sites (41-48) during 2005 (Table 5-5).

5.2.3 Fish

The fish communities in the two LTMN locations of Chenoweth Run watershed were rated as 'fair' based on the fish IBI during 2005 with a slightly higher fish IBI score at the upstream (EFFCR002) location than the downstream (EFFCR001) location (Table 5-6). Water quality ratings at the upstream Chenoweth Run site (EFFCR002) were 'poor' prior to the year 2000, but improved to 'fair' ratings in 2002-2005 (Table 5-4). The downstream site (EFCR001) was rated as 'poor' until 2003 samples, and it was 'fair' during 2005. The native species richness (NAT) score was the main metric contributing such changes in Chenoweth Run fish IBI scores at both locations.

The most upstream location (EFFFF001) at the mainstem Floyds Fork had low water quality ratings until 2003 (fair-very poor), but it had an 'excellent' rating during 2005 (Table 5-6). Metric score for native species richness was much higher in 2005 than previous surveys. The next location, EFFFF003, had 'excellent-good' ratings until the year 2000, but the quality rating decreased to 'fair' ratings during 2002-2005. Metric scores for the native species richness (NAT) were lower at this location during 2002-2005 than previous years (1999-2000). The most downstream location (EFFFF002) had 'poor' ratings during 2000-2002, and had 'fair' ratings during 2003-2005. Metric scores for native species richness and proportion of insectivores (%INSCT) were higher during 2003-2005 surveys than previous years at this location.

5.3 Hydrolab Data

5.3.1 Stream metabolism

Overall, the downstream location (EFFCR001) had higher GPP and CR values than the upstream location (EFFCR002) in Chenoweth Run (Table 5-7). GPP estimated at EFFCR002 during spring ranged in 2.40-6.48 g O_2/m^2/day, which was higher than summer (1.45-4.73 g O_2/m^2/day) and fall (0.75-4.03 g O_2/m^2/day) (Table 5-7). In EFFCR002 location, there was no seasonal difference in CR on average. However, there was a great deal of year-to-year variation of CR in EFFCR002 during spring (2.32-10.40 g O_2/m^2/day) and summer (2.91-11.77 g O_2/m^2/day), while it was more consistent during fall (4.86-8.50 g O_2/m^2/day).

In EFFCR001, GPP was also much higher during spring (6.76-11.43 g O_2/m^2/day) than summer (3.76-5.83 g O_2/m^2/day) and fall (2.60-7.57 g O_2/m^2/day). CR estimates were similar during three seasons in EFFCR001.

Stream metabolism estimates (GPP and CR) were higher in two downstream locations (EFFFF003 and EFFFF002) than the upstream location (EFFFF0001) in the main stem Floyd Fork (Table 5-8). This could be attributed to the possible impacts of increased watershed urbanization on stream ecosystem functions.

GPP at the most upstream location of mainstem Floyd Fork (EFFFF001) was low and similar in all three seasons (0.34-1.20 g O_2/m^2/day in spring, 0.17-1.28 g O_2/m^2/day in summer, 0.37-2.88 g O_2/m^2/day in fall) (Table 5-8). CR was highest during fall (9.15-21.68 g O_2/m^2/day), followed by summer (8.13-18.36 g O_2/m^2/day), and lowest during spring (0.90-11.73 g O_2/m^2/day).

At EFFFF003, GPP estimates were clearly higher during spring (1.16-4.91 g O_2/m^2/day) than summer (0.65-3.52 g O_2/m^2/day) and fall (0.81-2.09 g O_2/m^2/day). CR estimates were highest during fall (3.17-19.34 g O_2/m^2/day) followed by summer (8.13-16.79 g O_2/m^2/day), and lowest during spring (0.90-11.73 g O_2/m^2/day). There was not enough data to show any clear patterns of GPP and CR at EFFFF002 location (Table 5-8).

5.3.2 Dissolved oxygen, pH, and conductivity

Impact of the high degree of urbanization in the Chenoweth Run watershed was evident from the water quality parameters measured with Hydrolab sondes. Conductivity averaged for all seasons was much higher at the upstream location (873 µS/cm) than downstream location (697 µS/cm). Daily average DO was highest during winter (9.53-11.53 mg/L) and lowest during summer (2.68-7.70 mg/L) at the upstream LTMN location of Chenoweth Run (EFFCR002). Daily mean DO stayed above 5 mg/L except during summer 2005 and fall 2007. The pH values were slightly above the neutral (pH>7), except somewhat lower pH values were recorded during winter of years 2002 (6.60) and 2003 (6.89). Conductivity was highest during winter (728-2181 µS/cm) than other seasons (Table 5-9).

At EFFCR001, there were both seasonal and inter-annual variations in DO (Table 5-9). DO values were somewhat higher during spring (5.63-10.11 mg/L) than other seasons. The pH values were always in the neutral to slightly alkaline range (7.7-8.9) throughout the report period (2000-2007), except in winter 2005. Conductivity was highest during fall (670-969 µS/cm) and lowest during spring (594-775 µS/cm) on average.

Longitudinal changes of sonde paramters were not prominent in LTMN location in the main stem Floyds Fork. In EFFFF001 location, DO concentration was highest during winter (9.15-14.05 mg/L), followed by spring (8.16-11.74 mg/L), and values in summer (2.52-5.69 mg/L) and fall (2.68-6.73 mg/L) were similar throughout the report period (2000-2007) (Table 5-10). The pH in EFFFF001 was in the range of 7.23-8.62 and stayed above 7 except in winter 2006. Conductivity was highest during fall (387-811 µS/cm) and lowest in spring (452-541 µS/cm), and summer and winter had the similar conductivity values.

In EFFFF003, daily average DO concentrations were similar during winter (5.15-12.99 mg/L) and spring (3.36-12.39 mg/L) and they were higher than fall (2.77-8.93 mg/L) and summer (3.82-6.75 mg/L) (Table 5-10). Average DO concentration was mostly above 5.0 mg/L except on several occasions in summer and fall. The pH was also slightly higher during winter and spring than fall and summer, and mostly stayed above 7. Conductivity values were similar throughout the season in the EFFFF003, with highest valued during fall and lowest during spring.

In EFFFF002 location, DO varied a great deal and very low DO (<4 mg/L) readings occurred during all seasons (Table 5-10). The pH was higher during spring and winter than other seasons, and it mostly stayed above 7. Conductivity was similar during summer and fall, and they were higher than spring and winter.

5.4 Laboratory Data

In EFFCR002 location, concentrations of nitrogen compounds were generally low during 2000-2006, and it increased during 2007 samples (Table 5-11, Figure 5-1). For example, nitrate-nitrogen was in the range of 0.54-0.98 mg/L during 2000-2005, but it was much higher during 2007 (7.38 mg/L). Phosphorus concentration stayed during the report period, except a little higher average value during 2006 samples. Chloride concentration was high, ranging from 62 mg/L to 116 mg/L. Fecal coliform numbers were generally much higher in the ‘wet’ samples than ‘dry’ samples.

There was no water chemistry data available during 2000-2005 except fecal coliform at EFFCR001 location. Nitrogen concentrations were also high during 2007 samples at this location as well. Chloride concentration was high (56-89 mg/L) as it was in EFFCR002 (Table 5-11).

Water chemistry data was not available during years 2000-2005 at all of the mainstem Floyds Fork LTMN locations except fecal coliform counts (Table 5-12, Figure 5-2). In general concentrations of most water chemistry parameters were much lower than Chenoweth Run LTMN locations (Table 5-12). However, there were clear longitudinal trends of higher nitrogen and chloride concentrations among the LTMN location in Floyd Fork. For example, nitrate concentration increased from 0.57 mg/L at the upstream location (EFFFF001) to 2.71 mg/L (EFFFF003) and 2.90 mg/L (EFFFF002) at downstream locations during year 2007. This might be a result of increased urbanization and changing watershed landuse within this reach, between EFFFF001 and EFFFF002.

5.5 Watershed assessment based on the biological data

Both LTMN locations in Chenoweth Run watershed can be classified as ‘fair’ based on the 2005 biotic integrity assessments. Water quality based on diatom index was ‘good’ at both locations, which was higher than either macroinvertebrates or fish at both Chenoweth Run locations.

In the main stem Floyds Fork, the most upstream location (EFFFF001) can be classified as ‘good’ based on the 2005 estimates. Other two locations in Floyd Fork can be classified as ‘fair’. Macroinvertebrate communities were rated as ‘good’ at all three sites of Floyds Fork in 2005. Diatom index was ‘fair’ at three locations, while fish community rating was ‘excellent’ at the most upstream location (EFFF001) and ‘fair’ at two downstream locations.

EFFCR002	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	good	good	good	—	**good**
MBI	poor	—	—	—	fair	**poor**
Fish KBI	poor	—	fair	fair	—	**fair**
EFFCR001						
DBI	—	good	fair	good	—	**good**
MBI	fair	—	—	—	good	**fair**
Fish KBI	poor	—	poor	poor	—	**fair**
EFFFF001						
DBI	—	good	fair	fair	—	**fair**
MBI	poor	—	—	—	fair	**good**
Fish KBI	—	—	(poor)	(fair)—	—	**excellent**
EFFFF003						

DBI	—	fair	fair	fair	—	**fair**
MBI	fair	—	—	—	excellent	**good**
Fish KBI	good	—	fair	fair	—	**fair**
EFFFF002						
DBI	—	fair	fair	fair	—	**fair**
MBI	fair	—	—	—	excellent	**good**
Fish KBI	poor	—	poor	fair	—	**fair**

Table 5-1 Land use/cover characteristics of Chenoweth Run watershed.

EFFCR002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	33.49	30.05	37.55
Open Water	0.04	0.14	0.00
Dev. Open Space	14.64	10.31	30.88
Dev. Low Intensity	30.39	28.13	37.79
Dev. Medium Intensity	23.24	23.46	3.23
Dev. High Intensity	9.08	7.70	0.00
Barren Land	0.44	0.01	0.00
Deciduous Forest	14.65	24.00	21.20
Evergreen Forest	0.17	0.47	0.00
Mixed Forest	0.00	0.00	0.00
Shrub/Scrub	0.03	0.10	0.00
Grassland/herbaceous	0.29	0.27	0.00
Pasture/Hay	5.50	4.80	6.91
Cropland	1.53	0.61	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
EFFCR001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	20.98	16.90	0.20
Open Water	0.23	0.73	0.00
Dev. Open Space	13.36	8.19	19.35
Dev. Low Intensity	23.61	19.23	23.50
Dev. Medium Intensity	13.28	12.15	2.76
Dev. High Intensity	4.70	3.53	0.00
Barren Land	0.52	0.08	1.38
Deciduous Forest	27.00	42.79	9.68
Evergreen Forest	1.38	1.78	0.00
Mixed Forest	0.28	0.31	0.00
Shrub/Scrub	0.02	0.04	0.00
Grassland/herbaceous	1.83	2.40	0.92
Pasture/Hay	12.39	7.90	42.40
Cropland	1.40	0.83	0.00
Woody Wetlands	0.02	0.04	0.00
Emergent Herbaceous Wetlands	0.01	0.00	0.00

Table 5-2 Land use/cover characteristics of Floyds Fork watershed.

EFFFF001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	1.43	0.94	1.13
Open Water	0.60	1.26	0.00
Dev. Open Space	7.65	5.54	0.00
Dev. Low Intensity	1.39	1.08	0.00
Dev. Medium Intensity	0.47	0.29	0.00
Dev. High Intensity	0.18	0.05	0.00
Barren Land	0.08	0.12	0.00
Deciduous Forest	36.95	49.23	73.89
Evergreen Forest	1.56	1.68	3.10
Mixed Forest	0.07	0.07	0.00
Shrub/Scrub	0.06	0.10	0.00
Grassland/herbaceous	2.00	1.84	11.95
Pasture/Hay	42.88	34.56	11.06
Cropland	6.07	4.14	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.02	0.03	0.00

EFFFF003	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	2.54	1.41	0.65
Open Water	0.78	1.53	2.24
Dev. Open Space	8.44	6.25	0.00
Dev. Low Intensity	3.48	2.04	0.00
Dev. Medium Intensity	1.06	0.57	0.00
Dev. High Intensity	0.36	0.13	0.00
Barren Land	0.35	0.32	0.00
Deciduous Forest	38.30	50.70	73.99
Evergreen Forest	1.57	1.73	0.00
Mixed Forest	0.09	0.11	0.00
Shrub/Scrub	0.08	0.12	0.00
Grassland/herbaceous	3.11	2.77	23.77
Pasture/Hay	37.22	30.13	0.00
Cropland	5.10	3.45	0.00
Woody Wetlands	0.01	0.03	0.00
Emergent Herbaceous Wetlands	0.05	0.12	0.00

EFFFF002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	3.48	2.08	4.48
Open Water	0.70	1.40	0.00
Dev. Open Space	7.80	5.75	9.05
Dev. Low Intensity	4.61	2.85	0.90
Dev. Medium Intensity	1.80	1.06	6.33
Dev. High Intensity	0.60	0.26	0.00
Barren Land	0.37	0.32	0.45
Deciduous Forest	40.62	52.46	49.32
Evergreen Forest	2.80	2.80	8.60
Mixed Forest	0.33	0.35	0.00
Shrub/Scrub	0.08	0.12	0.00
Grassland/herbaceous	4.32	3.60	0.45
Pasture/Hay	30.85	24.95	19.46
Cropland	4.88	3.45	5.43
Woody Wetlands	0.16	0.43	0.00
Emergent Herbaceous Wetlands	0.08	0.21	0.00

Table 5-3 Diatom bioassessment index scores estimated in Chenoweth Run watershed.

EFFCR002	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	39	77	71	82	11	31	**52**	**GOOD**
2002	39	72	65	80	6	29	**49**	**GOOD**
2003	43	69	62	90	20	23	**51**	**GOOD**
Summer 05	37	78	83	67	5	24	**49**	**GOOD**
Fall 05	41	77	75	86	10	29	**53**	**EXCELLENT**
2005 All	39	77	79	77	8	27	**51**	**GOOD**
Overall	**40**	**75**	**71**	**81**	**10**	**27**	**51**	**GOOD**

EFFCR001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	35	69	68	95	13	15	**49**	**GOOD**
2002	36	63	59	91	3	17	**45**	**FAIR**
2003	36	68	65	89	8	15	**47**	**GOOD**
Summer 05	37	63	69	91	3	17	**47**	**GOOD**
Fall 05	39	59	67	95	25	17	**50**	**GOOD**
2005 All	38	61	68	93	14	17	**49**	**GOOD**
Overall	**36**	**65**	**65**	**92**	**10**	**16**	**47**	**GOOD**

Table 5-4 Diatom bioassessment index scores estimated in Floyds Fork watershed.

EFFFF001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	38	63	46	93	20	18	**46**	**GOOD**
2002	41	64	50	89	4	3	**42**	**FAIR**
2003	40	65	61	96	3	0	**44**	**FAIR**
Summer 05	40	62	42	93	0	5	**40**	**FAIR**
Fall 05	45	61	35	98	13	0	**42**	**FAIR**
2005 All	43	61	38	95	7	2	**41**	**FAIR**
Overall	**40**	**63**	**47**	**93**	**9**	**7**	**43**	**FAIR**

EFFFF003	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	36	70	43	93	9	17	**45**	**FAIR**
2002	35	68	59	82	9	14	**44**	**FAIR**
2003	33	75	78	71	0	5	**43**	**FAIR**
Summer 05	40	61	54	97	0	11	**44**	**FAIR**
Fall 05	42	62	25	94	23	6	**42**	**FAIR**
2005 All	41	62	39	96	11	9	**43**	**FAIR**
Overall	**37**	**68**	**52**	**88**	**8**	**12**	**44**	**FAIR**

EFFFF002	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	31	70	63	81	14	9	**45**	**FAIR**
2002	36	61	48	88	0	11	**41**	**FAIR**
2003	39	63	51	92	3	5	**42**	**FAIR**
Summer 05	43	63	49	97	8	12	**45**	**FAIR**
Fall 05	43	60	31	99	28	8	**45**	**FAIR**
2005 All	43	61	40	98	18	10	**45**	**FAIR**
Overall	**37**	**64**	**50**	**90**	**10**	**9**	**43**	**FAIR**

Table 5-5 Macroinvertebrate biotic integrity scores in Chenoweth Run and Floyds Fork watersheds.

Year	Metric	EFFCR002		EFFCR001		EFFFF001		EFFFF003		EEFFFF002	
		Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness	48	90.6	49	66.2	58	78.4	57	77.0	59	79.7
	EPT Richness	5	15.2	5	16.7	8	26.7	16	53.3	14	46.7
	m%EPT	12	13.8	31	42.5	13	17.8	15	20.6	14	19.2
	mHBI	7.75	28.8	7.73	33.0	8.27	25.1	5.61	63.7	6.28	54.0
	%Chir. and Oli.	48	52.4	19	81.8	51	49.5	29	71.7	7	93.9
	%Clinger	28	37.1	30	40.5	10	13.5	28	37.8	16	21.6
	%Ephemeroptera	0	0.0	—	—	—	—	—	—	—	—
	MBI		34.0		46.8		35.2		54.0		52.5
	Assessment		**Poor**		**Fair**		**Poor**		**Fair**		**Fair**
2004	Taxa Richness	34	46.0	28	37.8	39	52.7	42	56.8	29	39.2
	EPT Richness	7	23.3	4	13.3	7	23.3	16	53.3	9	30.0
	m%EPT	24.8	34.0	49.6	68.0	19.9	27.3	29.1	39.9	50.6	69.3
	mHBI	6.51	50.7	6.76	47.0	5.36	67.3	5.22	69.4	4.56	79.0
	%Chir. and Oli.	33.6	67.1	11.5	89.4	22.4	78.4	0.3	100.0	1.2	99.8
	%Clinger	71.3	96.4	87.1	117.7	58	78.4	85.9	100.0	93.3	100.0
	MBI		52.9		62.2		54.6		69.8		69.5
	Assessment		**Fair**		**Good**		**Fair**		**Exl.**		**Exl.**
2005	Taxa Richness	41	65.1	48	64.9	54	73.0	51	68.9	65	87.8
	EPT Richness	2	6.1	5	16.7	12	40.0	13	43.3	17	56.7
	m%EPT	3.46	4.0	17.88	24.5	25.37	34.8	24.03	32.9	25.46	34.9
	mHBI	6.48	45.1	6.48	51.2	5.95	58.9	5.03	72.2	6.02	57.7
	%Chir. and Oli.	36.54	63.9	36.5	64.2	12.13	88.8	12.13	84.9	25.77	75.0
	%Clinger	53.46	70.8	37.96	51.3	55.15	74.5	59.09	79.9	46.32	62.6
	%Ephemeroptera	3.46	5.2	—	—	—	—	—	—	—	—
	MBI		37.2		45.4		61.6		63.7		62.5
	Assessment		**Poor**		**Fair**		**Good**		**Good**		**Good**

Table 5-6 Fish IBI scores in Chenoweth Run and Floyds Fork watersheds.

Year	EFFCR002	EFFCR001	EFFFF001	EFFFF003	EFFFF002
1999-up	**NS**	**very poor**	**fair**	**fair**	**NS**
1999-dn	**NS**	**very poor**	**very poor**	**poor/fair**	**NS**
2000-up	**poor**	**poor**	**NS**	**good**	**poor**
2000-dn	**very poor**	**very poor**	**NS**	**excellent**	**poor**
2002	**fair**	**poor**	**(poor)**	**fair**	**poor**
Native	49	41	47	73	29
DMS	29	18	4	12	0
INT	29	18	4	38	0
WC	42	26	35	81	26
SL	29	18	44	42	25
%Insect_Ex_Tol	50	15	38	15	36
%OMNI	50	50	50	69	50
%TOL	50	50	50	86	50
IBI	41	30	**34**	52	27
2003	**fair**	**poor**	**(fair)**	**fair**	**fair**
Native	59	44	57	62	47
DMS	42	28	57	44	43
INT	32	18	16	14	0
WC	46	36	64	61	45
SL	40	18	44	42	39
%Insect_Ex_Tol	34	16	35	41	44
%OMNI	49	41	50	79	60
%TOL	48	52	45	60	55
IBI	44	32	**46**	50	42
2005	**fair**	**fair**	**excellent**	**fair**	**fair**
NAT	65	61	68	58	43
DMS	40	27	46	44	23
INT	44	18	17	15	3
SL	48	34	44	58	38
%INSCT	50	14	100	49	50
%TOL	50	61	57	50	50
%FHW	0	5	15	28	27
KIBI	39	36	55	35	46

Table 5-7 Gross primary production (g/m^2/day) and community respiration (g/m^2/day) in Chenoweth Run watershed.

EFFCR002	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2000	4.62	5.28	2.11	2.91	—	—
2001	—	—	2.69	3.71	1.18	5.29
2002	2.40	4.00	3.23	7.56	0.75	5.98
2003	5.83	7.25	2.53	5.67	2.72	4.86
2004	6.48	10.40	—	—	4.03	6.45
2005	2.91	9.07	4.73	11.77	3.64	6.00
2006	3.09	9.00	2.20	6.43	—	—
2007	4.02	2.32	1.45	4.67	1.14	8.50
EFFCR001	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2000	9.09	24.66	6.44	8.95	—	—
2001	—	—	5.23	4.65	3.46	8.57
2002	—	—	—	—	2.60	5.75
2003	11.43	10.82	5.83	8.59	5.22	16.32
2004	7.57	15.82	—	—	6.90	12.78
2005	9.65	16.13	4.87	18.54	4.15	16.13
2006	7.07	10.98	—	—	3.98	12.05
2007	6.76	15.13	3.76	11.77	7.57	8.73

Table 5-8 Gross primary production (g/m^2/day) and community respiration (g/m^2/day) in Floyds Fork watershed.

EFFFF001	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2000	—	—	1.28	8.13	—	—
2001	—	—	—	—	0.37	16.21
2002	—	—	—	—	0.18	10.17
2003	1.15	4.89	1.23	16.79	2.88	21.68
2004	0.78	6.67	0.36	8.18	0.80	16.45
2005	1.20	6.48	1.03	12.66	0.80	9.15
2006	0.85	11.73	0.17	18.36	0.37	12.14
2007	0.34	0.90	—	—	0.75	11.19
EFFFF003	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2000	—	—	2.11	10.39	—	—
2001	4.87	4.65	3.52	6.77	2.09	9.80
2002	4.91	8.93	1.72	11.86	1.73	19.34
2003	6.39	6.15	1.36	8.29	1.36	3.53
2004	2.93	11.28	0.65	5.85	0.81	12.26
2005	4.35	3.47	2.98	7.58	0.77	5.75
2006	1.16	18.53	0.95	4.82	0.92	6.01
2007	—	—	0.84	4.46	0.99	3.17
EFFFF002	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2000	—	—	—	—	—	—
2001	—	—	3.97	9.33	—	—
2002	—	—	0.84	20.83	—	—
2003	2.24	5.26	3.04	2.61	1.28	2.08
2004	4.27	16.78	—	—	—	—
2005	—	—	3.77	9.78	8.80	3.21
2006	—	—	1.25	6.47	—	—
2007	1.23	1.13	0.64	6.17	2.65	5.49

Table 5-9 Water temperature, DO, pH, and conductivity at EFFCR002 in Chenoweth Run watershed.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (μS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.9	11.2	16.9	9.92	6.97	13.66	7.70	7.39	8.03	697.2	652.5	726.5
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.0	9.2	14.7	9.75	7.88	12.04	7.76	7.59	7.96	690.6	660.9	721.1
2003	15.4	12.2	18.6	9.53	5.57	15.00	7.70	7.32	8.21	962.7	893.3	1076.5
2004	12.3	10.3	13.8	7.86	3.37	13.72	7.23	7.02	7.65	1060.7	680.1	1245.1
2005	15.1	12.5	17.5	5.25	2.68	8.65	—	—	—	615.1	581.3	679.3
2006	14.9	11.7	18.2	5.85	3.14	8.71	8.12	8.07	8.16	728.3	692.9	768.1
2007	7.6	6.1	9.1	13.23	10.08	17.28	7.35	7.10	7.78	835.9	815.9	859.3

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (μS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	23.5	21.6	25.5	7.70	5.54	9.83	7.61	7.28	7.86	611.3	474.6	666.0
2001	22.8	21.4	24.2	7.50	5.45	9.87	7.59	7.47	7.80	740.1	677.5	793.8
2002	23.6	22.2	24.9	5.78	2.95	8.71	7.51	7.42	7.66	752.7	660.9	795.8
2003	22.9	21.5	24.2	6.41	4.24	8.83	7.03	6.89	7.19	714.4	674.8	773.1
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	23.1	21.2	26.5	2.68	0.54	6.69	7.60	7.48	7.78	965.9	952.1	979.6
2006	21.0	19.5	22.6	5.92	4.40	7.60	7.45	7.25	7.65	664.6	562.8	752.4
2007	23.0	21.3	24.6	5.57	4.01	6.92	8.72	8.38	9.13	800.0	750.3	825.3

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (μS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.8	13.2	16.4	7.13	6.14	8.62	7.45	7.34	7.56	719.7	532.3	802.8
2002	13.2	12.1	14.4	6.82	6.16	7.67	8.21	8.15	8.29	782.4	775.7	789.8
2003	15.6	13.9	17.0	8.33	5.82	10.71	7.23	6.82	7.47	633.4	592.6	700.1
2004	14.7	12.6	16.6	8.45	4.88	12.28	7.75	7.48	8.01	841.9	828.2	859.1
2005	14.4	12.8	15.7	8.32	5.67	11.49	7.54	7.41	7.68	917.7	906.6	928.6
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	22.6	20.7	24.7	2.17	0.46	4.76	7.52	7.40	7.70	854.2	843.9	866.7

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (μS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	4.3	3.1	5.6	11.17	10.23	12.57	7.94	7.84	8.08	2181.0	1842.0	2725.4
2002	5.5	4.2	7.0	11.53	10.35	12.89	6.60	6.51	6.75	1323.8	1118.8	1608.3
2003	1.5	1.1	1.9	9.78	6.60	13.85	6.89	6.77	7.00	1147.4	1060.3	1212.3
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	3.0	1.9	4.0	12.96	10.24	15.70	8.02	7.77	8.29	736.2	694.5	788.7
2006	8.4	6.7	10.0	9.53	8.07	11.36	7.32	7.15	7.56	796.1	537.0	993.4
2007	6.7	5.8	7.5	9.83	8.50	12.01	—	—	—	727.5	691.9	906.5

Table 5-9 Continued, at EFFCR001.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	14.6	11.3	18.6	5.63	2.21	10.05	7.68	7.25	8.33	594.2	573.5	615.7
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	16.2	11.5	21.8	10.11	6.40	15.53	8.29	7.41	9.29	775.1	722.7	808.4
2004	14.5	10.0	20.3	7.53	4.92	11.57	8.27	7.46	9.24	614.7	460.9	653.2
2005	16.6	11.8	22.4	7.94	4.33	13.38	7.86	7.06	8.80	687.1	625.0	728.9
2006	15.6	11.5	20.9	9.02	6.57	12.38	8.35	7.78	9.07	393.8	372.8	412.3
2007	8.6	6.3	11.1	9.35	6.93	12.75	8.23	7.70	8.88	720.1	696.7	742.4

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	24.4	21.9	27.7	7.62	4.36	10.65	7.98	7.43	8.56	598.7	466.9	650.5
2001	23.8	20.8	27.9	8.62	6.92	10.70	7.93	7.58	8.42	720.8	677.2	775.7
2002	24.7	22.1	27.9	—	—	—	—	—	—	692.5	620.0	723.8
2003	24.2	21.4	27.7	7.65	5.78	10.35	8.13	7.62	8.79	601.7	584.2	623.9
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	24.7	21.7	28.6	4.45	2.92	6.69	7.74	7.33	8.35	565.8	553.8	578.4
2006	22.2	19.4	25.4	—	—	—	8.28	7.91	8.74	777.1	713.5	840.9
2007	24.3	21.2	28.1	6.19	4.75	7.93	8.20	7.88	8.60	754.0	715.8	791.4

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.5	12.7	18.4	8.50	6.94	10.75	7.91	7.54	8.35	670.1	518.5	741.6
2002	14.1	12.4	15.9	9.41	8.21	11.09	8.68	8.48	9.00	717.5	690.1	729.2
2003	17.8	14.2	21.0	6.68	4.49	12.07	8.63	8.13	9.20	685.3	668.4	700.9
2004	16.0	13.0	19.6	8.18	5.85	12.46	7.93	7.43	8.74	451.6	441.2	462.7
2005	16.5	14.0	19.7	6.17	4.68	9.14	7.93	7.44	8.71	924.8	905.6	943.3
2006	17.5	14.4	21.1	7.09	5.23	9.87	8.21	7.95	8.65	941.4	926.8	952.8
2007	23.2	20.5	26.9	8.16	5.84	13.60	8.27	7.81	9.07	968.9	944.2	986.5

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	2.0	1.1	3.1	10.22	8.97	12.21	7.81	7.38	8.31	781.0	762.4	798.9
2004	4.4	2.8	6.2	6.77	6.18	7.66	8.18	7.92	8.64	880.5	836.4	910.7
2005	3.5	1.8	5.1	7.37	6.34	8.94	6.74	6.57	6.98	572.9	565.5	583.1
2006	8.4	6.5	10.1	4.90	4.04	5.90	7.85	7.57	8.32	678.9	509.4	808.8
2007	7.0	5.8	8.9	10.66	8.78	12.11	8.24	8.02	8.51	673.1	568.9	988.0

Table 5-10 Daily water temperature, DO, pH, and conductivity at EFFFF001 in Floyd Fork watershed.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	11.2	10.1	12.1	—	—	—	8.27	8.18	8.34	470.7	453.3	479.4
2003	15.0	13.8	16.4	8.47	7.27	9.39	8.13	7.99	8.20	541.2	533.5	548.9
2004	13.0	11.7	14.5	8.26	7.64	8.72	7.95	7.83	8.01	534.1	529.5	540.5
2005	16.0	14.5	17.7	8.16	7.09	9.05	7.68	7.47	7.90	490.3	484.6	496.0
2006	14.4	12.8	16.1	5.55	4.38	6.62	7.80	7.62	8.00	452.2	429.9	462.9
2007	7.2	6.4	8.5	11.74	10.82	12.66	8.23	8.16	8.34	517.6	501.7	529.0

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	23.9	23.1	24.8	4.83	2.95	6.60	7.45	7.37	7.52	413.3	357.3	454.1
2001	23.6	22.4	25.1	—	—	—	7.43	7.24	7.66	644.9	608.7	735.1
2002	23.5	22.7	24.5	—	—	—	7.76	7.65	7.88	341.5	292.5	372.1
2003	23.8	22.8	25.2	2.52	1.27	4.03	7.74	7.59	8.26	493.0	360.2	511.5
2004	22.3	21.5	23.1	5.69	5.23	6.05	7.23	7.16	7.32	324.0	270.0	367.2
2005	25.1	24.1	26.5	3.33	2.34	4.52	7.48	7.42	7.56	719.0	709.8	733.2
2006	22.8	21.7	24.1	—	—	—	7.96	7.87	8.10	577.2	555.1	594.4
2007	24.0	23.0	25.3	—	—	—	8.62	8.54	8.68	870.7	850.1	889.9

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	13.3	12.7	14.4	4.00	3.00	4.77	8.05	7.82	8.48	455.3	424.4	472.3
2002	12.5	12.0	13.2	6.73	6.56	6.92	7.85	7.82	7.87	457.5	449.3	464.4
2003	13.7	13.0	14.5	2.68	0.75	4.70	7.84	7.76	7.91	541.5	535.3	554.1
2004	14.4	13.2	16.0	3.97	3.32	4.71	7.26	7.18	7.37	387.0	365.1	398.0
2005	15.1	14.6	15.8	6.56	5.99	7.07	7.35	7.32	7.38	707.1	704.1	711.4
2006	16.0	15.3	16.8	5.09	4.77	5.42	7.42	7.38	7.45	589.6	584.4	595.1
2007	21.5	20.3	23.0	4.37	3.46	5.28	7.31	7.25	7.38	811.4	770.5	823.5

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	0.0	-0.1	0.3	14.05	13.70	14.58	6.87	6.68	7.39	693.8	683.1	716.5
2002	2.8	1.9	3.4	11.42	10.36	12.55	7.90	7.78	8.00	520.9	505.1	555.7
2003	0.0	-0.1	0.2	13.11	12.64	13.55	8.11	8.08	8.13	585.1	572.4	592.1
2004	1.3	0.8	2.0	12.60	11.27	13.68	7.68	7.57	7.78	497.7	458.0	535.2
2005	0.8	0.3	1.3	13.05	12.60	13.38	8.19	8.17	8.21	495.5	467.3	506.7
2006	6.2	5.3	7.3	9.15	7.27	11.02	7.47	7.40	7.55	484.1	438.2	529.6
2007	4.2	3.6	5.6	10.60	9.36	12.09	8.00	7.94	8.09	512.7	437.4	748.9

Table 5-10 Continued, at EFFFF003.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.5	11.6	15.9	12.39	10.65	14.54	8.27	8.00	8.58	456.2	402.5	468.7
2001	19.8	18.0	22.0	8.23	4.69	13.18	8.07	7.81	8.34	562.0	540.1	580.6
2002	11.7	9.8	14.0	8.82	5.28	11.99	8.28	8.00	8.53	475.6	358.1	492.9
2003	15.6	13.0	18.3	9.94	6.53	14.49	8.28	8.06	8.53	529.8	466.1	546.6
2004	13.7	11.5	15.9	7.07	5.37	9.26	7.97	7.76	8.18	298.7	289.9	305.8
2005	16.8	14.2	19.3	10.23	7.75	13.77	7.79	7.55	8.05	539.9	515.1	549.3
2006	14.8	12.7	17.0	3.36	2.73	5.33	7.97	7.83	8.16	476.5	464.1	486.8
2007	—	—	—	—	—	—	—	—	—	—	—	—

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	24.7	23.3	26.6	4.01	1.39	6.20	7.51	7.35	7.67	288.2	259.9	339.3
2001	25.8	24.2	27.8	6.28	3.51	10.96	7.85	7.58	8.28	678.6	633.8	701.5
2002	25.3	24.3	26.5	3.82	2.62	5.27	7.84	7.63	8.05	494.0	463.0	526.9
2003	25.7	19.4	27.4	5.48	3.62	6.87	7.67	6.08	7.81	498.9	356.1	511.3
2004	22.4	21.1	24.0	6.65	6.19	7.30	7.74	7.65	7.89	318.7	269.4	385.5
2005	27.0	25.8	28.5	5.68	3.90	9.27	7.72	7.50	8.10	776.3	762.4	783.3
2006	24.2	23.0	25.4	6.75	5.74	8.23	7.84	7.71	7.97	654.9	620.6	671.0
2007	25.1	23.3	27.0	6.72	6.02	7.67	7.69	7.62	7.79	439.9	416.9	461.2

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.7	13.6	16.0	6.75	5.05	9.01	7.89	7.58	8.11	576.6	541.0	598.9
2002	13.1	12.3	13.9	2.77	1.37	4.06	7.82	7.77	7.88	498.4	482.6	507.9
2003	15.0	13.8	16.2	8.93	7.35	10.51	7.90	7.82	7.96	525.1	468.6	530.2
2004	15.3	14.3	16.5	5.19	3.44	5.94	8.01	7.88	8.12	424.8	415.0	429.3
2005	16.4	15.2	17.6	7.35	6.42	8.42	7.93	7.80	8.13	756.7	747.1	764.3
2006	16.9	15.6	18.0	7.47	6.56	8.61	7.60	7.50	7.71	777.4	736.2	812.5
2007	22.5	20.9	24.6	7.22	6.02	8.28	7.84	7.74	7.93	724.3	627.7	779.0

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	3.2	2.3	4.1	12.99	11.94	14.34	8.17	8.05	8.31	458.2	443.4	473.5
2003	0.1	0.0	0.7	5.15	1.57	7.76	8.10	7.90	8.21	594.6	582.3	602.6
2004	1.6	0.9	2.3	9.14	7.65	10.63	8.28	8.19	8.38	510.7	476.3	537.5
2005	1.1	0.5	1.8	7.19	5.37	8.65	8.21	8.16	8.26	514.7	505.6	523.0
2006	6.4	5.4	7.3	6.18	4.47	7.85	6.68	6.64	6.71	445.2	390.5	480.1
2007	5.0	4.3	6.4	11.11	10.00	12.14	8.20	8.03	8.50	519.9	498.0	538.7

Table 5-10 Continued, at EFFFF002.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.1	13.7	16.8	—	—	—	8.13	7.69	8.49	573.2	496.7	595.1
2002	11.7	10.4	12.9	11.08	8.33	13.52	8.37	8.18	8.53	475.9	464.5	490.2
2003	15.4	13.7	17.0	8.54	6.59	10.78	8.10	7.93	8.23	510.3	500.9	517.2
2004	13.9	12.3	15.6	3.25	1.27	5.49	8.21	8.04	8.29	371.8	360.0	379.0
2005	16.6	14.8	18.3	—	—	—	7.30	7.22	7.39	520.3	432.3	592.9
2006	15.1	13.7	16.6	—	—	—	6.88	6.58	7.24	573.0	553.6	604.8
2007	8.1	7.0	9.5	11.96	10.82	13.25	8.88	8.50	9.33	518.9	500.1	531.9

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	25.3	23.6	27.4	5.16	2.15	9.02	7.50	7.15	7.92	578.5	550.3	604.0
2002	25.2	24.1	26.4	—	—	—	7.52	7.25	7.84	576.5	539.4	604.4
2003	25.3	24.0	26.9	7.32	4.58	9.26	7.57	7.42	7.73	535.9	525.1	544.3
2004	22.6	21.6	23.8	—	—	—	7.27	7.20	7.33	748.2	723.8	775.2
2005	26.2	24.6	27.9	4.33	1.61	7.18	7.70	7.38	8.02	764.6	754.3	772.4
2006	23.7	22.3	25.2	6.33	5.29	7.64	7.73	7.60	7.86	556.2	529.7	575.1
2007	25.1	23.7	26.7	6.02	5.56	6.67	7.62	7.52	7.76	429.6	400.7	449.2

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.4	13.0	15.9	15.38	11.24	18.84	7.83	7.63	8.26	560.7	504.9	623.9
2002	13.2	12.6	14.0	—	—	—	7.71	7.57	7.85	543.2	525.0	565.3
2003	15.0	13.8	16.4	9.57	8.62	10.94	8.01	7.96	8.07	511.9	508.2	515.9
2004	14.7	13.5	15.9	—	—	—	7.60	7.44	7.74	—	—	—
2005	15.8	14.1	17.9	8.72	4.72	13.24	7.73	7.47	8.11	520.9	515.5	525.8
2006	16.9	15.8	18.0	—	—	—	7.77	7.57	7.92	614.2	607.6	620.2
2007	22.7	20.2	25.6	7.27	5.74	9.66	7.70	7.51	7.94	797.3	743.2	810.4

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	3.5	2.6	4.4	15.23	10.59	19.51	7.83	7.70	8.00	618.7	605.1	668.1
2003	-0.1	-0.7	0.2	16.87	16.06	17.84	8.71	8.64	8.76	555.3	465.5	621.5
2004	1.8	1.2	2.4	4.87	2.24	7.97	7.50	7.44	7.57	287.1	241.8	301.8
2005	1.2	0.6	1.9	5.99	3.65	7.94	7.88	7.82	7.93	506.6	497.1	518.9
2006	6.5	5.7	7.5	3.81	2.44	5.25	7.62	7.51	7.73	355.9	338.7	377.3
2007	5.0	4.4	5.6	13.09	12.52	13.70	7.85	7.80	7.92	516.8	493.9	549.4

Table 5-11 Summary of selected water chemistry parameters in Chenoweth Run watershed.

EFFCR002		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.25	0.12	0.13	0.26	0.03	0.03	0.03	2.28
	SD (Dry)	0.32	0.24	0.18	-	0.00	0.01	0.00	3.15
	Count (Dry)	16	7	3	1	4	3	4	2
	Mean (wet)	0.06	-	0.17	1.85	-	0.03	0.03	0.05
	SD (wet)	0.06	-	-	3.16	-	-	-	0.00
	Count (wet)	3	0	1	3	0	1	1	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	0.73	0.98	-	-	0.89	0.54	4.87	7.38
	SD (Dry)	0.19	0.21	-	-	0.24	0.37	4.15	9.24
	Count (Dry)	16	7	0	0	3	3	4	2
	Mean (wet)	0.50	-	-	2.46	-	0.76	0.46	1.07
	SD (wet)	0.23	-	-	-	-	-	-	0.61
	Count (wet)	3	0	0	1	0	1	1	2
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	1.04	1.15	-	-	-	-	0.76	3.29
	SD (Dry)	0.74	1.29	-	-	-	-	0.39	2.42
	Count (Dry)	16	7	0	0	0	0	3	2
	Mean (wet)	0.46	-	-	-	-	-	-	0.75
	SD (wet)	0.50	-	-	-	-	-	-	0.36
	Count (wet)	3	0	0	0	0	0	0	2
Ortho Phosphorus (mg/L)	Mean (Dry)	0.04	0.03	-	-	0.03	0.06	0.22	0.04
	SD (Dry)	0.01	0.00	-	-	0.00	0.07	0.28	0.02
	Count (Dry)	16	7	0	0	3	3	4	2
	Mean (wet)	0.03	-	-	0.03	-	0.03	0.03	0.03
	SD (wet)	0.00	-	-	-	-	-	-	0.00
	Count (wet)	3	0	0	1	0	1	1	2
Phosphorus (mg/L)	Mean (Dry)	0.72	0.10	0.04	0.03	0.04	0.05	0.19	0.30
	SD (Dry)	2.33	0.13	0.03	-	0.04	0.07	0.21	0.26
	Count (Dry)	16	7	3	1	4	3	5	3
	Mean (wet)	0.03	-	0.04	0.23	-	0.01	0.09	0.07
	SD (wet)	0.01	-	-	0.35	-	-	0.02	0.04
	Count (wet)	3	0	1	3	0	1	2	2
Chloride (mg/L)	Mean (Dry)	61.72	115.80	-	-	80.30	91.36	62.47	100.63
	SD (Dry)	24.52	10.18	-	-	13.77	14.91	9.85	11.48
	Count (Dry)	16	7	0	0	3	3	4	2
	Mean (wet)	54.23	-	-	334.97	-	38.81	15.10	56.61
	SD (wet)	5.51	-	-	-	-	-	-	16.40
	Count (wet)	3	0	0	1	0	1	1	2
BOD (mg/L)	Mean (Dry)	2.29	0.57	0.67	2.00	1.99	9.67	0.88	2.50
	SD (Dry)	2.54	0.19	0.29	-	0.82	11.59	0.75	2.12
	Count (Dry)	17	7	3	1	4	3	4	2
	Mean (wet)	1.00	-	0.50	6.33	-	2.00	4.00	1.50
	SD (wet)	0.00	-	-	5.86	-	-	-	0.71
	Count (wet)	3	0	1	3	0	1	1	2
TDS (mg/L)	Mean (Dry)	-	-	-	-	-	-	457.33	620.00
	SD (Dry)	-	-	-	-	-	-	21.01	31.11
	Count (Dry)	0	0	0	0	0	0	3	2
	Mean (wet)	-	-	-	-	-	-	-	397.00
	SD (wet)	-	-	-	-	-	-	-	123.04
	Count (wet)	0	0	0	0	0	0	0	2
TSS (mg/L)	Mean (Dry)	15.56	6.79	41.33	6.00	10.75	29.67	4.50	44.00
	SD (Dry)	21.76	6.99	47.88	-	6.70	34.08	2.38	50.91
	Count (Dry)	16	7	3	1	4	3	4	2
	Mean (wet)	2.00	-	11.00	17.67	-	31.00	82.00	9.50
	SD (wet)	1.73	-	-	10.26	-	-	-	9.19
	Count (wet)	3	0	1	3	0	1	1	2
Fecal Coliform (col/100 ml)	Mean (Dry)	1655	307	838	434	225	2021	337	298
	SD (Dry)	3104	454	2505	753	184	5322	269	372
	Count (Dry)	17	29	20	21	15	22	19	25
	Mean (wet)	70	2365	1170	1122	1598	1844	4816	5505
	SD (wet)	116	2347	1018	1002	1906	2501	7246	7881
	Count (wet)	3	7	9	8	16	9	15	9

Table 5-11 Continued.

EFFCR001		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	1.73	Nitrate-Nitrogen (mg/L)	6.42	8.21	Total Kjeldahl Nitrogen (mg/L)	1.17	2.66
	SD (Dry)	0.00	2.37		1.79	4.98		0.21	2.88
	Count (Dry)	3	2		3	2		3	2
	Mean (wet)	-	0.05		-	5.15		-	0.84
	SD (wet)	-	0.00		-	5.12		-	0.23
	Count (wet)	0	2		0	2		0	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.41	0.19	Phosphorus (mg/L)	0.43	0.32	Chloride (mg/L)	56.36	88.79
	SD (Dry)	0.29	0.18		0.14	0.23		3.51	24.47
	Count (Dry)	3	2		4	3		3	2
	Mean (wet)	-	0.15		-	0.08		-	59.21
	SD (wet)	-	0.18		-	0.06		-	19.93
	Count (wet)	0	2		0	2		0	2
BOD (mg/L)	Mean (Dry)	0.67	1.00	TDS (mg/L)	427.33	604.00	TSS (mg/L)	8.00	5.50
	SD (Dry)	0.29	0.00		70.32	53.74		1.73	2.12
	Count (Dry)	3	2		3	2		3	2
	Mean (wet)	-	1.50		-	402.00		-	5.50
	SD (wet)	-	0.71		-	124.45		-	2.12
	Count (wet)	0	2		0	2		0	2
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	1214	222	219	265	246	393	240	230
	SD (Dry)	3223	366	350	433	412	608	259	375
	Count (Dry)	25	23	20	23	15	22	19	25
	Mean (wet)	402	753	877	825	1410	1486	3432	1378
	SD (wet)	607	707	643	787	1877	1638	4009	1492
	Count (wet)	3	7	9	8	16	9	15	9

Table 5-12 Summary of selected water chemistry parameters at LTMN locations in Floyds Fork watershed.

EFFFF001		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.08	Nitrate-Nitrogen (mg/L)	1.03	0.57	Total Kjeldahl Nitrogen (mg/L)	0.55	0.86
	SD (Dry)	-	0.04		-	0.24		-	0.34
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.05		0.85	1.19		1.19	0.95
	SD (wet)	0.00	0.00		0.17	0.27		0.45	0.21
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.16	0.03	Phosphorus (mg/L)	0.06	0.32	Chloride	16.31	31.66
	SD (Dry)	-	0.00		-	0.41		-	27.04
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.14	0.18		0.22	0.20		9.92	17.47
	SD (wet)	0.01	0.06		0.09	0.23		0.87	15.73
	Count (wet)	2	2		3	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	404.00	433.00	TSS (mg/L)	6.00	6.00
	SD (Dry)	-	1.06		-	91.92		-	1.41
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	2.00	2.48		267.00	216.00		102.50	55.00
	SD (wet)	1.41	0.74		7.07	147.08		118.09	36.77
	Count (wet)	2	2		2	2		2	2
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	245	919	515	236	803	225	898	338
	SD (Dry)	841	2332	785	349	2611	252	2676	526
	Count (Dry)	22	30	29	22	18	20	17	23
	Mean (wet)	2427	-	-	1271	1605	2842	2029	5383
	SD (wet)	3952	-	-	2270	2147	6836	3543	10381
	Count (wet)	7	0	0	9	13	11	15	11

Table 5-12 Continued.

EFFFF003		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.00	2.71	Total Kjeldahl Nitrogen (mg/L)	0.66	0.84
	SD (Dry)	0.00	0.00		0.07	3.24		0.16	0.05
	Count (Dry)	3	2		3	2		3	2
	Mean (wet)	-	0.05		-	1.78		-	0.64
	SD (wet)	-	0.00		-	0.83		-	0.16
	Count (wet)	0	2		0	2		0	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.12	0.08	Phosphorus (mg/L)	0.15	0.08	Chloride	21.53	52.59
	SD (Dry)	0.04	0.01		0.04	0.07		5.63	44.84
	Count (Dry)	3	2		4	2		3	2
	Mean (wet)	-	0.11		-	0.11		-	38.90
	SD (wet)	-	0.02		-	0.11		-	11.36
	Count (wet)	0	2		0	2		0	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	326.00	472.00	TSS (mg/L)	9.00	9.00
	SD (Dry)	0.00	1.06		72.08	93.34		5.29	4.24
	Count (Dry)	3	2		3	2		3	2
	Mean (wet)	-	2.50		-	342.00		-	13.50
	SD (wet)	-	2.12		-	84.85		-	16.26
	Count (wet)	0	2		0	2		0	2
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	151	492	690	447	898	1177	2684	164
	SD (Dry)	288	1213	1065	678	1377	2623	12009	186
	Count (Dry)	19	30	29	31	31	31	29	23
	Mean (wet)	466	-	-	-	-	-	1225	1062
	SD (wet)	357	-	-	-	-	-	916	2619
	Count (wet)	8	0	0	0	0	0	5	11
EFFFF002		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.24	2.90	Total Kjeldahl Nitrogen (mg/L)	0.79	0.77
	SD (Dry)	0.00	0.00		0.19	3.39		0.05	0.23
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.03	0.05		1.08	1.01		0.96	0.97
	SD (wet)	-	0.00		-	0.16		-	0.05
	Count (wet)	1	2		1	2		1	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.15	0.07	Phosphorus (mg/L)	0.15	0.11	Chloride	19.22	56.24
	SD (Dry)	0.01	0.07		0.05	0.10		3.25	42.96
	Count (Dry)	2	2		3	2		2	2
	Mean (wet)	0.13	0.07		0.14	0.13		21.53	24.62
	SD (wet)	-	0.03		-	0.14		-	20.72
	Count (wet)	1	2		1	2		1	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	364.00	492.00	TSS (mg/L)	14.00	15.50
	SD (Dry)	0.00	1.06		45.25	124.45		11.31	6.36
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.50	2.50		276.00	304.00		12.00	31.50
	SD (wet)	-	0.71		-	73.54		-	6.36
	Count (wet)	1	2		1	2		1	2
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	-	196	1070	321	661	1523	153	312
	SD (Dry)	-	333	3394	492	888	6505	119	724
	Count (Dry)	0	22	23	23	14	23	16	25
	Mean (wet)	-	1069	3382	565	1325	547	2387	1571
	SD (wet)	-	1173	4017	780	1333	917	4077	3383
	Count (wet)	0	8	6	8	17	8	18	9

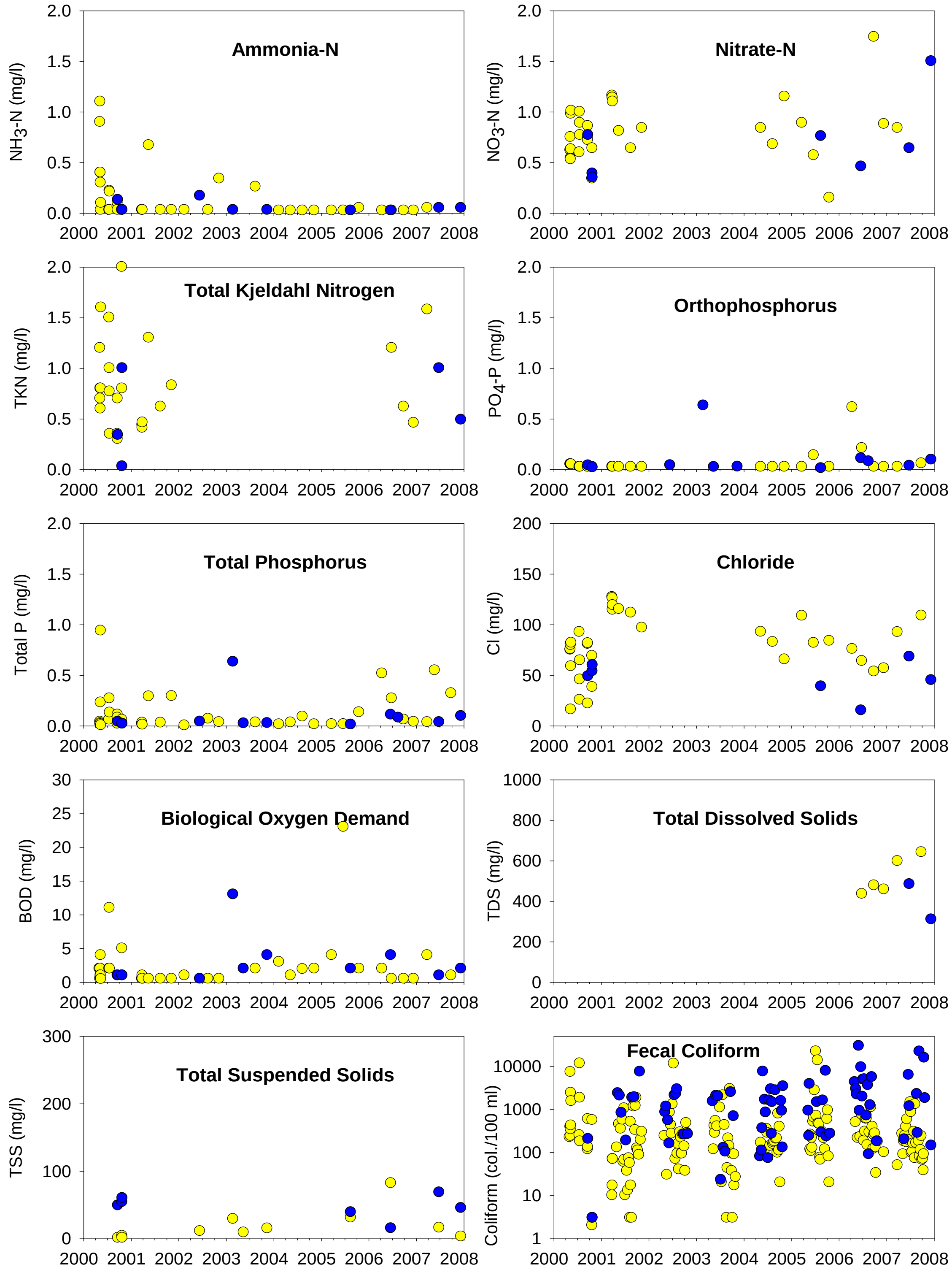

Figure 5-1 Major water chemistry parameters measured at EFFCR002 location in Chenoweth Run watershed. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

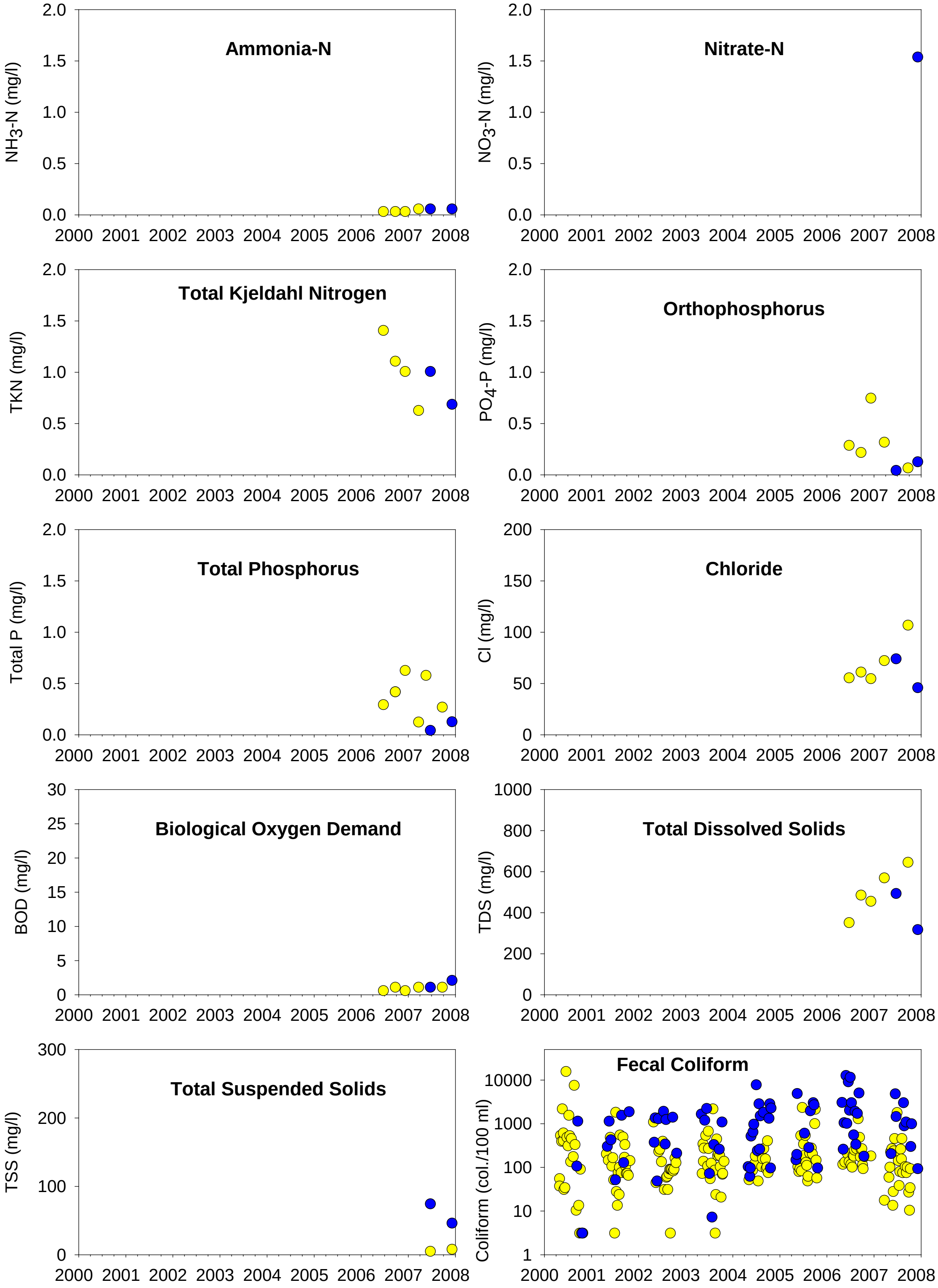

Figure 5-1 Continued, at EFFCR001 location.

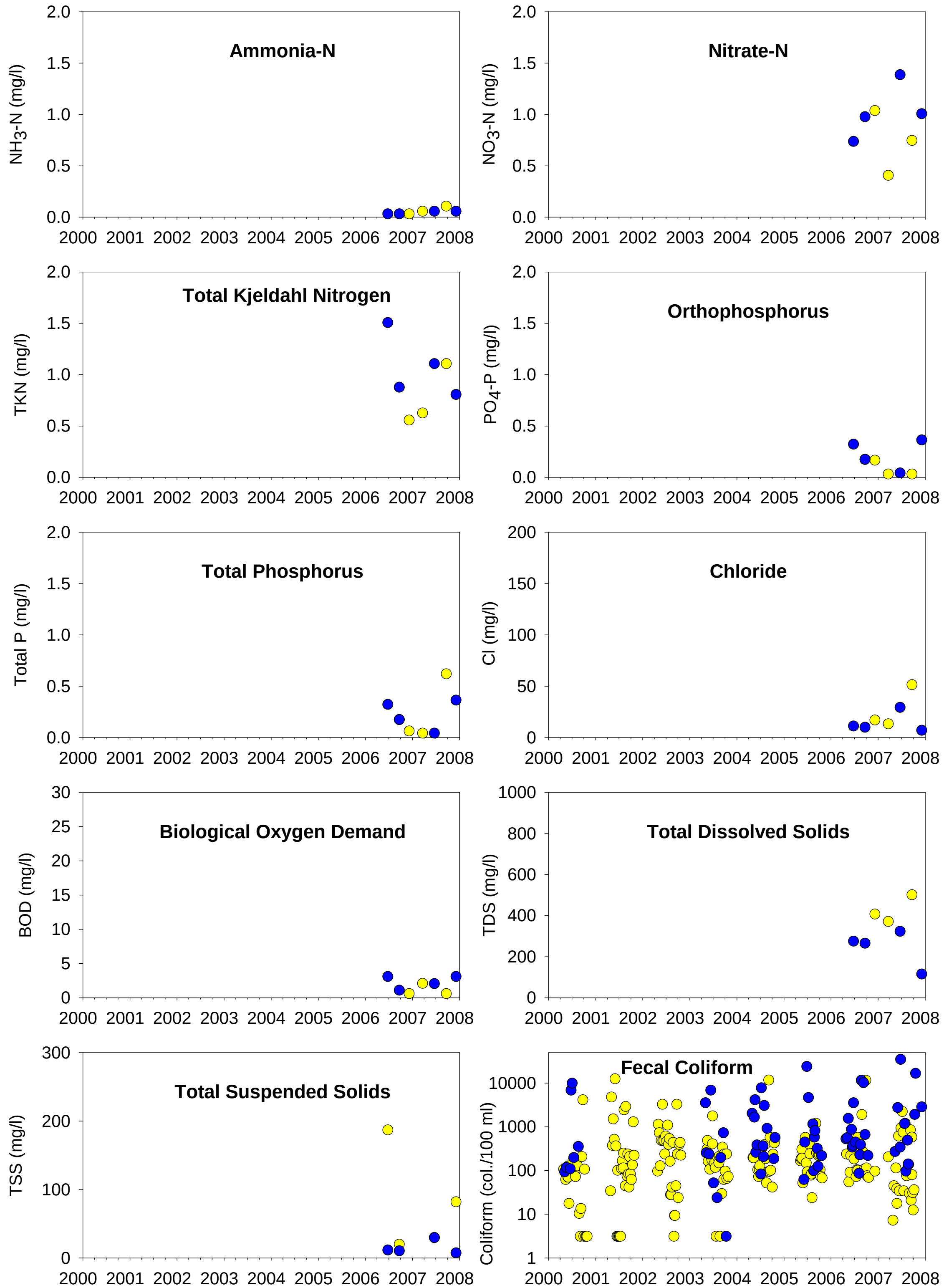

Figure 5-2 Major water chemistry parameters measured at EFFFF001 location in Floyds Fork watershed.

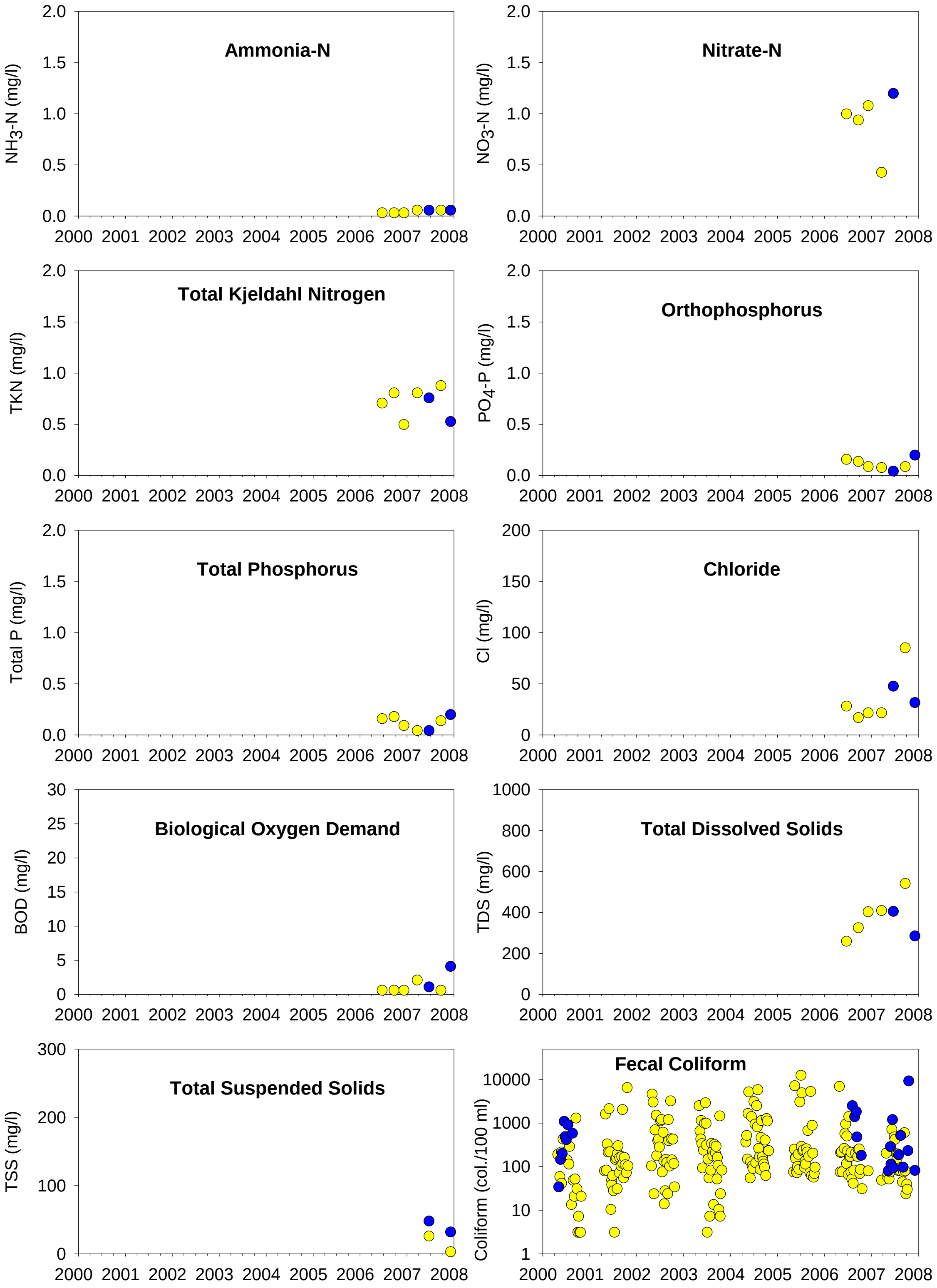

Figure 5-2 Continued, at EFFFF003 location.

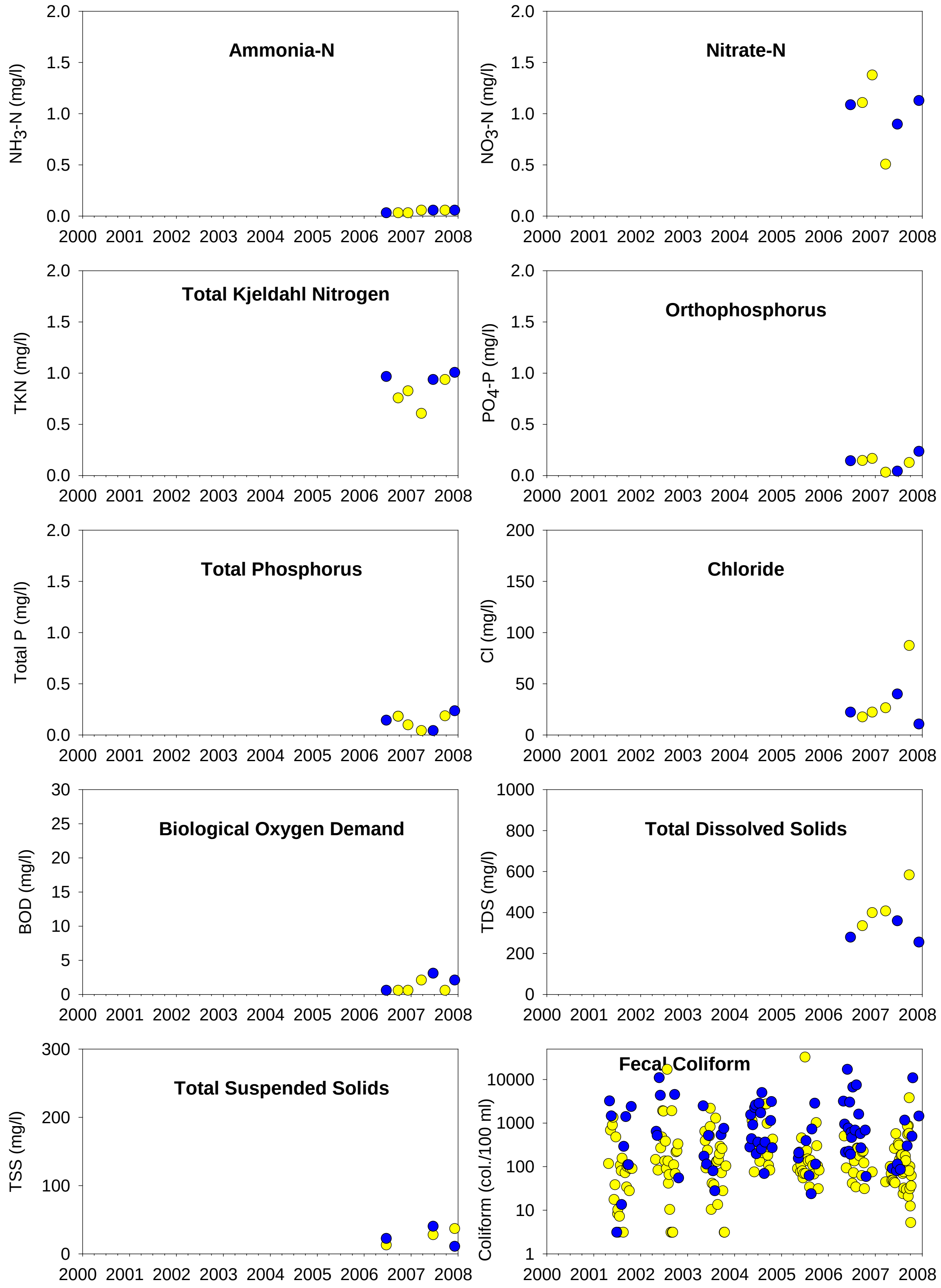

Figure 5-2 Continued, at EFFFF002 location.

Chapter 6 Goose Creek Watershed

6.1 Watershed Physical Characteristics

Goose Creek originates in Anchorage area and E. P. "Tom" Sawyer Park. It flows northwest toward the Ohio River. There are two LTMN locations in Goose Creek, upstream at Old Westport Road (EGCGC001) and downstream at US Hwy 42 (EGCGC002).

Little Goose Creek originates in the Indian Springs community and flows in the northwest direction. There is a LTMN location at US Hwy 42 (EGCLG001). It merges with Goose Creek downstream of EGCGC002. This report analyzes these two watersheds separately, since LTMN locations of two watersheds do not intersect each other.

The Goose Creek watershed contains almost half of its area developed lands of varying degrees with 10% of impervious surface coverage assessed at both LTMN locations (Table 6-1). The upstream portion of Goose Creek watershed is slightly more developed (53% developed and 36% forests) than the downstream portion (49% developed and 39% forests) based on the cumulative watershed landuse. The riparian buffer area is more impacted in the upstream (18.4%) portion of the Goose Creek watershed than the downstream portion (0.8%), based on the reach-scale (1000 meter from the LTMN location) riparian buffer zone imperviousness.

Little Goose Creek also contains about 65% of developed areas and 27% of forests with 18% of impervious coverage based on the landuse estimated at EGCLG001 location (Table 6-2). The watershed improves its quality in terms of its landuse pattern, which is evidenced by the reach-scale riparian buffer zone containing less imperviousness along the downstream gradient; 0% imperviousness for reach-scale (1000 meters from the LTMN location) buffer zone.

6.2 Biological Data

6.2.1 Diatom

EGCGC001: the overall water quality of Goose Creek at Old Westport Road (EGCGC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Good' (Table 6-3). The overall mean score of 47 reflects the lower range of 'Good' scores. In general, these data suggest water quality of Goose Creek at Old Westport Road seems to be declining somewhat over time (Table 6-3). Specifically, during the 2001 - 2003 sampling seasons, 74% of sample dates characterized water quality as 'Good' (mean DBI = 48). In contrast, during the 2005 sampling season, mean overall water quality was characterized as 'Fair' as only 30% of samples scored in the 'Good' range (mean DBI = 44).

The taxa richness (TR) yearly mean score increased from year 2001 (39) to 2002 (43) but decreased during 2005 (33) (Table 6-3). These data suggest that a number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score increased from year 2001 (68) to 2002 (75) but decreased during 2005 (70) (Table 6-3). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability

The siltation index (%NNS) yearly mean score increased from year 2001 (54) to 2003 (68) but decreased during 2005 (62) (Table 6-3). These data suggest that overall species composition shifted slightly away from those species adapted to living on silts and shifting sediments. In general, an increase in overall %NNS suggests a slight improvement in water quality. Loss of taxa within the genera *Navicula* and *Nitzschia* during 2005 may have contributed to the reduced TR that year.

The Shannon diversity index (SDI) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values throughout the study period were moderate and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly FGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. Loss of taxa within the Fragilaria group during 2005 may have contributed to the reduced TR that year.

The cymbella group richness (CGR) yearly mean score increased from year 2001 (9) to 2002 (18) but decreased during 2005 (6) (Table xx). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be deteriorating slightly. Loss of taxa within the Cymbella group during 2005 may have contributed to the reduced TR that year.

EGCGC002: The overall water quality of Goose Creek at US Highway 42 (EGCGC002) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Good' (Table 6-3). The overall mean score of 46 reflects the lower range of 'Good' scores. In general, these data suggest water quality of Goose Creek at US Highway 42 seems to be declining somewhat over time (Table 6-3). Specifically, during the 2001 – 2002 sampling seasons, 83% of sample dates characterized water quality as 'Good' (mean DBI = 48). In contrast, during subsequent sampling seasons (2003, 2005), mean overall water quality was characterized as 'Fair' as only 40% of samples scored in the 'Good' range (mean DBI = 45).

The taxa richness (TR) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability

The siltation index (%NNS) yearly mean score decreased from year 2001 (69) to 2005 (54) (Table 6-3). These data suggest that overall species composition shifted toward those species adapted to living on silts and shifting sediments. In general, a decrease in overall %NNS suggests a decline in water quality.

The Shannon diversity index (SDI) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values throughout the study period were moderate and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (25) to 2003 (5) but increased during 2005 (14) (Table 6-3). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be deteriorating slightly.

The cymbella group richness (CGR) yearly mean score decreased from year 2001 (11) to 2005 (5) (Table 6-3). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be deteriorating slightly.

EGCLG001: The overall water quality of Little Goose Creek at US Highway 42 (EGCLG001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Good' (Table 6-3). The overall mean score of 46 reflects the lower range of 'Good' scores. In general, these data suggest water quality of Little Goose Creek at US Highway 42 seems to be improving somewhat over time (Table 6-3). Specifically, during the 2001 – 2002 sampling seasons, 61% of sample dates characterized water quality as 'Good' (mean DBI = 46). During subsequent sampling seasons (2003, 2005), mean overall water quality was also characterized as 'Good' as 73% of samples scored in the 'Good' range (mean DBI = 47).

The taxa richness (TR) yearly mean score decreased from year 2001 (35) to 2003 (31), but increased during 2005 (38) (Table 6-3). Small, yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score increased from year 2001 (69) to 2003 (79), but decreased during 2005 (79) (Table 6-3). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The siltation index (%NNS) yearly mean score increased from year 2001 (59) to 2003 (85) but decreased during 2005 (66) (Table 6-3). These data suggest that overall species composition shifted away from those species adapted to living on silts and shifting sediments. In general, an increase in overall %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (89) to 2003 (74), but increased during 2005 (91) (Table 6-3). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values during 2001 and 2005 were moderate and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly FGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. An overall decrease with respect to this metric suggests site water quality may be deteriorating slightly.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 6-3). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. These taxa are widely considered to be indicators of good water quality. An overall increase with respect to this metric suggests site water quality may be improving slightly.

6.2.2 Macroinvertebrates

The macroinvertebrate communities at the two sites in the main stem Goose Creek were rated as 'fair' by the MBI in 2000 and 2004, but rated as 'poor' in 2005 (Table 6-4). The upstream site (EGCGC001) on the Goose Creek exhibited a slightly larger reduction in the MBI score from 2000 (48.5) to 2005 (33.0). However, overall MBI scores and MBI component metric scores were similar at the two sites. The lower MBI scores in 2005 were mainly due to the reduced taxa richness. There were 23 (EGCGC001) and 19 (EGCGC002) less taxa were collected during 2005 than 2000. In addition, EPT richness decreased by more than 50% from 2000 to 2005 in EGCGC001. Other metric scores were relatively consistent from 2000 to 2005 at these two sampling stations.

The MBI ratings in Little Goose Creek changes from ‘fair’ in 2003 to ‘good’ in 2004, then ‘fair’ in 2000 (Table 6-4). Again, one of the biggest differences from 2000 to 2005 was reduced taxa richness with 20 fewer taxa recorded in 2005 than 2000. This, however, was offset by increases in the % Clinger, % Chir. and Oli., and mHBI metrics in 2005, which ultimately resulted in the similar MBI scores in 2000 and 2005. The ‘good’ rating in 2004 was related to high scores for % Clinger and %Chir and Oli during this sampling year. The values for these two metrics were considerably higher in 2004 than they were in both 2000 and 2005.

6.2.3 Fish

The water quality rating based on fish IBI score was ‘good’ at both LTMN locations in the Goose Creek during 2005 (Table 6-5). It was an improvement in fish IBI ratings in the upstream location (EGCGC001) from previous years. Historically, during years 2000-2005, both sites had ‘fair’ to ‘good’ ratings and the overall fish IBI scores remain stable (44-51 at EGCGC001; 49-67 at EGCGC002). The downstream location (EGCGC002) always had better water quality ratings due to the higher native species richness metric scores than upstream location (EGCGC001).

In Little Goose Creek, the fish IBI based water quality rating fluctuated from ‘very poor’ (2000), to ‘fair’ (2002 and 2005), and to ‘good’ (2003) (Table 6-5). The metric scores for native species richness (NAT) were higher in 2003 (80) when the fish IBI rating was ‘good’ than surveys in 2002 (63) and 2005 (76).

6.3 Hydrolab Data

6.3.1 Stream metabolism

The two LTMN locations in Goose Creek had similar gross primary production estimates, while the community respiration was higher at the downstream location (EGCGC002) than upstream location (EGCGC001) (Table 6-6). GPP estimates during spring (5.4-7.4 g O_2/m^2/day) were higher than estimates during summer (1.2-4.3 g O_2/m^2/day) and fall (0.6-3.7 g O_2/m^2/day) in the upstream location of Goose Creek (EGCGC001) (Table 6-7). Community respiration was highest during fall (5.7-12.7 g O_2/m^2/day) in EGCGC001 location. Similar seasonal patterns of GPP and CR were observed in the downstream location of Goose Creek (EGCGC002) (Table 6-6).

Clear seasonal patterns in GPP and CR could not be derived at the Little Goose Creek location (EGCLG001) due to the lack of available data during summer and fall (Table 6-7). However, spring GPP estimates (2.7-4.0 g O_2/m^2/day) were higher than other seasons.

6.3.2 Dissolved oxygen, pH, and conductivity

There was not much of year-to-year variation in DO, pH, and conductivity values in Goose Creek (Table 6-8) and Little Goose Creek (Table 6-9). In Goose Creek, daily average DO concentrations were highest during winter, followed by spring, and they were similar in summer and fall (Table 6-8). Daily mean DO stayed above 5 mg/L throughout the year, but daily minimum values dropped below 4 mg/L occasionally during summer and fall in Goose Creek. The daily mean pH values were mostly higher than 7 except on a few occasions (e.g., spring

2006 and summer 2002 at EGCGC0001) in Goose Creek. Long-term average pH was slightly higher at the downstream location (8.1) than upstream location (7.9). Conductivity values were seasonally highly variable throughout Goose Creek, and it was highest during fall.

The daily average DO was highest during winter and lowest during summer in Little Goose Creek (Table 6-9). There were several occasions when mean daily DO was below 5 mg/L at this location, especially during summer and fall. Lack of dependable DO data measurements during summer and fall made impossible to provide a seasonal comparison in Little Goose Creek. The pH values stayed above7, and they were higher during spring and winter than summer and fall. Conductivity was highly variable when compared to year-to-year, and it was higher during spring (594 µS/cm) and winter (627 µS/cm) than summer (545 µS/cm) and fall (544 µS/cm) on average (Table 6-10).

6.4 Laboratory Data

Water chemistry data were collected only during years 2006 and 2007 except fecal coliform counts in Goose Creek (Table 6-10, Figure 6-1). The most water chemistry parameters were higher in downstream location (EGCGC002) than upstream location (EGCGC001). Nitrate-nitrogen concentrations were similar in upstream (1.34-1.47 mg/L from dry samples; 1.49-1.64 mg/L from wet samples) and downstream (1.06-1.72 mg/L from dry samples; 1.33-1.49 from wet samples) locations. Ammonia-nitrogen and ortho-phosphorus concentrations were below their detection limits. Chloride concentration and fecal coliform counts were much higher in downstream location than upstream location for both dry and wet samples (Table 6-10). Fecal coliform counts were higher in the samples collected during ‘wet’ period.

The nitrate-nitrogen concentration in Little Goose Creek (1.18-1.83 mg/L from dry samples; 1.42-1.95 mg/L from wet samples) was in the similar range as in Goose Creek (Table 6-11, Figure 6-2). Both ammonia-nitrogen and ortho-phosphorus concentrations were below their detection limits. Chloride concentration considerably higher during 2007 dry samples (91 mg/L) than other sample groups (27-40 mg/L) in Little Goose Creek (Table 6-11), which warrants further investigation in the future.

6.5 Watershed assessment based on the biological data

The water quality ratings of two locations at Goose Creek (EGCGC001 and EGCGC002) could be considered as ‘fair’ based on the combined biotic integrity indices on 2005. In EGCGC001, the diatom and macroinvertebrate maintained ‘good’ and ‘fair’ ratings until 2004, respectively, but were lower on 2005 with ‘fair’ and ‘poor’. However, the fish index was improved from ‘fair’ to ‘good’ during the same period in EGCGC001. All three biotic indices in EGCGC002 location were slightly lower in 2005 surveys than previous surveys. Water quality rating at Little Goose Creek could be also considered as ‘fair’. The three indices improved slightly over the time period of 2000-2005 in Little Goose Creek.

EGCGC001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	good	good	good	—	**fair**
MBI	fair	—	—	—	fair	**poor**
Fish KBI	fair	—	fair	fair	—	**good**
EGCGC002						
DBI	—	good	good	good		**fair**
MBI	fair	—	—	—	fair	**poor**
Fish KBI	good	—	fair	excellent	—	**good**
EGCLG001						
DBI	—	fair	good	good	—	**good**
MBI	fair	—	—	—	good	**fair**
Fish KBI	very poor	—	fair	good	—	**fair**

Table 6-1 Land use/cover characteristic of Goose Creek watershed.

EGCGC001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	10.61	5.04	18.41
Open Water	0.31	1.05	0.00
Dev. Open Space	15.02	6.51	40.81
Dev. Low Intensity	32.67	23.52	21.08
Dev. Medium Intensity	3.92	1.41	24.66
Dev. High Intensity	0.92	0.26	0.00
Barren Land	0.00	0.00	0.00
Deciduous Forest	33.92	55.98	13.45
Evergreen Forest	1.86	2.42	0.00
Mixed Forest	0.08	0.10	0.00
Shrub/Scrub	0.00	52.00	0.00
Grassland/herbaceous	0.87	0.67	0.00
Pasture/Hay	9.88	8.09	0.00
Cropland	0.55	0.00	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
EGCGC002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	9.92	3.91	0.75
Open Water	0.28	0.96	0.00
Dev. Open Space	17.65	4.93	10.80
Dev. Low Intensity	27.31	17.05	63.38
Dev. Medium Intensity	3.35	1.03	13.15
Dev. High Intensity	0.65	0.17	0.00
Barren Land	0.02	0.00	0.00
Deciduous Forest	36.33	65.34	10.80
Evergreen Forest	2.42	2.43	0.00
Mixed Forest	0.06	0.06	0.00
Shrub/Scrub	0.00	0.00	0.00
Grassland/herbaceous	1.85	1.27	0.00
Pasture/Hay	8.58	6.52	1.88
Cropland	1.50	0.19	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.04	0.00

Table 6-2 Land use/cover characteristic of Little Goose Creek watershed.

EGCLG001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	18.09	7.58	0.00
Open Water	0.20	0.83	0.00
Dev. Open Space	22.38	12.61	0.95
Dev. Low Intensity	28.17	16.54	6.64
Dev. Medium Intensity	10.42	5.22	0.00
Dev. High Intensity	4.50	1.31	0.00
Barren Land	0.04	0.09	0.00
Deciduous Forest	26.09	56.51	91.47
Evergreen Forest	1.28	0.89	0.95
Mixed Forest	0.05	0.20	0.00
Shrub/Scrub	0.00	0.00	0.00
Grassland/herbaceous	0.26	0.11	0.00
Pasture/Hay	6.13	5.69	0.00
Cropland	0.49	0.00	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00

Table 6-3 DBI scores estimated in Goose Creek and Little Goose Creek watersheds.

EGCGC001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	39	68	54	91	13	9	**46**	**GOOD**
2002	43	75	67	89	4	18	**49**	**GOOD**
2003	42	70	68	92	15	8	**49**	**GOOD**
Summer 05	34	72	75	83	8	3	**46**	**GOOD**
Fall 05	33	67	49	85	13	8	**43**	**FAIR**
2005 All	33	70	62	84	10	6	**44**	**FAIR**
Overall	**39**	**71**	**62**	**89**	**10**	**10**	**47**	**GOOD**
EGCGC002	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	36	73	69	87	25	11	**50**	**GOOD**
2002	41	71	58	90	7	11	**46**	**GOOD**
2003	36	72	70	84	5	6	**46**	**GOOD**
Summer 05	34	74	73	85	13	3	**47**	**GOOD**
Fall 05	35	67	35	78	15	6	**40**	**FAIR**
2005 All	35	71	54	82	14	5	**43**	**FAIR**
Overall	**37**	**72**	**61**	**86**	**14**	**8**	**46**	**GOOD**
EGCLG001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	35	69	59	89	9	3	**44**	**FAIR**
2002	32	78	81	73	3	15	**47**	**GOOD**
2003	31	79	85	74	8	6	**47**	**GOOD**
Summer 05	38	73	71	90	5	13	**49**	**GOOD**
Fall 05	38	66	60	92	5	9	**45**	**FAIR**
2005 All	38	70	66	91	5	11	**47**	**GOOD**
Overall	**35**	**73**	**71**	**83**	**6**	**9**	**46**	**GOOD**

Table 6-4 Macroinvertebrate biotic integrity scores in Goose Creek and Little Goose Creek watersheds.

Year	**Metric**	**EGCGC001**		**EGCGC002**		**EGCLG001**	
		Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness	59	111.32	54	101.89	59	111.32
	EPT Richness	11	33.33	11	33.33	8	24.24
	m%EPT	10	11.51	5	5.75	16	18.41
	mHBI	7.02	38.11	7.03	37.98	6.27	47.70
	%Chir. and Oli.	7	93.64	4	96.66	52	48.33
	%Clinger	38	50.33	19	25.17	28	37.09
	%Ephemerotpera	1	1.50	1	1.50	4	6.02
	MBI	--------	48.53	--------	43.18	--------	41.87
	Assessment	**--------**	**Fair**	**--------**	**Fair**	**--------**	**Fair**
2004	Taxa Richness	42	56.76	37	50	35	47.3
	EPT Richness	9	30	7	23.33	5	16.67
	m%EPT	11.5	15.75	19.1	26.16	32.2	44.11
	mHBI	5.62	63.57	6.21	55.01	5.16	70.25
	%Chir. and Oli.	13.7	87.17	5.6	95.35	8.4	92.53
	%Clinger	51.1	69.05	48.0	64.86	79.0	106.76
	MBI	--------	53.72	--------	52.45	--------	62.93
	Assessment	**--------**	**Fair**	**--------**	**Fair**	**--------**	**Good**
2005	Taxa Richness	36	57.14	35	55.56	39	61.90
	EPT Richness	5	15.15	8	24.24	7	21.21
	m%EPT	1.78	2.04	6.23	7.17	12.93	14.88
	mHBI	7.421	32.98	5.92	52.15	5.58	56.51
	%Chir. and Oli.	5.03	95.62	12.46	88.13	40.69	59.71
	%Clinger	19.23	25.47	17.56	23.26	41.96	55.57
	%Ephemerotpera	1.78	2.67	4.25	6.39	3.15	4.74
	MBI	--------	33.01	--------	36.70	--------	39.22
	Assessment	**--------**	**Poor**	**--------**	**Poor**	**--------**	**Fair**

Table 6-5 Fish IBI scores in Goose Creek and Little Goose Creek watersheds.

Site	**EGCGC001**	**EGCGC002**	**EGCLG001**
1999-up	**NS**	**poor**	**very poor**
1999-dn	**NS**	**good/excellent**	**very poor**
2000-up	**poor**	**good**	**very poor**
2000-dn	**fair**	**good**	**very poor**
2002	**fair**	**fair**	**fair**
Native	62	65	63
DMS	28	21	39
INT	28	21	41
WC	51	40	70
SL	45	62	45
%Insect_Ex_Tol	34	63	50
%OMNI	61	66	50
%TOL	40	62	50
IBI	44	50	51
2003	**fair**	**excellent**	**good**
Native	53	79	80
DMS	37	52	71
INT	26	33	28
WC	48	89	90
SL	43	62	69
%Insect_Ex_Tol	50	63	50
%OMNI	73	81	50
%TOL	60	77	50
IBI	49	67	61
2005	**good**	**good**	**fair**
NAT	70	78	76
DMS	35	51	58
INT	39	34	28
SL	51	69	53
%INSCT	100	49	50
%TOL	39	78	50
%FHW	41	15	18
KIBI	51	49	43

Table 6-6 Gross primary production and community respiration in Goose Creek watershed.

	Spring		**Summer**		**Fall**	
EGCGC001	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	7.40	7.46	4.25	5.57	—	—
2001	—	—	2.62	6.73	2.53	11.15
2002	7.01	8.20	2.04	6.71	—	—
2003	5.38	12.63	2.84	5.44	3.71	11.09
2004	—	—	1.24	3.33	1.17	11.63
2005	5.69	8.59	2.77	7.06	0.64	12.70
2006	—	—	1.72	7.89	2.64	5.66
2007	5.52	6.37	2.01	4.50	—	—
	Spring		**Summer**		**Fall**	
EGCGC002	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	7.33	13.09	—	—	—	—
2001	—	—	2.23	7.23	1.34	1.01
2002	7.76	12.78	3.45	4.69	1.85	16.16
2003	9.28	9.71	2.56	6.39	1.65	13.77
2004	14.48	13.72	1.34	10.33	0.54	10.61
2005	9.83	9.97	—	—	—	—
2006	8.02	14.58	—	—	1.36	11.16
2007	6.95	5.48	2.27	6.91	3.31	14.22

Table 6-7 Gross primary production and community respiration in Little Goose Creek watershed.

	Spring		**Summer**		**Fall**	
EGCLG001	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	3.32	10.69	1.17	8.35	—	—
2001	—	—	0.61	6.49	—	—
2002	4.02	8.19	—	—	—	—
2003	3.80	7.63	1.90	13.60	—	—
2004	3.89	9.16	—	—	0.24	9.68
2005	2.73	6.25	—	—	—	—
2006	3.87	8.81	1.00	12.25	1.06	19.73
2007	3.53	10.26	—	—	—	—

Table 6-8 Daily water temperature, DO, pH, and conductivity in the Goose Creek watershed, at EGCGC001 location.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.9	10.6	18.1	10.47	7.36	14.49	8.12	7.69	8.63	495.6	439.4	526.8
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.2	9.3	15.8	10.23	7.35	14.53	8.46	8.03	9.03	421.3	367.0	460.3
2003	15.5	11.0	20.7	7.41	4.84	11.02	7.32	7.12	7.72	549.2	484.3	583.6
2004	13.7	9.7	18.4	—	—	—	8.00	7.67	8.43	549.9	502.4	584.2
2005	15.9	11.4	21.1	9.19	6.36	12.85	7.55	7.22	8.00	544.5	497.4	574.8
2006	14.7	11.3	19.2	—	—	—	6.87	6.73	7.08	451.1	398.7	479.7
2007	8.5	6.7	10.5	11.54	9.15	14.85	8.35	8.07	8.75	525.7	510.5	538.7

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	23.5	21.1	26.2	7.92	5.14	11.69	7.77	7.46	8.06	522.9	389.3	578.8
2001	23.1	20.9	25.4	6.08	4.29	8.66	7.62	7.40	7.90	446.7	417.6	477.6
2002	23.5	21.7	25.4	5.37	4.01	7.26	6.97	6.30	7.66	554.6	485.8	628.3
2003	23.3	21.2	25.4	7.07	5.34	9.79	7.93	7.76	8.14	540.5	403.4	575.7
2004	20.6	19.1	22.5	7.74	6.90	8.93	7.56	7.35	7.88	303.6	266.6	330.0
2005	24.1	22.3	26.0	5.36	3.04	8.42	7.72	7.58	7.91	731.7	705.6	761.4
2006	20.9	18.8	23.1	5.24	4.07	6.95	8.16	7.94	8.39	529.1	495.0	552.2
2007	23.3	20.8	26.1	6.90	5.19	8.90	7.91	7.77	8.08	570.6	528.3	606.5

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.6	12.6	16.9	7.43	5.98	9.08	7.78	7.56	8.00	577.6	460.1	622.5
2002	13.4	12.1	15.0	—	—	—	8.02	7.90	8.22	563.3	556.9	573.2
2003	16.0	13.6	18.9	7.56	5.92	9.86	8.22	8.07	8.44	604.9	580.9	619.6
2004	15.0	13.3	16.7	6.39	5.03	7.72	7.68	7.57	7.79	581.4	572.3	590.7
2005	15.4	13.8	16.9	5.43	3.99	7.14	7.61	7.51	7.71	453.7	449.6	458.4
2006	16.4	14.4	18.5	8.80	7.62	10.42	8.08	7.99	8.19	599.8	594.2	604.2
2007	—	—	—	—	—	—	—	—	—	—	—	—

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	5.5	3.8	7.4	11.27	9.27	14.61	8.07	7.86	8.43	600.2	550.1	659.8
2003	1.7	0.5	2.9	16.18	14.34	17.84	8.38	7.27	8.67	562.6	486.6	577.8
2004	5.0	3.5	6.6	12.62	10.84	15.36	8.00	7.78	8.36	498.8	465.7	523.6
2005	4.4	3.0	5.9	12.42	11.34	14.04	8.25	8.13	8.49	499.4	491.1	506.8
2006	8.9	7.6	10.3	11.04	9.97	12.74	7.72	7.52	7.98	424.0	353.5	464.8
2007	7.7	6.4	9.4	10.95	8.73	12.94	8.01	7.85	8.11	499.9	465.2	508.6

Table 6-8 Continued, at EGCGC002 location.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.2	11.2	15.3	9.15	6.90	12.57	8.48	8.15	8.92	509.4	482.1	528.9
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	11.6	9.8	13.8	9.64	7.05	13.54	8.38	8.03	8.86	500.3	469.9	524.5
2003	14.7	12.3	17.2	10.00	7.07	14.82	7.44	7.01	7.92	569.3	382.5	597.0
2004	12.9	10.5	15.8	10.70	6.63	17.85	8.45	7.69	9.01	560.5	504.3	599.4
2005	15.0	12.6	18.2	10.01	5.66	15.51	8.25	7.73	8.81	537.8	494.0	565.8
2006	14.6	12.5	20.5	8.26	5.43	13.94	8.14	7.64	8.78	447.2	388.1	588.4
2007	8.0	6.8	17.4	12.04	10.04	18.53	8.55	7.86	8.90	533.8	512.9	545.3

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	21.8	20.7	23.0	7.23	6.45	8.49	7.53	7.43	7.64	429.7	410.8	452.6
2002	22.4	14.8	23.6	8.51	7.53	10.10	7.99	7.88	8.15	481.7	455.8	557.8
2003	21.9	13.3	22.9	7.67	6.82	9.34	8.27	7.50	8.37	572.5	426.8	617.8
2004	20.5	15.2	21.5	6.28	5.70	8.16	7.67	7.51	7.81	313.9	275.4	551.3
2005	22.3	19.0	23.3	9.21	5.40	11.55	7.20	7.17	7.74	649.5	569.5	662.6
2006	21.3	19.4	22.4	4.64	4.07	15.71	7.96	7.74	8.12	572.7	441.1	688.0
2007	22.7	18.7	24.2	7.46	6.30	17.56	8.09	7.87	8.21	550.1	522.3	577.6

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	13.2	12.2	14.9	10.43	9.49	11.47	7.91	7.73	8.04	571.3	458.1	628.3
2002	12.5	11.7	16.8	6.33	5.18	10.01	9.74	8.04	9.82	774.7	562.4	798.2
2003	14.3	11.5	15.2	6.99	6.47	9.94	8.17	7.65	8.24	611.5	515.0	619.8
2004	12.5	11.8	17.1	7.80	6.56	8.50	8.01	7.72	8.07	433.1	427.2	552.1
2005	56.7	19.2	58.9	5.15	4.70	13.86	7.91	7.72	7.98	470.3	465.1	580.0
2006	15.4	14.2	19.7	7.49	6.54	15.34	8.26	7.81	8.31	427.1	411.7	550.8
2007	20.7	20.1	21.2	5.61	3.36	17.50	7.68	7.52	7.91	715.8	573.3	739.8

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	4.2	3.0	5.2	12.37	11.16	14.19	8.17	8.02	8.38	636.8	607.2	687.3
2003	0.4	0.1	16.2	15.19	9.13	16.59	7.78	7.46	8.00	543.1	526.6	563.9
2004	3.7	2.7	11.8	8.54	7.93	10.20	8.40	7.75	8.62	316.9	308.6	529.7
2005	3.2	2.1	17.1	19.08	5.88	19.95	8.34	7.74	8.47	454.4	448.5	552.2
2006	8.5	7.3	19.5	10.61	9.84	13.85	7.87	7.67	8.05	378.5	330.5	582.9
2007	12.8	12.3	16.7	13.63	12.96	16.26	7.88	7.52	7.94	466.2	415.4	448.3

Table 6-9 Daily water temperature, DO, pH, and conductivity in the Little Goose Creek watershed, at EGCLG001 location.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.1	10.7	15.9	7.73	5.25	9.98	8.30	8.08	8.52	579.3	557.0	597.9
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	11.4	9.1	14.1	9.60	7.85	11.80	8.23	7.99	8.58	528.5	474.3	571.5
2003	14.3	11.4	17.5	9.13	7.14	11.97	8.14	7.91	8.41	660.1	631.9	684.0
2004	12.4	9.7	15.4	11.84	8.36	15.19	7.95	7.71	8.25	656.4	629.9	680.0
2005	14.4	11.3	17.8	9.26	7.47	11.37	7.95	7.79	8.16	599.6	546.0	626.7
2006	14.2	11.2	17.6	8.80	6.52	11.51	8.27	7.90	8.69	528.6	467.3	588.4
2007	7.9	6.5	9.5	10.00	8.59	11.38	8.18	8.01	8.42	603.6	584.9	617.8

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	22.2	20.8	23.7	6.48	5.23	7.25	7.99	7.90	8.06	503.9	388.9	591.5
2001	21.7	20.3	23.1	6.93	5.85	7.45	7.56	7.49	7.63	438.1	398.9	476.1
2002	22.4	21.6	23.3	—	—	—	7.63	7.54	7.74	497.5	461.6	522.9
2003	21.8	20.8	23.1	4.80	3.86	6.08	7.90	7.82	7.97	563.5	513.7	615.1
2004	21.1	19.9	22.1	—	—	—	7.59	7.41	7.70	302.6	199.4	347.1
2005	22.7	22.0	23.3	—	—	—	7.27	7.14	7.36	765.6	755.3	784.9
2006	20.0	18.7	21.4	5.51	4.69	6.29	8.05	7.88	8.16	745.6	675.7	787.3
2007	21.8	20.4	23.3	—	—	—	7.48	7.36	7.79	545.4	490.5	622.8

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	13.7	12.5	15.5	—	—	—	—	—	—	534.6	409.6	585.3
2002	13.1	12.2	14.1	7.58	7.09	7.98	8.30	8.23	8.41	573.0	563.1	583.2
2003	14.6	13.5	15.9	—	—	—	8.08	7.89	8.16	—	—	—
2004	12.4	11.9	13.0	7.75	7.37	8.01	7.78	7.73	7.81	460.5	459.7	461.2
2005	14.1	13.6	14.9	—	—	—	7.88	7.85	7.91	502.0	499.0	504.0
2006	15.0	14.1	16.4	4.26	3.36	5.58	8.00	7.96	8.03	515.7	481.5	543.1
2007	19.0	18.8	19.4	—	—	—	7.03	6.95	7.42	681.6	663.3	711.9

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	4.1	2.9	5.3	11.65	10.12	14.68	8.13	7.97	8.40	809.7	731.6	928.3
2003	0.4	0.1	0.9	13.26	12.14	15.04	8.09	7.83	8.33	598.6	563.0	623.0
2004	4.0	2.9	5.2	8.79	8.05	9.90	7.96	7.78	8.29	854.9	814.9	897.6
2005	3.4	2.3	4.5	13.36	12.27	14.73	7.75	7.55	8.03	487.4	471.3	502.3
2006	8.8	7.4	10.0	4.03	0.79	7.12	7.91	7.69	8.16	425.7	319.1	475.0
2007	7.4	6.1	9.0	11.52	10.80	12.52	8.06	7.95	8.24	586.7	563.7	633.5

Table 6-10 Summary of selected water chemistry parameters in Goose Creek.

EGCGC001	Year	2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.47	1.34	Total Kjeldahl Nitrogen (mg/L)	0.63	0.93
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.05		1.64	1.49		0.86	0.45
	SD (wet)	0.00	0.00		0.86	0.78		0.07	0.05
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.03	Phosphorus (mg/L)	0.04	0.04	Chloride	23.58	23.09
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.03		0.07	0.05		20.64	25.55
	SD (wet)	0.00	0.00		0.01	0.01		1.53	5.74
	Count (wet)	2	2		3	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	2.00	TDS (mg/L)	378.00	364.00	TSS (mg/L)	3.00	24.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	1.00	1.48		301.00	245.00		8.00	12.50
	SD (wet)	0.71	0.67		46.67	193.75		4.24	7.78
	Count (wet)	2	2		2	2		2	2
	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	300	410	475	196	306	290	326	456
	SD (Dry)	341	724	576	294	419	220	255	616
	Count (Dry)	22	30	29	23	17	22	20	22
	Mean (wet)	2144	-	-	565	1111	3877	1004	2502
	SD (wet)	2317	-	-	792	1379	6317	831	3855
	Count (wet)	5	0	0	9	14	9	12	11
EGCGC002	Year	2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.72	1.06	Total Kjeldahl Nitrogen (mg/L)	0.55	0.73
	SD (Dry)	-	0.00		-	0.45		-	0.16
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.05		1.33	1.49		0.62	0.90
	SD (wet)	0.00	0.00		1.47	0.59		0.00	0.57
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.03	Phosphorus (mg/L)	0.04	0.06	Chloride	48.72	62.87
	SD (Dry)	-	0.00		-	0.03		-	50.64
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.03		0.03	0.05		54.60	44.05
	SD (wet)	0.00	0.00		0.01	0.01		7.16	19.28
	Count (wet)	2	2		3	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	458.00	511.00	TSS (mg/L)	2.00	4.50
	SD (Dry)	-	1.06		-	117.38		-	2.12
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.75	1.48		416.00	259.00		24.00	8.50
	SD (wet)	0.35	0.67		82.02	224.86		22.63	2.12
	Count (wet)	2	2		2	2		2	2
	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	645	419	542	190	185	424	514	565
	SD (Dry)	1771	554	901	266	110	318	462	614
	Count (Dry)	20	30	28	24	17	22	20	23
	Mean (wet)	2117	-	-	712	2596	4203	834	3763
	SD (wet)	3501	-	-	1120	4292	6801	767	7335
	Count (wet)	13	0	0	8	14	9	12	11

Table 6-11 Summary of selected water chemistry parameters in Little Goose Creek.

EGCLC001	Year	2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.83	1.18	Total Kjeldahl Nitrogen (mg/L)	0.53	0.67
	SD (Dry)	-	0.00		-	0.65		-	0.07
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.05		1.95	1.42		1.07	0.57
	SD (wet)	0.00	0.00		0.41	0.59		0.19	0.10
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.08	0.03	Phosphorus (mg/L)	0.04	0.07	Chloride	27.20	91.41
	SD (Dry)	-	0.00		-	0.04		-	10.35
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.52	0.05		0.40	0.05		39.61	30.18
	SD (wet)	0.70	0.04		0.56	0.02		14.15	0.18
	Count (wet)	2	2		3	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	378.00	556.00	TSS (mg/L)	11.00	8.50
	SD (Dry)	-	1.06		-	36.77		-	4.95
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.75	1.48		434.00	245.50		12.00	13.00
	SD (wet)	0.35	0.67		76.37	146.37		9.90	5.66
	Count (wet)	2	2		2	2		2	2
	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	919	408	556	346	358	337	543	634
	SD (Dry)	2622	741	1000	589	401	322	773	637
	Count (Dry)	20	30	28	22	17	20	18	24
	Mean (wet)	5995	-	-	1036	974	5875	716	14347
	SD (wet)	9832	-	-	1625	955	12495	973	39490
	Count (wet)	9	0	0	10	14	11	14	10

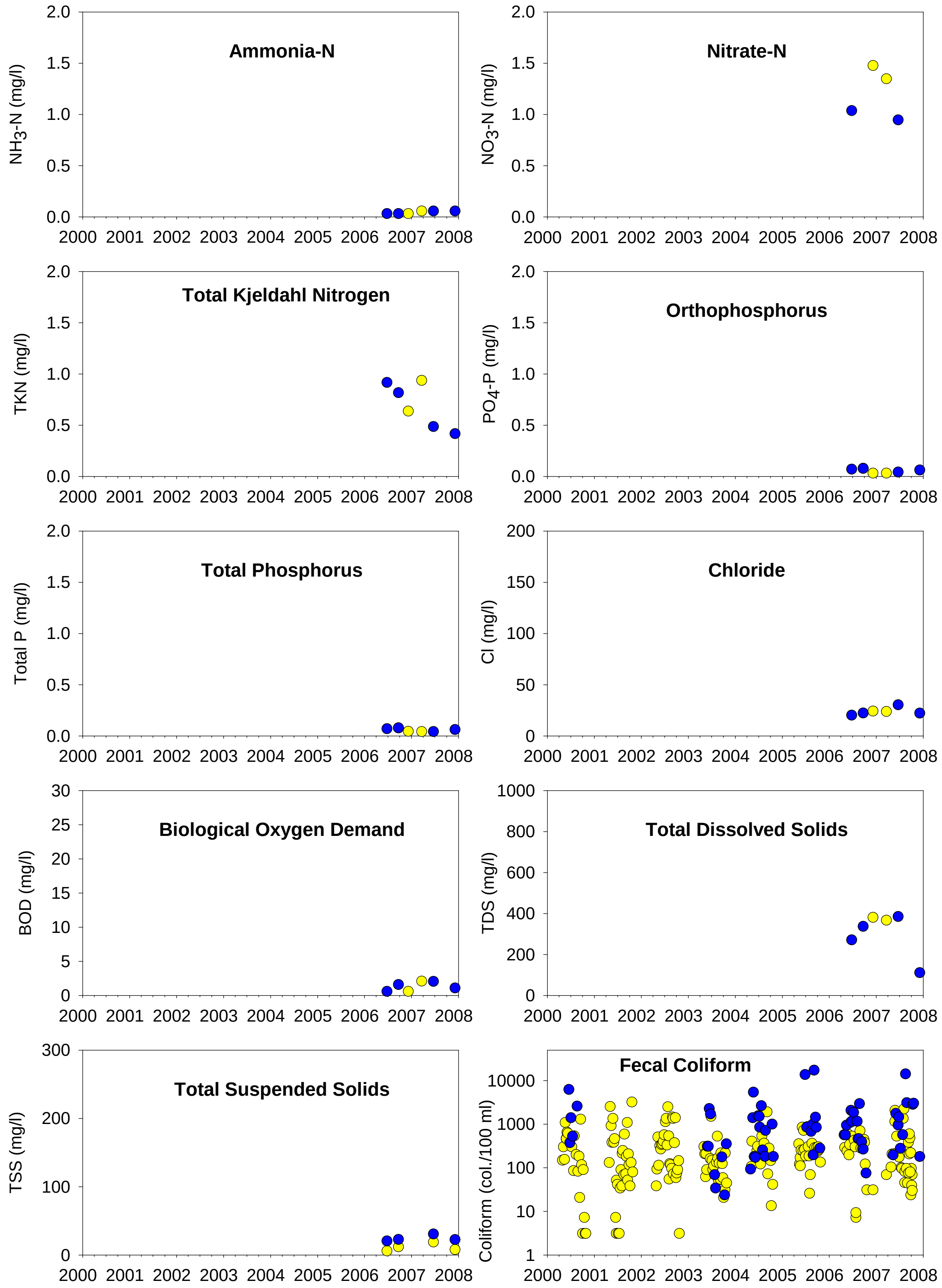

Figure 6-1 Major water chemistry parameters measured in Goose Creek watershed, at EGCGC001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

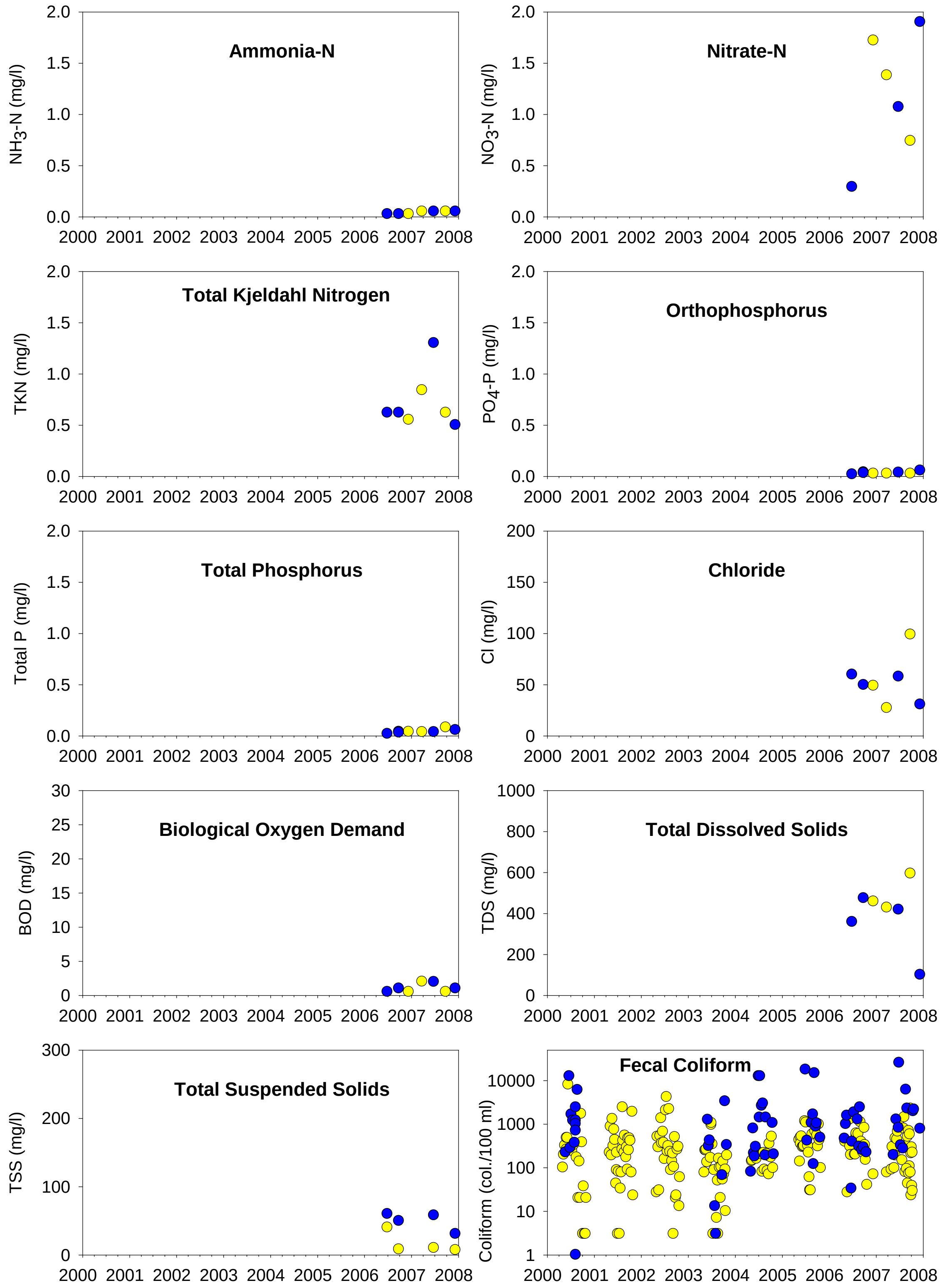

Figure 6-1 Continued, at EGCGC002 location.

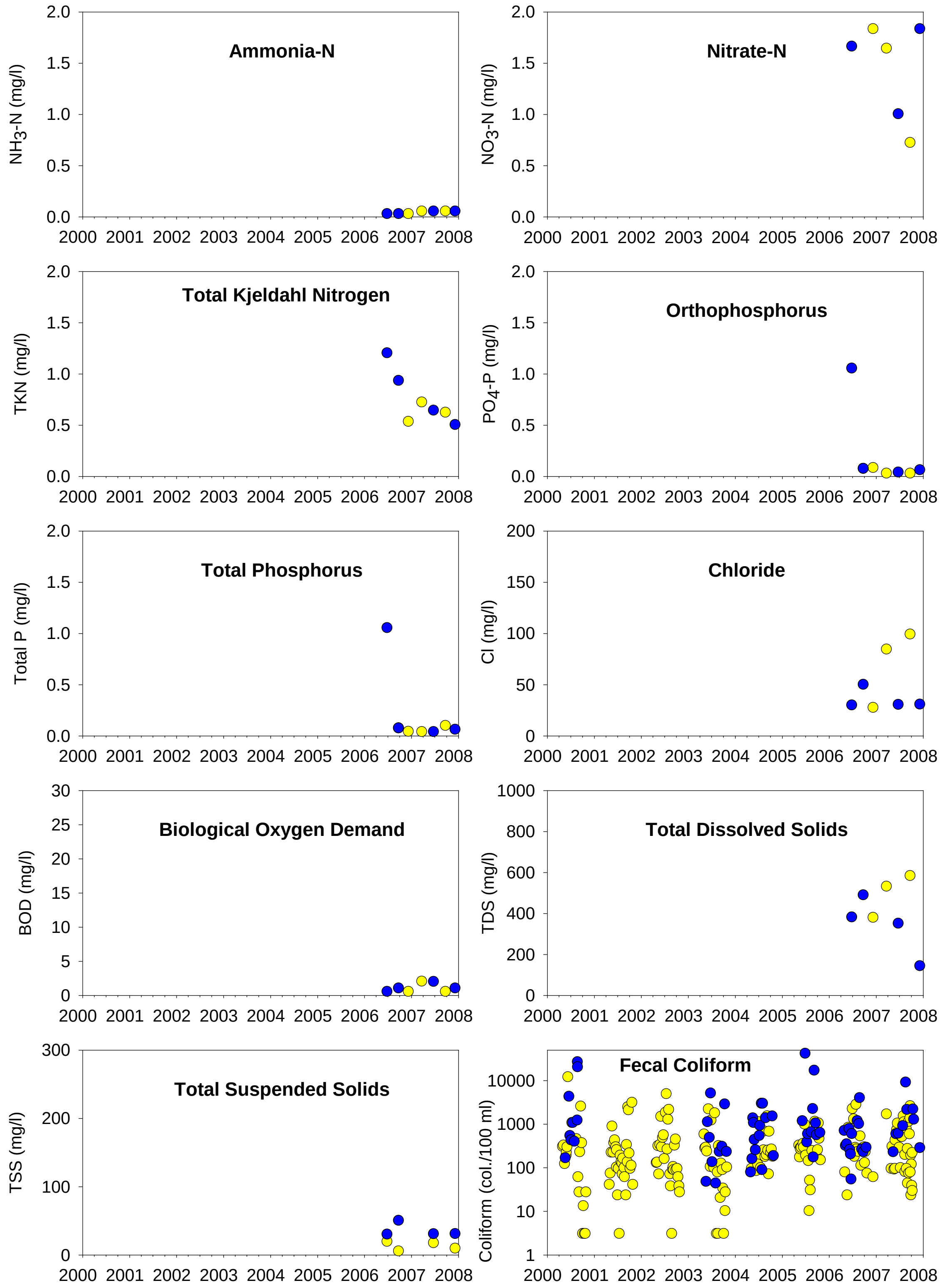

Figure 6-2 Major water chemistry parameters measured in Little Goose Creek watershed, at EGCLG001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 7 Harrods Creek Watershed

7.1 Watershed Physical Characteristics

Harrods Creek originates in Trimble County (East Fork) and flows west through Oldham County before entering Jefferson County. LTMN location in the main stem of Harrods Creek (EHCHC001) is located just outside of Jefferson County. Wolf Pen Branch, a tributary of Harrods Creek, originates in Worthington area and flow northwest and merging into Harrods Creek at the downstream of EHCHC001 location and eventually flows into Ohio River. There is one LTMN location (EHCWP002) in Wolf Pen Branch.

The Harrods Creek watershed contains less than 9% of developed areas with very small impervious surface coverage (1.3%) at its LTMN location (EHCHC001) (Table 7-1). The remaining area is consisted of forests (40%), pasture (42%), and cropland (7%). Stream riparian buffer zone development is also very limited and mostly forested (58% and 70% at watershed- and reach-scales).

The Wolf Pen Branch watershed contains 30% of developed area with 7% of impervious surface coverage at its LTMN location (EHCWP002) (Table 7-1). Forests (23%), pasture (21%) and cropland (25%) are other major landuse groups in this watershed. Riparian buffer areas in watershed-scale are mainly forested (72%), while it is mainly used for croplands (62%) in the reach-scale (1000 meters from the LTMN location).

7.2 Biological Data

7.2.1 Diatom

EHCHC001: The overall water quality of Harrods Creek at Covered Bridge Road (EHCHC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Good’ (Table 7-2). The overall mean score of 49 reflects the mid range of ‘Good’ scores. In general, these data suggest water quality of Harrods Creek at Covered Bridge Road seems to be improving somewhat over time (Table 7-2). Specifically, during the 2001 – 2003 sampling seasons, 70% of sample dates characterized water quality as ‘Good’ (mean DBI = 48). During 2005, mean overall water quality was also characterized as ‘Good’ as 100% of samples scored in the ‘Good’ range (mean DBI = 50).

The taxa richness (TR) yearly mean score was unchanged from year 2001 through 2003 (37), but increased during 2005 (41) (Table 7-2). Small, yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score varied little from year 2001 (71) to 2003 (72), but decreased during 2005 (67) (Table 7-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality.

The siltation index (%NNS) yearly mean score increased from year 2001 (65) to 2003 (71) but decreased during 2005 (62) (Table 7-2). These data suggest that overall species composition shifted toward those species adapted to living on silts and shifting sediments. In general, a decrease in overall %NNS suggests a decline in water quality.

The Shannon diversity index (SDI) yearly mean score increased from year 2002 (85) to 2005 (95) (Table 7-2). These data suggest the increase in SDI may have been related to the increase in TR. In general, the majority of SDI values throughout the study period were high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (10) to 2003 (3) but increased during 2005 (15) (Table 7-2). These taxa are widely considered to be indicators of good water quality. An overall increase with respect to this metric suggests site water quality may be improving slightly. It is possible new taxa from within this group were identified during 2005 and may have contributed to the increase in TR at that time.

The cymbella group richness (CGR) yearly mean score decreased from year 2001 (22) to 2003 (9) but increased during 2005 (21) (Table 7-2). These taxa are widely considered to be indicators of good water quality. An overall increase with respect to this metric suggests site water quality may be improving slightly. It is possible new taxa from within this group were identified during 2005 and may have contributed to the increase in TR at that time.

EHCWP002: The overall water quality of Wolf Pen Branch at 8200 Wolf Pen Branch Road 2 (EHCWP002) based on 10 diatom samples collected over one year (2005) may be characterized as ‘Good’ (Table 7-2). The overall mean score of 47 reflects the lower range of ‘Good’ scores. Only one year of data exists from this site, therefore it is not possible to discuss these data in terms of yearly trends. However, these data may be compared to the other study sites with respect to overall mean metric scores. For example, mean taxa richness (TR) at Wolf Pen Branch was 34, this metric is lower than the means of 24 other sites (Table 7-2). It is common for heavily shaded, nutrient-poor headwater streams, such as Wolf Pen Branch, to be unable to support highly diverse communities as needed resources are usually lacking.

In contrast to TR, mean pollution tolerance index (PTI = 75) and mean siltation index (%NNS = 79) at Wolf Pen Branch were among the highest values in the current study (Table ax). These data suggest the community was dominated by pollution sensitive species not within the *Navicula* or *Nitzschia* genera. Finally, mean Fragilaria group richness (FGR = 4) and mean Cymbella group richness (CGR = 4) at Wolf Pen Branch were among the lowest values in the current study (Table ax). It is unclear as to why these taxa were poorly represented in this stream.

7.2.2 Macroinvertebrates

The macroinvertebrate communities in the Harrods Creek (EHCHC001) were rated as ‘excellent’ during all three sampling years (Table 7-3). Taxa richness was reduced between the years 2000 (63) and 2005 (55). The lowest component metric scores were EPT Richness and %EPT, but these were still higher than in most other LTMN sites in Jefferson County.

The macroinvertebrate communities in Wolf Pen Branch (EHCWP002) were rated as ‘fair’ in 2004 and 2005, and were not sampled in 2000 (Table 7-3). The low EPT Richness and %EPT metrics have resulted in lower MBI scores in EHCWP002. During 2005, the %EPT, %Clinger and %Ephemeroptera metrics scored very low (<20).

7.2.3 Fish

The fish communities in Harrods Creek and Wolf Pen Branch had similar ratings based on fish biotic index during the period of 2002-2005: ‘fair’ on 2002, ‘good’ on 2003, and ‘fair’ on 2005 (Table 7-4). The metric for native fish species (NAT) changed during this period (51 & 59 to 62 & 66 to 44 & 61) reflecting the changes in the overall fish IBI ratings. The metric scores for NAT and intolerant species richness (INT) scores were higher at Wolf Pen Branch than Harrods Creek on all three surveys (2002-2005).

7.3 Hydrolab Data

7.3.1 Stream metabolism

The gross primary production was higher during spring (2.3-3.0 g O_2/m^2/day) than summer (0.6-1.7 g O_2/m^2/day) and fall (0.8-1.9 g O_2/m^2/day) in Harrods Creek (Table 7-5). Community respiration was higher during summer (3.4-5.3 g O_2/m^2/day) than spring (1.5-5.5 g O_2/m^2/day) and fall (1.6-4.6 g O_2/m^2/day). GPP estimates remained stable annually during 2000-2007, while the CR varied year-to-year (Table 7-5).

In Wolf Pen Branch, GPP was higher during spring (2.0-3.5 g O_2/m^2/day) than summer (0.7-1.2 g O_2/m^2/day) and fall (0.7-0.9 g O_2/m^2/day) (Table 7-5). CR estimates were not much different seasonally, while they were highly variable year-to-year.

7.3.2 Dissolved oxygen, pH, and conductivity

On average, the daily mean DO values were in the order of winter, spring, fall, and summer in Harrods Creek (EHCHC001) (Table 7-6). During spring, mean DO values showed a great deal of year-to-year variation, but it might be related to the stream water temperature changes in that period. Daily mean DO stayed above 5mg/L and daily minimum values stayed above 4 mg/L except summer 2007 at this location. The pH values (even daily minimum) always stayed above 7 in Harrods Creek. Conductivity was highest during winter on average with a great deal of year-to-year variation, while mean values of other seasons were similar (Table 7-6).

There were several years when sonde data were not available for any analysis, especially during summer and fall, in Wolf Pen Branch (Table 7-6). Based on the available data, daily mean DO stayed above 5 mg/L and daily minimum values stayed above 4 mg/L throughout the year at this location (Table 7-6). The mean daily pH values mostly stayed above 7 except during winter 2003. Seasonal average conductivity values during spring and winter were similar, which were higher than the estimates for summer and fall (Table 7-6).

7.4 Laboratory Data

Water chemistry data were collected only during years 2006 and 2007 except fecal coliform counts in Harrods Creek and Wolf Pen Branch (Table 7-7, Figure 7-1). Ammonia-nitrogen was below detection limits in both streams. Nitrate-nitrogen sampled during ‘dry’ period was slightly higher during 2007 (1.9 mg/L in EHCHC001; 2.43 mg/L in EHCWP002) than 2006 at both streams, although sample number was too small to draw a conclusion from this data set. Mean chloride concentration was also higher on 2007 than 2006 for both ‘wet’ and ‘dry’ samples. Overall, concentrations of various water chemistry parameters were slightly higher in Wolf Pen Branch than the main stem Harrods Creek (Table 7-7). Annual means of fecal coliform counts had ranges of 97-526 col/100mL for ‘dry’ samples, and 284-6811 col/100mL for ‘wet’ samples in Harrods Creek. The most of fecal coliform samples were from years 2004-2007 in Wolf Pen Branch, and they were higher during ‘wet’ samples (486-1555 col/100mL) than ‘dry’ samples (265-540 col/100mL).

7.5 Watershed assessment based on the biological data

Harrods Creek could be considered as a ‘good’ quality stream based on the three biological samples during 2005, and it maintained either ‘excellent’ or ‘good’ quality throughout the 2000-2005. While diatom index was ‘good’, macroinvertebrate index was ‘excellent’ during this period.

Biological communities in Wolf Pen Branch could be considered as ‘fair’ based on the combined biological indices during 2005. Both fish and macroinvertebrate indices were ‘fair’ ratings, while diatom index was ‘good’.

EHCHC001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	good	good	good	—	**good**
MBI	excellent	—	—	—	excellent	**excellent**
Fish KBI	excellent	—	fair	good	—	**fair**
EHCWP002	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	—	—	—	—	**good**
MBI	—	—	—	—	fair	**fair**
Fish KBI	—	—	fair	good	—	**fair**

Table 7-1 Land use/cover characteristic of Harrods Creek and Wolf Pen Branch.

EHCHC001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	1.32	0.63	0.15
Open Water	0.56	1.35	0.00
Dev. Open Space	6.49	3.34	0.00
Dev. Low Intensity	1.28	0.59	0.00
Dev. Medium Intensity	0.75	0.24	0.00
Dev. High Intensity	0.21	0.06	0.00
Barren Land	0.11	0.11	0.00
Deciduous Forest	37.67	54.70	62.05
Evergreen Forest	2.17	2.97	7.59
Mixed Forest	0.06	0.08	0.00
Shrub/Scrub	0.04	0.04	0.00
Grassland/herbaceous	1.82	1.70	26.34
Pasture/Hay	41.73	31.88	0.00
Cropland	7.04	2.77	0.00
Woody Wetlands	0.04	0.11	0.00
Emergent Herbaceous Wetlands	0.03	0.06	4.02
EHCWP002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	6.94	2.04	0.00
Open Water	0.21	0.84	2.23
Dev. Open Space	8.33	2.90	4.02
Dev. Low Intensity	12.93	4.50	3.13
Dev. Medium Intensity	8.26	1.83	0.00
Dev. High Intensity	0.89	0.00	0.00
Barren Land	0.31	0.00	0.00
Deciduous Forest	22.44	71.50	23.66
Evergreen Forest	0.16	0.80	4.91
Mixed Forest	0.00	0.00	0.00
Shrub/Scrub	0.66	0.00	0.00
Grassland/herbaceous	0.26	0.55	0.00
Pasture/Hay	20.63	15.69	62.05
Cropland	24.92	1.40	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00

Table 7-2 DBI scores estimated in Harrods Creek and Wolf Pen Branch.

EHCHC001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	37	71	65	90	10	22	**49**	**GOOD**
2002	37	73	67	85	0	21	**47**	**GOOD**
2003	37	72	71	87	3	9	**47**	**GOOD**
Summer 05	41	70	68	92	18	20	**51**	**GOOD**
Fall 05	42	64	56	97	13	21	**49**	**GOOD**
2005 All	41	67	62	95	15	21	**50**	**GOOD**
Overall	**38**	**70**	**66**	**90**	**8**	**19**	**49**	**GOOD**
EHCWP002	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
Summer 05	33	78	84	80	3	5	**47**	**GOOD**
Fall 05	35	71	74	91	5	3	**47**	**GOOD**
2005 All	**34**	**75**	**79**	**86**	**4**	**4**	**47**	**GOOD**

Table 7-3 Macroinvertebrate biotic integrity scores estimated in Harrods Creek and Wolf Pen Branch.

Year	Metric	EHCHC001		EHCWP002	
		Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness	63	85.14		
	EPT Richness	25	83.33		
	m%EPT	47	64.38		
	mHBI	5.69	62.55		
	%Chir. and Oli.	11	89.90		
	%Clinger	61	82.43		
	MBI	--------	77.96		
	Assessment	--------	**Excellent**		
2004	Taxa Richness	38	51.4	36	46
	EPT Richness	11	36.7	6	26.7
	m%EPT	54.6	74.8	12.9	26.4
	mHBI	4.30	82.7	6.42	48.6
	%Chir. and Oli.	1.6	99.4	31.7	99
	%Clinger	82.5	100.00	62.0	19.9
	MBI	--------	74.17	--------	44.40
	Assessment	--------	**Excellent**	--------	**Fair**
2005	Taxa Richness	55	74.32	56	88.89
	EPT Richness	15	50.00	17	51.52
	m%EPT	21.58	29.56	2.70	3.11
	mHBI	5.20	69.64	7.37	33.63
	%Chir. and Oli.	1.52	99.47	1.80	98.87
	%Clinger	74.47	100.00	15..02	19.89
	%Ephemeroptera	--------	--------	1.20	1.81
	MBI	--------	70.50	--------	42.53
	Assessment	--------	**Excellent**	--------	**Fair**

Table 7-4 Fish IBI scores estimated in Harrods Creek and Wolf Pen Branch.

Site	EHCHC001	EHCWP002
1999-up	**good**	**NS**
1999-dn	**good/excellent**	**NS**
2000-up	**good**	**NS**
2000-dn	**excellent**	**NS**
2002	**fair**	**fair**
Native	51	59
DMS	0	38
INT	4	38
WC	27	75
SL	40	39
%Insect_Ex_Tol	25	33
%OMNI	62	87
%TOL	70	28
IBI	35	50
2003	**good**	**good**
Native	62	66
DMS	55	38
INT	16	38
WC	56	85
SL	48	39
%Insect_Ex_Tol	51	33
%OMNI	79	91
%TOL	87	48
IBI	57	55
2005	**fair**	**fair**
NAT	44	61
DMS	35	35
INT	0	38
SL	23	39
%INSCT	68	100
%TOL	83	24
%FHW	50	0
KIBI	42	39

Table 7-5 Gross primary production (g O_2/m^2/day) and community respiration (g O_2/m^2/day) estimated in Harrods Creek and Wolf Pen Branch.

EHCHC001	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2000	3.03	0.45	1.67	4.61	—	—
2001	2.97	4.24	1.22	3.42	0.79	4.19
2002	—	—	—	—	—	—
2003	3.12	3.64	0.72	4.64	1.24	2.75
2004	2.31	5.45	0.55	3.66	—	—
2005	2.43	3.71	—	—	1.03	1.64
2006	2.35	1.97	—	—	0.92	1.65
2007	—	—	1.30	5.34	1.88	4.60
EHCWP002	**Spring**		**Summer**		**Fall**	
	GPP	CR	GPP	CR	GPP	CR
2001	—	—	—	—	0.74	6.44
2002	3.45	2.50	—	—	—	—
2003	2.10	5.08	0.88	6.51	0.73	4.48
2004	2.01	17.90	0.65	7.20	—	—
2005	2.49	4.08	1.17	4.67	0.86	7.25
2006	3.23	8.78	—	—	—	—
2007	—	—	1.22	5.69	—	—

Table 7-6 Daily water temperature, DO, pH, and conductivity in Harrods Creek (EHCHC001).

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.4	11.4	15.5	12.12	9.79	15.44	8.22	8.04	8.38	414.1	406.2	419.9
2001	18.1	16.3	20.2	8.54	6.50	11.51	8.05	7.78	8.32	518.5	508.5	527.1
2002	9.4	3.3	13.1	—	—	—	6.92	8.28	8.49	381.8	449.7	471.1
2003	15.5	13.3	17.8	9.52	7.32	12.36	8.28	8.00	8.53	402.7	394.5	412.8
2004	13.2	11.3	15.3	7.85	6.21	10.01	7.53	7.33	7.72	457.0	437.7	463.6
2005	16.2	13.8	18.7	8.91	7.04	12.14	7.91	7.68	8.14	351.0	342.7	357.6
2006	14.2	12.4	16.3	10.74	8.94	13.61	8.43	8.14	8.71	413.9	399.6	427.9
2007	6.6	5.5	7.6	13.02	11.72	14.51	7.94	7.55	8.11	503.7	495.8	512.1
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	25.1	23.8	26.5	5.47	4.44	6.79	8.02	7.84	8.23	336.1	301.6	354.6
2001	24.6	23.5	26.0	6.29	5.34	7.85	7.75	7.65	7.88	454.3	447.4	462.1
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	24.1	23.2	25.2	5.19	4.51	6.17	7.59	7.51	7.70	416.1	411.3	421.5
2004	22.5	21.2	24.0	5.91	5.44	6.46	8.00	7.90	8.12	328.7	285.5	372.1
2005	26.0	24.8	27.7	—	—	—	7.75	7.59	7.92	535.1	527.8	541.6
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	25.8	23.6	28.5	4.59	3.79	5.85	8.02	7.79	8.35	420.3	408.0	438.6
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.1	13.1	15.1	7.3	6.6	8.3	8.1	7.8	8.2	370.1	351.2	391.1
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	14.7	13.6	15.8	8.6	7.6	10.1	8.2	8.0	8.3	514.8	504.8	536.9
2004	14.7	13.8	15.7	12.5	11.5	14.4	8.1	8.0	8.2	293.2	291.8	294.6
2005	15.9	15.2	17.0	8.8	8.0	10.6	7.9	7.8	8.0	381.3	378.5	383.1
2006	16.4	15.3	17.5	9.0	8.2	10.1	8.1	8.0	8.2	441.3	426.3	463.4
2007	22.4	21.2	23.9	5.4	4.6	7.2	7.7	7.6	8.3	519.2	489.0	498.6
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	0.2	-0.1	0.7	14.14	13.48	15.14	8.23	8.16	8.31	677.1	661.3	699.4
2002	2.9	1.8	3.7	14.94	13.70	16.73	8.16	8.08	8.26	519.5	502.0	552.4
2003	0.1	0.0	0.4	10.32	9.93	10.80	9.09	9.05	9.13	545.4	534.8	568.0
2004	1.4	0.7	2.3	15.60	14.55	16.85	8.18	8.10	8.22	565.4	530.2	612.3
2005	1.4	0.7	2.2	—	—	—	6.68	6.15	6.75	247.1	244.4	249.4
2006	6.6	5.7	7.7	9.41	8.89	10.11	8.37	8.24	8.51	393.2	360.2	429.3
2007	4.5	4.0	5.2	10.39	9.53	11.23	8.05	7.98	8.11	477.1	466.3	508.7

Table 7-6 Continued, in Wolf Pen Branch (EHCWP002).

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	11.5	8.0	15.9	11.21	9.42	13.40	8.47	8.10	9.10	428.9	368.7	462.7
2003	14.0	10.3	18.2	9.43	7.74	10.97	8.21	8.02	8.48	518.6	439.3	547.9
2004	12.4	8.5	17.9	5.76	4.49	6.73	8.08	7.78	8.57	517.6	424.3	569.6
2005	14.3	10.2	19.2	9.93	8.42	11.42	8.16	7.94	8.46	522.5	462.5	554.0
2006	14.7	11.2	19.0	8.61	7.14	10.35	8.19	7.82	8.70	386.5	337.8	414.3
2007	—	—	—	—	—	—	—	—	—	—	—	—
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	21.1	19.3	23.0	7.06	6.25	7.81	8.16	8.03	8.33	498.2	451.8	526.8
2004	19.6	18.1	21.1	7.03	6.61	7.51	8.20	8.06	8.34	447.9	402.7	484.9
2005	22.0	20.0	24.3	7.57	6.79	8.45	7.78	7.69	7.96	404.3	359.0	436.6
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	21.1	19.2	23.3	6.77	5.99	7.80	8.39	8.32	8.49	542.2	527.9	558.2
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	12.8	11.0	14.7	8.65	7.98	9.29	8.20	8.02	8.37	376.4	314.1	403.0
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	14.6	12.6	16.5	9.04	8.35	9.67	8.12	8.04	8.25	407.1	386.8	434.1
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	14.0	12.4	16.0	8.32	7.45	9.03	7.86	7.79	7.92	450.8	418.4	603.0
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	—	—	—	—	—	—	—	—	—	—	—	—
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	4.6	2.7	6.6	10.64	8.85	11.81	8.59	8.41	8.92	442.3	335.7	482.8
2003	1.0	0.4	2.0	11.82	10.39	12.60	6.62	5.95	7.28	462.9	401.7	497.8
2004	4.4	2.7	6.0	12.15	10.92	13.75	7.70	7.45	8.22	605.5	466.2	637.6
2005	4.5	3.0	5.9	12.54	11.62	13.56	8.17	7.75	8.46	478.8	442.1	495.1
2006	9.0	7.5	10.6	10.45	9.43	11.45	7.98	7.76	8.24	433.3	352.2	482.9
2007	—	—	—	—	—	—	—	—	—	—	—	—

Table 7-7 Summary of selected water chemistry parameters Harrods Creek and Wolf Pen Branch.

EHCHC001	**Year**	**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.05	1.90	Total Kjeldahl Nitrogen (mg/L)	0.57	1.10
	SD (Dry)	-	0.00		-	2.47		-	0.14
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.05		0.86	1.10		0.56	0.79
	SD (wet)	0.00	0.00		0.71	0.25		0.17	0.09
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.34	Phosphorus (mg/L)	0.04	0.32	Chloride	14.09	52.61
	SD (Dry)	-	0.30		-	0.40		-	50.52
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.04	0.03		0.08	0.17		11.68	18.45
	SD (wet)	0.02	0.00		0.02	0.19		2.24	13.96
	Count (wet)	2	2		3	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	348.00	446.00	TSS (mg/L)	8.00	10.50
	SD (Dry)	-	1.06		-	67.88		-	7.78
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	1.00	1.98		280.00	214.00		8.00	28.50
	SD (wet)	0.71	0.04		19.80	152.74		1.41	17.68
	Count (wet)	2	2		2	2		2	2

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	437	210	97	120	234	115	526	172
	SD (Dry)	831	595	138	146	625	113	1410	382
	Count (Dry)	22	19	18	21	17	21	18	24
	Mean (wet)	6811	539	1370	874	1423	284	330	1559
	SD (wet)	15627	750	1915	1091	2781	211	325	4338
	Count (wet)	9	11	10	11	14	11	14	10

EHCWP002	**Year**	**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.14	2.43	Total Kjeldahl Nitrogen (mg/L)	0.41	0.82
	SD (Dry)	-	0.00		-	1.58		-	0.07
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.05		0.92	0.96		0.84	0.61
	SD (wet)	0.00	0.00		0.50	0.23		0.23	0.16
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.27	Phosphorus (mg/L)	0.04	0.06	Chloride	22.49	64.97
	SD (Dry)	-	0.34		-	0.03		-	34.01
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.04	0.03		0.27	0.06		16.35	36.92
	SD (wet)	0.02	0.00		0.34	0.03		7.38	4.17
	Count (wet)	2	2		3	2		2	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	326.00	458.00	TSS (mg/L)	4.00	27.50
	SD (Dry)	-	1.06		-	14.14		-	24.75
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.75	2.48		280.00	263.00		19.50	27.50
	SD (wet)	0.35	0.74		16.97	171.12		9.19	0.71
	Count (wet)	2	2		2	2		2	2

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	-	187	-	-	265	306	509	540
	SD (Dry)	-	-	-	-	224	273	1176	729
	Count (Dry)	-	1	-	-	17	20	18	24
	Mean (wet)	-	-	-	-	486	1064	778	1555
	SD (wet)	-	-	-	-	735	1890	905	2973
	Count (wet)	-	-	-	-	14	10	14	10

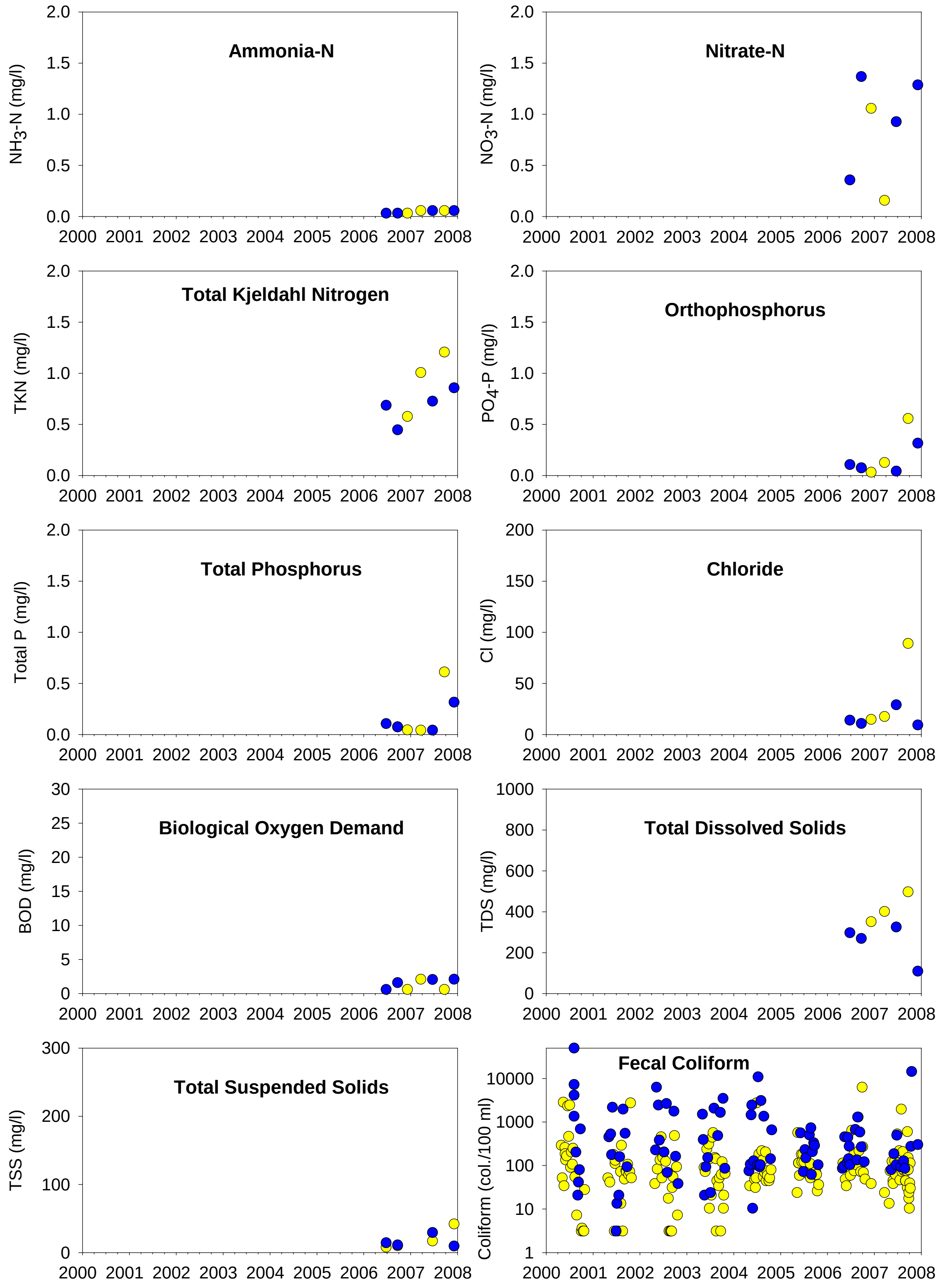

Figure 7-1 Major water chemistry parameters measured in Harrods Creek watershed, at EHCHC001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

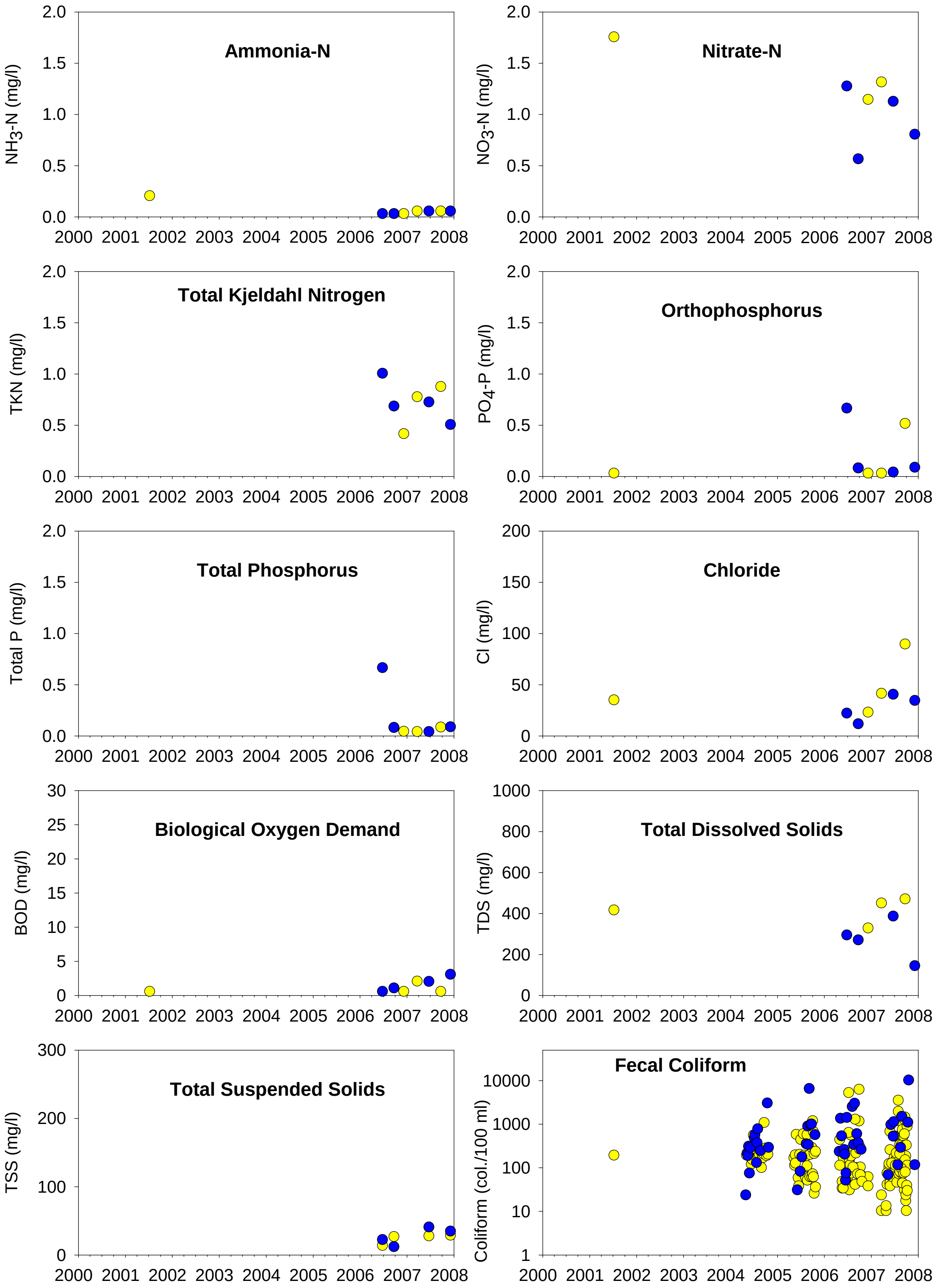

Figure 7-1 Continued, at EHCWP002 location.

Chapter 8 Middle Fork Beargrass Creek Watershed

8.1 Watershed Physical Characteristics

The Middle Fork of Beargrass Creek originates in Anchorage and Middletown areas and flow west through the major urban areas of Louisville Metro. Its watershed also includes Cherokee and Seneca Metro Parks. There are three LTMN locations, the upstream at Browns Lane (EMIMI009), the middle location at Old Cannons Lane (EMIMI002), and the downstream location at Lexington Road (EMIMI010). Cherokee and Seneca Parks are located in between the EMIMI002 and EMIMI010. It flows into South Fork Beargrass Creek just upstream of LTMN location at Brownsboro Road (ESFSF006).

Due to the longitudinal connectivity of the three LTMN locations in MFBC watershed, data are presented following the order of upstream-downstream linkage: EMIMI009-EMIMI002-EMIMI010.

The Middle Fork of Beargrass Creek watershed is highly developed (Table 8-1). The cumulative watershed scale landuse patterns estimated at three LTMN locations contained large proportion of developed lands (72.4-75.7%), while forested areas were very small (19.6-23.2%). Watershed imperviousness was also high at all three LTMN locations with range of 22.4-24.1%. Riparian buffer zone development at watershed scale was also pronounced at all locations with more than 50% of the area developed (54.0-59.6%). The 1000m reach-scale riparian buffer zone landuse at two upstream LTMN locations (EMIMI009 and EMIMI002) exceeded 90%, indicating heavy developments in the areas close to stream channel.

8.2 Biological Data

8.2.1 Diatom

EMIMI009: The overall water quality of the Middle Fork of Beargrass Creek at Browns Lane (EMIMI009) based on 29 diatom samples collected over three years (2002 – 03, 2005) may be characterized as ‘Excellent’ (Table 8-2). The overall mean score of 53 reflects the lower range of ‘Excellent’ scores, but was the second highest overall mean score in the current study (Table 8-2). In general, these data suggest water quality of Middle Fork Beargrass Creek at Browns Lane seems to be declining somewhat over time (Table 8-2). Specifically, during the 2002 and 2003 sampling seasons, 63% of sample dates characterized water quality as ‘Excellent’ (mean DBI = 55). During the 2005 sampling season, mean overall water quality was characterized as ‘Good’ as only 10% of samples scored in the ‘Excellent’ range (mean DBI = 49).

The taxa richness (TR) yearly mean score decreased from year 2002 (54) through 2005 (42) (Table 8-2). These data suggest that a significant number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality. Despite the overall decrease in TR during the study period, this site had the highest overall mean TR score (48) in the current study (Table 8-2).

The pollution tolerance index (PTI) yearly mean score increased from year 2002 (63) to 2003 (69), but decreased during 2005 (66) (Table 8-2). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability. Perhaps some of those species lost with respect to TR between 2002 and 2003 were pollution tolerant species. This net loss may have contributed to the increase observed with respect to the PTI during this timeframe.

The siltation index (%NNS) yearly mean score increased from year 2002 (57) to 2003 (68), but decreased during 2005 (56) (Table 8-2). Small, yearly %NNS fluctuations, as seen here, are well within the limits of expected yearly natural variability. Perhaps some of those species lost with respect to TR between 2002 and 2003 were *Navicula* or *Nitzschia* species. This net loss may have contributed to the increase observed with respect to the %NNS during this timeframe.

The Shannon diversity index (SDI) yearly mean score decreased from year 2002 (97) to 2003 (87), but increased during 2005 (92) (Table 8-2). Small, yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2002 (32) to 2005 (15) (Table 8-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

The cymbella group richness (CGR) yearly mean score decreased from year 2002 (26) to 2003 (21) but increased during 2005 (23) (Table 8-2). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of CGR values were moderate/high and indicative of good water quality.

EMIMI002: The overall water quality of Middle Fork Beargrass Creek at Old Cannons Lane (EMIMI002) based on 38 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Excellent’ (Table 8-2). The overall mean score of 54 reflects the lower range of ‘Excellent’ scores, but was the highest overall mean DBI score in the current study (Table 8-2). In general, these data suggest water quality of Middle Fork Beargrass Creek at Old Cannons Lane seems to be declining somewhat over time (Table 8-2). Specifically, during the 2001 and 2002 sampling seasons, 72% of sample dates characterized water quality as ‘Excellent’ (mean DBI = 56). During subsequent sampling seasons (2003, 2005), mean overall water quality was characterized as ‘Good’ as only 50% of samples scored in the ‘Excellent’ range (mean DBI = 52).

The taxa richness (TR) yearly mean score decreased from year 2001 (54) through 2005 (36) (Table 8-2). These data suggest that a significant number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score increased from year 2001 (68) to 2005 (74) (Table 8-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution sensitive. In general, an increase in the PTI suggests an improvement in water quality.

The siltation index (%NNS) yearly mean score increased from year 2001 (56) to 2003 (78) but decreased slightly during 2005 (75) (Table 8-2). These data suggest that overall species composition shifted away from those species adapted to living on silts and shifting sediments. In general, an increase in overall %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score decreased significantly from year 2001 (97) to 2005 (70) (Table 8-2). These yearly SDI fluctuations, track well with the changes seen in TR and largely mirror those seen in %NNS and suggests a correlation among these parameters (Table 8-2). Additionally, these data suggest that one or more species may have numerically dominated the community and adversely affected overall distribution, thereby further reducing the SDI. In general, decreases as those seen here in the yearly mean SDI suggest a decline in overall water quality.

The fragilaria group richness (FGR) yearly mean score decreased significantly from year 2001 (73) to 2005 (17) (Table 8-2). This site had the highest yearly mean FGR score (73) as well as the highest overall mean FGR score (34) (Table 8-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

The cymbella group richness (CGR) yearly mean score increased from year 2001 (14) to 2003 (26) but decreased during 2005 (17) (Table 8-2). These taxa are widely considered to be indicators of good water quality. An overall increase with respect to this metric suggests site water quality may be improving slightly.

EMIMI010: The overall water quality of Middle Fork Beargrass Creek at Lexington Road 2 (EMIMI010) based on 20 diatom samples collected over two years (2003 and 2005) may be characterized as ‘Good’ (Table 8-2). The overall mean score of 51 reflects the upper range of ‘Good’ scores. In general, these data suggest water quality of Middle Fork Beargrass Creek at Lexington Road 2 seems to be declining somewhat over time (Table 8-2). Specifically, during the 2003 sampling season, 70% of sample dates characterized water quality as ‘Excellent’ (mean DBI = 54). During the 2005 sampling season, mean overall water quality was characterized as ‘Good’ as no samples scored in the ‘Excellent’ range (mean DBI = 47).

The taxa richness (TR) yearly mean score decreased slightly from year 2003 (48) to 2005 (44) (Table 8-2). These data suggest that species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality. This site had the third highest overall mean TR score (46) in the current study (Table 8-2).

The pollution tolerance index (PTI) yearly mean score decreased slightly from year 2003 (73) to 2005 (68) (Table 8-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality.

The siltation index (%NNS) yearly mean score decreased from year 2003 (73) to 2005 (64) (Table 8-2). These data suggest that overall species composition shifted toward those species adapted to living on silts and shifting sediments. In general, a decrease in overall %NNS suggests a decline in water quality.

The Shannon diversity index (SDI) yearly mean score increased from year 2003 (81) to 2005 (89) (Table 8-2). These data suggest the increase in SDI may have been related to a shift toward a more even distribution of those species present especially given the decrease in TR. In general, the majority of SDI values throughout the study period were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2003 (28) to 2005 (12) (Table 8-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

The cymbella group richness (CGR) yearly mean score decreased from year 2003 (24) to 2005 (7) (Table 8-2). These taxa are widely considered to be indicators of good water quality.

An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

8.2.2 Macroinvertebrates

The macroinvertebrate communities in Middle Fork of Beargrass Creek were rated as 'fair' at all three sampling sites in 2000 and 2004, but were rated as 'poor' in 2005 (Table 8-3). Lower MBI scores in 2005 seem to be a result of reduced %Clinger metric. For example, %Clinger decreased from 55.1% in 2004 to 2.9% in EMIMI002 on 2005. This trend in reduced %Clinger was observed at all three sites when comparing 2004 and 2005 metrics. In addition EPT taxa richness decreased at all three sites from 2004 to 2005. Other metrics showed no discernable trends within time period.

8.2.3 Fish

The fish communities in two upstream locations (EMIMI009 and EMIMI002) were rated as 'fair', but it was 'poor' at the downstream location (EMIMI010) in Middle Fork of Beargrass Creek (Table 8-4). The fish IBI at EMIMI009 and EMIMI002 were rated as 'poor' during on 2002, and they were improved slightly to 'fair' on 2005 samples. Higher metric scores of native specie richness (NAT) might be the main factor for the improvement. The downstream site (EMIMI010) had 'poor' rating on 2005, and its score for native species was low.

8.3 Hydrolab Sonde Data

8.3.1 Stream metabolism

The gross primary production estimates were highest in the most upstream location (EMIMI009) and lowest at the most downstream location (EMIMI010) in Middle Fork Beargrass Creek (Table 8-5), and such longitudinal trend was pronounced during spring. Community respiration estimates did not have any longitudinal changes. GPP estimates were highest in spring and lowest in fall at all three sites, while the CR estimates did not exhibit any seasonal trends (Table 8-5).

8.3.2 Dissolved oxygen, pH, and conductivity

Much of Hydrolab sonde data was either unavailable or unusable in LTMN locations located in Middle Fork Beargrass Creek watershed, especially during summer and fall. However, there were some clear longitudinal and seasonal trends in parameters collected.

In EMIMI009, mean daily dissolved oxygen stayed above 5 mg/L except summer 2003 (Table 8-6). They were highest during winter (9.55-12.60 mg/L) followed by spring (7.12-10.89 mg/L), and they were similar in summer (4.69-10.03 mg/L) and fall (5.14-8.89 mg/L). Daily minimum DO lower than 4.0 mg/L was recorded several seasons at this location (summer 2003 and 2005, fall 2005 and 2007). Mean daily pH values above 7 except summer 2006, and they were very stable annually. Mean conductivity values were in the order of spring (533-772 µS/cm), winter (363-905 µS/cm), fall (445-817 µS/cm) and summer (397-673 µS/cm) in EMIMI009.

In EMIMI002, mean daily DO stayed above 5 mg/L except summer and fall of year 2005 (Table 8-6). It was highest during winter (9.96-12.49 mg/L) followed by spring (6.01-11.26 mg/L) and fall (4.40-8.53 mg/L), and lowest during summer (4.23-7.67 mg/L). Daily minimum DO lower than 4.0 mg/L was recorded on several occasions during summer and fall in EMIMI002. Mean daily pH stayed mostly above 7, while daily minimum pH below 7 was recorded in spring 2003. Mean conductivity value highest in winter, followed by spring, summer, and fall in EMIMI002.

Mean daily DO was highest during winter, followed by spring, fall, and winter in EMIMI010 (Table 8-6). During summer, DO was extremely low (1.65-5.11 mg/L daily mean) and the daily minimum value dropped below 4.0 mg/L. Mean pH was above 7 except on summer 2001 and winter 2006. Conductivity was highest during winter lowest during summer, while spring and fall were similar on average.

Overall the averaged DO concentration was from upstream to downstream in Middle Fork Beargrass Creek. There was no longitudinal change in pH, but conductivity was decreasing from upstream to downstream (Table 8-6).

8.4 Laboratory Data

Water chemistry data were collected at different time periods from the tree LTMN locations in Middle Fork Beargrass Creek (Table 8-7, Figure 8-1). Water chemistry data were collected during 2006-2007, and fecal coliform counts were collected during 2003-2007 at EMIMI009. Nitrate-nitrogen concentration was higher from ‘wet’ samples (2.11 mg/L and 1.24 mg/L in 2006 and 2007, respectively) than ‘dry’ samples (1.73 mg/L and 0.81 mg/L in 2006 and 2007, respectively). Chloride concentration was higher in ‘dry’ samples than ‘wet’ samples.

In EMIMI002 location, water chemistry data were collected during years of 2002, 2004, 2006, and 2007 with different frequencies. Several water chemistry parameters, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), total phosphorus, and BOD were lower in the 2006-2007 samples than 2001 samples (dry period).

Water chemistry data were collected since 2004 in EMIMI010 location (Table 8-7). Ammonia-nitrogen, TKN, ortho-phosphorus, total phosphorus, were increased in 2007 samples than earlier 2004 samples (dry period).

Longitudinal trends of water chemistry parameters would provide some additional insights on how the watershed use affects stream ecosystem. In Middle Fork Beargrass Creek, several parameters increased along the longitudinal gradient. For example, ammonia-nitrogen, total phosphorus, and chloride concentrations were higher at the most downstream location (EMIMI010) than two upstream locations.

8.5 Watershed assessment based on the biological data

Based on three biotic indices from 2005, two upstream locations in Middle Fork Beargrass Creek could be considered as ‘fair’, while the down stream location (EMIMI010) was ‘poor’. Three biotic indices presented different water quality ratings in EMIMI009 and EMIMI002 locations throughout the samplings in 2002-2005. For example, water quality ratings for diatom, macroinvertebrates, and fish were ‘good’, ‘poor’ and ‘fair’, respectively, in EMIMI002 and EMIMI009 locations during 2005. Water quality ratings based on these biotic indices did not show any chronological trends in Middle Fork Beargrass Creek.

EMIMI009	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	—	excellent	excellent	—	**good**
MBI	—	—	—	—	fair	**poor**
Fish KBI	—	—	poor	fair	—	**fair**
EMIMI002						
DBI	—	excellent	good	excellent	—	**good**
MBI	fair	—	—	—	fair	**poor**
Fish KBI	fair	—	poor	poor	—	**fair**
EMIMI010						
DBI	—	—	—	excellent	—	**good**
MBI	—	—	—	—	fair	**poor**
Fish KBI	—	—	—	—	—	**poor**

Table 8-1 Land use/cover characteristics of Middle Fork Beargrass Creek.

EMIMI009	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	24.07	17.02	20.82
Open Water	0.21	0.35	0.00
Dev. Open Space	29.20	20.74	3.30
Dev. Low Intensity	26.15	22.12	10.38
Dev. Medium Intensity	11.95	8.82	39.15
Dev. High Intensity	6.15	3.56	46.23
Barren Land	0.08	0.12	0.00
Deciduous Forest	19.14	34.76	0.94
Evergreen Forest	1.89	1.40	0.00
Mixed Forest	0.07	0.01	0.00
Shrub/Scrub	0.01	0.00	0.00
Grassland/herbaceous	0.57	0.55	0.00
Pasture/Hay	1.96	2.78	0.00
Cropland	2.60	4.68	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.02	0.10	0.00

EMIMI002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	24.07	17.81	18.06
Open Water	0.21	0.40	0.00
Dev. Open Space	31.13	23.90	38.71
Dev. Low Intensity	26.94	22.88	8.29
Dev. Medium Intensity	11.50	8.67	26.27
Dev. High Intensity	6.13	4.12	17.97
Barren Land	0.07	0.10	0.00
Deciduous Forest	17.62	31.95	8.76
Evergreen Forest	1.90	1.32	0.00
Mixed Forest	0.05	0.01	0.00
Shrub/Scrub	0.01	0.00	0.00
Grassland/herbaceous	0.65	0.54	0.00
Pasture/Hay	1.60	2.25	0.00
Cropland	2.17	3.78	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.01	0.08	0.00

EMIMI010	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	22.37	15.51	15.15
Open Water	0.30	0.32	0.00
Dev. Open Space	30.22	22.33	24.32
Dev. Low Intensity	26.51	20.35	22.97
Dev. Medium Intensity	10.57	7.89	1.35
Dev. High Intensity	5.15	3.44	0.00
Barren Land	0.05	0.08	0.00
Deciduous Forest	20.52	38.45	40.54
Evergreen Forest	2.64	1.61	9.46
Mixed Forest	0.06	0.01	0.00
Shrub/Scrub	0.01	0.00	0.00
Grassland/herbaceous	1.08	0.57	0.45
Pasture/Hay	1.21	1.81	0.00
Cropland	1.64	3.05	0.00
Woody Wetlands	0.01	0.00	0.00
Emergent Herbaceous Wetlands	0.05	0.08	0.90

Table 8-2 DBI scores estimated in Middle Fork Beargrass Creek.

EMIMI009	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2002	54	63	57	97	32	26	**55**	**EXCELLENT**
2003	49	69	68	87	30	21	**54**	**EXCELLENT**
Summer 05	39	68	63	88	18	18	**49**	**GOOD**
Fall 05	44	64	49	97	13	28	**49**	**GOOD**
2005 All	42	66	56	92	15	23	**49**	**GOOD**
Overall	**48**	**66**	**60**	**92**	**26**	**23**	**53**	**EXCELLENT**
EMIMI002								
2001	54	68	56	97	73	14	**60**	**EXCELLENT**
2002	45	72	74	81	20	20	**52**	**GOOD**
2003	43	73	78	79	30	26	**55**	**EXCELLENT**
Summer 05	30	79	87	47	5	14	**44**	**FAIR**
Fall 05	43	70	62	92	28	20	**52**	**GOOD**
2005 All	36	74	75	70	17	17	**48**	**GOOD**
Overall	**44**	**73**	**71**	**81**	**34**	**20**	**54**	**EXCELLENT**
EMIMI010								
2003	48	73	73	81	28	24	**54**	**EXCELLENT**
Summer 05	39	70	70	78	10	3	**45**	**FAIR**
Fall 05	48	65	57	99	13	11	**49**	**GOOD**
2005 All	44	68	64	89	12	7	**47**	**GOOD**
Overall	**46**	**70**	**68**	**85**	**20**	**15**	**51**	**GOOD**

Table 8-3 Macroinvertebrate biotic integrity scores estimated in Middle Fork Beargrass Creek.

		EMIMI009		EMIMI002		EMIMI010	
Year	Metric	Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness			48	64.86		
	EPT Richness			8	20.00		
	m%EPT			10	23.29		
	mHBI			8.13	46.73		
	%Chir. and Oli.			10	90.91		
	%Clinger			19	25.68		
	MBI			------	45.25		
	Assessment			------	**Fair**		
2004	Taxa Richness	34	46	32	43.2	31	41.9
	EPT Richness	5	16.7	7	23	6	20
	m%EPT	4.4	6	17.2	23.6	6.2	8.49
	mHBI	6.93	44.6	5.59	64	5.85	60
	%Chir. and Oli.	11.3	89.6	27.5	73.2	27.4	73.3
	%Clinger	30.1	40.7	55.1	74.5	53.4	72.2
	MBI	------	40.60	------	50.30	------	46.00
	Assessment	------	**Fair**	------	**Fair**	------	**Fair**
2005	Taxa Richness	34	45.95	27	36.49	34	45.95
	EPT Richness	3	10.00	6	20.00	3	10.00
	m%EPT	7.90	10.83	6.67	9.13	0.98	1.34
	mHBI	7.66	34.03	7.03	43.13	7.40	37.68
	%Chir. and Oli.	11.68	89.21	5.40	95.56	11.76	89.13
	%Clinger	12.37	16.72	2.86	3.86	20.59	27.82
	MBI	------	34.45	------	34.70	------	35.32
	Assessment	------	**Poor**	------	**Poor**	------	**Poor**

Table 8-4 Fish IBI scores estimated in Middle Fork Beargrass Creek.

Site	EMIMI009	EMIMI002	EMIMI010
1999-up	**NS**	**fair**	**NS**
1999-dn	**NS**	**poor**	**NS**
2000-up	**NS**	**poor**	**NS**
2000-dn	**NS**	**fair**	**NS**
2002	**Poor**	**Poor**	**NS**
Native	53	47	
DMS	12	11	
INT	13	11	
WC	38	55	
SL	21	19	
%Insect_Ex_Tol	9	20	
%OMNI	50	50	
%TOL	50	48	
IBI	31	33	
2003	**Fair**	**Poor**	**NS**
Native	69	34	
DMS	41	8	
INT	31	8	
WC	64	32	
SL	47	17	
%Insect_Ex_Tol	31	6	
%OMNI	50	23	
%TOL	50	50	
IBI	48	22	
2005	**Fair**	**Fair**	**Poor**
NAT	60	47	35
DMS	28	32	6
INT	31	11	6
SL	39	11	15
%INSCT	50	100	50
%TOL	33	60	50
%FHW	0	14	34
KIBI	40	44	27

Table 8-5 Gross primary production (g/m^2/day) and community respiration (g/m^2/day) estimated in Middle Fork Beargrass Creek.

	Spring		**Summer**		**Fall**	
EMIMI009	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	—	—	—	—	—	—
2001	9.35	7.46	3.70	3.79	1.53	5.47
2002	5.46	3.27	2.82	5.68	1.35	3.51
2003	4.28	7.15	1.48	9.16	2.53	5.13
2004	5.84	6.51	0.95	5.39	—	—
2005	3.65	8.11	2.69	8.48	1.88	10.31
2006	4.60	6.19	3.65	1.34	—	—
2007	—	—	2.29	4.29	3.58	8.09

	Spring		**Summer**		**Fall**	
EMIMI002	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	4.96	6.16	—	—	—	—
2001	—	—	2.09	6.92	0.98	6.12
2002	4.66	7.70	2.01	6.92	1.25	2.90
2003	3.73	9.32	—	—	—	—
2004	4.18	9.17	—	—	0.66	7.32
2005	—	—	1.81	7.54	1.10	8.54
2006	—	—	—	—	1.48	3.03
2007	2.65	3.34	1.60	2.89	2.69	5.62

	Spring		**Summer**		**Fall**	
EMIMI010	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	—	—	—	—	—	—
2001	2.33	4.28	—	—	0.73	3.67
2002	0.51	1.02	1.95	7.36	0.96	1.71
2003	—	—	—	—	1.14	5.76
2004	2.06	5.75	0.53	7.75	0.36	6.14
2005	—	—	—	—	0.36	9.09
2006	1.40	1.91	1.38	5.28	0.33	3.05
2007	0.74	3.72	0.79	5.47	0.68	7.90

Table 8-6 Water temperature, DO, pH, and conductivity in Middle Fork Beargrass Creek, at EMIMI009

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	16.6	14.2	19.9	10.89	6.60	18.10	7.53	7.19	8.09	723.4	686.6	746.7
2002	12.4	10.5	14.8	11.59	9.08	16.93	7.90	7.66	8.30	605.7	578.7	626.4
2003	14.7	11.9	18.2	8.72	6.64	12.14	7.65	7.46	7.97	771.9	686.3	783.1
2004	13.5	10.6	17.0	10.22	7.24	15.02	7.79	7.56	8.16	744.2	684.5	756.6
2005	15.3	12.3	19.0	7.12	4.90	10.48	7.04	6.73	7.51	532.9	506.8	555.1
2006	14.4	12.4	17.5	9.59	7.28	13.53	7.76	7.55	8.12	754.4	736.3	766.1
2007	—	—	—	—	—	—	—	—	—	—	—	—

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	21.7	20.0	24.0	8.45	5.42	11.98	7.24	7.12	7.38	653.7	566.4	692.1
2002	22.6	21.1	24.1	7.22	5.49	9.61	7.32	7.19	7.47	547.4	525.5	573.6
2003	21.7	20.1	23.4	4.69	3.79	5.83	7.47	7.36	7.61	632.5	572.9	676.3
2004	20.0	19.0	21.1	6.74	6.11	7.56	7.14	7.05	7.25	400.8	351.5	468.4
2005	24.0	22.4	25.7	5.13	3.46	7.22	7.75	7.65	7.86	673.1	536.4	698.8
2006	20.2	18.3	22.2	10.03	7.99	12.34	6.90	6.80	7.03	397.1	296.3	428.9
2007	21.8	19.6	24.3	7.81	6.24	9.77	7.61	7.51	7.73	673.1	636.0	705.2

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	16.0	14.7	17.6	7.72	6.71	9.29	7.21	7.00	7.34	561.0	370.7	638.4
2002	15.1	14.3	15.9	8.89	8.09	10.15	7.45	7.39	7.51	660.0	626.1	694.6
2003	16.6	14.8	18.3	8.39	7.07	10.68	7.51	7.38	7.63	643.1	567.8	650.1
2004	15.7	13.9	17.3	—	—	—	7.51	7.31	7.61	444.6	393.0	449.7
2005	16.5	15.0	18.1	5.14	3.85	6.89	7.54	7.45	7.66	573.4	566.5	578.9
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	22.8	21.3	24.3	6.39	3.31	9.52	7.37	7.27	7.63	817.0	802.8	832.6

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	8.1	6.9	9.4	10.23	8.29	14.02	7.70	7.54	8.03	904.8	821.6	1035.7
2003	4.5	3.3	5.7	12.60	10.30	16.64	7.97	7.61	8.29	711.6	680.0	762.7
2004	7.1	6.2	8.3	11.90	10.30	15.34	7.70	7.54	7.97	363.4	342.5	388.2
2005	7.0	6.0	8.1	11.89	10.60	14.01	7.83	7.75	7.99	567.0	553.7	589.3
2006	10.1	8.6	11.3	9.55	8.45	10.96	7.56	7.46	7.67	702.3	519.5	908.2
2007	—	—	—	—	—	—	—	—	—	—	—	—

Table 8-6 Continued, at EMIMI002.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	14.4	12.4	16.3	9.59	6.72	14.08	8.09	7.80	8.45	628.0	612.6	636.0
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.7	10.9	14.2	8.99	5.30	14.39	7.59	7.28	7.98	594.6	568.6	623.4
2003	16.1	13.8	18.6	6.01	3.62	9.31	7.00	6.76	7.32	773.5	762.0	783.8
2004	14.4	12.1	17.2	6.68	4.00	10.45	8.07	7.79	8.46	684.0	670.7	695.7
2005	—	—	—	—	—	—	—	—	—	—	—	—
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	8.9	7.6	10.3	11.26	9.42	13.97	7.89	7.76	8.05	666.9	646.8	678.6

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	24.2	22.4	26.5	5.14	3.71	7.21	7.49	7.42	7.61	566.1	530.7	627.3
2002	24.8	23.3	26.5	5.10	3.70	7.04	7.43	7.32	7.59	567.5	490.3	598.8
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	25.1	23.7	27.0	4.23	2.68	6.17	7.48	7.40	7.61	751.9	736.9	763.4
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	23.8	21.8	25.5	7.67	6.43	9.56	7.81	7.73	7.91	655.4	609.2	687.2

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.5	14.2	17.1	6.32	5.52	7.44	7.56	7.45	7.65	517.1	388.6	581.5
2002	14.2	13.3	15.1	8.53	7.77	9.70	8.03	7.96	8.10	666.3	651.2	678.6
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	14.7	13.7	15.9	5.34	4.47	6.24	7.31	7.26	7.38	406.0	403.0	408.1
2005	16.2	15.0	17.5	4.45	3.51	5.76	7.54	7.41	7.65	543.0	537.0	556.5
2006	17.2	15.6	18.6	8.49	7.46	9.88	7.93	7.88	7.99	690.0	684.2	694.0
2007	23.1	21.7	24.8	6.33	4.40	10.04	7.57	7.48	7.71	765.8	754.3	772.8

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	6.2	5.1	7.3	11.61	9.59	15.56	8.10	7.91	8.40	915.7	820.1	1173.6
2003	2.1	1.4	2.9	12.49	10.46	15.63	8.16	8.01	8.35	750.9	716.3	798.7
2004	5.9	5.0	6.9	11.02	9.55	13.70	7.82	7.63	8.03	850.2	820.7	896.2
2005	5.3	4.3	6.2	11.32	9.98	13.18	7.50	7.38	7.65	582.2	577.5	587.9
2006	9.8	7.9	11.4	9.96	8.53	11.73	7.45	7.28	7.71	550.5	489.2	647.3
2007	9.1	8.3	9.9	10.71	9.93	11.84	7.81	7.73	7.87	662.2	593.3	752.7

Table 8-6 Continued, at EMIMI010

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	19.4	16.9	22.7	7.5	5.5	9.9	7.4	7.3	7.6	684.5	518.7	726.5
2002	12.5	11.3	13.9	9.4	7.8	11.3	8.0	7.9	8.2	602.4	539.3	627.4
2003	16.4	13.9	20.0	—	—	—	7.5	7.4	7.6	733.7	634.5	757.5
2004	14.3	11.5	18.5	7.0	5.2	9.0	7.8	7.6	8.0	672.7	563.2	709.5
2005	16.6	13.7	20.9	—	—	—	7.9	7.8	8.1	513.5	443.0	551.8
2006	15.7	13.6	18.0	9.2	7.4	10.9	7.9	7.7	8.1	744.8	703.1	769.9
2007	8.0	6.7	9.6	9.1	8.1	9.9	7.9	7.8	8.0	667.2	638.5	687.0
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	24.1	21.7	27.1	1.65	0.33	4.36	6.84	6.64	7.09	—	—	—
2002	25.6	23.8	27.5	2.68	0.43	5.54	7.93	7.76	8.03	—	—	—
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	21.6	20.6	22.7	2.13	1.46	2.82	7.60	7.46	7.81	391.8	275.4	465.7
2005	24.6	21.2	28.1	—	—	—	7.31	7.21	7.40	—	—	—
2006	22.6	20.4	25.5	5.11	3.57	6.26	7.51	7.43	7.60	658.2	538.4	770.1
2007	25.0	22.6	28.3	3.82	3.19	4.61	7.55	7.50	7.62	559.9	508.1	600.1
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.0	13.1	17.4	7.39	5.95	8.90	7.03	6.77	7.42	—	—	—
2002	13.4	12.5	14.5	8.95	7.73	11.84	7.58	7.52	7.63	663.4	653.5	675.4
2003	15.6	13.0	18.4	5.81	4.85	6.94	7.90	7.82	7.97	—	—	—
2004	15.6	14.4	17.0	4.38	3.58	5.23	7.58	7.53	7.63	402.3	348.0	418.9
2005	14.8	11.9	18.8	—	—	—	7.66	7.59	7.73	—	—	—
2006	16.8	15.2	18.3	7.17	6.83	7.42	—	—	—	924.0	912.1	937.6
2007	23.1	21.8	24.5	—	—	—	7.17	7.13	7.21	721.0	711.9	728.9
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	3.0	2.2	4.0	13.61	11.73	15.66	7.98	7.86	8.11	1118.6	1022.2	1225.2
2002	4.7	3.6	5.9	10.74	9.80	11.85	7.94	7.79	8.06	909.3	777.2	1213.7
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	3.5	2.5	4.5	9.16	8.75	9.65	7.82	7.41	7.91	583.2	542.5	588.8
2006	9.0	7.9	10.2	7.36	6.88	7.88	6.94	6.70	7.13	700.8	555.9	915.8
2007	7.7	7.1	8.4	9.97	9.23	10.61	8.08	7.99	8.18	671.0	566.0	904.0

Table 8-7 Summary of selected water chemistry parameters at LTMN locations in Middle Fork Beargrass Creek, at EMIMI009

		2006	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.73	0.81	Total Kjeldahl Nitrogen (mg/L)	0.62	0.75
	SD (Dry)	-	0.00		-	0.24		-	0.18
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.03	0.05		2.11	1.24		0.73	0.99
	SD (wet)	0.00	0.00		0.66	0.53		0.03	0.16
	Count (wet)	2	2		2	2		2	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.04	Phosphorus (mg/L)	0.08	0.05	Chloride	48.71	53.43
	SD (Dry)	-	0.02		-	0.01		-	38.64
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	0.05	0.05		0.05	0.11		38.22	31.73
	SD (wet)	0.04	0.04		0.01	0.11		5.69	27.49
	Count (wet)	2	2		2	2		2	2
BOD (mg/L)	Mean (Dry)	1.00	1.50	TDS (mg/L)	398.00	414.00	TSS (mg/L)	21.00	12.00
	SD (Dry)	-	0.71		-	212.13		-	9.90
	Count (Dry)	1	2		1	2		1	2
	Mean (wet)	8.75	2.50		396.00	350.00		10.65	24.50
	SD (wet)	11.67	0.71		11.31	73.54		0.92	30.41
	Count (wet)	2	2		2	2		2	2

		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	-	-	-	297	932	917	1239	1388
	SD (Dry)	-	-	-	721	1431	770	1478	742
	Count (Dry)	-	-	-	14	24	23	14	22
	Mean (wet)	-	-	-	943	904	3331	1474	3468
	SD (wet)	-	-	-	1061	643	3704	1546	3221
	Count (wet)	-	-	-	4	7	9	19	12

Table 8-7 Continued, at EMIMI002.

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	-	0.20	0.03	-	0.03	-	0.03	0.05
	SD (Dry)	-	0.16	-	-	0.00	-	-	0.00
	Count (Dry)	-	22	1	-	5	-	1	2
	Mean (wet)	-	-	-	-	0.03	-	0.03	0.05
	SD (wet)	-	-	-	-	0.01	-	0.00	0.00
	Count (wet)	-	-	-	-	17	-	2	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	-	1.35	2.65	-	0.79	-	1.59	0.78
	SD (Dry)	-	0.59	-	-	1.07	-	-	0.45
	Count (Dry)	-	25	1	-	2	-	1	2
	Mean (wet)	-	-	-	-	1.20	-	2.08	1.07
	SD (wet)	-	-	-	-	0.28	-	0.81	1.07
	Count (wet)	-	-	-	-	17	-	2	11
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	-	2.00	-	-	0.37	-	0.56	0.84
	SD (Dry)	-	0.84	-	-	0.18	-	-	0.04
	Count (Dry)	-	13	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	0.65	-	0.66	1.13
	SD (wet)	-	-	-	-	0.24	-	0.06	0.45
	Count (wet)	-	-	-	-	17	-	2	14
Ortho Phosphorus (mg/L)	Mean (Dry)	-	0.03	0.03	-	0.03	-	0.03	0.04
	SD (Dry)	-	0.00	-	-	0.00	-	-	0.02
	Count (Dry)	-	26	1	-	4	-	1	2
	Mean (wet)	-	-	-	-	0.03	-	0.05	0.06
	SD (wet)	-	-	-	-	0.01	-	0.04	0.05
	Count (wet)	-	-	0	-	17	-	2	2
Phosphorus (mg/L)	Mean (Dry)	-	0.35	0.55	-	0.20	-	0.07	0.09
	SD (Dry)	-	0.57	-	-	0.19	-	-	0.04
	Count (Dry)	-	33	1	-	2	-	1	2
	Mean (wet)	-	-	-	-	0.10	-	0.06	0.27
	SD (wet)	-	-	-	-	0.05	-	0.03	0.11
	Count (wet)	-	-	-	-	16	-	2	13
Chloride (mg/L)	Mean (Dry)	-	64.46	65.27	-	38.98	-	49.70	63.29
	SD (Dry)	-	35.84	-	-	53.14	-	-	25.51
	Count (Dry)	-	25	1	-	2	-	1	2
	Mean (wet)	-	-	-	-	71.98	-	39.57	32.26
	SD (wet)	-	-	-	-	30.99	-	4.25	24.85
	Count (wet)	-	-	-	-	17	-	2	2
BOD (mg/L)	Mean (Dry)	-	6.20	-	-	1.00	-	0.50	1.00
	SD (Dry)	-	2.76	-	-	0.61	-	-	0.00
	Count (Dry)	-	32	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	2.22	-	1.00	4.00
	SD (wet)	-	-	-	-	1.20	-	0.71	2.83
	Count (wet)	-	-	-	-	18	-	2	2
TDS (mg/L)	Mean (Dry)	-	472.67	-	-	430.00	-	378.00	482.00
	SD (Dry)	-	88.46	-	-	-	-	-	231.93
	Count (Dry)	-	3	-	-	1	-	1	2
	Mean (wet)	-	-	-	-	392.94	-	417.00	323.00
	SD (wet)	-	-	-	-	146.54	-	26.87	171.12
	Count (wet)	-	-	-	-	17	-	2	2
TSS (mg/L)	Mean (Dry)	-	108.85	-	-	1.50	-	8.00	10.50
	SD (Dry)	-	114.59	-	-	1.37	-	-	7.78
	Count (Dry)	-	34	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	11.53	-	9.60	111.40
	SD (wet)	-	-	-	-	10.18	-	3.39	74.34
	Count (wet)	-	-	-	-	17	-	2	15
Fecal Coliform (col/100 ml)	Mean (Dry)	476	34893	935	390	228	371	548	724
	SD (Dry)	1106	86847	2259	592	353	386	595	1005
	Count (Dry)	19	63	29	23	29	23	14	22
	Mean (wet)	12349	-	-	1505	532	1404	3887	55638
	SD (wet)	20394	-	-	1823	791	1917	9113	69688
	Count (wet)	8	-	-	9	24	9	19	26

Table 8-7 Continued, at EMIMI010

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	-	-	-	-	0.13	-	0.03	1.78
	SD (Dry)	-	-	-	-	0.24	-	-	2.44
	Count (Dry)	-	-	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	0.05	-	0.03	0.05
	SD (wet)	-	-	-	-	0.11	-	0.00	0.00
	Count (wet)	-	-	-	-	18	-	2	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	-	-	-	-	1.36	-	1.12	0.81
	SD (Dry)	-	-	-	-	0.06	-	-	-
	Count (Dry)	-	-	-	-	2	-	1	1
	Mean (wet)	-	-	-	-	1.10	-	2.05	1.36
	SD (wet)	-	-	-	-	0.25	-	0.94	1.03
	Count (wet)	-	-	-	-	18	-	2	11
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	-	-	-	-	0.41	-	0.75	2.61
	SD (Dry)	-	-	-	-	0.22	-	-	2.54
	Count (Dry)	-	-	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	0.89	-	0.99	1.08
	SD (wet)	-	-	-	-	0.29	-	0.16	0.24
	Count (wet)	-	-	-	-	17	-	2	11
Ortho Phosphorus (mg/L)	Mean (Dry)	-	-	-	-	0.03	-	0.10	0.24
	SD (Dry)	-	-	-	-	0.00	-	-	0.25
	Count (Dry)	-	-	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	0.04	-	0.06	0.05
	SD (wet)	-	-	-	-	0.05	-	0.05	0.03
	Count (wet)	-	-	-	-	18	-	2	2
Phosphorus (mg/L)	Mean (Dry)	-	-	-	-	0.05	-	0.15	0.42
	SD (Dry)	-	-	-	-	0.05	-	-	0.40
	Count (Dry)	-	-	-	-	4	-	1	2
	Mean (wet)	-	-	-	-	0.17	-	0.06	0.22
	SD (wet)	-	-	-	-	0.08	-	0.03	0.11
	Count (wet)	-	-	-	-	17	-	2	11
Chloride (mg/L)	Mean (Dry)	-	-	-	-	110.14	-	47.72	69.74
	SD (Dry)	-	-	-	-	49.36	-	-	14.06
	Count (Dry)	-	-	-	-	2	-	1	2
	Mean (wet)	-	-	-	-	66.57	-	65.57	29.50
	SD (wet)	-	-	-	-	35.85	-	6.89	21.79
	Count (wet)	-	-	-	-	17	-	2	2
BOD (mg/L)	Mean (Dry)	-	-	-	-	1.40	-	0.50	3.50
	SD (Dry)	-	-	-	-	1.47	-	-	3.54
	Count (Dry)	-	-	-	-	5	-	1	2
	Mean (wet)	-	-	-	-	2.33	-	1.00	3.00
	SD (wet)	-	-	-	-	1.56	-	0.71	1.41
	Count (wet)	-	-	-	-	18	-	2	2
TDS (mg/L)	Mean (Dry)	-	-	-	-	438.00	-	392.00	493.00
	SD (Dry)	-	-	-	-	-	-	-	80.61
	Count (Dry)	-	-	-	-	1	-	1	2
	Mean (wet)	-	-	-	-	371.60	-	433.00	310.00
	SD (wet)	-	-	-	-	127.73	-	46.67	42.43
	Count (wet)	-	-	-	-	15	-	2	2
TSS (mg/L)	Mean (Dry)	-	-	-	-	20.50	-	27.00	19.50
	SD (Dry)	-	-	-	-	17.68	-	-	13.44
	Count (Dry)	-	-	-	-	2	-	1	2
	Mean (wet)	-	-	-	-	33.80	-	15.70	81.18
	SD (wet)	-	-	-	-	20.91	-	0.99	85.70
	Count (wet)	-	-	-	-	15	-	2	11
Fecal Coliform (col/100 ml)	Mean (Dry)	-	-	-	-	1460	719	30423	12372
	SD (Dry)	-	-	-	-	2033	1291	108685	16506
	Count (Dry)	-	-	-	-	23	24	14	23
	Mean (wet)	-	-	-	-	3500	4375	3960	64887
	SD (wet)	-	-	-	-	11151	8528	6283	173601
	Count (wet)	-	-	-	-	25	8	19	19

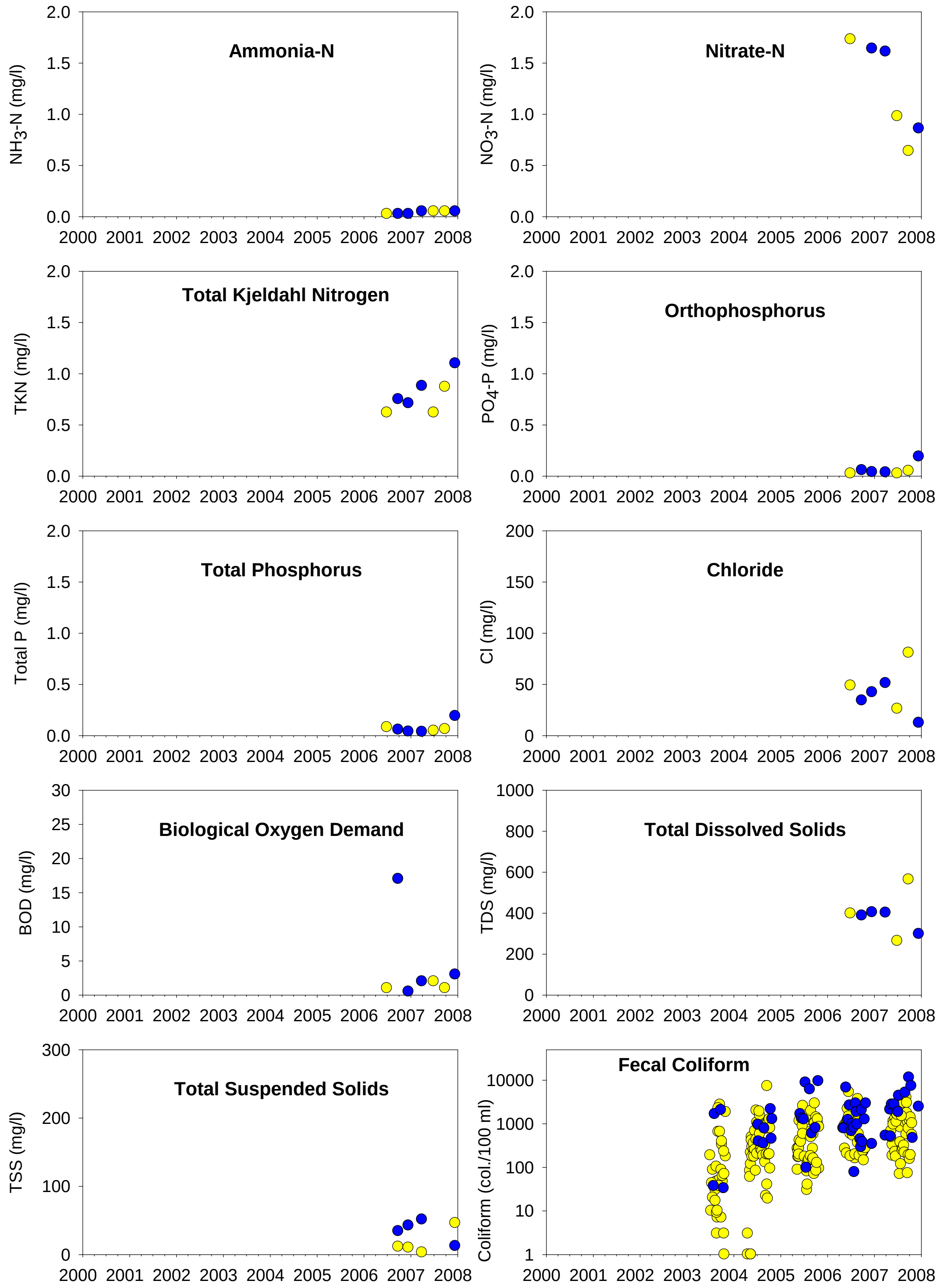

Figure 8-1 Major water chemistry parameters measured in Middle Fork Beargrass Creek, at EMIMI009. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

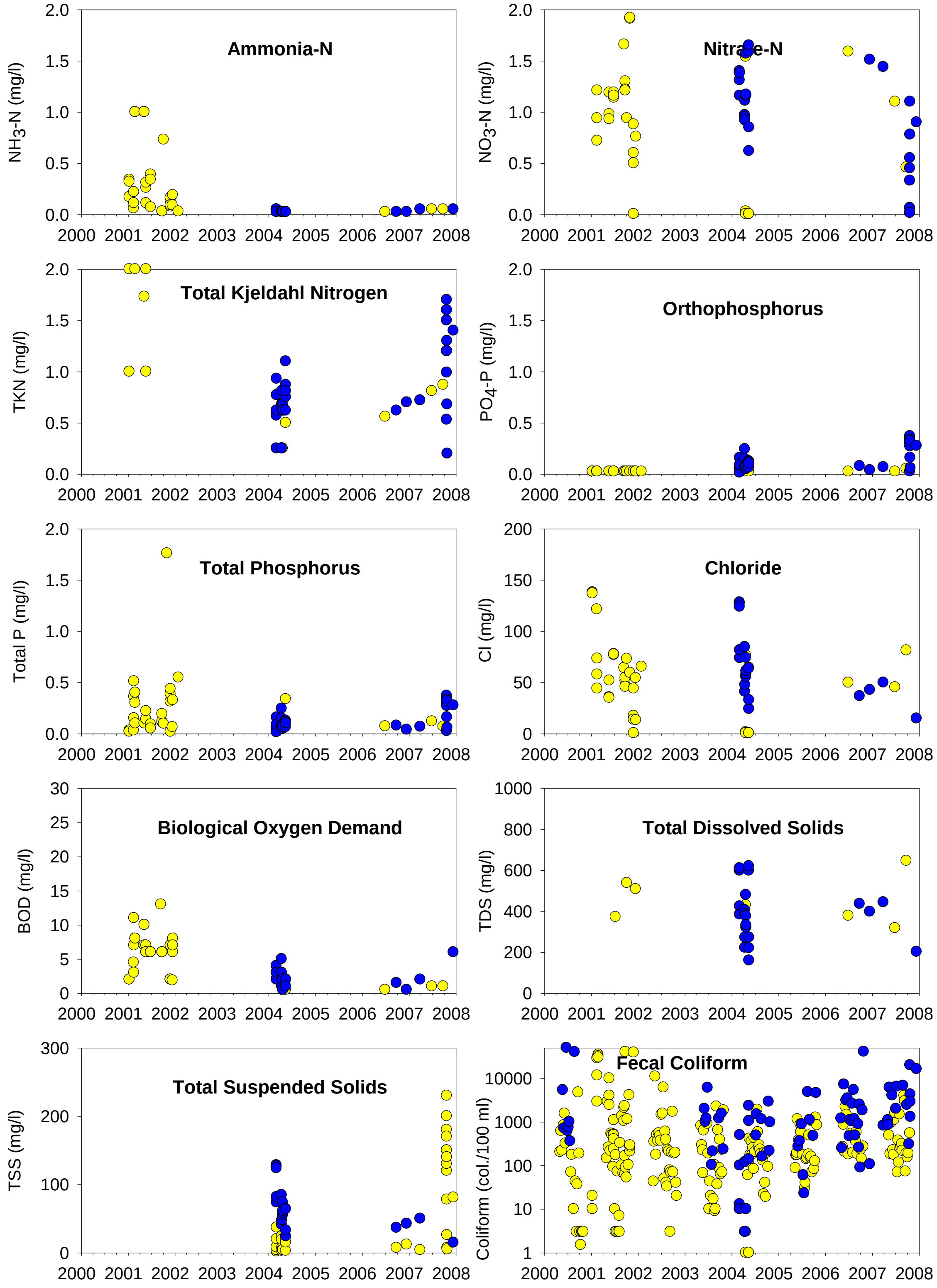

Figure 8-1 Continued, at EMIMI002.

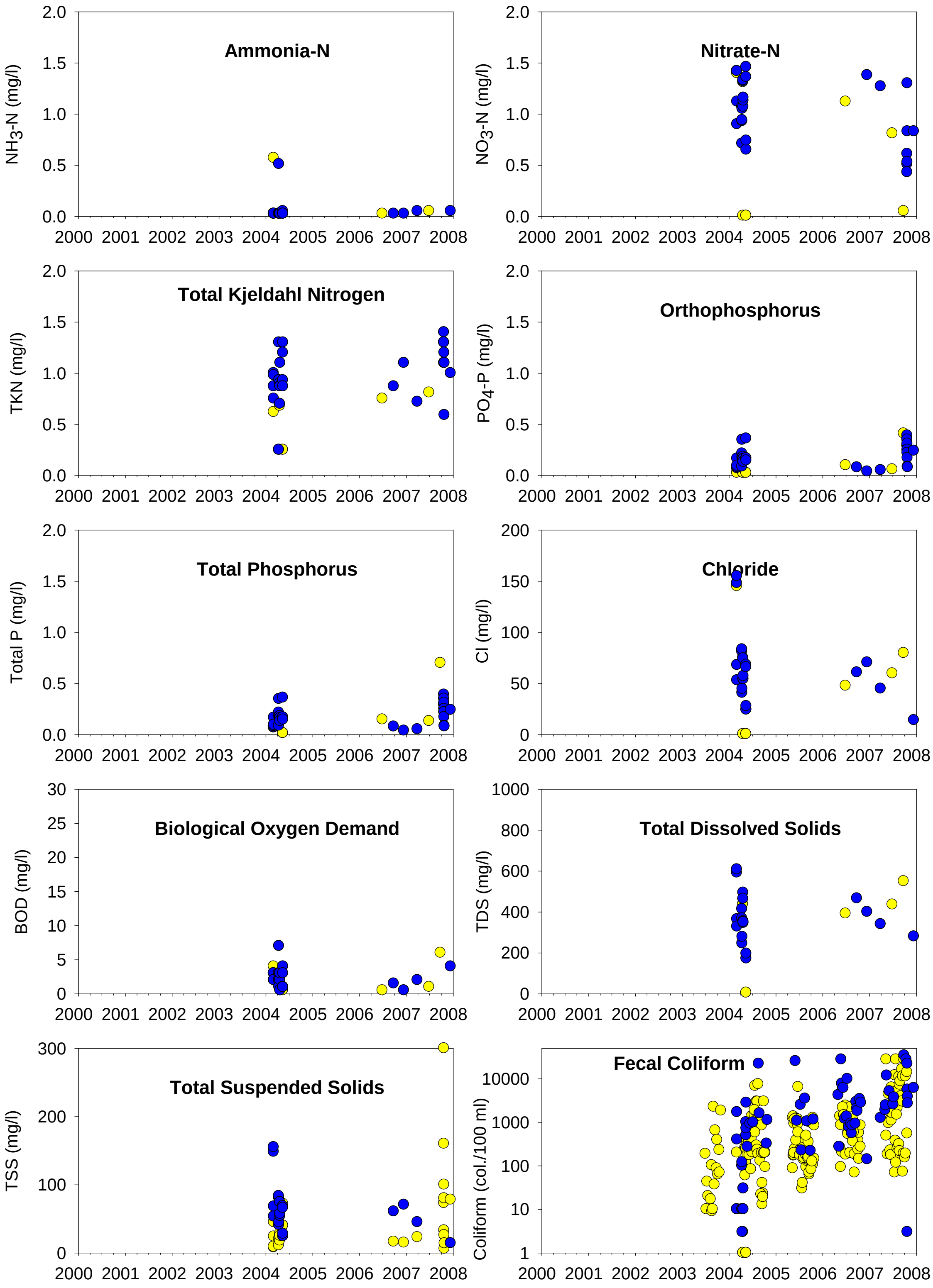

Figure 8-1 Continued, at EMIMI010.

Chapter 9 Muddy Fork Beargrass Creek

9.1 Watershed Physical Characteristics

The Muddy Fork of Beargrass Creek originates in the Woodlawn Park area, initially flows to north before turning west parallel to Ohio River. It merges into South Fork Beargrass Creek just downstream of a LTMN location at Brownsboro Road (ESFSF006). There is one LTMN location at Mockingbird Valley Road (EMUMU001).

The Muddy Fork of Beargrass Creek watershed contains about 45% of developed areas and 52% of forests (Table 9-1). Impervious surfaces comprises in an average 8.8% of total watershed. Riparian areas of this stream contain higher proportion of forests (69% at overall stream and 62% at reach scale) than the overall watershed.

9.2 Biological Data

9.2.1 Diatom

Overall water quality of the Muddy Fork of Beargrass Creek at Mockingbird Valley Road (EMUMU001) based on 29 diatom samples collected over three years (2002 – 03, 2005) may be characterized as ‘Good’ (Table 9-2). The overall mean score of 50 reflects the mid range of ‘Good’ scores. In general, these data suggest water quality of Muddy Fork Beargrass Creek at Mockingbird Valley Road seems to be declining over time (Table 9-2). Specifically, during the 2002 and 2003 sampling seasons, all sample dates characterized water quality as either ‘Good’ (37%) or ‘Excellent’ (63%) (mean DBI = 53). During the 2005 sampling season, mean overall water quality was characterized as ‘Fair’ as only 30% of sample dates scored in the ‘Good’ range while no samples scored in the ‘Excellent’ range (mean DBI = 45).

The taxa richness (TR) yearly mean score decreased from year 2002 (48) to 2005 (41) (Table 9-2). These data suggest that species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score decreased slightly from year 2002 (69) to 2005 (65) (Table 9-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality.

The siltation index (%NNS) yearly mean score increased from year 2002 (61) to 2003 (77), but decreased during 2005 (58) (Table 9-2). Small, overall yearly %NNS fluctuations, as seen here, are well within the limits of expected yearly natural variability. Perhaps some of those species lost with respect to TR between 2002 and 2003 were *Navicula* or *Nitzschia* species. This net loss may have contributed to the increase observed with respect to the %NNS during this timeframe.

The Shannon diversity index (SDI) yearly mean score decreased from year 2002 (97) to 2003 (85), but increased during 2005 (94) (Table 9-2). Small, overall yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score increased from year 2002 (24) to 2003 (30) but decreased significantly during 2005 (7) (Table 9-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining slightly. Taxa lost from within this group likely contributed to the overall decrease in TR throughout this study.

The cymbella group richness (CGR) yearly mean score decreased from year 2002 (19) to 2005 (4) (Table 9-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the overall decrease in TR throughout this study.

9.2.2 Macroinvertebrates

The macroinvertebrate communities in the Muddy Fork of Beargrass Creek generally score the lowest of all LTMN sampling sites (Table 9-3). EMUMU001 was not sampled in 2000. In 2004 and 2005, this site scored the lowest MBI score of all 28 LTMN sites, resulting in ‘poor’ and ‘very poor’ ratings, respectively. In 2004 the MBI was 26.10 and it fell to 17.19 in 2005. In 2005, EMUMU001 scored <10 for four of the seven component MBI metrics including EPT Richness, m%EPT, %Clinger, and %Ephemeroptera.

9.2.3 Fish

The fish community in Muddy Fork Beargrass Creek at Mockingbird Valley Road site showed an improving trend thorough three samplings at 2002 (fair), 2003 (good), and 2005 (excellent) (Table 9-4). Several metric scores, such as native species richness (NAT), intolerant species richness (INT), and % insectivores (%INSCT), showed improvements in EMUMU001 during this period.

9.3 Hydrolab Sonde Data

9.3.1 Stream metabolism

Only limited amount of reliable sonde data was available to estimate GPP and CR in the Muddy Fork Beargrass Creek location (Table 9-5). GPP was higher during spring than summer and fall, which were in the similar range. CR was also highest in spring, followed by summer and fall.

9.3.2 Dissolved oxygen, pH, and conductivity

Much of the Hydrolab sonde data, especially dissolved oxygen, was either unavailable or unreliable in EMUMU001 (Table 9-6). DO was higher during spring and winter than summer or fall. Daily mean DO was above 5 mg/L, and daily minimum DO was above 4.0 mg/L except summer 2005 (Table 9-6). Mean daily pH was generally highest during summer (7.05-7.98) and lowest during winter (6.35-7.4), and it was lower than 7 on several occasions (spring 2005, fall 2004 and 2005, winter 2004 and 2005). Mean daily conductivity values were in the order of winter (667-909 µS/cm), summer (491-1071 µS/cm), fall (322-1055 µS/cm) and spring (595-718 µS/cm) in EMUMU001.

9.4 Laboratory Data

Water chemistry samples were collected with irregular intervals in Muddy fork Beargrass Creek (Table 9-7; Figure 9-1). During 2004, most of waters samples were collected as ‘wet’ period samples. Based on the ‘dry’ period samples, nitrate-nitrogen concentration decreased in 2007 (0.95 mg/L) when compared to 2004 samples (1.70 mg/L), while total phosphorus concentration during 2007 was higher than 2004. Chloride concentration was lower during 2007 (57 mg/L) than 2004 (83 mg/L).

9.5 Watershed assessment based on the biological data

There was a great discrepancy in water quality ratings among three biotic integrity indices in Muddy Fork Beargrass Creek, especially on 2005. The table below shows the diatom community shows a ‘fair’ water quality rating, macroinvertebrate community shows a ‘very poor’ rating, and fish community shows an ‘excellent’ rating. There was also a great deal of fluctuations in water quality ratings through the sampling period for all biological component during 2002-2005.

EMUMU001	2000	2001	2002	2003	2004	2005
DBI	—	—	—	excellent	—	**fair**
MBI	—	—	—	—	poor	**very poor**
Fish KBI	—	—	fair	good	—	**excellent**

Table 9-1 Land use/cover characteristics of Muddy Fork Beargrass.

Class	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	8.86	6.50	12.72
Open Water	0.02	0.00	0.00
Dev. Open Space	29.24	17.27	18.06
Dev. Low Intensity	12.94	10.87	13.22
Dev. Medium Intensity	2.59	2.56	7.05
Dev. High Intensity	0.58	0.09	0.00
Barren Land	0.00	0.00	0.00
Deciduous Forest	40.41	63.43	59.03
Evergreen Forest	11.83	5.60	2.64
Mixed Forest	0.10	0.00	0.00
Shrub/Scrub	0.00	0.00	0.00
Grassland/herbaceous	0.01	0.00	0.00
Pasture/Hay	1.45	0.18	0.00
Cropland	0.76	0.00	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.05	0.00	0.00

Table 9-2 DBI scores estimated in Muddy Fork Beargrass Creek.

ECCCC001	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2002	48	69	61	97	24	19	**53**	**EXCELLENT**
2003	39	69	77	85	30	13	**52**	**GOOD**
Summer 05	42	69	69	91	0	6	**46**	**GOOD**
Fall 05	40	62	46	96	13	2	**43**	**FAIR**
2005 All	41	65	58	94	7	4	**45**	**FAIR**
Overall	**Overall**	**42**	**68**	**65**	**92**	**20**	**12**	**GOOD**

Table 9-3 Macroinvertebrate biotic integrity scores in Muddy Fork Beargrass Creek.

Year	**Metric**	**EMUMU001**	
		Raw Score	Metric Score
2004	Taxa Richness	24	32.4
	EPT Richness	2	6.7
	m%EPT	0.8	1.1
	mHBI	7.77	32.4
	%Chir. and Oli.	21.1	79.7
	%Clinger	3.0	3.0
	MBI	--------	26.10
	Assessment	--------	**Poor**
2005	Taxa Richness	40	63.49
	EPT Richness	1	3.03
	m%EPT	0	0.00
	mHBI	7.29	34.65
	%Chir. and Oli.	84.91	15.19
	%Clinger	3.02	4.00
	%Ephemeroptera	0	0.00
	MBI	--------	17.19
	Assessment	--------	**Very Poor**

Table 9-4 Fish IBI scores in Muddy Fork Beargrass Creek.

Year	**EMUMU001**
2002	**Fair**
Native	69
DMS	21
INT	21
WC	40
SL	46
%Insect_Ex_Tol	44
%OMNI	52
%TOL	48
IBI	42
2003	**Good**
Native	81
DMS	75
INT	33
WC	57
SL	65
%Insect_Ex_Tol	52
%OMNI	58
%TOL	57
IBI	60
2005	**Excellent**
NAT	100
DMS	73
INT	45
SL	81
%INSCT	74
%TOL	79
%FHW	0
KIBI	59

Table 9-5 Gross primary production and community respiration at EMUMU001 location, Muddy Fork Beargrass Creek.

Year	**Spring**		**Summer**		**Fall**	
	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)
2003	4.98	6.43	—	—	—	—
2004	3.79	13.17	—	—	—	—
2005	—	—	0.81	10.36	—	—
2006	—	—	0.27	4.84	0.23	3.73
2007	—	—	0.19	4.48	1.07	7.11

Table 9-6 Daily water temperature, DO, pH, and conductivity at EMUMU001 location, Muddy Fork Beargrass Creek.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2003	14.0	10.9	17.4	9.74	7.02	13.56	7.45	7.12	7.88	718.0	656.5	736.2
2004	12.7	10.6	15.0	6.43	4.19	9.50	7.34	7.20	7.53	704.8	664.2	715.1
2005	14.1	9.0	21.1	—	—	—	6.24	5.86	6.80	—	—	—
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	7.3	5.8	8.9	10.94	10.20	11.65	7.99	7.95	8.05	595.3	562.6	626.9
Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2003	21.9	20.8	23.1	—	—	—	7.56	7.39	7.66	491.3	480.8	503.5
2004	20.8	20.5	21.3	—	—	—	7.05	7.04	7.06	1070.8	1031.2	1085.4
2005	23.1	21.5	24.8	4.31	3.52	4.97	7.32	7.21	7.40	791.7	687.7	827.7
2006	20.2	14.7	21.7	7.02	5.43	7.32	7.86	7.89	7.93	600.6	607.2	644.7
2007	22.5	20.7	24.4	6.82	6.49	7.10	7.98	7.93	8.02	667.3	638.5	687.5
Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2003	15.4	14.6	16.2	—	—	—	7.38	7.36	7.42	1055.4	973.2	1142.2
2004	13.0	11.3	14.5	—	—	—	6.68	6.59	6.86	322.5	318.0	331.4
2005	15.4	14.0	17.2	—	—	—	6.77	6.41	7.23	656.6	637.5	680.5
2006	15.6	14.1	17.1	8.45	8.00	8.78	7.82	7.78	7.85	727.7	697.8	744.2
2007	21.8	20.1	23.3	6.23	5.60	7.10	7.97	7.92	8.03	721.6	700.3	730.3
Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	5.6	5.2	6.2	—	—	—	6.83	6.71	6.96	909.5	869.2	945.2
2005	7.6	7.0	8.2	—	—	—	6.35	5.98	6.80	—	—	—
2006	9.1	8.1	10.1	—	—	—	7.03	6.79	7.32	834.5	584.2	961.6
2007	—	—	—	10.9	10.5	11.4	7.4	7.4	7.5	667.0	641.0	678.7

Table 9-7 Summary of selected water chemistry parameters at EMUMU001 location, Muddy Fork Beargrass Creek.

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.38	-	-	-	0.03	-	0.03	0.05
	SD (Dry)	-	-	-	-	0.00	-	-	0.00
	Count (Dry)	1	0	0	0	4	0	1	2
	Mean (wet)	-	-	-	-	0.03	-	0.03	0.05
	SD (wet)	-	-	-	-	0.01	-	0.00	0.00
	Count (wet)	0	0	0	0	17	0	2	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	3.26	-	-	-	1.70	-	1.73	0.95
	SD (Dry)	-	-	-	-	0.04	-	-	0.40
	Count (Dry)	1	0	0	0	2	0	1	2
	Mean (wet)	-	-	-	-	1.73	-	2.27	1.39
	SD (wet)	-	-	-	-	0.32	-	1.07	0.22
	Count (wet)	0	0	0	0	17	0	2	2
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	1.47	-	-	-	0.25	-	0.44	0.62
	SD (Dry)	-	-	-	-	0.00	-	-	0.00
	Count (Dry)	1	0	0	0	4	0	1	2
	Mean (wet)	-	-	-	-	0.58	-	0.89	0.70
	SD (wet)	-	-	-	-	0.31	-	0.11	0.08
	Count (wet)	0	0	0	0	17	0	2	2
Ortho Phosphorus (mg/L)	Mean (Dry)	0.09	-	-	-	0.03	-	0.08	0.06
	SD (Dry)	-	-	-	-	0.00	-	-	0.01
	Count (Dry)	1	0	0	0	4	0	1	2
	Mean (wet)	-	-	-	-	0.03	-	0.07	0.06
	SD (wet)	-	-	-	-	0.01	-	0.06	0.05
	Count (wet)	0	0	0	0	17	0	2	2
Phosphorus (mg/L)	Mean (Dry)	0.09	-	-	-	0.03	-	0.08	0.09
	SD (Dry)	-	-	-	-	0.02	-	-	0.00
	Count (Dry)	1	0	0	0	3	0	1	2
	Mean (wet)	-	-	-	-	0.08	-	0.07	0.15
	SD (wet)	-	-	-	-	0.03	-	0.03	0.11
	Count (wet)	0	0	0	0	17	0	2	2
Chloride (mg/L)	Mean (Dry)	58.60	-	-	-	83.09	-	50.21	56.98
	SD (Dry)	-	-	-	-	11.32	-	-	17.66
	Count (Dry)	1	0	0	0	2	0	1	2
	Mean (wet)	-	-	-	-	54.89	-	34.55	30.80
	SD (wet)	-	-	-	-	11.01	-	6.22	27.21
	Count (wet)	0	0	0	0	17	0	2	2
BOD (mg/L)	Mean (Dry)	-	-	-	-	2.13	-	1.00	1.00
	SD (Dry)	-	-	-	-	2.59	-	-	0.00
	Count (Dry)	0	0	0	0	4	0	1	2
	Mean (wet)	-	-	-	-	3.62	-	1.00	2.50
	SD (wet)	-	-	-	-	6.95	-	0.71	0.71
	Count (wet)	0	0	0	0	17	0	2	2
TDS (mg/L)	Mean (Dry)	474.00	-	-	-	455.00	-	444.00	498.00
	SD (Dry)	-	-	-	-	21.21	-	-	130.11
	Count (Dry)	1	0	0	0	2	0	1	2
	Mean (wet)	-	-	-	-	408.50	-	425.00	344.00
	SD (wet)	-	-	-	-	48.20	-	7.07	110.31
	Count (wet)	0	0	0	0	16	0	2	2
TSS (mg/L)	Mean (Dry)	246.00	-	-	-	8.00	-	4.00	14.00
	SD (Dry)	-	-	-	-	1.41	-	-	9.90
	Count (Dry)	1	0	0	0	2	0	1	2
	Mean (wet)	-	-	-	-	18.47	-	33.40	49.50
	SD (wet)	-	-	-	-	15.25	-	0.85	57.28
	Count (wet)	0	0	0	0	17	0	2	2
Fecal Coliform (col/100 ml)	Mean (Dry)	13800	-	-	-	421	369	745	688
	SD (Dry)	-	-	-	-	415	295	721	1004
	Count (Dry)	1	0	0	0	23	23	14	23
	Mean (wet)	-	-	-	-	562	1226	3279	1804
	SD (wet)	-	-	-	-	891	1134	9949	3149
	Count (wet)	0	0	0	0	25	8	19	11

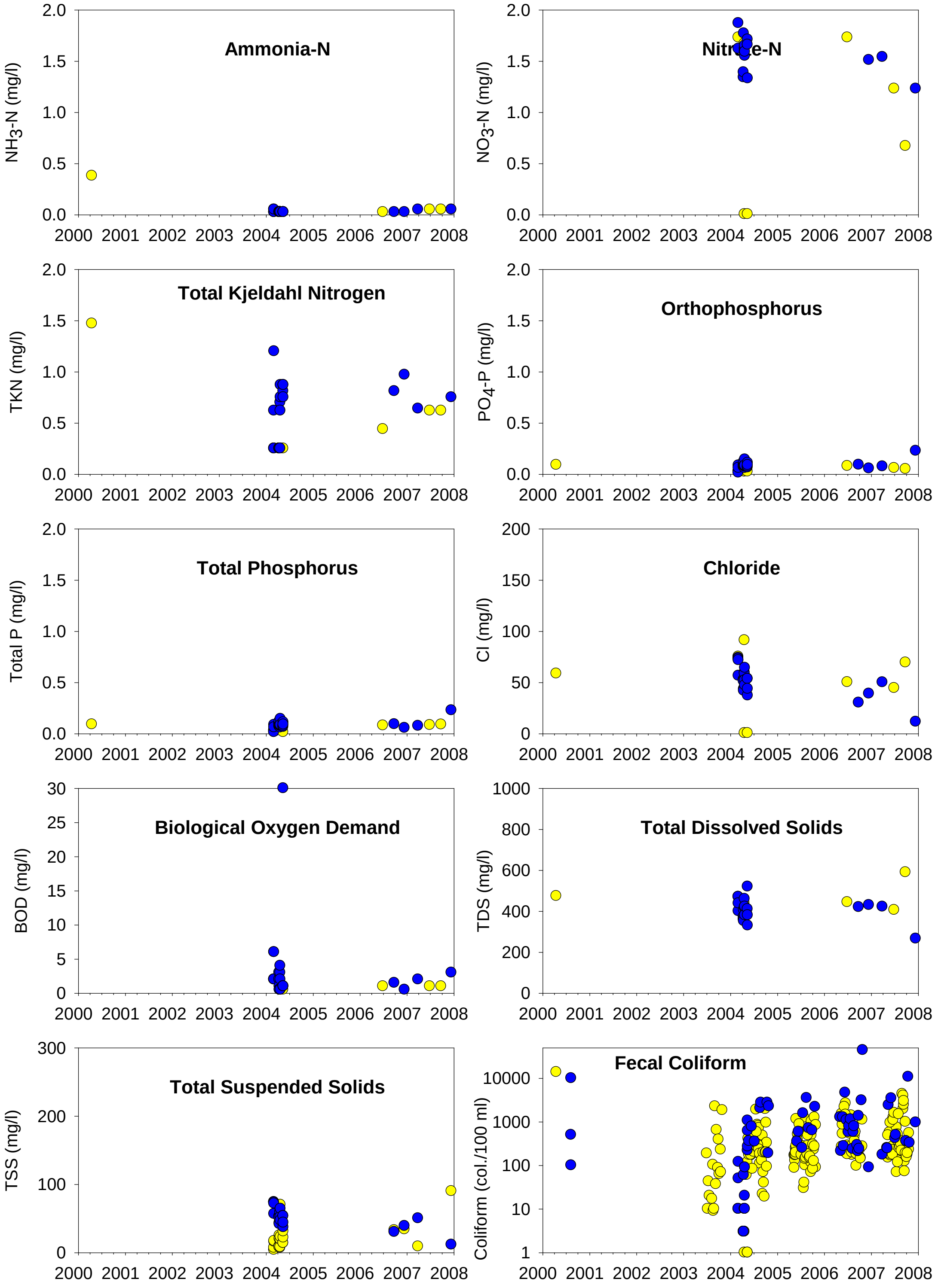

Figure 9-1 Major water chemistry parameters measured at EMUMU001 location. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 10 Pennsylvania Run

10.1 Watershed Physical Characteristics

Pennsylvania Run (PR) originates from McNeely Lake and flows south. It merges with Cedar Creek in Jefferson County after its LTMN location (EPRPR001) as Cedar Creek, which eventually flows into Floyds Fork downstream of Floyds Fork at Bardstown Road (EFFFF002).

The Pennsylvania Run watershed contains about 42% of developed areas and 41% of forests (Table 10-1). Impervious surfaces comprises in an average 8.6% of watershed. Riparian buffer zone in the watershed-scale contains larger proportion of forest (55%) than the overall watershed, but the reach-scale riparian area contains smaller proportion of forests (33%) (Table 10-1).

10.2 Biological Data

10.2.1 Diatom

The overall water quality of Penn Run at Mt. Washington Road (EPRPR001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Fair’ (Table 10-2). The overall mean score of 44 reflects the upper range of ‘Fair’ scores. In general, these data suggest water quality of Penn Run at Mt. Washington Road seems to be improving somewhat over time (Table 10-2). Specifically, during the 2001 and 2002 sampling seasons, 83% of sample dates characterized water quality as ‘Fair’ (mean DBI = 42). During the 2003 and 2005 sampling seasons, mean overall water quality was characterized as ‘Good’ as only 47% of samples scored in the ‘Fair’ range (mean DBI = 46).

The taxa richness (TR) yearly mean score decreased from year 2001 (40) to 2003 (36), but increased during 2005 (42) (Table 10-2). Small, overall yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score revealed no real discernable pattern throughout the study period (Table 10-2). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability

The siltation index (%NNS) yearly mean score increased from year 2001 (53) to 2003 (68), but decreased during 2005 (62) (Table 10-2). Small, yearly %NNS fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, an increase in overall %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (90) to 2003 (83), but increased during 2005 (91) (Table 10-2). Small, overall yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. These yearly SDI fluctuations, track well with the changes seen in TR. In general, the majority of SDI values were moderate/high and indicative of good water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (7) to 2003 (0), but increased substantially during 2005 (12) (Table 10-2). These data indicate that species within the Fragilaria group were completely absent during 2003, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving somewhat.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 10-2). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. These taxa are widely considered to be indicators of good water quality. An overall increase with respect to this metric (2005) suggests site water quality may be improving slightly.

10.2.2 Macroinvertebrates

The macroinvertebrate communities in the Pennsylvania Run were rated as ‘very poor’ in 2000 and ‘fair’ in 2004 and 2005 (Table 10-3). Low scores for the MBI at EPRPR001 were due primarily to low metric scores for EPT Richness and %EPT. Except for EPT Richness and %EPT, all MBI scores were greater than 50 in Pennsylvania Run in 2005. Additionally, EPRPR001 scored very low in these two metrics during all three sampling dates.

10.2.3 Fish

Water quality rating based on the fish community in Pennsylvania Run at Mt. Washington Road site continuously improved throughout the sampling period: from ‘very poor’ (1999), ‘good’ (2002 and 2003), to ‘excellent’ (2005). Metric score for % insectivore (%INSCT) increased through this period, while other metric scores fluctuated during this period at EPRPR001. Metric score for native species richness (NAT) was lower in 2005 than previous years, but the overall IBI rating was improved.

10.3 Hydrolab Sonde Data

10.3.1 Stream metabolism

The Gross Primary Production estimates during spring (4.6-9.46 mg O_2/m^2/day) were higher than estimates in summer (0.4-1.6 mg O_2/m^2/day) and fall (0.8-1.0 mg O_2/m^2/day) (Table 10-5). CR was highest during fall (7.6-16.6 mg O_2/m^2/day), followed by summer (0.4-1.7 mg O_2/m^2/day), and it was lowest in spring (4.6-9.5 mg O_2/m^2/day).

10.3.2 Dissolved oxygen, pH, and conductivity

The daily mean DO was highest in spring (9.0-13.2 mg/L) and lowest during summer (2.1-7.9 mg/L) (Table 10-6). Daily mean DO stayed above 5 mg/L during spring, fall (except 2005), and winter, but it dropped lower than 5 mg/L during the summer. Daily mean pH was mostly higher than 7 except summer 2005. Mean pH values were similar in spring (6.3-8.5) and winter (7.1-8.8), and they were higher than summer and fall. Mean daily conductivity values were highly variable, and it was in the order of summer (356-871 µS/cm), fall (360-774 µS/cm), winter (418-809 µS/cm) and spring (265-841 µS/cm) in EPRPR001 location.

10.4 Laboratory Data

Before 2006, only fecal coliform data was collected in Pennsylvania Run (Table 10-7, Figure 10-1). Nitrogen (ammonia and nitrate), phosphorus (ortho-P and total phosphorus), and chloride concentration were higher during 2007 than 2006 (Table 10-7). In general, chemical concentrations were higher in samples from ‘dry’ period than ‘wet’. Fecal coliform counts were highly variable, but it was lower during 2006 and 2007 than the preceding years.

10.5 Watershed assessment based on the biological data

There was a discrepancy in water quality ratings among three biotic indices in Pennsylvania Run. In 2005, diatom community had a ‘good’ water quality rating, macroinvertebrate community had a ‘fair’ rating, and fish community had an ‘excellent’ rating. However, there were improving trends in all three biotic integrity indices in 2000-2005: diatom from ‘fair’ to ‘good’, macroinvertebrates from ‘very poor’ to ‘fair’, and fish from ‘fair’ to ‘excellent’.

EPRPR001	2000	2001	2002	2003	2004	2005
DBI	—	fair	fair	fair	—	**good**
MBI	very poor	—	—	—	fair	**fair**
Fish KBI	fair	—	good	good	—	**excellent**

Table 10-1 Land use/cover characteristics of Pennsylvania Run watershed at EPRPR001 LTMN location.

Class	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	8.57	4.63	0.32
Open Water	1.48	5.01	0.46
Dev. Open Space	17.95	15.71	10.05
Dev. Low Intensity	20.87	12.00	0.00
Dev. Medium Intensity	2.62	1.01	0.00
Dev. High Intensity	0.63	0.32	0.00
Barren Land	0.11	0.25	0.00
Deciduous Forest	36.57	48.89	27.40
Evergreen Forest	3.39	5.24	5.94
Mixed Forest	0.82	0.84	0.00
Shrub/Scrub	0.00	0.00	0.00
Grassland/herbaceous	2.38	1.32	0.00
Pasture/Hay	11.66	8.72	56.16
Cropland	1.31	0.00	0.00
Woody Wetlands	0.20	0.63	0.00
Emergent Herbaceous Wetlands	0.02	0.06	0.00

Table 10-2 DBI scores estimated in Pennsylvania Run.

ECCCC001	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2001	40	65	53	90	7	5	**43**	**FAIR**
2002	38	61	46	88	4	9	**41**	**FAIR**
2003	36	65	68	83	0	5	**43**	**FAIR**
Summer 05	39	69	71	85	8	12	**47**	**GOOD**
Fall 05	46	62	52	97	15	15	**48**	**GOOD**
2005 All	42	65	62	91	12	14	**48**	**GOOD**
Overall	**39**	**64**	**56**	**89**	**7**	**9**	**44**	**FAIR**

Table 10-3 Macroinvertebrate biotic integrity scores in Pennsylvania Run.

Year	**Metric**	**EPRPR001**	
		Raw Score	Metric Score
2000	Taxa Richness	36	48.65
	EPT Richness	3	10.00
	m%EPT	1	1.37
	mHBI	8.73	18.43
	%Chir. and Oli.	91	9.09
	%Clinger	9	12.16
	MBI	--------	16.62
	Assessment	--------	**Very Poor**
2004	Taxa Richness	45	60.8
	EPT Richness	12	40
	m%EPT	8.8	12.1
	mHBI	6.67	48.3
	%Chir. and Oli.	55	45.5
	%Clinger	35.1	47.4
	MBI	--------	42.40
	Assessment	--------	**Fair**
2005	Taxa Richness	43	58.11
	EPT Richness	8	26.67
	m%EPT	4.58	6.28
	mHBI	6.13	56.20
	%Chir. and Oli.	21.49	79.30
	%Clinger	58.45	78.99
	MBI	--------	50.93
	Assessment	--------	**Fair**

Table 10-4 Fish IBI scores in Pennsylvania Run.

Year	**EPRPR001**
1999-up	**very poor**
1999-dn	**very poor**
2000-up	**poor**
2000-dn	**fair**
2002	**Good**
Native	72
DMS	27
INT	28
WC	59
SL	52
%Insect_Ex_Tol	57
%OMNI	100
%TOL	100
IBI	62
2003	**Good**
Native	70
DMS	72
INT	19
WC	47
SL	52
%Insect_Ex_Tol	61
%OMNI	84
%TOL	72
IBI	60
2005	**Excellent**
NAT	59
DMS	50
INT	32
SL	52
%INSCT	100
%TOL	56
%FHW	3
KIBI	58

Table 10-5 Gross primary production and community respiration at EPRPR001 location of Pennsylvania Run.

	Spring		**Summer**		**Fall**	
Year	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)
2000	6.10	7.75	1.03	8.77	—	—
2001	—	—	1.06	9.27	0.94	8.92
2002	4.60	6.04	0.42	13.58	—	—
2003	—	—	0.83	9.63	0.89	16.62
2004	—	—	1.72	1.25	—	—
2005	9.46	10.39	—	—	1.04	15.14
2006	5.78	8.20	0.45	12.51	0.80	7.89
2007	7.58	4.45	1.58	8.32	0.97	7.59

Table 10-6 Daily water temperature, DO, pH, and conductivity at EPRPR001 location of Pennsylvania Run.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.8	11.1	17.1	9.65	6.39	13.79	7.84	7.32	8.54	423.8	411.6	432.7
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	11.7	9.4	14.5	10.30	8.03	13.27	7.88	7.34	8.65	381.0	366.7	396.6
2003	15.0	12.0	18.3	—	—	—	8.22	7.89	8.86	602.2	537.0	673.6
2004	12.6	10.4	14.6	—	—	—	6.30	6.24	6.49	841.1	713.5	929.7
2005	16.3	12.7	20.0	8.96	4.20	15.58	8.06	7.52	8.69	439.9	410.9	462.7
2006	15.1	12.3	19.1	9.09	5.89	13.81	8.30	7.82	8.95	264.6	251.4	273.4
2007	9.8	8.0	11.6	13.19	9.46	19.10	8.46	8.06	8.98	479.6	462.9	490.2

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	23.5	22.1	25.2	4.61	3.76	5.47	7.27	6.91	7.43	470.5	416.5	502.9
2001	21.7	20.4	23.2	4.44	3.63	5.44	—	—	—	572.0	551.0	601.3
2002	22.4	21.2	23.8	2.09	1.58	2.51	7.21	7.09	7.36	620.1	610.3	631.9
2003	23.8	22.0	25.4	3.82	2.62	4.78	7.32	7.14	7.44	438.5	375.4	455.7
2004	24.2	22.3	25.8	7.94	6.94	9.15	7.08	6.96	7.19	355.6	275.9	368.8
2005	22.8	20.9	25.0	—	—	—	6.66	6.52	6.78	870.7	848.4	890.3
2006	22.0	20.2	23.9	3.40	2.67	6.63	7.63	7.45	7.78	531.2	443.4	593.0
2007	22.5	20.3	25.1	5.17	4.16	6.12	7.62	7.37	8.11	705.0	688.9	719.9

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	13.3	11.7	15.2	6.25	5.36	7.15	7.21	6.99	7.45	578.3	437.3	647.0
2002	13.3	12.2	14.4	—	—	—	7.43	7.33	7.57	411.2	401.5	418.8
2003	14.6	13.1	16.0	—	—	—	7.29	7.22	7.40	609.9	520.2	690.8
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	14.6	12.8	17.0	3.22	2.57	3.94	6.99	6.78	7.21	500.4	477.2	508.6
2006	16.0	14.6	17.5	6.24	5.74	6.99	7.85	7.80	7.91	359.8	351.6	366.4
2007	21.4	20.1	22.7	5.05	3.94	5.76	7.23	6.88	8.69	774.0	752.9	811.9

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	1.5	1.1	2.0	—	—	—	8.83	8.73	8.98	431.9	420.6	439.6
2004	3.7	3.0	4.4	—	—	—	7.08	7.03	7.13	809.6	686.5	909.9
2005	3.2	2.1	4.2	7.91	7.20	9.10	7.84	7.58	8.35	421.0	405.0	428.9
2006	6.8	5.8	7.9	—	—	—	7.77	7.56	7.99	418.1	355.2	480.8
2007	6.2	5.5	7.0	8.72	8.06	9.77	8.09	8.00	8.26	431.7	418.2	450.8

Table 10-7 Summary of selected water chemistry parameters at EPRPR001 location of Pennsylvania Run.

	Year	2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.17	Nitrate-Nitrogen (mg/L)	1.42	4.02	Total Kjeldahl Nitrogen (mg/L)	1.11	0.58
	SD (Dry)	0.00	0.16		0.02	5.24		0.42	0.02
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.03	0.05		0.62	1.57		0.68	0.89
	SD (wet)	-	0.00		-	0.61		-	0.30
	Count (wet)	1	2		1	2		1	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.18	0.74	Phosphorus (mg/L)	0.13	0.72	Chloride	11.26	53.24
	SD (Dry)	0.00	0.73		0.02	0.85		2.40	38.85
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.16	0.26		0.13	0.19		16.02	22.98
	SD (wet)	-	0.34		-	0.07		-	12.38
	Count (wet)	1	2		1	2		1	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	270.00	463.00	TSS (mg/L)	7.50	7.50
	SD (Dry)	0.00	1.06		25.46	131.52		2.12	4.95
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.50	2.50		174.00	346.00		6.00	9.50
	SD (wet)	-	2.12		-	124.45		-	4.95
	Count (wet)	1	2		1	2		1	2

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	845	719	966	1774	245	2021	323	202
	SD (Dry)	1921	1257	2488	7970	224	6907	248	257
	Count (Dry)	23	30	28	25	14	23	16	25
	Mean (wet)	6570	-	-	2195	742	3309	4179	2133
	SD (wet)	7415	-	-	4810	997	5734	10736	3264
	Count (wet)	4	0	0	6	17	8	18	9

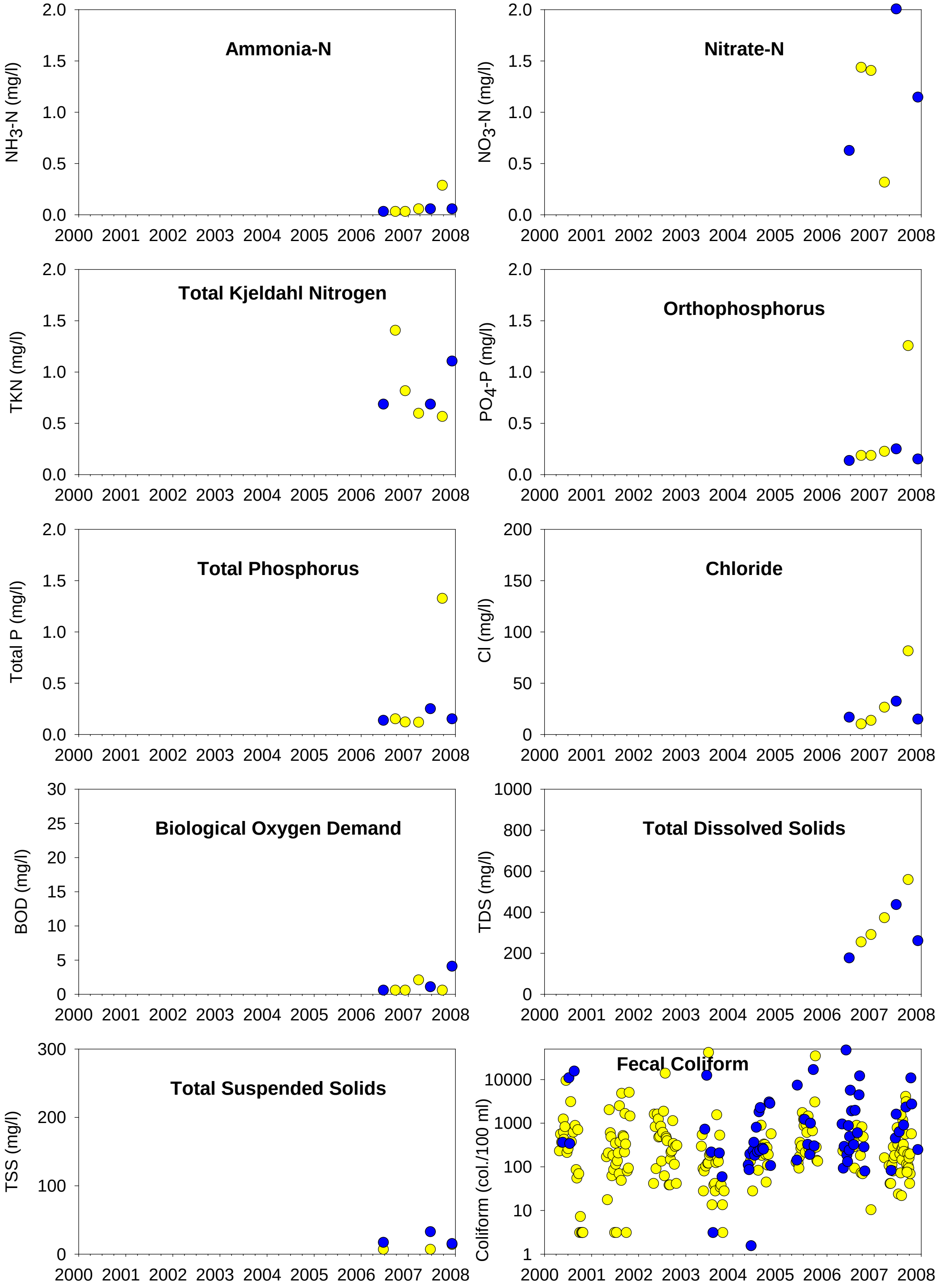

Figure 10-1 Major water chemistry parameters measured at EPRPR001 location of Pennsylvania Run. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 11 Pond Creek Watershed

11.1 Watershed Physical Characteristics

Pond Creek originates in the Jeffersontown area, flows to southwest and west, and turning to southwest before flowing into Ohio River. It starts as Fern Creek, changes to Northern Ditch, and finally becomes Pond Creek at further downstream. There are four LTMN locations at the main stem Pond Creek: the most upstream location, Fern Creek at Old Bardstown Road (EPCFC001); the second location, Northern Ditch at Preston Hwy (EPCND001); the third location, Pond Creek at Manslick Road (EPCPC001); the most downstream location, Pond Creek at Pendleton Road (EPCPC002). There are a couple of impoundments just below the EFCFC001 location at Wildwood Country Club and Woodhaven Country Club. Due to the longitudinal connectivity of LTMN locations in Fern Creek-Northern Ditch-Pond Creek, all data are presented following the order of upstream-downstream linkage: EPCFC001-EPCND001-EPCPC001-EPCPC002.

The Pond Creek watershed is highly developed when the landuse patterns were assessed at all four LTMN locations (Table 11-1). The cumulative watershed landuse at LTMN locations in Pond Creek contains 60%-67% of developed areas with only 28-34% of forests. Impervious surface coverage was also high with 17-25% at the whole watershed scale at each LTMN location.

At the most upstream location, Fern Creek at Old Bardstown Road (EPCFC001), the watershed contained 63% of developed lands and 30% forests, and overall impervious surface coverage was 17% (Table 11-1). Riparian areas of the watershed area also very well developed at the whole watershed (43% developed) and reach scales (51% developed).

At Northern Ditch at Preston Highway (EPCND001), the watershed contained 65% of developed lands and 28% of forests, and overall imperviousness was 17% (Table 11-1). The watershed-scale riparian buffer zone development (50%) was similar to Fern Creek location, but development within 1000 meters from the LTMN location was extremely high (84%) with very high imperviousness (35%).

At Pond Creek at Manslick Road (EPCPC001), the watershed contained 67% of developed areas and 29% of forests with 25% of imperviousness. Riparian buffer zone contains smaller proportion of developed areas (60% at watershed-scale, 54% at reach-scale) than the overall watershed area, with much smaller proportion of impervious surface coverage (18% at watershed-scale, and 1% at reach-scale).

At the most downstream location, Pond Creek at Pendleton Road (EPCPC002), the watershed contained 60% of developed areas and 34% of forests with 21% of impervious surface. As with the EPCPC001 location, riparian area contains smaller proportion of developed areas (50% at watershed-scale, 19% at reach-scale) with much smaller proportion of impervious surface coverage (18% at watershed-scale, and 2% at reach-scale) than overall watershed landuse.

Brier Creek originates in Metz Gap and Jefferson Hill close to the Jefferson County Memorial Forest and flows west before merging into Pond Creek approximately 2.2 km downstream of EPCPC002 location. Brier Creek is described as an independent watershed from Pond Creek. MSD maintains one LTMN location in Brier Creek.

The Brier Creek watershed contains less than 1% of developed areas, 83% of forests, and 16% of grasslands-pastures (Table 11-2). Watershed-scale imperviousness was very low (0.05%). Riparian buffer zone of Brier Creek contained larger proportion of grassland-pasture areas (27% at watershed-scale, 35% at reach-scale), possibly influencing the water quality close to LTMN location.

11.2 Biological Data

11.2.1 Diatom

EPCFC001: The overall water quality of Fern Creek at Old Bardstown Road (EPCFC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Fair' (Table 11-3). The overall mean score of 44 reflects the upper range of 'Fair' scores. In general, these data suggest water quality of Fern Creek at Old Bardstown Road seems to be relatively constant over time (Table 11-3). Specifically, during the 2001 and 2002 sampling seasons, 72% of sample dates characterized water quality as 'Fair' (mean DBI = 44). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as 'Fair' as 73% of samples scored in the 'Fair' range (mean DBI = 44).

The taxa richness (TR) yearly mean score decreased from year 2001 (34) to 2003 (28), but increased substantially during 2005 (40) (Table 11-3). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality. This site's mean overall TR score (33) was among the lowest observed in the current study (Table 11-3).

The pollution tolerance index (PTI) yearly mean score decreased slightly from year 2002 (79) to 2005 (70) (Table 11-3). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality. This site's mean overall PTI score (75) was among the highest observed in the current study.

The siltation index (%NNS) yearly mean score increased from year 2001 (69) to 2003 (80), but decreased during 2005 (67) (Table 11-3). These data suggest that overall species composition shifted slightly toward those species adapted to living on silts and shifting sediments. In general, a decrease in overall %NNS suggests a decline in water quality. This site's mean overall %NNS score (76) was among the highest observed in the current study and suggests siltation is not an issue at this site.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (83) to 2003 (60), but increased during 2005 (73) (Table 11-3). These yearly SDI fluctuations, track well with the changes seen in TR. In general, decreases as those seen here in the yearly mean SDI suggest a decline in overall water quality. This site's mean overall SDI score (73) was among the lowest observed in the current study.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (13) to 2003 (0), but increased during 2005 (8) (Table 11-3). These data indicate that species within the Fragilaria group were completely absent during 2003, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving somewhat.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 11-3). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. This site's mean overall CGR score (2) was the lowest observed in the current study and is indicative of impaired water quality.

EPCND001: The overall water quality of Northern Ditch at Preston Highway (EPCND001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Fair' (Table 11-3). The overall mean score of 40 reflects the lower range of 'Fair' scores and was the lowest overall mean DBI score in the current study. In general, these data suggest water quality of Northern Ditch at Preston Highway seems to be declining somewhat over time (Table 11-3). Specifically, during the 2001 and 2002 sampling seasons, 56% of sample dates characterized water quality as 'Fair' (mean DBI = 41). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as 'Fair' as 47% of samples scored in the 'Fair' range however, the mean DBI was lower (mean DBI = 39).

The taxa richness (TR) yearly mean score decreased from year 2002 (38) to 2003 (33), but increased during 2005 (40) (Table 11-3). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score increased slightly from year 2001 (58) to 2003 (61) but decreased during 2005 (53) (Table 11-3). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality. This site's mean overall PTI score (58) was the lowest observed in the current.

The siltation index (%NNS) yearly mean score increased from year 2001 (37) to 2005 (49) (Table 11-3). These data suggest that overall species composition shifted slightly away from those species adapted to living on silts and shifting sediments. In general, an increase in overall %NNS suggests an improvement in water quality. This site's mean overall %NNS score (46) was among the lowest observed in the current study and strongly suggests siltation is an issue at this site.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (90) to 2003 (81), but increased during 2005 (88) (Table 11-3). These yearly SDI fluctuations, track well with the changes seen in TR. In general, small decreases as those seen here in the yearly mean SDI suggest a slight decline in overall water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (9) to 2003 (0), but increased during 2005 (15) (Table 11-3). These data indicate that species within the Fragilaria group were completely absent during 2003, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving somewhat.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 11-3). Small, yearly CGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. This site's mean overall CGR score (2) was the lowest observed in the current study and is indicative of impaired water quality.

EPCPC001: The overall water quality of Pond Creek at Manslick Road (EPCPC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Poor' (Table 11-3). The overall mean score of 40 is well below the upper limit of 'Poor' scores and was the lowest mean overall DBI score in the current study. In general, these data suggest water quality of Pond Creek at Manslick Road seems to be relatively constant over time (Table 11-3). Specifically, during the 2001 and 2002 sampling seasons, all sample dates characterized water quality as ‘Poor’ (mean DBI = 39). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as ‘Poor’ as all samples scored in the ‘Poor’ range (mean DBI = 42). It is important to note, Pond Creek at Manslick Road is one of only four sites in the current study, which is scored based on criteria for the Pennyroyal Bioregion. This Bioregion’s criterion, are more rigorous than those of the Bluegrass Bioregion sites, of which, there are 24.

The taxa richness (TR) yearly mean score decreased from year 2001 (40) to 2003 (36), but increased during 2005 (45) (Table 11-3). These data suggest that species new to this site were identified and species replacement was ongoing throughout the study. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score increased slightly from year 2001 (57) to 2003 (67) but decreased during 2005 (57) (Table 11-3). These data suggest that species composition shifted somewhat throughout the study, but the net effect was minimal. In general, it appears the community is a fairly even mix of pollution tolerant and pollution sensitive species. This site’s mean overall PTI score (61) was among the lowest observed in the current study.

The siltation index (%NNS) yearly mean score increased from year 2001 (26) to 2003 (52), but decreased during 2005 (27) (Table 11-3). These data suggest that overall species composition shifted throughout the study, but strongly favors those species adapted to living on silts and shifting sediments. In general, a low overall %NNS, as seen at this site, suggests an impaired stream system. This site’s mean overall %NNS score (32) was the lowest observed in the current study and strongly suggests siltation is an issue at this site.

The Shannon diversity index (SDI) yearly mean score decreased slightly from year 2001 (96) to 2003 (93), but increased during 2005 (97) (Table 11-3). Small, overall yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values were high and suggested good water quality. This site’s mean overall SDI score (95) was among the highest observed in the current study.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (11) to 2003 (3), but increased during 2005 (12) (Table 11-3). These data indicate that species within the Fragilaria group were largely absent during 2003, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving somewhat.

The cymbella group richness (CGR) yearly mean score increased slightly from year 2001 (5) to 2003 (8) but decreased during 2005 (2) (Table 11-3). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining slightly.

EPCPC002: The overall water quality of Pond Creek at Pendleton Road (EPCPC002) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Poor’ (Table 11-3). The overall mean score of 44 is below the upper limit of ‘Poor’ scores and was among the lowest mean overall DBI scores in the current study. In general, these data suggest water quality of Pond Creek at Pendleton Road seems to be relatively constant over time (Table 11-3). Specifically, during the 2001 and 2002 sampling seasons, 89% of sample dates characterized water quality as ‘Poor’ (mean DBI = 45). During subsequent sampling years (2003, 2005), mean overall water quality was also characterized as ‘Poor’ as 93% of samples scored in the ‘Poor’ range (mean DBI = 44). It is important to note, Pond Creek at Pendleton Road is one of only four sites in the current study, which is scored based on criteria for the Pennyroyal Bioregion. This Bioregion’s criterion, are more rigorous than those of the Bluegrass Bioregion sites, of which, there are 24.

The taxa richness (TR) yearly mean score remained largely unchanged from year 2001 (40) through 2003 (39), but increased during 2005 (43) (Table 11-3). Small, yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, an increase in TR suggests an improvement in water quality.

The pollution tolerance index (PTI) yearly mean score decreased from year 2001 (69) to 2005 (54) (Table 11-3). These data suggest that species composition shifted in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality.

The siltation index (%NNS) yearly mean score decreased substantially from year 2001 (58) to 2005 (36) (Table 11-3). These data suggest that overall species composition shifted toward those species adapted to living on silts and shifting sediments. In general, a decrease in overall %NNS suggests a decline in water quality and suggests siltation is an issue at this site.

The Shannon diversity index (SDI) yearly mean score decreased slightly from year 2001 (94) to 2003 (90), but increased during 2005 (96) (Table 11-3). Small, overall yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values was high and suggested good water quality. This site’s mean overall SDI score (94) was among the highest observed in the current study.

The fragilaria group richness (FGR) yearly mean score remained largely unchanged from year 2001 (10) through 2003 (8), but increased slightly during 2005 (11) (Table 11-3). Small, yearly FGR fluctuations, as seen here, are well within the limits of expected yearly natural variability. The increase with respect to this metric during 2005 suggests site water quality may be improving somewhat.

The cymbella group richness (CGR) yearly mean score increased from year 2001 (7) to 2003 (12) but decreased during 2005 (2) (Table 11-3). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining slightly.

EPCBC001: The overall water quality of Brier Creek at Bear Camp Road (EPCBC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Fair’ (Table 11-4). The overall mean score of 52 reflects the mid range of ‘Fair’ scores. In general, these data suggest water quality of Brier Creek @ Bear Camp Road seems to be declining over time (Table 11-4). Specifically, during the 2001 and 2002 sampling seasons, only 6% of sample dates characterized water quality as ‘Poor’ (mean DBI = 56). During the 2003 and 2005 sampling seasons, mean overall water quality was characterized as ‘Poor’ as 73% of samples scored in the ‘Poor’ range (mean DBI = 48). It is important to note, Brier Creek at Bear Camp Road is one of only four sites in the current study, which is scored based on criteria for the Pennyroyal Bioregion. This Bioregion’s criterion, are more rigorous than those of the Bluegrass Bioregion sites, of which, there are 24.

The taxa richness (TR) yearly mean score decreased from year 2001 (41) to 2003 (34), but increased slightly during 2005 (37) (Table 11-4). Small, overall yearly TR fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, a decrease in overall TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score increased from year 2001 (67) to 2003 (77), but decreased during 2005 (68) (Table 11-4). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability. Perhaps some of those species lost with respect to TR between 2001 and 2003 were pollution tolerant species. This net loss may have contributed to the increase observed with respect to the PTI during this timeframe.

The siltation index (%NNS) yearly mean score increased from year 2001 (64) to 2003 (80), but decreased slightly during 2005 (76) (Table 11-4). These data suggest that overall species composition shifted away from those species adapted to living on silts and shifting sediments. In general, an increase in overall %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (89) to 2003 (64), but increased during 2005 (72) (Table 11-4). These yearly SDI fluctuations, track well with the changes seen in TR and largely mirror those seen in %NNS and suggests a correlation among these parameters (Table 11-4). In general, decreases as those seen here in the yearly mean SDI suggest a decline in overall water quality. This site’s mean overall SDI score (76) was among the lowest observed in the current study.

The fragilaria group richness (FGR) yearly mean score decreased significantly from year 2001 (53) to 2003 (8), but increased during 2005 (21) (Table 11-4). It is uncommon for FGR yearly mean scores to fluctuate as widely as observed at this site and it is unclear as to why such fluctuations occurred. This site’s mean overall FGR score (30) was among the highest observed in the current study and is indicative of good water quality.

The cymbella group richness (CGR) yearly mean score revealed no real discernable pattern throughout the study period (Table 11-4). It is uncommon for CGR yearly mean scores to fluctuate as widely as observed at this site and it is unclear as to why such fluctuations occurred. This site’s mean overall CGR score (27) was the highest observed in the current study and is indicative of good water quality (Table 11-4).

11.2.2 Macroinvertebrates

The macroinvertebrate communities in EPCFC001 were rated as ‘poor’ in 2000, ‘good’ in 2004, and ‘fair’ in 2005 (Table 11-5). Changes from 2000 to 2004 and 2005 were primarily the result of increased %Chir. and Oli. metric scores along with an increase in %Clinger metric. The %Clinger most likely increased due to the decrease in %Chir. and Oli. EPT richness and m%EPT were extremely low in all three surveys at EPCFC001.

At EPCND001, macroinvertebrate communities were rated ‘poor’ during all three sampling years (Table 11-5). All component MBI metrics scored 50 or below at EPCND001 in 2005. Two downstream sites, EPCPC001 and EPCPC002, scored mostly ‘fair’ (Table 11-5). The MBI scores at two locations were similar during all three sampling years, although scores were slightly higher in upstream location (EPCPC001) than downstream (EPCPC002). At both EPCPC001 and EPCPC002, the EPT richness metric scored consistently low during all three sampling years.

The MBI scores at Brier Creek site (EPCBC001) were highest of all the Pond Creek sites for macroinvertebrate communities (Table 11-5). The overall MBI score changed from 41.59 (Fair) in 2000, to 63.80 (Good) in 2003, and to 50.53 (Fair) in 2005. Proportion of EPT insects (%EPT) followed the similar changes as the overall MBI scores during this period. The %Clinger metric scores (16.39% in 2005) were lowest in Brier Creek.

11.2.3 Fish

Two upstream locations in Pond Creek watershed (EPCFC001 and EPCND001) showed improvements in water quality ratings, from 'poor' in 2002 to 'fair' (EPCFC001) and 'excellent' (EPCND001) in 2005, based on fish communities (Table 11-6). Native species richness (NAT) and insectivorous fish species (%INSCT) metric scores were higher in 2005 than 2002, which might have contributed to the improved fish IBI scores in 2005. Other metric scores fluctuated in three sampling events during 2002-2005.

Two downstream locations, EPCPC001 and EPCPC002, had 'very poor' fish IBI ratings until 2003, and they slightly improved to 'poor' in 2005 (Table 11-6). None of the component metric scores were higher than 50 percentile in these two locations on 2002-2005 samplings, and some metric scores were 'zero'.

Brier Creek had a much better fish community, 'excellent' in 2002 and 2003, and 'good' in 2005, when compared to other LTMN location in Pond Creek watershed (Table 11-6). All of the component metric scores were higher than 50 percentiles in this stream. Scores for native species richness (NAT), intolerant species richness (INT), and % insectivorous species (%INSCT) were very high in all surveys.

11.3 Hydrolab Data

11.3.1 Stream metabolism

Overall, the two upstream locations in Pond Creek watershed had higher GPP and CR values than two downstream locations (Table 11-7). At EPCFC001 location, GPP was highest during spring (5.62-8.15 g O_2/m^2/day), while it was similar in summer (0.35-1.63 g O_2/m^2/day) and fall (0.77-2.5 g O_2/m^2/day) (Table 11-7).

At EPCND001, the most of spring sonde data were not usable to estimate GPP and CR, thus only summer and fall estimates were available. GPP and CR were similar during summer (GPP: 3.77-10.6 g O_2/m^2/day, CR: 5.75-15.03 g O_2/m^2/day) and fall (GPP: 4.25-6.49 g O_2/m^2/day, CR: 5.39-10.82 g O_2/m^2/day) at the Northern Ditch location (Table 11-7).

At EPCPC001, the most of sonde data from spring were not usable to estimate GPP and CR, thus they were calculated for summer and fall. Available metabolism data showed slightly higher GPP and CR during fall than summer (Table 11-7).

At EPCPC002 location, GPP was highest during spring (0.72-3.13 g O_2/m^2/day), followed by fall (0.37-1.85 g O_2/m^2/day), and lowest in summer (0.33-2.29 g O_2/m^2/day) (Table 11-7). CR estimates were similar during summer (2.15-5.11 g O_2/m^2/day) and spring (1.81-4.52 g O_2/m^2/day), which were higher than fall (1.46-4.39 g O_2/m^2/day).

At Brier Creek, GPP estimates were similar in spring (0.66-3.08 g O_2/m^2/day) and summer (1.32-5.74 g O_2/m^2/day), and they were higher than estimates from fall (0.06-1.95 g O_2/m^2/day) (Table 11-8). CR estimates were very high during summer (5.97-13.98 g O_2/m^2/day) and fall (6.52-12.74 g O_2/m^2/day), which were much higher than spring estimates (3.38-7.49 g O_2/m^2/day).

11.3.2 Dissolved oxygen, pH, and conductivity

The Impact of the high degree of urbanization in the Pond Creek watershed was evident from the water quality parameters, especially dissolved oxygen and conductivity measured with Hydrolab sondes (Table 11-9). Dissolved oxygen concentration averaged over whole year was highest in Northern Ditch location (9.96 mg/L), followed by EPCPC002 (8.31 mg/L), EPCFC001 (7.36 mg/L), and lowest at EPCPC001 (7.19 mg/L). Overall mean conductivity was in the order of EPCFC001 (688 µS/cm), EPCPC001 (642 µS/cm), EPCND001 (608 µS/cm), and EPCPC002 (515 µS/cm).

At the EPCFC001 location, the daily average DO was highest during winter (3.87-12.74 mg/L) and lowest during summer (3.94-7.05 mg/L), and the daily mean DO stayed above 5.0 mg/L most of time. Daily mean pH was mostly higher than 7, except on winter 2002. Conductivity was highest during summer (622-768 µS/cm) and lowest during fall (458-757 µS/cm).

At the EPCND001 location, the daily mean DO was also highest during winter, followed by spring, fall, and lowest in summer. There was a huge diurnal variation of DO at this location, especially during summer and fall, as evidenced by the diurnal DO range (min-max). Although the mean DO stayed above 5.0 mg/L, the daily minimum DO dropped below 4.0 mg/L on several occasions during summer. Daily mean pH was mostly higher than 7, except on spring 2007. Conductivity was highest during winter (496-823 µS/cm) and lowest during spring (299-586 µS/cm) at this location.

At the EPCPC001 location, dissolved oxygen data obtained from sonde were unreliable on several occasions, especially during spring and summer (Table 11-9). Mean daily DO was below 5.0 mg/L during several summer and fall periods with daily minimum falling below 4.0 mg/L. Daily mean pH was mostly higher than 7, except on spring 2004. Conductivity was highest in winter (413-1461 µS/cm), followed by spring (473-1472 µS/cm) and summer (492-821 µS/cm), and lowest in fall (508-619 µS/cm) at EPCPC001.

At the EPCPC002 location, daily mean DO was below 5.0 mg/L during most summer with daily minimum falling below 4.0 mg/L (Table 11-9). Daily mean pH was mostly higher than 7, except on summer 2000. Conductivity was highest during winter (326-1224 µS/cm), followed by fall (432-658 µS/cm) and spring (299-574 µS/cm), and lowest in summer (313-516 µS/cm).

The mean daily DO at Brier Creek was below 5.0 mg/L on several occasions during summer and fall with the daily minimum DO was below 4.0 mg/L (Table 11-10). The overall mean daily pH was 7.05 at EPCBC001 location, which was considerably lower than other LTMN locations in Pond Creek watershed. Daily mean pH was mostly below 7.0 during summer and fall at this location. Conductivity was also much lower than other sites, with seasonal average raging in 203-334 µS/cm.

11.4 Laboratory Data

There was no water chemistry data available during 2000-2005 except fecal coliform in Pond Creek watershed, and number of samples during 2006 and 2007 was limited (mostly 2) (Table 11-11, Figure 11-1). Major water chemistry parameter values estimated at LTMN locations in Pond Creek watershed is summarized in Table 11-11. Ammonia-nitrogen concentration was mostly below the detection limit at all sites. Nitrate-nitrogen concentration was highest at the most upstream location (EPCFC001) (3.26 mg/L during 2007, ‘dry’ samples). Other three downstream locations had similar nitrate-nitrogen values ranging in 0.02-0.77 mg/L (during 2007, ‘dry’ samples). Chloride concentration was also highest at EPCFC001 (55.6 mg/L from 2007 ‘dry’ samples), and it ranged in 30-37 mg/L at other locations (dry samples).

Water chemistry data were not available during years 2000-2005 for Brier Creek except fecal coliform counts (Table 11-12, Figure 11-2). Most ammonia-nitrogen and ortho-phosphorus concentrations were below the detection limits. Nitrate-nitrogen (0.05 mg/L during 2007, ‘dry’ samples) and chloride concentrations (21.96 mg/L during 2007, ‘dry’ samples) were much lower than other LTMN locations in Pond Creek (Table 11-11, Table 11-12).

11.5 Watershed assessment based on the biological data

There was a longitudinal degradation of water quality ratings in LTMN locations in Pond Creek watershed when it was considered for the year 2005. Water quality at two upstream locations (EPCFC001 and EPCND001) could be classified as ‘fair’ based on the combined biotic integrity indices during 2005, while they were ‘poor’ at two downstream locations (EPCPC001 and EPCPC002). Overall, water quality ratings at two downstream locations have been consistently low with ‘poor’ ratings during 2000-2005 surveys.

Three biological indices in Brier Creek estimated in 2005 were different: diatoms with ‘poor’, macroinvertebrates with ‘fair’, and fish with ‘good’ ratings. During 2000-2005, Brier Creek had maintained ‘good’ water quality ratings. It is worthy to mention that Brier Creek is located in the Pennyroyal Region not the Bluegrass Region as other Pond Creek sites, thus would have lower water quality ratings with same biotic index scores when compared to other LTMN locations.

EPCFC001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	good	fair	fair	—	**fair**
MBI	poor	—	—	—	good	**fair**
Fish KBI	very poor	—	poor	fair	—	**fair**
EPCND001						
DBI	—	poor	fair	poor	—	**fair**
MBI	poor	—	—	—	poor	**poor**
Fish KBI	poor	—	poor	fair	—	**excellent**
EPCPC001						
DBI	—	poor	poor	poor	—	**poor**
MBI	fair	—	—	—	fair	**fair**
Fish KBI	very poor		very poor	very poor	—	**poor**
EPCPC002						
DBI	—	poor	poor	poor	—	**poor**
MBI	poor	—	—	—	fair	**fair**
Fish KBI	very poor	—	very poor	very poor	—	**poor**
EPCBC001						
DBI	—	good	good	poor	—	**poor**
MBI	fair	—	—	—	good	**fair**
Fish KBI	very poor	—	excellent	excellent	—	**good**

Table 11-1 Land use/cover characteristics of Pond Creek watershed.

EPCFC001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	16.76	10.20	1.44
Open Water	0.09	0.09	0.00
Dev. Open Space	24.17	17.32	39.71
Dev. Low Intensity	34.20	24.37	3.92
Dev. Medium Intensity	3.44	1.36	7.35
Dev. High Intensity	0.93	0.00	0.00
Barren Land	0.25	0.33	0.00
Deciduous Forest	28.80	45.03	45.10
Evergreen Forest	0.79	1.87	3.43
Mixed Forest	0.18	0.56	0.00
Shrub/Scrub	0.00	0.00	0.00
Grassland/herbaceous	0.15	0.06	0.49
Pasture/Hay	5.29	6.20	0.00
Cropland	1.70	2.78	0.00
Woody Wetlands	0.01	0.04	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00

EPCND001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	16.91	10.83	35.16
Open Water	0.15	0.43	0.00
Dev. Open Space	27.42	21.46	41.70
Dev. Low Intensity	27.50	19.68	16.59
Dev. Medium Intensity	7.37	5.99	15.70
Dev. High Intensity	3.14	2.59	9.87
Barren Land	0.44	0.56	0.00
Deciduous Forest	27.09	41.44	16.14
Evergreen Forest	0.80	1.44	0.00
Mixed Forest	0.18	0.35	0.00
Shrub/Scrub	0.01	0.00	0.00
Grassland/herbaceous	0.60	0.57	0.00
Pasture/Hay	3.20	3.33	0.00
Cropland	1.92	1.68	0.00
Woody Wetlands	0.18	0.43	0.00
Emergent Herbaceous Wetlands	0.02	0.05	0.00

EPCPC001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	24.65	18.14	0.89
Open Water	0.38	0.70	0.00
Dev. Open Space	23.82	23.53	1.81
Dev. Low Intensity	21.80	19.97	31.67
Dev. Medium Intensity	11.04	10.05	19.91
Dev. High Intensity	10.47	5.75	0.00
Barren Land	0.47	0.31	0.00
Deciduous Forest	28.17	34.81	26.70
Evergreen Forest	0.76	1.03	0.00
Mixed Forest	0.05	0.09	0.00
Shrub/Scrub	0.01	0.00	0.00
Grassland/herbaceous	0.44	0.49	0.00
Pasture/Hay	1.14	1.53	19.91
Cropland	0.46	0.38	0.00
Woody Wetlands	0.96	1.31	0.00
Emergent Herbaceous Wetlands	0.02	0.04	0.00

Table 11-1 Continued.

EPCPC002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	21.02	16.34	1.76
Open Water	0.38	0.70	0.00
Dev. Open Space	22.44	21.40	14.16
Dev. Low Intensity	20.08	16.89	4.42
Dev. Medium Intensity	9.24	7.89	0.00
Dev. High Intensity	8.34	4.29	0.00
Barren Land	0.43	0.29	0.00
Deciduous Forest	33.54	40.24	15.93
Evergreen Forest	0.73	0.85	0.00
Mixed Forest	0.05	0.06	0.00
Shrub/Scrub	0.02	0.01	0.00
Grassland/herbaceous	0.83	1.29	0.00
Pasture/Hay	2.15	3.05	63.27
Cropland	0.38	0.32	0.00
Woody Wetlands	1.35	2.59	2.21
Emergent Herbaceous Wetlands	0.04	0.14	0.00

Table 11-2 Land use/cover characteristics of Brier Creek watershed.

EPCBC001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	0.05	0.08	0.11
Open Water	0.00	0.00	0.00
Dev. Open Space	0.96	1.76	3.18
Dev. Low Intensity	0.00	0.00	0.00
Dev. Medium Intensity	0.00	0.00	0.00
Dev. High Intensity	0.00	0.00	0.00
Barren Land	0.00	0.00	0.00
Deciduous Forest	82.87	71.05	62.27
Evergreen Forest	0.03	0.00	0.00
Mixed Forest	0.00	0.00	0.00
Shrub/Scrub	0.20	0.00	0.00
Grassland/herbaceous	1.08	1.15	34.55
Pasture/Hay	14.61	25.55	0.00
Cropland	0.00	0.00	0.00
Woody Wetlands	0.24	0.48	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00

Table 11-3 DBI scores estimated in Pond Creek watershed.

EPCFC001	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2001	34	74	69	83	13	2	46	GOOD
2002	28	79	86	57	1	2	42	FAIR
2003	28	78	86	60	0	3	43	FAIR
Summer 05	35	76	76	72	5	0	44	FAIR
Fall 05	44	65	57	95	10	3	46	GOOD
2005 All	40	70	67	84	8	2	45	FAIR
Overall	**33**	**75**	**76**	**73**	**6**	**2**	**44**	**FAIR**
EPCND001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	35	58	37	90	9	0	38	POOR
2002	38	60	55	91	11	3	43	FAIR
2003	33	61	44	81	0	3	37	POOR
Summer 05	38	49	42	84	8	3	37	POOR
Fall 05	42	57	55	91	23	2	45	FAIR
2005 All	40	53	49	88	15	2	41	FAIR
Overall	**37**	**58**	**46**	**88**	**10**	**2**	**40**	**FAIR**
EPCPC001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	40	57	26	96	11	5	39	POOR
2002	37	66	34	92	3	3	39	POOR
2003	36	67	52	93	3	8	43	POOR
Summer 05	47	58	33	99	13	2	42	POOR
Fall 05	42	55	20	94	10	2	37	POOR
2005 All	45	57	27	97	12	2	40	POOR
Overall	**40**	**61**	**32**	**95**	**8**	**4**	**40**	**POOR**
EPCPC002	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	40	69	58	94	10	7	46	POOR
2002	42	65	47	95	7	3	43	POOR
2003	39	67	57	90	8	12	46	POOR
Summer 05	47	58	48	97	8	3	43	POOR
Fall 05	40	51	25	94	15	2	38	POOR
2005 All	43	54	36	96	11	2	41	POOR
Overall	**41**	**63**	**48**	**94**	**9**	**5**	**44**	**POOR**

Table 11-4 DBI scores estimated in Brier Creek watershed.

EPCBC001	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2001	41	67	64	89	53	26	57	GOOD
2002	38	72	73	76	31	42	55	GOOD
2003	34	77	80	64	8	22	47	POOR
Summer 05	33	74	77	62	20	18	47	POOR
Fall 05	41	63	75	83	23	12	49	POOR
2005 All	37	68	76	72	21	15	48	POOR
Overall	**38**	**70**	**73**	**76**	**30**	**27**	**52**	**FAIR**

Table 11-5 Macroinvertebrate biotic integrity scores in Pond Creek and Brier Creek.

Year	**Metric**	**EPCFC001**		**EPCND001**		**EPCPC001**		**EPCPC002**		**EPCBC001**	
		Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness	54	101.89	48	64.86	42	56.76	51	68.92	51	96.23
	EPT Richness	3	9.09	8	26.67	8	26.67	8	26.67	9	27.27
	m%EPT	5	5.75	10	13.70	22	30.14	16	21.92	26	29.92
	mHBI	7.04	37.85	8.13	27.14	6.76	47.02	7.09	42.24	8.05	24.94
	%Chir. and Oli.	55	45.31	52	48.48	39	61.62	66	34.34	36	64.44
	%Clinger	26	34.44	2	2.70	18	24.32	7	9.46	7	9.27
	%Ephemeroptera	1	1.50	-------	-------	-------	-------	-------	-------	26	39.10
	MBI	-------	33.69	-------	30.59	-------	41.09	-------	33.92	-------	41.59
	Assessment	-------	**Poor**	-------	**Poor**	-------	**Fair**	-------	**Poor**	-------	**Fair**
2004	Taxa Richness	34	46	28	37.8	25	33.8	31	41.9	28	37.8
	EPT Richness	7	23.3	7	23.3	8	26.7	6	20	6	20
	m%EPT	11.5	15.8	6.8	9.3	18.4	25.2	42.0	57.5	92.9	127.3
	mHBI	5.67	62.8	5.98	58.4	6.05	57.3	5.48	65.6	4.75	76.2
	%Chir. and Oli.	8.9	92	42.1	58.5	1.9	99.1	42.0	58.6	3.0	98
	%Clinger	78.4	105.6	2.7	3.7	86.0	116	34.9	47.2	17.6	23.8
	MBI	-------	62.90	-------	31.80	-------	59.70	-------	48.50	-------	63.80
	Assessment	-------	**Good**	-------	**Poor**	-------	**Fair**	-------	**Fair**	-------	**Good**
2005	Taxa Richness	38	60.32	37	50.00	42	56.76	40	54.05	57	90.48
	EPT Richness	4	12.12	4	13.33	7	23.33	9	30.00	16	48.48
	m%EPT	5.75	5.05	4.12	5.65	6.58	15.03	30.58	41.89	41.92	48.24
	mHBI	4.39	54.37	7.73	32.93	10.97	49.60	6.74	47.33	6.00	51.14
	%Chir. and Oli.	16.96	83.61	73.20	27.07	29.78	70.93	39.67	60.94	38.14	62.28
	%Clinger	75.15	99.53	0.34	0.46	52.04	70.32	24.79	33.50	12.37	16.39
	%Ephemeroptera	4.09	6.16	-------	-------	-------	-------	-------	-------	24.39	36.69
	MBI	-------	45.88	-------	21.57	-------	47.66	-------	44.62	-------	50.53
	Assessment	-------	**Fair**	-------	**Poor**	-------	**Fair**	-------	**Fair**	-------	**Fair**

Table 11-6 Fish IBI scores in Pond Creek and Brier Creek.

Year	**EPCFC001**	**EPCND001**	**EPCPC001**	**EPCPC002**	**EPCBC001**
1999-up	**NS**	**NS**	**NS**	**very poor**	**NS**
1999-dn	**NS**	**NS**	**NS**	**very poor**	**NS**
2000-up	**very poor**	**poor**	**very poor**	**very poor**	**fair**
2000-dn	**very poor**	**poor**	**very poor**	**very poor**	**very poor**
2002	**Poor**	**Poor**	**Very Poor**	**Very Poor**	**Excellent**
Native	50	48	7	16	100
DMS	36	14	0	0	55
INT	37	15	0	0	55
WC	53	31	5	3	100
SL	37	23	0	0	72
%Insect_Ex_Tol	0	36	0	13	60
%OMNI	0	59	0	50	100
%TOL	0	39	0	50	85
IBI	27	33	2	17	78
2003	**Fair**	**Fair**	**Very Poor**	**Very Poor**	**Excellent**
Native	57	59	13	16	98
DMS	36	50	0	10	83
INT	37	18	0	0	51
WC	62	56	9	13	94
SL	37	43	0	0	68
%Insect_Ex_Tol	31	20	0	5	85
%OMNI	37	69	0	31	100
%TOL	31	74	0	35	100
IBI	41	49	3	14	85
2005	**Fair**	**Excellent**	**Poor**	**Poor**	**Good**
NAT	59	65	28	31	100
DMS	34	60	4	11	69
INT	36	18	0	0	51
SL	37	51	0	5	84
%INSCT	100	100	50	50	100
%TOL	26	51	35	50	68
%FHW	0	0	12	15	0
KIBI	39	57	19	24	62

Table 11-7 Gross primary production (g O_2/m^2/day) and community respiration (g O_2/m^2/day) in Pond Creek watershed.

EPCFC001	Spring		Summer		Fall	
	GPP	CR	GPP	CR	GPP	CR
2000	5.62	12.14	0.56	16.72	—	—
2001	8.15	10.87	1.04	6.74	0.77	12.46
2002	—	—	1.14	8.38	0.78	16.72
2003	—	—	0.78	7.37	0.89	14.62
2004	8.02	18.06	0.35	20.03	1.78	6.76
2005	7.90	12.93	1.24	12.43	1.04	15.62
2006	5.95	13.99	1.63	8.78	1.22	11.14
2007	6.97	17.57	—	—	2.50	11.91

EPCND001	Spring		Summer		Fall	
	GPP	CR	GPP	CR	GPP	CR
2000	9.81	8.31	—	—	—	—
2001	—	—	4.94	15.03	4.15	7.27
2002	—	—	10.60	13.80	—	—
2003	—	—	5.88	8.34	6.49	6.32
2004	—	—	3.77	5.75	6.46	10.82
2005	—	—	—	—	6.35	7.30
2006	—	—	6.60	9.60	4.25	5.39
2007	4.53	3.82	—	—	—	—

EPCPC001	Spring		Summer		Fall	
	GPP	CR	GPP	CR	GPP	CR
2000	—	—	0.36	5.27	—	—
2001	0.56	3.70	0.52	4.04	0.84	5.02
2002	—	—	0.23	2.13	—	—
2003	—	—	0.11	5.30	1.24	5.04
2004	—	—	—	—	1.36	9.30
2005	—	—	—	—	0.37	4.19
2006	0.41	5.52	—	—	0.18	0.57
2007	0.34	2.09	—	—	—	—

EPCPC002	Spring		Summer		Fall	
	GPP	CR	GPP	CR	GPP	CR
2000	—	—	1.43	3.97	—	—
2001	0.94	3.18	0.68	3.54	—	—
2002	0.57	2.54	0.74	2.47	0.37	1.46
2003	0.72	4.52	0.33	2.73	1.85	2.28
2004	3.13	1.81	0.37	2.15	0.74	3.20
2005	1.25	2.73	0.66	5.11	0.74	4.39
2006	1.05	3.02	0.54	3.52	0.48	1.81
2007	1.00	3.76	2.29	2.31	1.66	1.69

Table 11-8 Gross primary production (g/m^2/day) and community respiration (g/m^2/day) in Brier Creek watershed.

EPCBC001	Spring		Summer		Fall	
	GPP	CR	GPP	CR	GPP	CR
2000	2.55	3.83	5.74	12.31	—	—
2001	—	—	2.33	10.79	0.35	11.98
2002	1.29	4.37	—	—	1.95	6.84
2003	—	—	2.65	13.37	1.78	9.99
2004	1.71	4.39	1.32	9.56	0.62	8.31
2005	3.08	6.48	1.69	13.98	0.06	12.74
2006	2.11	7.49	3.15	16.40	2.15	6.52
2007	0.66	5.83	1.84	5.97	2.26	13.80

Table 11-9 Water temperature, DO, pH, and conductivity at EPCFC001 in Pond Creek watershed.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.7	11.1	16.4	8.55	6.37	11.28	7.03	6.94	7.16	688.6	669.5	695.8
2001	17.2	14.9	20.0	8.77	6.21	13.24	8.00	7.73	8.44	746.0	710.0	755.1
2002	12.1	9.4	15.1	—	—	—	7.79	7.67	7.90	707.0	677.5	717.4
2003	14.9	11.4	18.9	—	—	—	7.76	7.53	8.10	615.3	484.9	624.3
2004	13.1	9.7	17.2	7.68	4.92	12.78	8.45	8.40	8.50	665.7	650.3	675.4
2005	15.1	11.5	18.8	8.84	5.98	13.53	8.05	7.68	8.59	566.0	543.4	581.7
2006	14.3	11.2	18.2	7.95	5.56	11.43	7.63	7.45	7.94	639.9	579.6	664.4
2007	8.0	6.3	9.8	8.87	6.65	12.59	8.22	7.94	8.63	715.6	694.8	727.3
Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	22.5	21.2	23.8	3.94	3.39	4.28	7.65	7.53	7.72	653.5	560.2	685.7
2001	21.9	20.5	23.2	6.28	5.29	7.25	7.45	7.32	7.56	679.5	641.0	711.9
2002	22.5	21.3	23.6	6.71	6.16	7.44	7.70	7.64	7.77	724.0	699.2	729.0
2003	21.9	20.6	23.3	6.84	6.31	7.36	7.97	7.89	8.05	682.7	596.1	722.7
2004	20.9	19.6	22.0	3.17	2.90	3.48	7.76	7.65	7.85	622.5	537.5	673.0
2005	22.2	20.9	23.4	5.29	4.60	6.09	7.68	7.64	7.74	962.0	949.2	971.6
2006	20.1	18.6	21.3	7.05	6.15	7.96	7.34	7.26	7.46	675.1	610.7	719.0
2007	22.1	20.5	23.7	—	—	—	7.93	7.87	8.00	767.9	747.1	782.6
Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.5	12.9	16.3	6.78	6.31	7.34	7.62	7.48	7.73	665.2	510.4	724.0
2002	14.1	13.1	15.1	5.59	5.02	6.20	7.75	7.67	7.83	757.4	736.7	764.3
2003	15.8	14.0	17.5	5.94	5.48	6.61	7.48	7.39	7.65	612.0	604.5	616.2
2004	14.6	12.9	16.2	8.73	7.74	9.88	7.52	7.42	7.66	457.6	437.1	463.6
2005	15.9	14.4	17.6	5.57	5.07	6.10	7.27	7.24	7.30	497.3	473.4	505.9
2006	16.5	14.9	17.9	6.87	6.21	7.63	7.60	7.53	7.67	769.9	695.7	780.2
2007	21.3	19.6	23.1	6.05	5.18	7.66	7.63	7.57	7.73	889.1	876.7	895.1
Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	6.6	5.0	8.2	8.78	7.32	11.11	6.73	6.55	6.93	850.0	755.6	945.0
2003	2.5	1.5	3.6	12.74	11.59	14.50	7.96	7.86	8.12	755.1	743.1	779.1
2004	5.5	3.8	6.9	9.24	6.89	11.90	7.39	6.41	7.74	629.8	497.2	672.1
2005	5.7	4.4	6.8	9.28	8.61	10.78	7.71	7.63	7.86	638.2	589.6	646.9
2006	9.2	7.5	10.6	3.87	3.53	5.12	7.56	7.43	7.71	668.3	506.0	786.8
2007	7.9	7.0	8.9	9.37	8.55	10.63	8.02	7.94	8.13	658.5	614.0	700.3

Table 11-9 Continued, at EPCND001.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	14.8	11.6	18.9	11.04	6.22	17.75	7.77	7.21	8.27	547.0	519.4	569.2
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.7	9.6	15.8	13.06	8.20	19.37	8.60	8.05	9.06	612.9	586.3	641.9
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	15.1	11.0	20.1	—	—	—	7.60	7.07	8.05	644.6	541.4	666.2
2005	17.8	12.8	23.8	—	—	—	7.82	7.36	8.17	471.1	450.5	485.5
2006	15.7	12.6	19.6	—	—	—	6.98	6.89	7.20	309.9	299.2	319.5
2007	8.2	6.1	10.6	12.29	9.78	15.56	8.24	7.98	8.55	589.2	575.9	600.5

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	27.3	22.8	32.6	1.93	0.37	8.16	7.80	7.29	8.50	625.0	564.8	657.3
2002	27.9	23.8	33.3	6.41	1.28	14.39	8.00	7.43	8.77	636.8	590.9	664.7
2003	26.0	22.2	30.5	6.92	3.88	10.91	8.73	8.09	9.46	520.2	433.1	560.9
2004	23.5	21.2	26.4	7.56	5.50	10.32	7.65	7.40	7.95	337.4	234.7	386.6
2005	28.0	23.8	32.8	—	—	—	7.02	6.76	7.17	746.5	714.5	792.6
2006	23.9	19.9	28.6	7.07	3.97	11.30	7.41	7.02	7.90	638.2	565.4	675.9
2007	—	—	—	—	—	—	—	—	—	—	—	—

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.5	12.4	19.3	8.11	6.03	12.07	7.85	7.51	8.29	495.7	424.0	530.8
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	16.9	13.6	21.0	9.30	6.09	15.24	7.98	7.73	8.31	563.5	481.6	576.5
2004	16.7	12.5	21.5	7.33	4.07	12.60	7.93	7.42	8.56	704.6	648.9	722.7
2005	16.9	12.8	22.1	9.02	5.60	14.15	7.61	7.46	7.82	493.9	482.3	502.9
2006	17.3	14.5	20.8	8.90	6.83	12.23	7.87	7.68	8.12	924.1	903.1	939.1
2007	—	—	—	—	—	—	—	—	—	—	—	—

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	4.9	3.3	6.9	—	—	—	7.84	7.54	8.24	786.5	737.8	861.5
2003	0.8	0.2	1.8	15.72	13.41	19.03	8.48	8.24	8.65	701.0	691.0	719.2
2004	3.9	2.7	5.3	13.48	11.65	16.62	7.23	7.02	7.52	823.5	797.2	844.3
2005	3.0	1.7	4.3	11.71	10.64	13.17	8.06	7.86	8.35	670.9	639.5	681.8
2006	8.2	7.0	9.4	—	—	—	7.62	7.53	7.72	496.1	462.5	530.0
2007	6.6	5.6	7.5	11.95	10.75	14.95	8.03	7.93	8.20	614.6	511.3	642.9

Table 11-9 Continued, at EPCPC001.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	13.2	11.9	14.7	8.39	7.88	8.70	7.82	7.74	7.88	559.6	541.2	568.4
2001	19.6	17.5	21.9	7.51	6.33	8.69	7.74	7.54	7.94	633.1	623.1	638.8
2002	12.9	11.0	15.0	—	—	—	8.34	8.23	8.47	457.3	447.4	472.7
2003	17.4	14.9	19.9	4.35	3.55	5.27	7.07	6.96	7.21	671.1	655.7	681.2
2004	11.0	10.7	11.2	—	—	—	6.44	6.39	6.48	1472.2	1435.0	1514.2
2005	17.2	15.6	19.5	—	—	—	7.19	7.05	7.32	473.4	465.9	486.4
2006	16.1	13.6	18.9	7.30	6.52	8.13	8.17	7.98	8.41	545.8	521.2	567.0
2007	7.7	5.0	9.6	11.19	8.40	11.84	8.00	7.85	8.44	574.3	454.3	2550.8

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	27.3	25.2	29.7	5.07	4.27	6.45	7.42	7.31	7.59	499.2	409.1	564.2
2001	27.8	26.0	29.8	2.73	1.90	3.24	7.34	7.23	7.47	561.1	513.2	613.1
2002	27.9	26.8	29.0	6.22	5.18	7.51	8.48	8.31	8.69	539.7	515.4	559.0
2003	27.0	25.2	29.0	4.75	3.87	6.01	7.28	7.12	7.56	491.9	373.2	574.8
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	27.5	26.6	28.6	—	—	—	7.06	7.04	7.08	821.5	804.2	835.1
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	28.6	27.1	30.3	7.79	6.03	9.74	7.87	7.69	8.15	620.6	602.9	641.7

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	16.5	15.1	18.0	7.05	5.04	8.72	7.65	7.50	7.84	536.1	386.5	599.5
2002	14.0	12.8	15.3	2.94	1.70	4.21	8.30	8.09	8.52	554.7	526.5	599.7
2003	17.6	16.3	18.9	6.53	4.79	8.03	8.03	7.89	8.18	534.9	517.8	544.0
2004	17.2	16.1	18.6	5.70	4.98	6.87	7.91	7.85	7.97	611.5	603.3	623.1
2005	17.6	17.0	18.6	7.41	6.93	7.86	7.91	7.81	8.02	508.5	498.1	521.6
2006	18.5	16.7	20.4	8.43	7.53	9.94	8.15	8.08	8.25	523.3	513.1	533.4
2007	24.4	23.7	25.3	—	—	—	7.56	7.40	7.76	619.6	578.1	644.8

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	1.3	0.1	2.7	11.56	10.55	13.00	7.77	7.67	7.89	1461.6	1304.3	1604.3
2002	4.6	3.6	5.8	10.94	9.73	12.47	8.22	8.10	8.40	845.4	729.9	1018.7
2003	0.3	0.0	0.8	13.15	12.54	13.84	9.56	9.31	9.63	743.1	706.2	780.8
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	3.1	2.4	3.8	5.23	3.45	7.50	7.08	6.99	7.17	584.2	573.0	595.7
2006	7.3	6.4	8.5	3.48	1.38	6.00	7.72	7.58	7.89	412.7	351.9	458.3
2007	5.6	4.8	6.5	11.87	11.29	12.64	7.74	7.63	7.88	475.3	450.4	510.2

Table 11-9 Continued, at EPCPC002.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	12.7	12.0	13.5	—	—	—	7.37	7.31	7.66	299.0	285.4	308.2
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.1	10.8	13.5	8.63	8.13	9.29	7.35	7.29	7.43	442.5	434.2	453.3
2003	15.8	14.0	17.7	5.69	4.99	6.60	8.00	7.95	8.08	573.8	565.7	582.3
2004	13.8	11.8	15.8	11.65	8.53	15.12	8.27	7.78	8.64	—	—	—
2005	16.2	14.3	18.0	8.18	6.82	9.58	7.74	7.54	8.00	566.8	552.2	579.4
2006	15.4	13.9	17.2	7.31	6.10	8.34	7.44	7.25	7.64	474.8	444.6	494.5
2007	8.4	7.2	12.8	7.37	5.23	8.69	7.54	7.32	7.76	401.8	304.1	429.0

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	26.4	25.2	27.6	4.28	3.49	5.35	6.16	6.08	6.22	432.5	340.0	551.1
2001	25.0	24.2	26.1	4.82	3.97	5.70	7.48	7.37	7.63	516.2	488.6	554.8
2002	25.7	24.7	26.8	6.35	5.63	7.51	7.88	7.77	8.04	408.5	397.1	421.2
2003	25.5	24.6	26.6	5.15	4.56	5.79	7.50	7.40	7.60	388.4	339.8	453.2
2004	24.7	23.7	25.8	6.05	5.63	6.51	7.41	7.34	7.48	312.6	290.2	334.1
2005	24.9	23.4	26.4	3.25	2.72	3.97	7.01	6.89	7.18	432.6	384.2	452.3
2006	23.8	22.6	25.2	4.40	3.85	5.10	7.27	7.17	7.37	510.7	458.2	597.1
2007	26.1	24.5	28.1	5.43	1.48	7.26	7.07	6.77	7.28	481.4	442.9	522.3

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.4	14.3	16.6	12.95	10.85	18.55	7.34	7.22	7.53	432.1	357.9	549.7
2002	14.1	13.3	14.9	8.90	8.54	9.32	8.11	8.05	8.18	552.4	529.6	570.6
2003	15.5	14.7	16.4	7.23	5.54	8.35	7.21	6.82	7.45	617.3	588.1	700.0
2004	15.1	13.8	16.3	15.05	12.13	17.69	7.27	7.13	7.42	547.3	500.3	567.9
2005	15.9	14.8	17.1	5.41	4.63	7.11	7.73	7.66	7.81	431.2	428.5	434.6
2006	18.0	17.1	19.1	7.44	6.82	8.22	7.90	7.81	7.95	657.8	613.0	740.8
2007	22.7	21.4	24.3	7.19	3.94	9.72	7.35	7.10	7.54	531.2	519.9	542.4

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	2.5	1.7	3.2	8.64	6.92	10.64	7.55	7.39	7.71	1223.8	1068.2	1504.0
2002	4.5	3.0	6.4	12.27	9.65	15.37	8.14	7.85	8.48	504.3	439.2	528.4
2003	0.0	-0.2	0.2	15.15	14.54	15.78	8.03	7.94	8.13	688.5	675.2	705.0
2004	2.3	1.6	3.0	11.43	10.69	12.14	7.88	7.75	8.00	325.5	308.4	351.2
2005	1.9	1.3	2.7	9.87	9.17	10.42	7.92	7.87	7.98	498.5	486.4	509.4
2006	6.9	5.8	8.0	8.42	7.98	8.88	7.85	7.75	7.97	528.2	445.4	591.9
2007	—	—	—	—	—	—	—	—	—	—	—	—

Table 11-10 Water temperature, DO, pH, and conductivity at EPCBC001 in Brier Creek.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	12.8	10.5	15.4	9.99	8.74	11.47	7.24	7.12	7.38	182.2	179.6	185.1
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	10.7	8.6	13.0	9.58	8.63	10.57	6.85	6.79	6.94	193.3	191.4	196.0
2003	14.1	10.9	17.5	11.57	5.98	13.18	7.45	7.35	7.57	198.9	192.0	202.7
2004	12.5	9.3	16.2	9.37	8.03	10.62	7.21	7.03	7.36	215.5	213.8	218.6
2005	14.8	11.4	18.8	8.60	6.90	10.48	7.03	6.87	7.36	221.2	219.4	225.9
2006	14.0	11.7	16.8	3.97	2.47	5.62	7.31	7.21	7.47	194.6	188.4	200.9
2007	8.0	6.2	10.4	9.23	8.43	9.96	7.09	7.01	7.15	220.2	193.8	198.9
Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	23.3	21.9	24.9	5.34	2.84	11.14	6.76	6.69	6.82	330.9	308.1	356.1
2001	23.8	21.9	26.1	3.79	1.46	7.40	6.90	6.78	7.06	331.6	318.0	348.9
2002	24.2	23.1	25.4	—	—	—	6.54	6.48	6.62	291.6	279.7	305.6
2003	23.7	22.3	25.4	3.29	1.99	6.23	7.63	7.57	7.69	314.1	303.9	327.5
2004	22.5	20.6	24.5	4.55	3.59	5.99	6.57	6.48	6.65	247.3	241.2	254.8
2005	24.1	22.6	25.9	2.12	0.91	4.40	6.53	6.48	6.58	323.5	319.0	329.6
2006	22.2	20.5	24.0	2.44	0.88	6.56	7.32	7.28	7.35	401.7	373.1	426.3
2007	24.7	22.9	27.1	5.37	2.78	9.41	6.86	6.76	6.97	434.5	431.5	438.4
Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	13.6	12.3	15.1	4.30	3.41	5.44	6.73	6.67	6.77	347.0	331.7	359.4
2002	13.7	12.6	14.8	7.94	6.69	9.89	6.68	6.61	6.79	286.7	283.9	290.8
2003	15.8	14.3	17.4	5.82	4.82	7.80	6.78	6.69	6.84	295.5	285.4	315.1
2004	14.4	13.2	15.6	6.00	5.18	7.23	6.92	6.85	7.02	270.4	237.7	281.8
2005	14.7	13.7	15.9	3.08	2.45	4.10	6.50	6.45	6.54	225.1	223.8	226.3
2006	16.8	15.1	18.6	7.43	6.26	9.40	7.16	7.10	7.21	379.9	376.3	388.8
2007	21.6	19.9	23.2	2.86	1.44	5.22	7.31	7.24	7.45	429.2	423.7	433.3
Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	2.9	1.8	3.9	11.37	10.69	12.08	8.15	8.00	8.37	387.7	365.9	425.4
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	1.1	0.4	2.0	7.88	7.55	8.24	7.23	7.16	7.28	218.2	208.4	234.4
2004	2.8	1.7	4.0	12.37	11.67	13.09	7.48	7.26	7.70	219.1	190.1	239.1
2005	2.8	1.6	4.0	11.20	10.59	11.75	6.93	6.88	6.99	164.1	151.7	171.0
2006	7.0	5.6	8.4	6.45	5.78	7.05	6.65	6.59	6.74	151.1	129.8	165.7
2007	—	—	—	—	—	—	—	—	—	—	—	—

Table 11-11 Summary of selected water chemistry parameters in Pond Creek.

EPCFC001		2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	2.83	3.26	Total Kjeldahl Nitrogen (mg/L)	0.51	0.88
	SD (Dry)	0.00	0.00		0.44	1.95		0.07	0.17
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.03	0.05		2.48	1.83		0.56	1.07
	SD (wet)	-	0.00		-	0.98		-	0.19
	Count (wet)	1	2		1	2		1	2
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.44	0.31	Phosphorus (mg/L)	0.35	0.28	Chloride	38.26	55.56
	SD (Dry)	0.25	0.09		0.19	0.23		2.28	21.59
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	0.46	0.33		0.64	0.32		39.91	28.12
	SD (wet)	-	0.33		-	0.05		-	25.71
	Count (wet)	1	2		1	2		1	2
BOD (mg/L)	Mean (Dry)	0.50	1.25	TDS (mg/L)	478.00	573.50	TSS (mg/L)	7.00	8.50
	SD (Dry)	0.00	1.06		16.97	94.05		2.83	4.95
	Count (Dry)	2	2		2	2		2	2
	Mean (wet)	1.00	1.50		478.00	573.50		22.00	27.50
	SD (wet)	-	0.71		16.97	94.05		-	4.95
	Count (wet)	1	2		2	2		1	2
		2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	2374	1014	1116	517	303	1190	368	617
	SD (Dry)	5104	1786	2564	578	212	1702	378	663
	Count (Dry)	27	30	29	24	15	21	17	25
	Mean (wet)	-	-	-	1211	1071	1236	5648	3921
	SD (wet)	-	-	-	490	985	1102	12619	4746
	Count (wet)	0	0	0	5	16	10	17	9
EPCND001		2006	2007		2006	2007		2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.00	0.02	Total Kjeldahl Nitrogen (mg/L)	0.63	0.93
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.05		1.39	0.86		0.70	0.73
	SD (wet)	0.00	0.00		0.32	0.84		0.33	0.16
	Count (wet)	2	3		2	3		2	3
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.12	0.03	Phosphorus (mg/L)	0.04	0.10	Chloride	26.31	30.09
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.14	0.04		0.17	0.10		19.89	24.72
	SD (wet)	0.04	0.03		0.09	0.07		13.53	2.29
	Count (wet)	2	3		3	3		2	3
BOD (mg/L)	Mean (Dry)	0.50	6.00	TDS (mg/L)	384.00	348.00	TSS (mg/L)	7.00	23.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	1.75	2.33		303.00	284.67		41.00	13.00
	SD (wet)	1.77	0.58		142.84	75.00		42.43	8.19
	Count (wet)	2	3		2	3		2	3
		2000	2001	2002	2003	2004	2005	2006	2007
Fecal Coliform (col/100 ml)	Mean (Dry)	179	915	545	353	209	286	493	683
	SD (Dry)	438	2666	1021	826	506	483	1183	2391
	Count (Dry)	21	30	29	26	20	22	17	21
	Mean (wet)	2641	-	-	240	555	4748	1540	2088
	SD (wet)	3788	-	-	398	1037	12958	3141	3324
	Count (wet)	6	0	0	5	12	10	16	12

Table 11-11 Continued.

EPCPC001		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	0.70	0.77	Total Kjeldahl Nitrogen (mg/L)	0.63	0.62
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.05		0.60	0.70		0.91	1.26
	SD (wet)	0.00	0.00		0.05	0.35		0.13	0.82
	Count (wet)	2	3		2	3		2	3
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.14	0.09	Phosphorus (mg/L)	0.06	0.17	Chloride	32.35	37.57
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.14	0.03		0.21	0.22		29.33	38.59
	SD (wet)	0.05	0.01		0.10	0.12		24.78	13.69
	Count (wet)	2	3		2	3		2	3
BOD (mg/L)	Mean (Dry)	1.00	2.00	TDS (mg/L)	370.00	360.00	TSS (mg/L)	44.00	70.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	3.00	3.33		264.00	325.33		87.50	132.67
	SD (wet)	1.41	2.31		115.97	65.77		47.38	130.70
	Count (wet)	2	3		2	3		2	3
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	428	355	1202	499	145	354	877	283
	SD (Dry)	753	578	2952	1165	80	649	1888	300
	Count (Dry)	23	30	29	20	20	20	16	22
	Mean (wet)	4386	-	-	884	1186	1764	1498	3351
	SD (wet)	6019	-	-	2295	1546	3241	1698	5291
	Count (wet)	5	0	0	10	12	12	17	12
EPCPC002		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	0.78	0.62	Total Kjeldahl Nitrogen (mg/L)	0.75	1.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.05		0.64	0.55		0.71	0.70
	SD (wet)	0.00	0.00		0.04	0.57		0.42	0.05
	Count (wet)	2	3		2	3		2	3
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.11	0.05	Phosphorus (mg/L)	0.04	0.05	Chloride	23.16	30.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.10	0.03		0.17	0.08		20.63	30.53
	SD (wet)	0.11	0.00		0.18	0.04		15.44	7.95
	Count (wet)	2	3		2	3		2	3
BOD (mg/L)	Mean (Dry)	0.50	1.00	TDS (mg/L)	310.00	318.00	TSS (mg/L)	11.00	7.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	2.25	1.17		266.00	308.67		96.50	12.33
	SD (wet)	2.47	0.76		144.25	115.90		95.46	5.51
	Count (wet)	2	3		2	3		2	3
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	87	118	97	240	142	166	250	72
	SD (Dry)	68	122	95	352	84	102	510	62
	Count (Dry)	20	14	20	22	21	23	14	23
	Mean (wet)	3814	504	2129	1567	1322	4979	1503	2057
	SD (wet)	7160	688	2399	2363	1469	12208	3125	3931
	Count (wet)	8	16	9	8	11	9	19	10

Table 11-12 Summary of selected water chemistry parameters in Brier Creek.

EPCBC001		**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	0.11	0.05	Total Kjeldahl Nitrogen (mg/L)	1.20	0.93
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.22		0.54	0.59		0.74	0.91
	SD (wet)	0.00	0.29		0.21	0.64		0.10	0.34
	Count (wet)	2	3		2	3		2	3
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.03	Phosphorus (mg/L)	0.04	0.04	Chloride	12.35	21.96
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.06	0.03		0.10	0.05		5.66	11.92
	SD (wet)	0.05	0.00		0.05	0.03		1.77	10.70
	Count (wet)	2	3		3	3		2	3
BOD (mg/L)	Mean (Dry)	1.00	1.00	TDS (mg/L)	190.00	262.00	TSS (mg/L)	4.00	8.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.75	1.67		129.00	160.00		26.50	12.33
	SD (wet)	0.35	0.58		26.87	83.88		4.95	7.02
	Count (wet)	2	3		2	3		2	3

		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	257	154	218	442	315	713	852	1237
	SD (Dry)	418	223	705	754	446	1554	708	3431
	Count (Dry)	20	14	20	21	21	22	14	23
	Mean (wet)	1169	274	1063	490	1266	1218	1090	1935
	SD (wet)	1184	461	2498	590	2910	1511	1082	2492
	Count (wet)	8	16	9	9	11	9	19	10

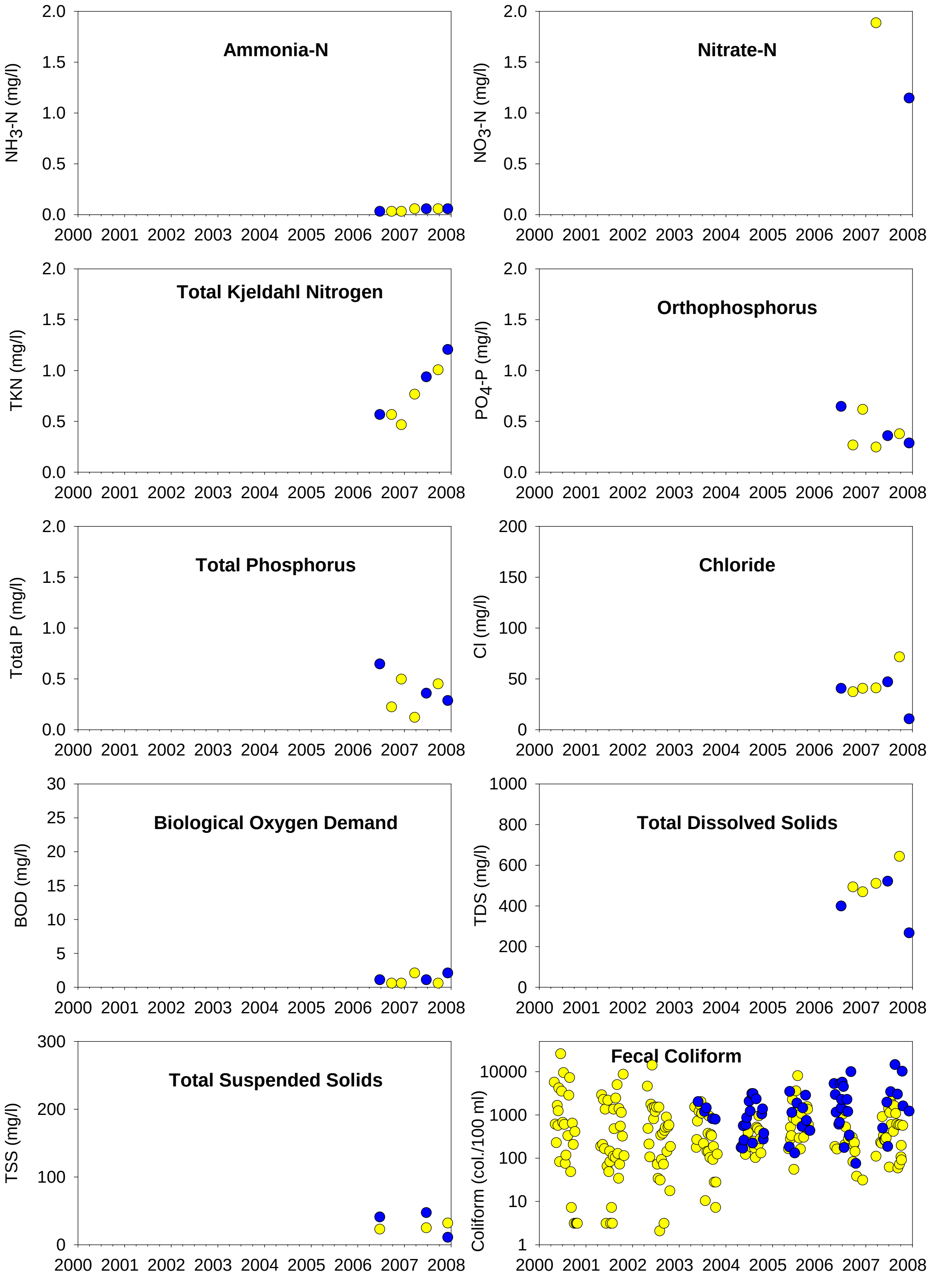

Figure 11-1 Major water chemistry parameters measured at EPCFC001 location in Pond Creek. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

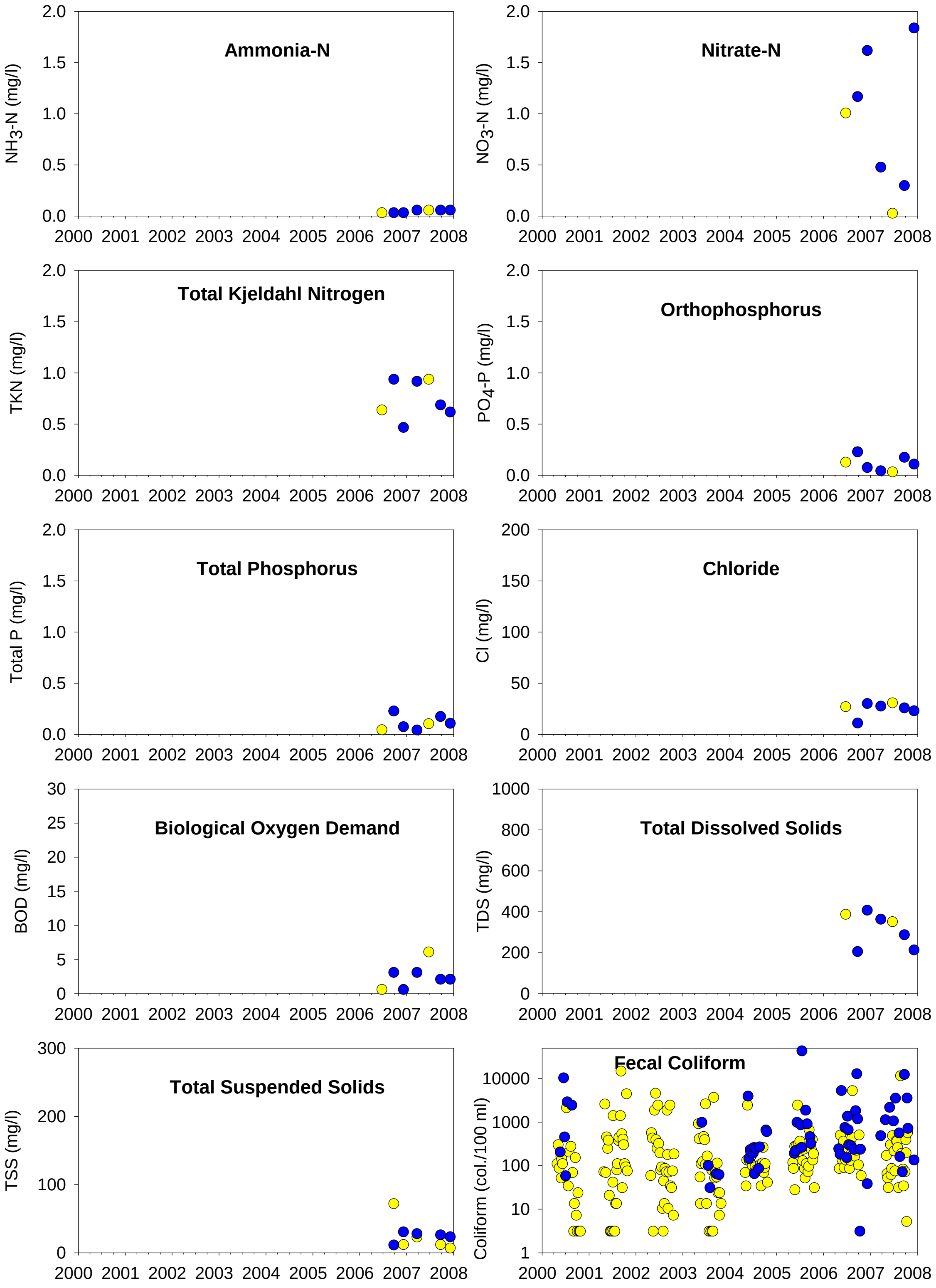

Figure 11-1 Continued, at EPCND001.

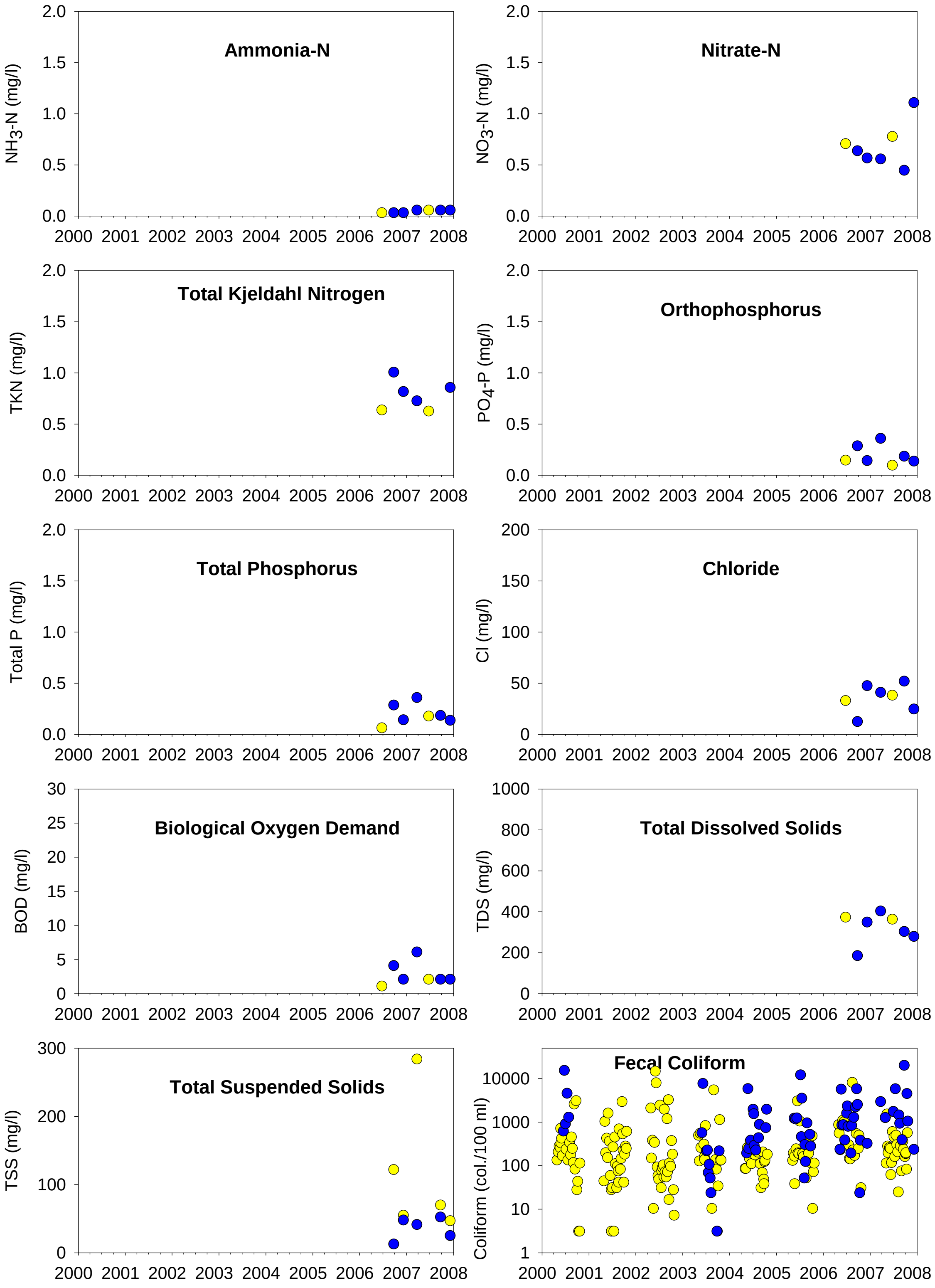

Figure 11-1 Continued, at EPCPC001.

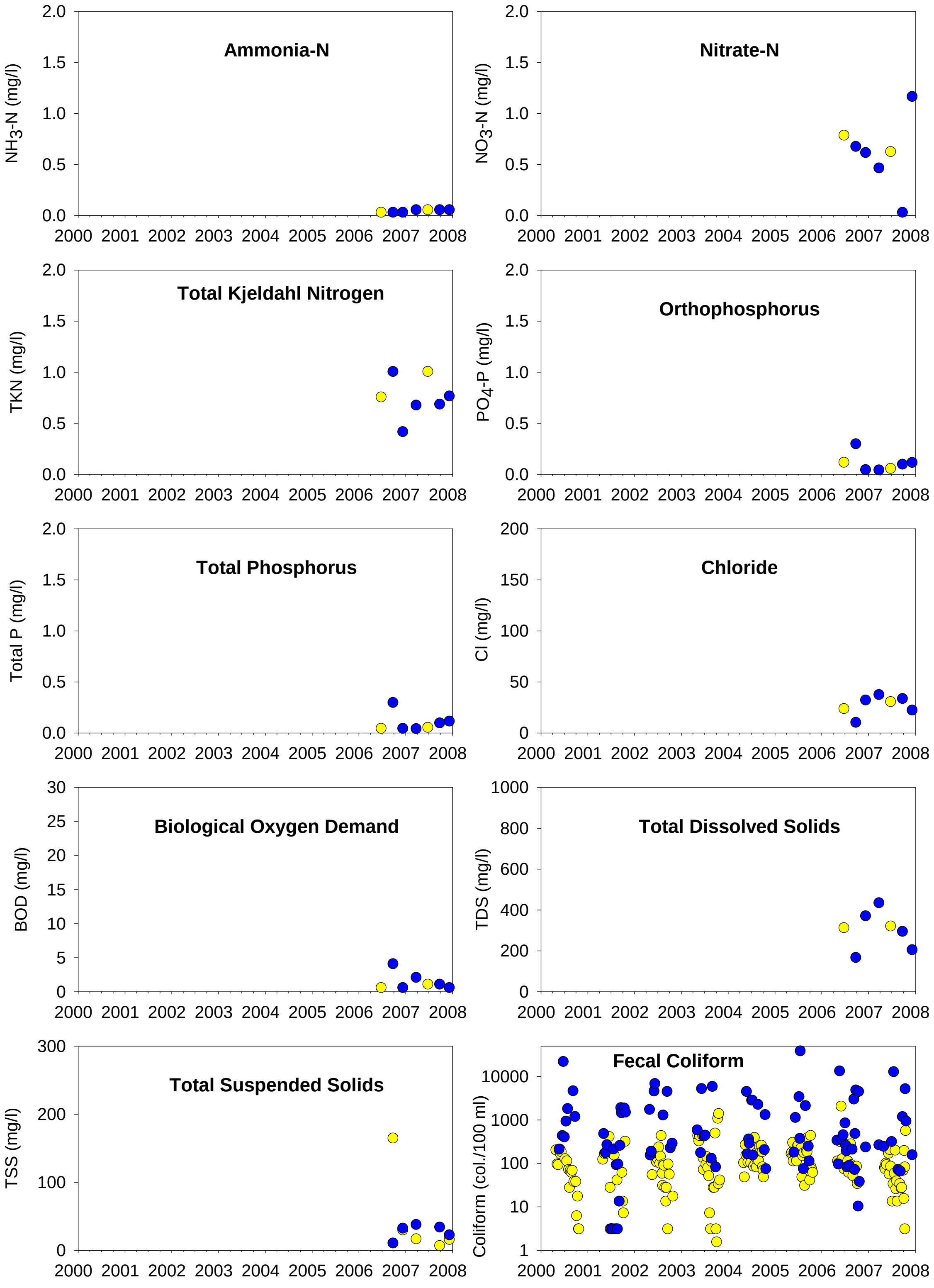

Figure 11-1 Continued, at EPCPC002.

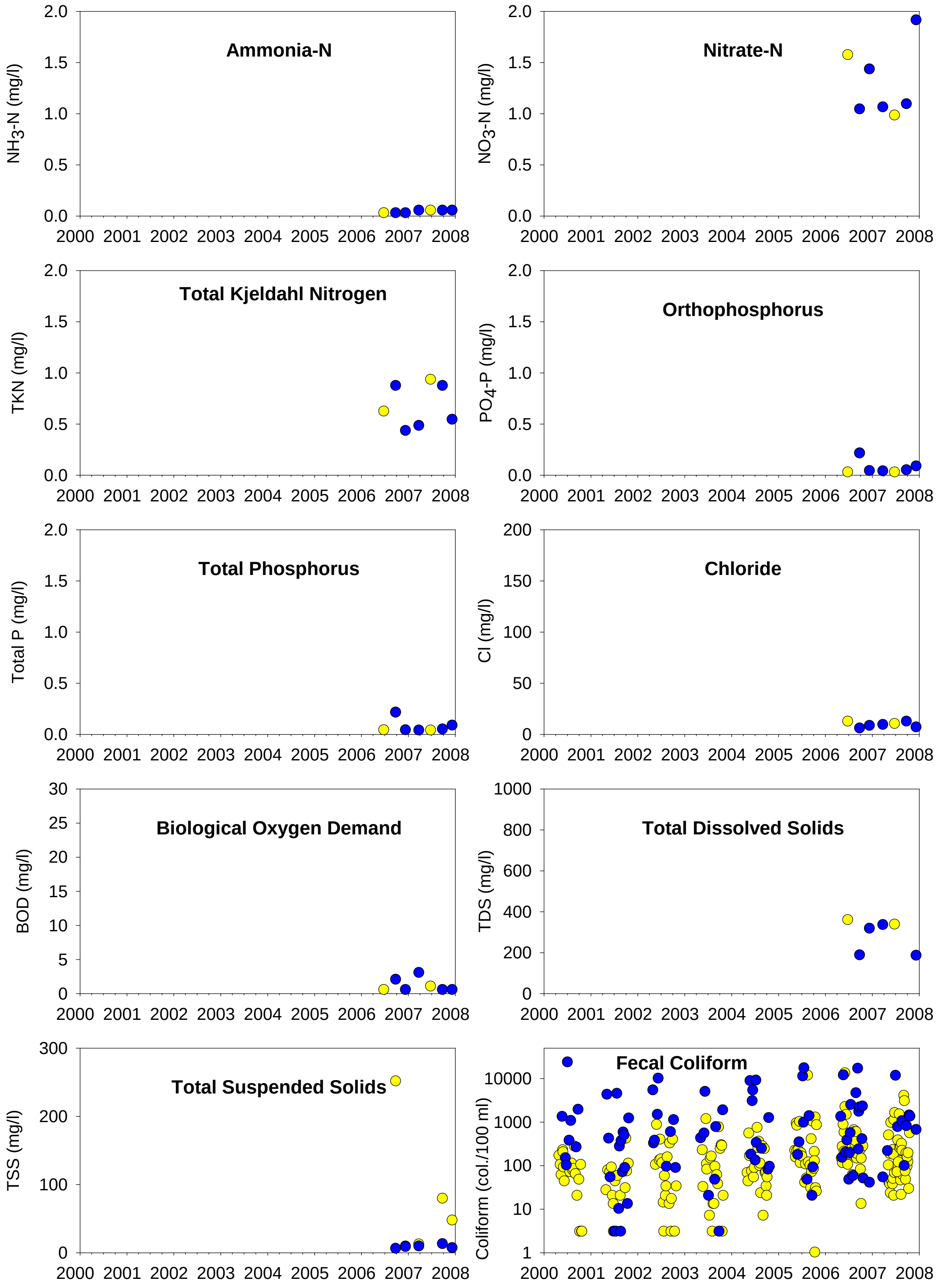

Figure 11-2 Major water chemistry parameters measured at Brier Creek. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 12 South Fork of Beargrass Creek Watershed

12.1 Watershed Physical Characteristics

The South Fork of Beargrass Creek originates in the Forest Hills and Jeffersontown areas and initially flows to west before turning to north, then flowing into Ohio River. There are three LTMN locations, the most upstream location at Trevillian Way (ESFSF001), the middle location at Schiller Ave (ESFSF002), and the downstream location at Brownsboro Road (ESFSF006). Middle Fork Beargrass Creek merges into South Fork approximately 1.3 km upstream of ESFSF006.

Due to the longitudinal connectivity of the three LTMN locations in SFBC watershed, data are presented following the order of upstream-downstream linkage: ESFSF001-ESFSF002-ESFSF006.

The South Fork of Beargrass Creek watershed is highly developed with the cumulative watershed imperviousness of 32% (ESFSF001), 30% (ESFSF002), and 28% (ESFSF006) (Table 12-1). This is much higher than another highly developed watershed in Jefferson County, Middle Fork Beargrass Creek, which has 24% of imperviousness. The cumulative watershed landuse patterns estimated at three LTMN locations in the South Fork of Beargrass Creek watershed contain large proportion of developed lands (78-85%), and the intensity of development was higher in the upstream portion of the watershed. Forested areas were very small (12.5-18.8%) in this watershed. Riparian buffer zone was also very well developed with 61-71% developed lands at the whole watershed-scale, and 75-99% at the reach-scale assessment.

12.2 Biological Data

12.2.1 Diatom

ESFSF001: The overall water quality of the South Fork of Beargrass Creek at Trevilian Way (ESFSF001) based on 38 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Good’ (Table 12-2). The overall mean score of 49 reflects the mid range of ‘Good’ scores. In general, these data suggest water quality of the South Fork of Beargrass Creek at Trevilian Way seems to be declining somewhat over time (Table 12-2). Specifically, during the 2001 and 2002 sampling seasons, 94% of sample dates characterized water quality as ‘Good’ or ‘Excellent’ (mean DBI = 52). During subsequent sampling seasons (2003, 2005), mean overall water quality seemed to decline as only 70% of samples scored in the ‘Good’ or ‘Excellent’ ranges (mean DBI = 48).

The taxa richness (TR) yearly mean score decreased from year 2001 (41) to 2005 (36) (Table 12-2). These data suggest that a number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score revealed no real discernable pattern throughout the study period (Table 12-2). Small, yearly PTI fluctuations, as seen here, are well within the limits of expected yearly natural variability.

The siltation index (%NNS) yearly mean score increased from year 2001 (74) to 2003 (81), but decreased substantially during 2005 (53) (Table 12-2). These data suggest that overall species composition shifted toward those species adapted to living on silts and shifting sediments. In general, a decrease in overall %NNS suggests a decline in water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (84) to 2003 (72), but increased during 2005 (89) (Table 12-2). Fluctuations in SDI, as seen here, are usually related to species distribution becoming more even since TR values were reasonably constant.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (28) to 2005 (12) (Table 12-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining slightly. Taxa lost from within this group may have contributed to the overall decrease in TR throughout this study.

The cymbella group richness (CGR) yearly mean score decreased from year 2002 (24) to 2005 (12) (Table 12-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining slightly. Taxa lost from within this group may have contributed to the overall decrease in TR throughout this study.

ESFSF002: The overall water quality of the South Fork of Beargrass Creek at Schiller Avenue Ramp (ESFSF002) based on 37 diatom samples collected over four years (2001 – 03, 2005) may be characterized as ‘Good’ (Table 12-2). The overall mean score of 49 reflects the mid range of ‘Good’ scores. In general, these data suggest water quality of the South Fork of Beargrass Creek at the Schiller Avenue Ramp seems to be declining somewhat over time (Table 12-2). Specifically, during the 2001 and 2002 sampling seasons, 61% of sample dates characterized water quality as ‘Good’ (mean DBI = 52). During subsequent sampling seasons (2003, 2005), mean overall water quality seemed to decline as only 32% of samples scored in the ‘Good’ range (mean DBI = 47).

The taxa richness (TR) yearly mean score decreased from year 2002 (47) to 2005 (32) (Table 12-2). These data suggest that a significant number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score decreased slightly from year 2001 (69) to 2005 (64) (Table 12-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution tolerant. In general, a decrease in the PTI suggests a decline in water quality.

The siltation index (%NNS) yearly mean score increased from year 2001 (70) to 2003 (78), but decreased during 2005 (67) (Table 12-2). These data suggest that overall species composition shifted throughout the study. In general, a decrease in overall %NNS suggests a decline in water quality.

The Shannon diversity index (SDI) yearly mean score decreased significantly from year 2002 (96) to 2005 (68) (Table 12-2). These yearly SDI fluctuations, track well with the changes seen in TR and provides some hint as to the correlation between these parameters (Table 12-2). Additionally, these data suggest that one or more species may have numerically dominated the community and adversely affected overall distribution, thereby further reducing the SDI. In general, decreases as those seen here in the yearly mean SDI suggest a decline in overall water quality.

The fragilaria group richness (FGR) yearly mean score decreased substantially from year 2001 (32) to 2005 (3) (Table 12-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

The cymbella group richness (CGR) yearly mean score decreased from year 2002 (20) to 2005 (2) (Table 12-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

ESFSF006: The overall water quality of the South Fork of Beargrass Creek at Brownsboro Road (ESFSF006) based on 29 diatom samples collected over three years (2002 – 03, 2005) may be characterized as 'Good' (Table 12-2). The overall mean score of 50 reflects the mid range of 'Good' scores. In general, these data suggest water quality of the South Fork of Beargrass Creek at Brownsboro Road seems to be declining somewhat over time (Table 12-2). Specifically, during the 2002 and 2003 sampling seasons, 53% of sample dates characterized water quality as 'Good' (mean DBI = 53). During the 2005 sampling season, mean overall water quality seemed to decline as only 30% of samples scored in the 'Good' range and overall water quality was characterized as 'Fair' (mean DBI = 44).

The taxa richness (TR) yearly mean score decreased significantly from year 2002 (53) to 2005 (41) (Table 12-2). These data suggest that a significant number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality. This site had the second highest overall mean TR score (47) in the current study (Table 12-2).

The pollution tolerance index (PTI) yearly mean score increased slightly from year 2002 (53) to 2005 (59) (Table 12-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution sensitive. In general, an increase in the PTI suggests an improvement in water quality. This site's mean overall PTI score (58) was the lowest observed in the current study (Table 12-2).

The siltation index (%NNS) yearly mean score revealed no real discernable pattern throughout the study period (Table 12-2). Small, yearly %NNS fluctuations, as seen here, are well within the limits of expected yearly natural variability

The Shannon diversity index (SDI) yearly mean score varied little from year 2002 (97) to 2005 (96) (Table 12-2). Small, overall yearly SDI fluctuations, as seen here, are well within the limits of expected yearly natural variability. In general, the majority of SDI values were high and indicative of good water quality. This site's mean overall SDI score (96) was the highest observed in the current study (Table 12-2).

The fragilaria group richness (FGR) yearly mean score decreased from year 2002 (36) to 2005 (10) (Table 12-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study. This site's mean overall FGR score (27) was among the highest observed in the current study (Table 12-2).

The cymbella group richness (CGR) yearly mean score decreased from year 2003 (22) to 2005 (6) (Table 12-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study.

12.2.2 Macroinvertebrates

The macroinvertebrate communities in the South fork of Beargrass Creek were rated as 'poor' to 'very poor' by the MBI at all three sampling sites during all three sampling years except for the 2004 at ESFSF001 which was assessed as 'fair' (Table 12-3). Additionally, MBI scores decreased from 2000 to 2005 at all sites. These three sites score below 50 for all component metrics, but values are particularly low for EPT Richness, m%EPT, and %Clinger. For example, only one EPT taxa was recorded from ESFSF001 in 2005, and the m%EPT and %Clinger values were 3.54% and 1.57% respectively. Additionally, the one EPT taxa recorded at ESFSF001 was *Caenis sp.*, a highly pollution-tolerant mayfly.

The 'fair' rating for ESFSF001 in 2004 is most likely due to error in sample processing. The sample was only composed of 34% Chir. and Oli., which was considerably less than all other samples taken from that sampling site (78% in 2000 and 92% in 2005). Because of this, it is believed that the chironomids and oligochaetes were underrepresented in 2004 at ESFSF001, which affected not only the calculation of %Chir and Oli, but also inflated the %Clinger score as well. The 'true' MBI score at ESFSF001 in 2004 would probably be closer to the values reported for 2000 and 2005 ('very poor').

12.2.3 Fish

The quality of fish communities were degrading along the longitudinal pathway in the South Fork of Beargrass Creek based on the survey conducted in 2005, as they were rated as 'good' in the upstream (ESFSF001), 'poor' in ESFSF002, and 'very poor' in the downstream (ESFSF006) (Table 12-4). Most component metric scores, e.g. native species richness (NAT), intolerant species richness (INT), % insectivores (%INSCT), showed the similar longitudinal trends during the 2005 survey (Table 12-4).

The fish community improved from 'poor' to 'good' in the upstream ESFSF001 location during 2002-2005 period. The native species richness (NAT) did not change during the period, but the %INSCT improved from 26 to 100. Fish IBI scores in ESFSF002 location did not change considerably during the same period, and only one survey was conducted in ESFSF006 location.

12.3 Hydrolab Sonde Data

12.3.1 Stream metabolism

The sonde data in the South Fork of Beargrass Creek had many gaps and unreliable data to calculate the stream metabolism. The gross primary production and community respiration estimates were highest in the mid-reach location (ESFSF002) and lowest the upstream location (ESFSF001) (Table 12-5). In ESFSF001 location, averaged GPP estimates were similar in summer (0.71-2.32 g O_2/m^2/day) and fall (0.32-3.79 g O_2/m^2/day), which were higher than spring estimates (0.72-1.35 g O_2/m^2/day). CR estimates were also similar during summer (3.15-6.58 g O_2/m^2/day) and fall (1.36-10.31 g O_2/m^2/day), and they were higher than spring estimates (0.77-6.32 g O_2/m^2/day) in ESFSF001.

At ESFSF002, GPP estimates were similar during spring (2.9-5.52 g O_2/m^2/day) and summer (2.65-6.73 g O_2/m^2/day), and they were higher than fall estimates (2.18-5.39 g O_2/m^2/day). CR estimates were higher in summer than spring and fall estimates.

There were only a couple of seasonal data sets available to estimate GPP and CR in ESFSF006 location (Table 12-5). Overall both GPP was highest during summer and lowest in the fall, while CR estimates were highest in summer and lowest during spring.

12.3.2 Dissolved oxygen, pH, and conductivity

At ESFSF001, the mean daily dissolved oxygen stayed above 5 mg/L except on a few occasions during summer and fall (Table 12-6). It was highest during winter (overall mean 14.17 mg/L) followed by spring (8.62 mg/L), fall (6.44 mg/L), and lowest during summer (5.35 mg/L). Daily minimum DO lower than 4.0 mg/L was recorded in several summer and fall at this location (summer 2001, 2004, and 2007; fall 2001, 2005 and 2007). Daily mean pH was above 7 except spring 2000 and 2006 and summer 2004, and it was very stable annually. Mean conductivity values were in the order of winter (565-1242 µS/cm), spring (440-656 µS/cm), summer (363-724 µS/cm) and fall (435-678 µS/cm) in ESFSF001. Overall, averaged winter conductivity was lower during later years (2005-2007; average 639 µS/cm) than earlier years (2001-2003; average 1161 µS/cm).

At ESFSF002, the mean daily DO was lower than 5 mg/L on several summer and fall seasons (Table 12-6). On average, it was highest during winter (6.55-13.63 mg/L), followed by spring (5.3-7.74 mg/L) and fall (3.8-7.8 mg/L), and lowest during summer (3.05-11.03 mg/L). Daily minimum DO lower than 4.0 mg/L was recorded on several occasions during summer and fall. Mean daily pH was above 7 except summer and fall of 2005. Mean conductivity values were highest in winter, followed by spring and fall, and lowest in summer in ESFSF002. Averaged winter conductivity was lower during later years (2005-2007; average 663 µS/cm) than earlier years (2001-2003; average 1095 µS/cm) in ESFSF001.

Most of dissolved oxygen data from the ESFSF006 location were either unusable or unreliable for analysis (Table 12-6). Mean daily DO was highest during winter, followed by spring and fall, and lowest in summer (Table 12-6). Mean pH was below 7 on several occasions, in spring 2005 and 2006, summer 2003 and 2004, and winter 2005. Averaged conductivity values were similar during spring (690 µS/cm) and winter (692 µS/cm), which were higher than summer (541 µS/cm) and fall (538 µS/cm).

Overall, the averaged DO was highest at the upstream location (ESFSF001) and lowest at middle location (ESFSF002). The pH was slightly lower in the downstream location (ESFSF006) than two upstream locations, while conductivity was lowest in the upstream location (ESFSF001) than other sites.

12.4 Laboratory Data

Water chemistry data were collected extensively during the years of 2002, 2004, and 2007 in the South Fork of Beargrass Creek, while fecal coliform counts were collected constantly during 2000-2007 (Table 12-7, Figure 12-1). The concentrations of nitrogen compounds (ammonia- and nitrate-nitrogen) collected during ‘dry’ period were lower during 2007 than 2001 at all three LTMN locations. For example, nitrate-nitrogen concentrations during 2001 (‘dry’ period) were 1.08, 1.47, and 1.49 mg/L at three LTMN locations, but they were 0.84, 0.76, and 0.54 mg/L during 2007. Nitrogen concentrations were decreasing along the longitudinal gradient in the South Fork of Beargrass Creek during 2007.

Chloride concentrations were also lower during 2007 when compared to previous years (2001 and 2004), especially at two downstream locations (Table 12-7). Longitudinally, chloride concentrations were higher at downstream ESFSF006 location than two upstream locations during 2007. Phosphorus compounds did not show either chronological or longitudinal trends in the South Fork of Beargrass Creek. Fecal coliform counts were higher from ‘wet’ samples than ‘dry’ samples at all three sites (Table 12-7).

12.5 Watershed assessment based on the biological data

Based on three biotic indices from 2005, three LTMN locations in the South Fork of Beargrass Creek could be considered as ‘poor’, although the quality at upstream location (ESFSF001) was slightly better than other locations. Diatom index had consistently scored ‘good’ or ‘excellent’ at all three sites through 2001-2003, but it scored ‘fair’ in 2005 at all sites. Diatom, overall, resulted in higher ratings than other biological parameters in the South Fork of Beargrass Creek (except 2005 at ESFSF001).

ESFSF001	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
DBI	—	Good	good	good	—	**fair**
MBI	vey poor	—	—	—	fair	**very poor**
Fish KBI	very poor	—	poor	fair	—	**good**
ESFSF002						
DBI	—	Good	good	excellent	—	**fair**
MBI	poor	—	—	—	very poor	**very poor**
Fish KBI	poor	—	poor	very poor	—	**poor**
ESFSF006						
DBI	—	Good	excellent	fair	—	**fair**
MBI	—	—	—	—	poor	**poor**
Fish KBI	—	—	—	—	—	**very poor**

Table 12-1 Land use/cover characteristics of the South Fork of Beargrass Creek.

ESFSF001	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	32.02	25.23	2.72
Open Water	0.09	0.37	0.00
Dev. Open Space	24.14	21.76	19.00
Dev. Low Intensity	35.86	29.72	28.05
Dev. Medium Intensity	16.83	14.37	35.75
Dev. High Intensity	8.30	5.45	16.74
Barren Land	0.33	0.56	0.00
Deciduous Forest	11.66	24.41	0.45
Evergreen Forest	0.88	0.86	0.00
Mixed Forest	0.02	0.00	0.00
Shrub/Scrub	0.03	0.08	0.00
Grassland/herbaceous	0.23	1.06	0.00
Pasture/Hay	0.96	0.70	0.00
Cropland	0.60	0.33	0.00
Woody Wetlands	0.05	0.31	0.00
Emergent Herbaceous Wetlands	0.02	0.00	0.00
ESFSF002	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	30.30	21.60	18.11
Open Water	0.07	0.28	0.00
Dev. Open Space	23.93	23.43	37.27
Dev. Low Intensity	33.92	26.33	11.82
Dev. Medium Intensity	16.80	12.09	26.36
Dev. High Intensity	7.21	4.22	8.18
Barren Land	0.28	0.60	0.00
Deciduous Forest	14.56	28.41	16.36
Evergreen Forest	1.27	1.05	0.00
Mixed Forest	0.02	0.00	0.00
Shrub/Scrub	0.02	0.07	0.00
Grassland/herbaceous	0.27	1.11	0.00
Pasture/Hay	0.74	0.53	0.00
Cropland	0.46	0.25	0.00
Woody Wetlands	0.41	1.64	0.00
Emergent Herbaceous Wetlands	0.04	0.00	0.00
ESFSF006	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	28.44	20.20	37.60
Open Water	0.19	0.32	0.00
Dev. Open Space	25.53	21.95	36.77
Dev. Low Intensity	29.21	22.86	8.07
Dev. Medium Intensity	15.90	11.19	28.25
Dev. High Intensity	7.39	5.03	2.24
Barren Land	0.15	0.31	0.00
Deciduous Forest	16.89	32.63	24.66
Evergreen Forest	1.91	1.30	0.00
Mixed Forest	0.04	0.00	0.00
Shrub/Scrub	0.01	0.03	0.00
Grassland/herbaceous	0.64	0.79	0.00
Pasture/Hay	0.91	1.15	0.00
Cropland	0.99	1.65	0.00
Woody Wetlands	0.18	0.73	0.00
Emergent Herbaceous Wetlands	0.06	0.06	0.00

Table 12-2 DBI scores estimated in the South Fork of Beargrass Creek.

ESFSF001	**TR**	**PTI**	**%NNS**	**SDI**	**FGR**	**CGR**	**Mean**	**Water Quality**
2001	41	68	74	84	28	14	**52**	**GOOD**
2002	38	71	74	77	23	24	**51**	**GOOD**
2003	37	71	81	72	20	21	**51**	**GOOD**
Summer 05	35	69	64	85	10	12	**46**	**GOOD**
Fall 05	37	64	42	92	13	11	**43**	**FAIR**
2005 All	36	67	53	89	12	12	**45**	**FAIR**
Overall	**38**	**69**	**70**	**80**	**20**	**18**	**49**	**GOOD**
ESFSF002								
2001	40	69	70	85	32	14	**52**	**GOOD**
2002	47	62	58	96	25	20	**51**	**GOOD**
2003	43	64	78	86	26	18	**53**	**EXCELLENT**
Summer 05	33	55	56	77	3	0	**38**	**POOR**
Fall 05	31	75	81	56	3	4	**42**	**FAIR**
2005 All	32	64	67	68	3	2	**40**	**FAIR**
Overall	**41**	**65**	**68**	**84**	**22**	**13**	**49**	**GOOD**
ESFSF006								
2002	53	53	53	97	36	15	**51**	**GOOD**
2003	49	63	58	96	37	22	**54**	**EXCELLENT**
Summer 05	43	55	55	97	10	3	**44**	**FAIR**
Fall 05	38	63	52	94	10	9	**45**	**FAIR**
2005 All	41	59	53	96	10	6	**44**	**FAIR**
Overall	**47**	**58**	**55**	**96**	**27**	**14**	**50**	**GOOD**

Table 12-3 Macroinvertebrate biotic integrity scores in the South Fork of Beargrass Creek Watershed.

Year	Metric	**ESFSF001**		**ESFSF002**		**ESFSF006**	
		Raw Score	Metric Score	Raw Score	Metric Score	Raw Score	Metric Score
2000	Taxa Richness	31	41.89	22	29.73	--------	--------
	EPT Richness	5	16.67	7	23.33	--------	--------
	m%EPT	4	5.48	17	23.29	--------	--------
	mHBI	7.52	35.99	7.9	30.48	--------	--------
	%Chir. and Oli.	78	22.22	75	25.25	--------	--------
	%Clinger	1	1.35	11	14.86	--------	--------
	MBI	--------	20.60	--------	24.49	--------	--------
	Assessment	--------	**Very Poor**	--------	**Poor**	--------	--------
2004	Taxa Richness	23	31.1	19	25.7	27	36.5
	EPT Richness	2	6.7	4	13.3	5	16.7
	m%EPT	0.3	0.4	6	8.22	0.2	0.3
	mHBI	6.11	56.5	7.08	42.4	8.47	21.9
	%Chir. and Oli.	34	66.7	79	21.2	36.5	64.6
	%Clinger	62.2	84.1	5.2	7	1.2	1.6
	MBI	--------	40.90	--------	19.60	--------	23.60
	Assessment	--------	**Fair**	--------	**Very Poor**	--------	**Poor**
2005	Taxa Richness	27	36.49	37	50.00	36	48.65
	EPT Richness	1	3.33	4	13.33	2	6.67
	m%EPT	3.54	4.85	1.77	2.43	0	0.00
	mHBI	8.45	22.54	8.47	22.23	8.34	24.07
	%Chir. and Oli.	92.13	7.95	85.46	14.69	53.85	46.62
	%Clinger	1.57	2.13	9.22	12.46	3.17	4.28
	MBI	--------	12.88	--------	19.19	--------	21.71
	Assessment	--------	**Very Poor**	--------	**Very Poor**	--------	**Poor**

Table 12-4 Fish IBI scores estimated in the South Fork of Beargrass Creek.

Site	ESFSF001	ESFSF002	ESFSF006
1999-up	**very poor**	**NS**	**NS**
1999-dn	**very poor**	**NS**	**NS**
2000-up	**poor**	**very poor**	**NS**
2000-dn	**very poor**	**poor**	**NS**
2002	**Poor**	**Poor**	**NS**
Native	42	30	
DMS	12	5	
INT	13	5	
WC	28	17	
SL	13	13	
%Insect_Ex_Tol	26	5	
%OMNI	56	33	
%TOL	54	37	
IBI	30	18	
2003	**Fair**	**Very Poor**	**NS**
Native	45	34	
DMS	34	8	
INT	13	8	
WC	38	32	
SL	21	17	
%Insect_Ex_Tol	30	0	
%OMNI	50	0	
%TOL	50	0	
IBI	35	12	
2005	**Good**	**Poor**	**Very Poor**
NAT	41	30	28
DMS	11	8	6
INT	25	21	7
SL	29	24	15
%INSCT	100	3	0
%TOL	79	50	0
%FHW	5	50	0
KIBI	48	23	9

Table 12-5 Gross primary production (g/m^2/day) and community respiration (g/m^2/day) estimated in the South Fork of Beargrass Creek.

	Spring		Summer		Fall	
ESFSF001	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	0.73	3.30	0.71	4.43	—	—
2001	—	—	2.08	6.58	0.32	10.31
2002	0.72	1.72	2.32	6.01	0.34	3.43
2003	1.00	1.82	—	—	1.32	1.36
2004	0.93	0.19	0.97	5.95	1.87	2.12
2005	0.76	6.32	—	—	1.88	7.86
2006	—	—	—	—	—	—
2007	1.35	0.77	1.52	3.15	3.79	6.36
	Spring		**Summer**		**Fall**	
ESFSF002	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	5.52	13.14	—	—	—	—
2001	—	—	2.65	16.18	2.78	10.13
2002	3.21	15.48	6.73	15.45	—	—
2003	4.81	19.33	3.31	13.19	2.18	21.35
2004	2.90	10.58	—	—	4.18	12.80
2005	3.27	11.73	3.50	19.88	5.39	12.31
2006	—	—	—	—	2.94	14.92
2007	—	—	—	—	2.28	9.63
	Spring		**Summer**		**Fall**	
ESFSF006	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)	GPP (g/m^2/d)	CR (g/m^2/d)
2000	—	—	—	—	—	—
2001	—	—	—	—	—	—
2002	—	—	—	—	1.69	1.66
2003	—	—	2.20	21.97	0.92	12.04
2004	1.39	1.24	—	—	—	—
2005	—	—	—	—	0.81	20.24
2006	—	—	1.95	12.04	—	—
2007	2.54	4.18	2.42	10.87	—	—

Table 12-6 Water temperature, DO, pH, and conductivity in the South Fork of Beargrass Creek, at ESFSF001

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	14.9	12.8	17.2	8.12	7.18	9.10	6.87	4.97	7.20	509.7	502.9	521.9
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.9	11.7	14.3	6.61	4.92	9.08	7.81	7.72	7.93	535.4	503.5	585.1
2003	16.7	14.6	19.3	8.85	7.80	10.01	7.90	7.81	7.98	706.7	679.8	742.7
2004	14.5	12.4	16.8	10.49	9.56	11.56	7.20	7.04	7.34	656.5	612.5	710.7
2005	16.8	14.4	19.3	5.76	5.08	6.70	7.76	7.66	7.85	440.7	402.1	469.6
2006	14.7	14.1	15.4	—	—	—	6.80	6.78	6.82	478.5	452.3	502.0
2007	8.3	5.6	10.0	11.92	10.51	13.11	7.88	7.77	8.43	639.5	607.6	661.7

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	26.3	24.7	28.3	5.29	4.59	6.31	7.84	7.52	8.11	448.4	359.1	521.0
2001	26.0	24.4	28.1	4.74	3.66	6.78	7.45	7.25	8.01	430.2	331.9	456.6
2002	26.3	25.1	27.8	5.78	4.27	8.13	7.63	7.45	7.95	509.0	485.2	534.0
2003	—	—	—	—	—	—	—	—	—	—	—	—
2004	23.2	21.6	24.5	4.99	3.74	9.19	6.82	6.80	6.86	363.6	297.6	422.5
2005	26.6	25.6	27.8	—	—	—	7.51	7.43	7.59	724.6	672.4	794.2
2006	24.0	22.5	25.7	—	—	—	7.15	7.09	7.18	516.9	486.9	552.0
2007	26.2	24.3	28.4	5.96	3.77	8.98	7.63	7.47	8.37	602.2	565.1	622.8

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	16.4	15.3	18.0	2.64	2.35	3.00	7.42	7.32	7.55	435.0	347.9	487.8
2002	14.4	13.6	15.2	7.98	7.55	8.46	7.88	7.85	7.93	548.3	542.4	555.5
2003	17.2	16.1	18.4	9.39	8.50	10.80	7.57	7.52	7.65	482.3	458.0	512.1
2004	17.7	16.7	18.9	9.21	7.74	11.07	8.16	7.93	8.43	368.4	347.2	391.5
2005	18.8	17.9	19.8	3.68	1.12	5.69	6.87	6.70	6.97	575.3	548.5	620.4
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	23.5	22.2	24.8	5.74	1.98	9.00	7.50	7.35	8.02	678.5	647.7	718.3

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	4.0	3.3	5.0	12.80	12.02	13.98	8.08	7.98	8.19	1242.7	1093.3	1367.5
2002	5.4	4.4	6.2	—	—	—	7.88	7.82	8.00	963.2	795.7	1366.3
2003	1.5	0.9	2.6	13.82	13.04	14.71	7.94	7.85	8.01	661.9	599.3	750.6
2004	4.2	3.4	5.2	15.89	14.82	16.85	7.81	7.74	7.89	826.8	790.2	921.0
2005	3.6	2.5	4.6	—	—	—	7.73	7.70	7.79	565.9	561.3	571.0
2006	9.4	8.7	10.0	—	—	—	7.21	7.13	7.28	595.2	496.9	666.0
2007	7.7	6.9	9.4	—	—	—	7.44	7.28	7.64	671.7	631.1	682.2

Table 12-6 Continued, at ESFSF002.

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	14.3	12.0	17.0	7.74	5.68	11.00	7.88	7.72	8.10	635.5	621.7	648.5
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.4	10.8	14.6	6.77	5.71	8.11	—	—	—	574.4	513.0	598.9
2003	15.9	13.9	18.8	5.30	2.95	8.24	8.58	8.39	8.88	750.7	734.7	768.9
2004	13.2	11.6	15.3	8.04	7.09	9.91	7.53	7.38	7.80	608.2	570.2	639.8
2005	16.0	14.3	18.2	7.46	5.87	10.16	7.36	7.28	7.51	576.9	555.8	598.7
2006	15.6	13.6	18.2	—	—	—	7.06	6.99	7.11	809.1	761.1	850.5
2007	8.5	7.2	10.1	—	—	—	7.69	7.56	7.87	568.6	549.2	586.5

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	25.3	23.8	27.5	3.79	2.61	5.88	7.19	7.09	7.39	426.5	386.4	487.9
2002	24.2	23.0	26.2	5.74	3.58	10.65	7.12	6.97	7.53	524.7	507.1	537.7
2003	24.6	23.5	26.0	5.16	3.67	7.76	7.09	6.96	7.34	387.8	355.6	417.8
2004	22.7	21.5	24.7	—	—	—	7.15	7.02	7.27	445.3	382.2	527.4
2005	24.6	23.2	27.2	3.05	1.82	5.78	6.93	6.75	7.45	844.9	834.6	864.0
2006	22.8	21.5	24.6	—	—	—	7.36	7.16	7.53	614.3	392.7	698.8
2007	24.8	23.5	26.6	11.03	9.44	13.11	7.38	7.32	7.53	439.1	379.4	500.0

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	15.3	14.0	17.6	7.54	6.51	10.03	7.28	7.07	7.50	366.7	306.8	462.0
2002	13.8	13.1	14.5	—	—	—	7.61	7.54	7.71	682.6	544.2	721.4
2003	15.7	14.5	17.2	3.80	2.73	5.54	7.27	7.14	7.40	529.4	441.0	589.4
2004	15.0	13.5	17.3	7.34	5.93	10.68	7.33	7.17	7.76	480.5	473.8	488.4
2005	16.1	14.9	18.1	7.80	6.05	12.17	6.90	6.69	7.49	678.8	668.8	693.6
2006	17.3	16.5	18.2	5.49	3.82	7.44	7.25	6.95	7.44	721.5	702.0	751.1
2007	21.9	20.5	24.1	6.34	5.30	8.05	7.45	7.20	8.24	702.8	681.5	714.3

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	3.1	2.4	4.3	13.63	11.81	16.10	7.70	7.57	7.84	1230.0	1021.3	1685.2
2002	5.3	4.6	7.1	11.21	9.90	13.38	9.28	8.89	9.82	711.4	496.4	843.3
2003	1.3	0.8	2.1	6.55	6.13	7.37	7.93	7.88	8.01	711.1	674.9	758.0
2004	4.0	3.1	4.9	11.91	10.65	14.10	7.70	7.60	7.84	517.1	479.2	565.4
2005	3.4	2.4	4.2	6.86	6.01	7.72	7.72	7.67	7.76	432.9	410.1	452.9
2006	8.7	7.5	9.7	8.78	7.76	10.21	7.90	7.79	8.04	669.6	547.7	785.1
2007	7.6	6.9	8.5	9.21	8.30	10.97	7.34	7.24	7.46	691.3	636.8	752.2

Table 12-6 Continued, at ESFSF006

Spring	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	18.8	17.2	21.2	—	—	—	7.30	7.05	7.78	642.1	622.6	669.7
2002	12.2	10.4	14.5	—	—	—	7.44	7.18	7.75	614.1	425.3	666.6
2003	14.9	13.9	15.7	—	—	—	7.36	7.27	7.41	735.8	706.6	750.6
2004	13.8	12.7	15.1	9.07	5.64	12.52	7.45	7.26	7.65	728.5	708.1	745.3
2005	16.3	14.9	18.3	—	—	—	6.41	6.37	6.44	602.1	564.3	637.3
2006	15.5	13.6	18.6	—	—	—	6.48	6.43	6.51	837.3	756.3	898.1
2007	8.2	7.0	9.9	11.00	9.48	13.21	7.78	7.63	8.00	674.1	636.3	699.3

Summer	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	24.8	23.8	26.3	—	—	—	7.00	6.94	7.05	470.1	429.4	505.5
2002	24.7	24.1	25.5	—	—	—	7.05	6.95	7.18	557.0	528.4	588.3
2003	24.8	23.7	26.4	—	—	—	6.88	6.78	7.02	534.2	480.0	591.3
2004	22.7	22.5	23.0	—	—	—	6.15	6.14	6.16	687.8	674.1	703.2
2005	25.3	24.8	26.0	—	—	—	7.33	7.29	7.42	358.0	352.1	365.7
2006	22.7	21.5	24.2	4.88	3.02	6.40	7.32	7.24	7.42	657.9	513.3	750.8
2007	24.8	23.6	26.7	4.45	2.50	6.84	7.36	7.23	7.61	522.4	459.3	567.1

Fall	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	11.9	9.7	13.8	9.05	7.01	11.32	7.64	7.33	7.90	186.7	0.0	419.9
2003	15.7	14.9	17.0	5.94	5.04	7.16	7.53	7.47	7.61	634.7	625.0	641.5
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	16.5	16.1	17.2	—	—	—	7.20	7.16	7.23	470.8	462.8	474.9
2006	17.0	16.0	18.6	8.56	7.08	11.02	7.56	7.48	7.73	716.8	678.6	760.8
2007	22.5	22.1	23.1	—	—	—	7.21	7.18	7.24	682.0	669.5	692.0

Winter	Temperature			DO			pH			Conductivity		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	4.8	3.7	6.1	8.82	7.32	11.45	7.49	6.87	7.93	968.5	853.2	1113.1
2003	1.0	0.5	1.4	14.54	12.52	18.24	7.69	7.23	8.00	638.7	628.9	655.5
2004	3.8	3.1	4.7	—	—	—	7.68	7.53	7.83	375.9	355.8	393.8
2005	4.1	3.5	4.9	—	—	—	6.98	6.87	7.12	978.5	944.4	996.7
2006	8.7	7.8	9.9	—	—	—	7.54	7.28	7.73	533.0	487.9	581.7
2007	7.6	7.1	8.3	10.15	8.74	11.96	7.68	7.57	7.79	661.1	581.9	717.8

Table 12-7 Summary of selected water chemistry parameters at LTMN locations in the South Fork of Beargrass Creek, at ESFSF001

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	-	0.24	0.57	-	0.03	-	0.03	0.30
	SD (Dry)	-	0.20	-	-	0.00	-	-	0.35
	Count (Dry)	0	27	1	0	2	0	1	2
	Mean (wet)	-	-	-	-	0.03	-	0.03	0.05
	SD (wet)	-	-	-	-	0.01	-	0.00	0.00
	Count (wet)	0	0	0	0	17	0	2	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	-	1.08	1.73	-	1.08	-	1.26	0.84
	SD (Dry)	-	0.53	-	-	-	-	-	0.09
	Count (Dry)	0	29	1	0	1	0	1	2
	Mean (wet)	-	-	-	-	1.03	-	1.81	0.93
	SD (wet)	-	-	-	-	0.25	-	0.81	0.74
	Count (wet)	0	0	0	0	18	0	2	8
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	-	1.90	-	-	0.31	-	0.87	1.10
	SD (Dry)	-	1.06	-	-	0.08	-	-	0.14
	Count (Dry)	0	13	0	0	2	0	1	2
	Mean (wet)	-	-	-	-	0.80	-	0.79	1.06
	SD (wet)	-	-	-	-	0.37	-	0.04	0.12
	Count (wet)	0	0	0	0	19	0	2	11
Ortho Phosphorus (mg/L)	Mean (Dry)	-	0.04	0.03	-	0.03	-	0.03	0.03
	SD (Dry)	-	0.06	-	-	0.00	-	-	0.00
	Count (Dry)	0	30	1	0	2	0	1	2
	Mean (wet)	-	-	-	-	0.03	-	0.07	0.05
	SD (wet)	-	-	-	-	0.01	-	0.07	0.03
	Count (wet)	0	0	0	0	18	0	2	2
Phosphorus (mg/L)	Mean (Dry)	-	0.28	-	-	0.03	-	0.04	0.11
	SD (Dry)	-	0.24	-	-	-	-	-	0.04
	Count (Dry)	0	37	0	0	1	0	1	2
	Mean (wet)	-	-	-	-	0.11	-	0.07	0.23
	SD (wet)	-	-	-	-	0.06	-	0.04	0.12
	Count (wet)	0	0	0	0	18	0	2	11
Chloride (mg/L)	Mean (Dry)	-	48.40	65.67	-	64.57	-	46.83	47.77
	SD (Dry)	-	33.26	-	-	-	-	-	43.18
	Count (Dry)	0	30	1	0	1	0	1	2
	Mean (wet)	-	-	-	-	61.06	-	41.39	35.04
	SD (wet)	-	-	-	-	27.93	-	10.53	19.68
	Count (wet)	0	0	0	0	19	0	2	2
BOD (mg/L)	Mean (Dry)	-	8.29	-	-	0.75	-	0.50	3.00
	SD (Dry)	-	7.02	-	-	0.35	-	-	0.00
	Count (Dry)	0	33	0	0	2	0	1	2
	Mean (wet)	-	-	-	-	2.50	-	1.00	3.00
	SD (wet)	-	-	-	-	1.53	-	0.71	1.41
	Count (wet)	0	0	0	0	18	0	2	2
TDS (mg/L)	Mean (Dry)	-	458.00	-	-	422.00	-	380.00	370.00
	SD (Dry)	-	45.25	-	-	-	-	-	251.73
	Count (Dry)	0	2	0	0	1	0	1	2
	Mean (wet)	-	-	-	-	409.76	-	405.00	369.00
	SD (wet)	-	-	-	-	153.27	-	21.21	9.90
	Count (wet)	0	0	0	0	17	0	2	2
TSS (mg/L)	Mean (Dry)	-	295.47	61.93	94.67	7.00	-	11.00	33.50
	SD (Dry)	-	367.24	92.70	92.66	-	-	-	12.02
	Count (Dry)	0	34	120	63	1	0	1	2
	Mean (wet)	-	-	-	57.14	53.21	-	16.05	79.23
	SD (wet)	-	-	-	70.46	28.92	-	4.17	106.20
	Count (wet)	0	0	0	43	121	0	2	11
Fecal Coliform (col/100 ml)	Mean (Dry)	293	31058	2380	775	507	258	464	580
	SD (Dry)	829	73216	5189	1713	1521	394	622	652
	Count (Dry)	22	62	29	23	25	24	13	22
	Mean (wet)	3851	-	-	523	285	1643	2177	55185
	SD (wet)	4707	-	-	1102	411	1745	3579	142878
	Count (wet)	6	0	0	7	27	8	20	20

Table 12-7 Continued, at ESFSF002.

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	-	0.36	-	-	0.03	-	0.03	0.05
	SD (Dry)	-	0.32	-	-	0.00	-	-	0.00
	Count (Dry)	0	10	0	0	3	0	1	2
	Mean (wet)	-	0.52	-	-	0.36	-	0.03	0.05
	SD (wet)	-	0.39	-	-	0.62	-	0.00	0.00
	Count (wet)	0	15	0	0	17	0	2	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	-	1.47	-	-	1.18	-	1.48	0.76
	SD (Dry)	-	0.62	-	-	-	-	-	0.20
	Count (Dry)	0	9	0	0	1	0	1	2
	Mean (wet)	-	0.95	-	-	0.90	-	1.94	0.94
	SD (wet)	-	0.31	-	-	0.24	-	0.85	0.17
	Count (wet)	0	14	0	0	18	0	2	3
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	-	1.50	-	-	0.45	-	1.00	0.99
	SD (Dry)	-	1.00	-	-	0.17	-	-	0.16
	Count (Dry)	0	4	0	0	3	0	1	2
	Mean (wet)	-	4.26	-	-	2.45	-	1.35	1.63
	SD (wet)	-	2.44	-	-	2.90	-	0.35	0.59
	Count (wet)	0	9	0	0	18	0	2	3
Ortho Phosphorus (mg/L)	Mean (Dry)	-	0.03	-	-	0.03	-	0.03	0.03
	SD (Dry)	-	0.00	-	-	0.00	-	-	0.00
	Count (Dry)	0	9	0	0	3	0	1	2
	Mean (wet)	-	0.04	-	-	0.06	-	0.14	0.05
	SD (wet)	-	0.07	-	-	0.07	-	0.06	0.04
	Count (wet)	0	14	0	0	19	0	2	2
Phosphorus (mg/L)	Mean (Dry)	-	0.09	-	-	0.05	-	0.08	0.12
	SD (Dry)	-	0.04	-	-	0.05	-	-	0.04
	Count (Dry)	0	9	0	0	3	0	1	2
	Mean (wet)	-	0.37	-	-	0.62	-	0.13	0.25
	SD (wet)	-	0.24	-	-	0.66	-	0.06	0.15
	Count (wet)	0	20	0	0	19	0	2	3
Chloride (mg/L)	Mean (Dry)	-	88.54	-	-	69.46	-	51.25	47.90
	SD (Dry)	-	31.14	-	-	-	-	-	43.03
	Count (Dry)	0	9	0	0	1	0	1	2
	Mean (wet)	-	40.70	-	-	53.82	-	45.07	34.61
	SD (wet)	-	22.58	-	-	35.18	-	11.42	21.35
	Count (wet)	0	14	0	0	18	0	2	2
BOD (mg/L)	Mean (Dry)	-	3.50	-	-	1.00	-	1.00	2.50
	SD (Dry)	-	2.27	-	-	0.87	-	-	0.71
	Count (Dry)	0	8	0	0	3	0	1	2
	Mean (wet)	-	13.38	-	-	18.29	-	5.75	3.50
	SD (wet)	-	6.81	-	-	25.21	-	7.42	2.12
	Count (wet)	0	18	0	0	17	0	2	2
TDS (mg/L)	Mean (Dry)	-	452.00	-	-	436.00	-	398.00	367.00
	SD (Dry)	-	-	-	-	-	-	-	250.32
	Count (Dry)	0	1	0	0	1	0	1	2
	Mean (wet)	-	490.00	-	-	335.06	-	419.00	295.00
	SD (wet)	-	-	-	-	151.39	-	35.36	100.41
	Count (wet)	0	1	0	0	17	0	2	2
TSS (mg/L)	Mean (Dry)	-	12.78	-	-	10.00	-	24.00	40.50
	SD (Dry)	-	8.51	-	-	-	-	-	23.33
	Count (Dry)	0	9	0	0	1	0	1	2
	Mean (wet)	-	462.63	-	-	118.05	-	14.55	156.67
	SD (wet)	-	402.83	-	-	124.27	-	2.05	124.71
	Count (wet)	0	19	0	0	19	0	2	3
Fecal Coliform (col/100 ml)	Mean (Dry)	4051	30147	699	743	367	1083	833	3461
	SD (Dry)	14573	145026	1121	1772	415	3136	790	6090
	Count (Dry)	26	24	16	20	26	24	13	22
	Mean (wet)	1620	68295	3989	2093	3037	7726	6237	5679
	SD (wet)	1527	141151	4518	2936	5581	15225	8677	3092
	Count (wet)	2	32	13	10	29	8	20	13

Table 12-7 Continued, at ESFSF006

	Year	2000	2001	2002	2003	2004	2005	2006	2007
Ammonia-Nitrogen (mg/L)	Mean (Dry)	-	5.83	0.69	-	0.14	-	0.03	0.05
	SD (Dry)	-	18.38	-	-	0.27	-	-	0.00
	Count (Dry)	0	13	1	0	5	0	1	2
	Mean (wet)	-	0.64	-	-	0.13	-	0.03	0.05
	SD (wet)	-	0.37	-	-	0.31	-	0.00	0.00
	Count (wet)	0	21	0	0	16	0	2	2
Nitrate-Nitrogen (mg/L)	Mean (Dry)	-	1.49	2.59	-	1.24	-	1.31	0.54
	SD (Dry)	-	0.82	-	-	0.05	-	-	0.08
	Count (Dry)	0	10	1	0	3	0	1	2
	Mean (wet)	-	0.84	-	-	0.95	-	1.99	1.28
	SD (wet)	-	0.30	-	-	0.24	-	1.01	1.02
	Count (wet)	0	17	0	0	16	0	2	11
Total Kjeldahl Nitrogen (mg/L)	Mean (Dry)	-	2.50	-	-	0.61	-	0.87	0.91
	SD (Dry)	-	2.35	-	-	0.33	-	-	0.13
	Count (Dry)	0	6	0	0	5	0	1	2
	Mean (wet)	-	4.28	-	-	1.42	-	1.16	1.20
	SD (wet)	-	2.44	-	-	1.06	-	0.48	0.38
	Count (wet)	0	6	0	0	15	0	2	11
Ortho Phosphorus (mg/L)	Mean (Dry)	-	0.05	0.03	-	0.03	-	0.09	0.08
	SD (Dry)	-	0.09	-	-	0.01	-	-	0.02
	Count (Dry)	0	11	1	0	6	0	1	2
	Mean (wet)	-	0.13	-	-	0.03	-	0.12	0.04
	SD (wet)	-	0.15	-	-	0.01	-	0.06	0.02
	Count (wet)	0	18	0	0	16	0	2	2
Phosphorus (mg/L)	Mean (Dry)	-	0.22	0.35	-	0.06	-	0.13	0.15
	SD (Dry)	-	0.21	-	-	0.06	-	-	0.06
	Count (Dry)	0	14	1	0	4	0	1	2
	Mean (wet)	-	0.45	-	-	0.31	-	0.10	0.29
	SD (wet)	-	0.20	-	-	0.21	-	0.09	0.20
	Count (wet)	0	21	0	0	15	0	2	10
Chloride (mg/L)	Mean (Dry)	-	85.84	63.28	-	93.65	-	56.72	67.21
	SD (Dry)	-	33.24	-	-	35.76	-	-	23.30
	Count (Dry)	0	10	1	0	3	0	1	2
	Mean (wet)	-	32.76	-	-	60.34	-	57.97	32.22
	SD (wet)	-	21.39	-	-	27.84	-	9.64	21.91
	Count (wet)	0	17	0	0	16	0	2	2
BOD (mg/L)	Mean (Dry)	2.50	10.91	-	-	2.70	-	0.50	1.50
	SD (Dry)	-	14.18	-	-	2.17	-	-	0.71
	Count (Dry)	1	11	0	0	5	0	1	2
	Mean (wet)	-	25.95	-	-	6.84	-	5.75	4.01
	SD (wet)	-	22.01	-	-	7.39	-	7.42	1.40
	Count (wet)	0	21	0	0	16	0	2	2
TDS (mg/L)	Mean (Dry)	-	460.00	-	-	312.67	-	430.00	492.00
	SD (Dry)	-	-	-	-	257.36	-	-	107.48
	Count (Dry)	0	1	0	0	3	0	1	2
	Mean (wet)	-	514.00	-	-	383.75	-	436.00	297.00
	SD (wet)	-	-	-	-	133.39	-	39.60	43.84
	Count (wet)	0	1	0	0	16	0	2	2
TSS (mg/L)	Mean (Dry)	20.00	110.09	-	-	9.33	-	15.00	16.00
	SD (Dry)	-	190.22	-	-	5.51	-	-	1.41
	Count (Dry)	1	11	0	0	3	0	1	2
	Mean (wet)	-	260.10	-	-	116.38	-	9.00	168.82
	SD (wet)	-	324.33	-	-	316.49	-	4.24	189.22
	Count (wet)	0	21	0	0	16	0	2	11
Fecal Coliform (col/100 ml)	Mean (Dry)	350	14558	-	1285	1090	550	1327	1349
	SD (Dry)	-	25930	-	1856	1791	628	559	1548
	Count (Dry)	1	13	0	15	26	24	13	23
	Mean (wet)	23833	160800	-	125	3480	3031	7815	85364
	SD (wet)	35757	177880	-	203	7100	2824	10497	137716
	Count (wet)	3	19	0	3	24	8	20	20

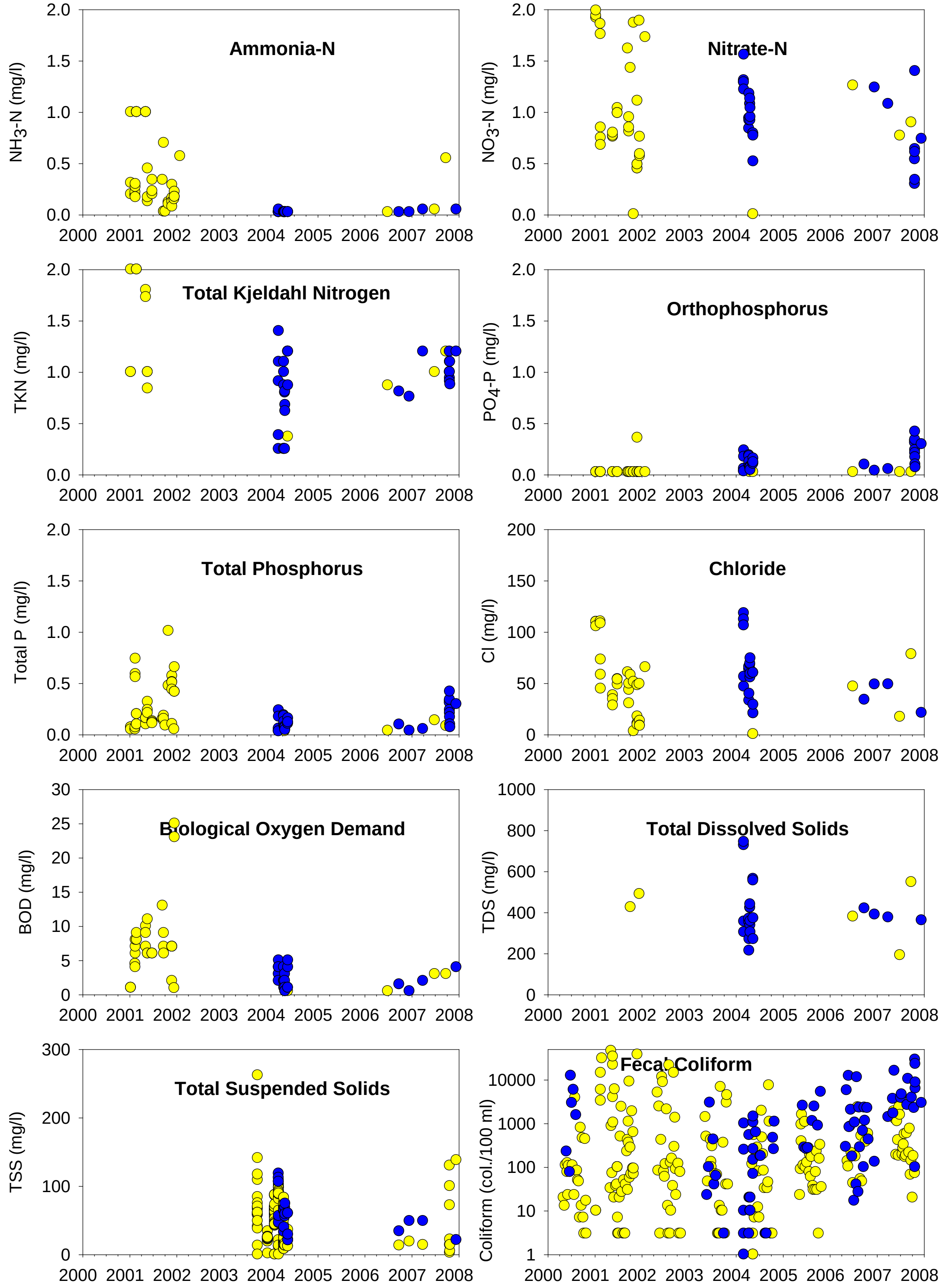

Figure 12-1 Major water chemistry parameters measured in the South Fork of Beargrass Creek, at ESFSF001. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

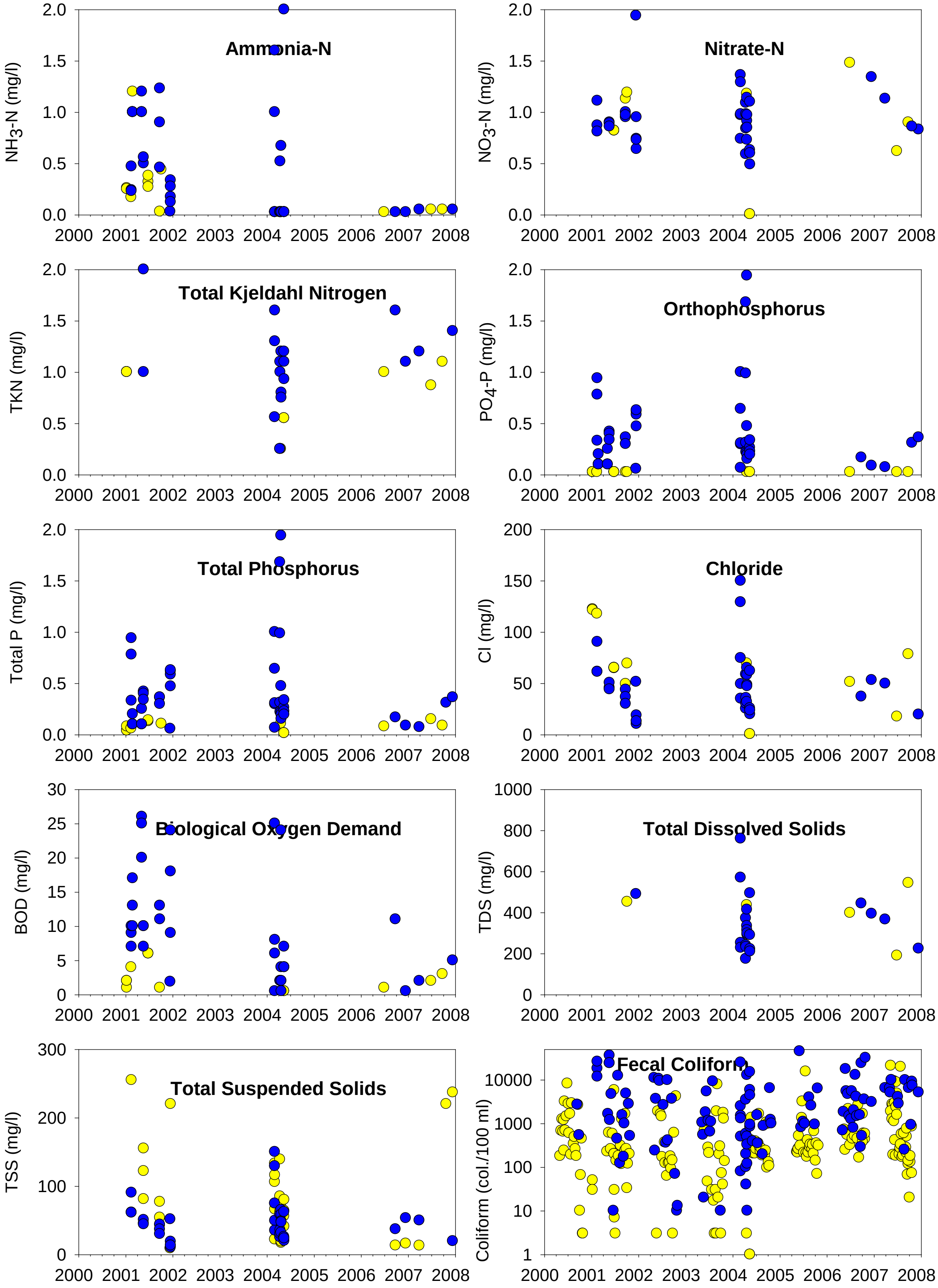

Figure 12-1 Continued, at ESFSF002.

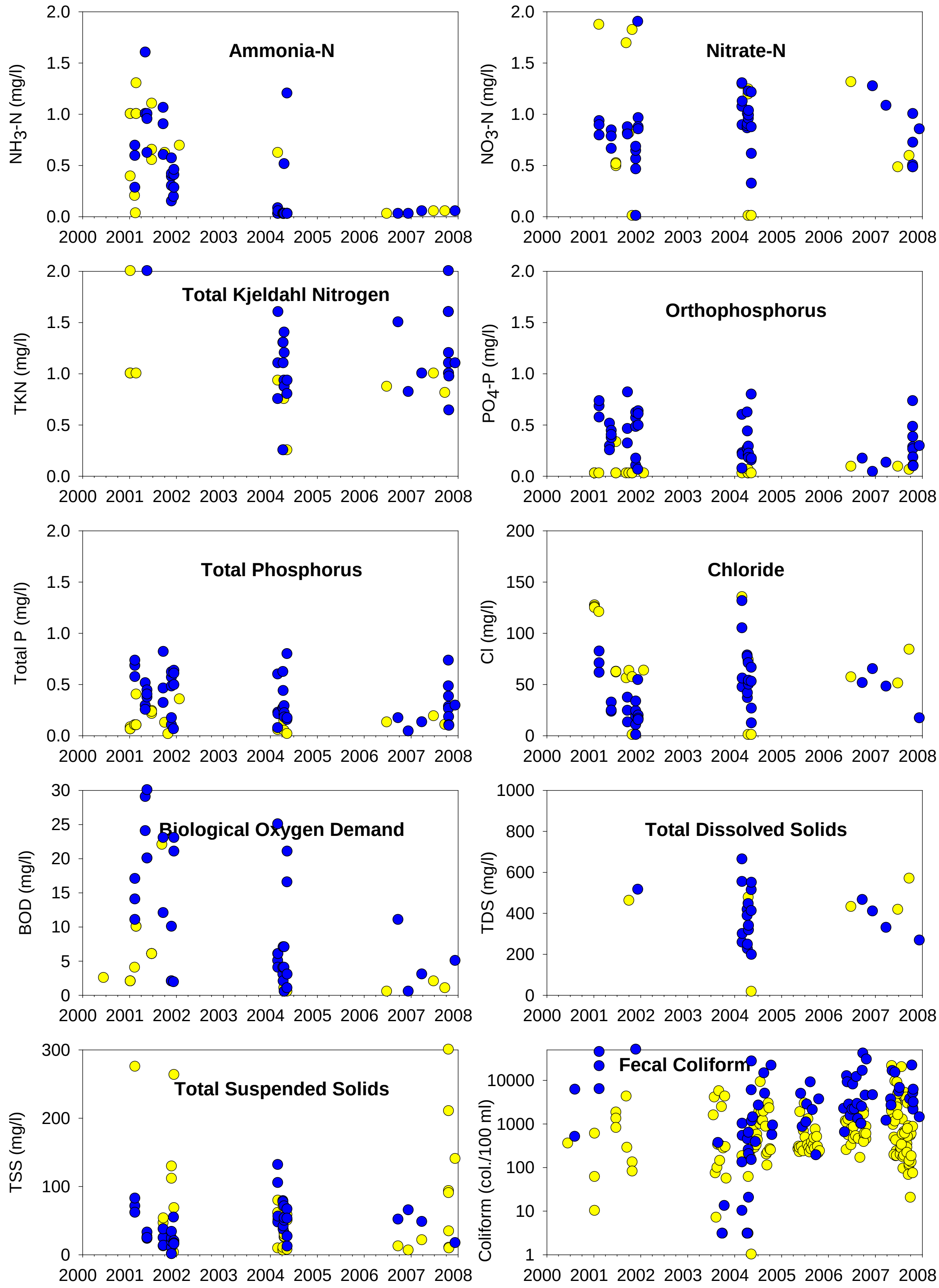

Figure 12-1 Continued, at ESFSF006.

Chapter 13 Otter Creek

13.1 Watershed Physical Characteristics

Otter Creek originates at Rineyville area (Hardin County), flowing north through Meade County and Fort Knox Military Reservation before entering Ohio River. There is one LTMN site, at Otter Creek Park (EOCOC001).

The Otter Creek watershed is relatively undeveloped with only 11.7% of developed lands, 36% of forests, and 50% of pasture and agricultural areas (Table 13-1). It has very low levels of imperviousness in both watershed (2%) and riparian buffer zone (1%).

13.2 Biological Data

13.2.1 Diatom

EOCOC001: The overall water quality of Otter Creek at Highway 1638 (EOCOC001) based on 33 diatom samples collected over four years (2001 – 03, 2005) may be characterized as 'Fair' (Table 13-2). The overall mean score of 50 reflects the lower range of 'Fair' scores. In general, these data suggest water quality of Otter Creek at Highway 1638 seems to be improving slightly over time (Table 13-2). Specifically, during the 2001 and 2002 sampling seasons, 61% of sample dates characterized water quality as 'Poor' (mean DBI = 49). During subsequent sampling years (2003, 2005), mean overall water quality was characterized as 'Fair' as 60% of samples scored in the 'Fair' range (mean DBI = 50). It is important to note, Otter Creek at Highway 1638 is one of only four sites in the current study, which is scored based on criteria for the Pennyroyal Bioregion. This Bioregion's criterion, are more rigorous than those of the Bluegrass Bioregion sites, of which, there are 24.

The taxa richness (TR) yearly mean score decreased from year 2001 (45) to 2005 (40) (Table 13-2). These data suggest that a number of species were lost as the study progressed. In general, a decrease in TR suggests a decline in water quality.

The pollution tolerance index (PTI) yearly mean score increased from year 2001 (65) to 2005 (78) (Table 13-2). These data suggest that species composition shifted somewhat in favor of those species identified as pollution sensitive. In general, an increase in the PTI suggests an improvement in water quality.

The siltation index (%NNS) yearly mean score increased from year 2001 (45) to 2005 (79) (Table 13-2). These data suggest that overall species composition shifted significantly away from those species adapted to living on silts and shifting sediments. In general, an increase in overall %NNS suggests an improvement in water quality.

The Shannon diversity index (SDI) yearly mean score decreased from year 2001 (96) to 2005 (85) (Table 13-2). These yearly SDI fluctuations, track well with the changes seen in TR and provides some hint as to the correlation between these parameters (Table 13-2). In general, decreases as those seen here in the yearly mean SDI suggest a decline in overall water quality.

The fragilaria group richness (FGR) yearly mean score decreased from year 2001 (10) to 2003 (0), but increased during 2005 (8) (Table 13-2). These data indicate that species within the Fragilaria group were completely absent during 2002 and 2003, but rebounded during 2005. Taxa within this group are widely considered to be indicators of good water quality. The increase with respect to this metric during 2005 suggests site water quality may be improving somewhat. This site's mean overall FGR score (5) was among the lowest observed in the current study (Table 13-2).

The cymbella group richness (CGR) yearly mean score decreased from year 2002 (29) to 2005 (19) (Table 13-2). These taxa are widely considered to be indicators of good water quality. An overall decrease with respect to this metric suggests site water quality may be declining. Taxa lost from within this group likely contributed to the decrease in TR throughout this study. This site's mean overall CGR score (24) was among the highest observed in the current study (Table 13-2).

13.2.2 Macroinvertebrates

The macroinvertebrate communities in Otter Creek were rated as 'good' in 2000 and 2005, and as 'excellent' in 2004 (Table 13-3). In 2000, the taxa richness metric attained the maximum value of 100, and the %EPT metric scored 100 in 2005. In 2005, a low score for the %Clinger metric (5.05) was the metric that reduced the overall MBI score.

13.2.3 Fish

Water quality rating based on the fish community in Otter Creek has slightly improved from 'poor' (2002) and 'very poor' (2003) to 'fair' during 2005 survey (Table 13-4). Native species richness (NAT) score was much higher in 2005 than previous surveys, and other metrics also showed improvements during the same period. The most metric scores were 'zero' in 2003 survey, resulting in the extremely low overall fish IBI score at Otter Creek.

13.3 Hydrolab Sonde Data

13.3.1 Stream metabolism

The GPP estimates were highest during fall (0.81-2.88 g O_2/m^2/day), followed by summer (0.67-2.81 mg O_2/m^2/day), and lowest during spring (0.75-2.66 g O_2/m^2/day) in Otter Creek (Table 13-5). CR estimates were in the order of summer (0.86-9.8 g O_2/m^2/day), fall (0.07-10.02 g O_2/m^2/day), and spring (1.93-9.91 g O_2/m^2/day).

13.3.2 Dissolved oxygen, pH, and conductivity

The daily mean DO was in the order of winter (9.69-12.03 mg/L), spring (5.81-10.36 mg/L), fall (5.98-11.38 mg/L), and summer (4.36-9.02 mg/L) (Table 13-6). It was mostly above 5.0 mg/L except summer 2001 when the daily minimum was below 4.0 mg/L. Daily mean pH was always higher than 7, and the overall daily mean pH was 7.92 at this location. Mean daily conductivity values were highest during winter, followed by fall, and they were similar in spring and summer.

13.4 Laboratory Data

Before 2006, only fecal coliform data was collected in Otter Creek (Table 13-7, Figure 13-1). Ammonia-nitrogen and ortho-phosphorus concentrations were below the detection limits. Nitrate-nitrogen and TKN concentrations were higher during 2006 than 2007 samples when 'dry' samples were compared. The overall mean chloride concentration in Otter Creek was 10 mg/L, which was the lowest among all LTMN sites. Fecal coliform counts were highly variable and they were higher in 'wet' period samples than 'dry' period samples.

13.5 Watershed assessment based on the biological data

There was a discrepancy in water quality ratings among three biotic integrity indices in Otter Creek. In the year 2005, diatom and fish were rated 'fair', while macroinvertebrate community had a 'good' rating. Water quality ratings based on diatom and fish in 2005 improved from earlier years.

EPRPR001	2000	2001	2002	2003	2004	2005
DBI	—	poor	poor	poor	—	**fair**
MBI	good	—	—	—	excellent	**good**
Fish KBI	—	—	poor	very poor	—	**fair**

Table 13-1 Land use/cover characteristics of Otter Creek watershed.

Class	Watershed (%)	Stream Buffer (%)	1000 m Buffer (%)
Imperviousness	1.98	0.98	3.28
Open Water	0.30	0.49	0.00
Dev. Open Space	8.32	6.44	1.33
Dev. Low Intensity	2.44	1.98	0.00
Dev. Medium Intensity	0.74	0.46	0.00
Dev. High Intensity	0.25	0.06	0.00
Barren Land	1.39	0.41	0.00
Deciduous Forest	34.18	43.47	96.44
Evergreen Forest	1.54	1.76	0.00
Mixed Forest	0.43	0.73	0.44
Shrub/Scrub	0.18	0.16	0.00
Grassland/herbaceous	1.77	1.23	0.00
Pasture/Hay	36.17	34.27	0.00
Cropland	12.26	8.34	0.44
Woody Wetlands	0.02	0.08	0.00
Emergent Herbaceous Wetlands	0.02	0.10	1.33

Table 13-2 DBI scores estimated in Otter Creek.

EOCOC001	TR	PTI	%NNS	SDI	FGR	CGR	Mean	Water Quality
2001	45	65	45	96	10	25	**48**	**POOR**
2002	42	71	60	93	0	29	**49**	**POOR**
2003	38	75	77	81	0	25	**49**	**POOR**
Summer 05	35	80	84	74	5	15	**49**	**POOR**
Fall 05	45	75	74	96	10	23	**54**	**FAIR**
2005 All	40	78	79	85	8	19	**51**	**FAIR**
Overall	**41**	**72**	**64**	**90**	**5**	**24**	**50**	**FAIR**

Table 13-3 Macroinvertebrate biotic integrity scores in Otter Creek.

Year	Metric	EOCOC001	
		Raw Score	Metric Score
2000	Taxa Richness	82	100.00
	EPT Richness	19	63.33
	m%EPT	20	27.40
	mHBI	6.27	54.14
	%Chir. and Oli.	18	82.83
	%Clinger	21	28.38
	MBI	--------	59.18
	Assessment	--------	**Good**
2004	Taxa Richness	36	48.7
	EPT Richness	7	23.3
	m%EPT	67.7	92.7
	mHBI	4.44	80.7
	%Chir. and Oli.	3.8	97.2
	%Clinger	62.1	83.9
	MBI	--------	71.10
	Assessment	--------	**Excellent**
2005	Taxa Richness	36	48.65
	EPT Richness	13	43.33
	m%EPT	88.79	100.00
	mHBI	3.51	94.18
	%Chir. and Oli.	1.44	99.56
	%Clinger	3.74	5.05
	MBI	--------	65.13
	Assessment	--------	**Good**

Table 13-4 Fish IBI scores in Otter Creek.

Year	EOCOC001
1999-up	**fair**
1999-dn	**fair**
2000-up	**NS**
2000-dn	**NS**
2002	**Poor**
Native	25
DMS	0
INT	8
WC	15
SL	0
%Insect_Ex_Tol	30
%OMNI	82
%TOL	89
IBI	31
2003	**Very Poor**
Native	18
DMS	26
INT	8
WC	0
SL	0
%Insect_Ex_Tol	0
%OMNI	0
%TOL	0
IBI	6
2005	**Fair**
NAT	54
DMS	28
INT	10
SL	47
%INSCT	63
%TOL	67
%FHW	72
KIBI	45

Table 13-5 Gross primary production and community respiration estimated at EOCOC001 location, Otter Creek.

Year	Spring		Summer		Fall	
	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)	GPP ($g/m^2/d$)	CR ($g/m^2/d$)
2000	—	—	—	—	—	—
2001	—	—	1.51	9.80	2.20	0.07
2002	0.75	2.89	1.57	8.49	0.81	3.30
2003	1.41	2.63	2.77	3.44	2.13	10.02
2004	2.66	3.26	—	—	2.42	5.93
2005	1.24	9.91	2.81	5.78	2.88	5.26
2006	1.42	3.91	—	—	—	—
2007	1.18	1.93	0.67	0.86	—	—

Table 13-6 Daily water temperature, DO, pH, and conductivity measured at EOCOC001 location, Otter Creek.

Spring	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	—	—	—	—	—	—	—	—	—	—	—	—
2002	12.4	10.7	14.7	9.45	8.70	10.33	8.16	8.09	8.25	410.9	403.3	420.6
2003	14.1	12.2	16.8	9.62	8.54	10.84	8.01	7.91	8.14	331.4	322.6	341.6
2004	13.8	10.7	17.7	10.36	8.47	12.65	8.13	7.98	8.31	404.3	351.4	433.8
2005	14.9	12.0	18.9	5.81	4.89	6.88	7.60	7.37	7.91	346.9	336.1	356.4
2006	14.8	11.6	19.1	8.88	7.42	10.45	7.45	7.31	7.67	285.9	270.9	296.5
2007	10.2	9.0	11.7	10.90	10.16	11.94	8.02	7.88	8.23	428.7	414.9	442.4

Summer	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	23.9	20.6	27.7	4.36	3.40	5.70	7.85	7.72	8.03	357.4	332.5	379.2
2002	22.6	20.2	25.9	5.35	4.03	7.11	7.96	7.80	8.14	344.6	273.2	400.3
2003	22.5	19.9	25.8	8.28	6.86	10.31	7.67	7.51	7.86	435.3	380.0	474.8
2004	—	—	—	—	—	—	—	—	—	—	—	—
2005	23.3	20.6	26.8	6.99	5.43	8.95	7.86	7.71	8.03	475.9	427.3	512.7
2006	21.1	18.6	24.4	—	—	—	7.44	7.40	7.48	535.3	476.6	574.9
2007	20.3	18.3	23.2	9.02	8.46	9.59	8.01	7.88	8.19	339.6	316.0	366.2

Fall	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	14.1	11.7	16.7	11.38	9.95	13.65	7.92	7.82	8.03	488.7	440.6	519.0
2002	13.1	11.9	14.6	9.29	8.64	10.23	8.52	8.43	8.69	436.2	425.8	445.9
2003	15.0	12.7	18.0	5.98	4.76	7.89	7.67	7.52	7.95	502.5	455.5	529.3
2004	14.8	12.1	17.7	8.50	6.84	10.75	7.91	7.82	8.02	534.7	500.4	563.3
2005	15.1	12.6	17.8	8.85	7.24	11.41	8.17	8.09	8.29	588.3	540.9	616.9
2006	—	—	—	—	—	—	—	—	—	—	—	—
2007	21.2	19.4	22.9	—	—	—	7.74	7.62	7.91	615.1	595.8	638.0

Winter	Temperature (°C)			DO (mg/L)			pH			Conductivity (µS/cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
2000	—	—	—	—	—	—	—	—	—	—	—	—
2001	5.5	4.8	6.4	12.03	11.14	13.80	8.23	8.11	8.45	595.3	554.0	651.5
2002	6.8	5.5	8.1	11.29	9.81	13.66	7.99	7.86	8.21	473.3	438.4	510.5
2003	4.7	3.6	5.9	—	—	—	8.27	8.14	8.52	422.2	404.5	432.7
2004	6.9	5.8	8.1	11.85	11.00	13.32	7.77	7.66	7.97	536.3	520.7	549.2
2005	7.3	6.2	8.2	11.28	10.59	12.58	7.70	7.59	7.88	380.9	369.9	389.9
2006	10.1	9.0	10.9	9.69	9.20	10.41	7.82	7.70	7.94	235.0	214.0	251.3
2007	9.7	9.2	10.3	10.53	8.29	16.33	8.14	8.04	8.23	433.2	403.7	454.8

Table 13-7 Summary of selected water chemistry parameters measured at EOCOC001 location, Otter Creek.

	Year	**2006**	**2007**		**2006**	**2007**		**2006**	**2007**
Ammonia-Nitrogen (mg/L)	Mean (Dry)	0.03	0.05	Nitrate-Nitrogen (mg/L)	1.57	0.98	Total Kjeldahl Nitrogen (mg/L)	0.62	0.93
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.03	0.05		1.24	1.35		0.65	0.63
	SD (wet)	0.00	0.00		0.28	0.48		0.31	0.21
	Count (wet)	2	3		2	3		2	3
Ortho-Phosphorus (mg/L)	Mean (Dry)	0.03	0.03	Phosphorus (mg/L)	0.04	0.04	Chloride	12.23	10.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	0.06	0.03		0.15	0.06		6.80	9.25
	SD (wet)	0.05	0.00		0.10	0.02		1.85	2.86
	Count (wet)	2	3		3	3		2	3
BOD (mg/L)	Mean (Dry)	0.50	1.00	TDS (mg/L)	358.00	336.00	TSS (mg/L)	18.00	26.00
	SD (Dry)	-	-		-	-		-	-
	Count (Dry)	1	1		1	1		1	1
	Mean (wet)	1.25	1.33		251.00	622.67		130.00	46.00
	SD (wet)	1.06	1.44		91.92	634.34		171.12	33.51
	Count (wet)	2	3		2	3		2	3

	Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Fecal Coliform (col/100 ml)	Mean (Dry)	92	75	146	177	159	723	1156	69
	SD (Dry)	74	102	212	281	185	2367	3430	46
	Count (Dry)	20	14	19	21	21	23	14	23
	Mean (wet)	3541	759	2128	1068	2552	3448	2368	1779
	SD (wet)	7969	1418	3322	1663	3474	6201	4398	3431
	Count (wet)	8	16	9	8	11	9	19	10

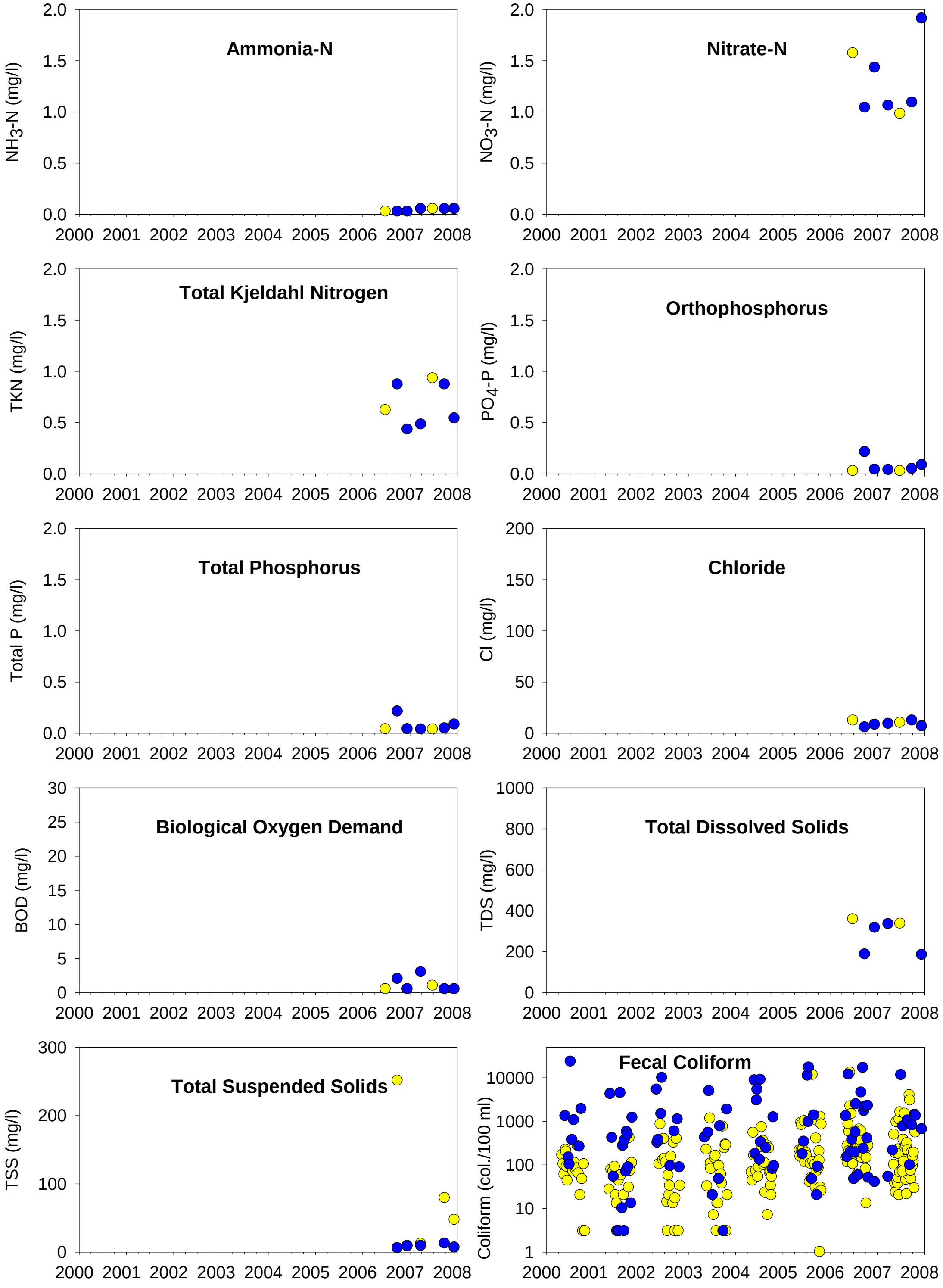

Figure 13-1 Major water chemistry parameters measured at EOCOC001 location of Otter Creek. Yellow and blue symbols represent samples taken during dry and wet periods, respectively.

Chapter 14 Summary and Recommendations

14.1 Summary of Stream Monitoring Data

Three biological communities, diatom, macroinvertebrates, and fish, were sampled to assess the stream water quality in LTMN sites. They represent the biological components at different trophic levels in streams with different feeding habits, habitats, and life spans. Comprehensive assessment efforts encompassing different, yet interacting biotic components coupled with water quality samples (laboratory-oriented chemical analyses) should be appraised periodically to ensure they are meeting regulatory and planning assessment needs.

14.1.1 Diatom

Since 2001, the Louisville Metropolitan Sewer District (MSD) has collected a total of 860 diatom samples from 28 local stream locations through its Long Term Monitoring Network (LTMN) program as a means of assessing overall water quality within those streams using the diatom bioassessment index (DBI). Diatom communities, on artificial substrates, were sampled during 2001- 2003, and 2005 throughout the report period (2000 – 2007). Specifically, diatom samples were collected from 22 LTMN locations (2001 – 198 samples), 26 locations (2002 – 228 samples and 2003 – 165 samples), and 27 locations (2005 – 269 samples). Not all sites were sampled during any one sampling year as sampling regimes were altered to best address informational needs. Additionally, one site, Mill Creek Cutoff at Old Cane Run Road, was not sampled during 2003 and 2005 as the creek is now intermittent due to a flow diversion.

In general, the diatom bioassessment index (DBI) assesses overall water quality of a stream by asking the following questions: what lives in the stream, how are they distributed, are they pollution sensitive, and are they adapted to living on silt or sediment. Based on the average score of those parameters when compared to a reference value, water quality is categorized as ‘Poor’, ‘Fair’, ‘Good’, or ‘Excellent’. With respect to the present study, when all data, collected over all four years, are considered collectively, approximately 16% of sites sampled were categorized as having ‘Poor’ water quality, while 34% were categorized as ‘Fair’, 43% were categorized as ‘Good’, and 8% were categorized as ‘Excellent’ (Table 14-1).

As mentioned above, the collective data suggest water quality of the majority of sites is at least ‘Good’. However, if the data are considered on a yearly basis, a slightly different view emerges. Specifically, during 2001, water quality of 50% of sites sampled was categorized as ‘Poor’ or ‘Fair’ (Table 14-1). During 2002 and 2003, water quality of 46% of sites sampled was categorized as ‘Poor’ or ‘Fair’, while 54% were categorized as ‘Good’ or ‘Excellent’ (Table 14-1). These data suggest overall water quality of those streams sampled seems to be improving slightly over time. In contrast, during 2005, water quality of 56% of sites sampled was categorized as ‘Poor’ or ‘Fair’, while 44% were categorized as ‘Good’ or ‘Excellent’ (Table 14-1). While these yearly differences within the various water quality categories may not be significant, and may simply be related to changes in sampling regimes or variations of annual flow regimes, etc., these changes still suggest vigilance and continued monitoring.

14.1.2 Macroinvertebrates

Macroinvertebrate communities were sampled three times (2000, 2004, and 2005) during the report period, 2000-2007, to assess the stream water quality using the macroinvertebrate biotic integrity in LTMN locations. Macroinvertebrate samples were collected in 22 LTMN locations in 2000, while all 28 sites were sampled in 2004 and 2005. These 6 sites were added to the LTMN site list during the later years (Table 14-2).

It seems the overall water quality in LTMN sites improved from 2000 to 2004, but may have degraded slightly during the 2004-2005 period (Figure 14-2). In 2000, the most LTMN sites (20 sites; 91%) were in the 'fair' or lower water quality ratings, while only 2 sites had either 'excellent' or 'good' ratings. Overall water quality of LTMN sites seemed to be higher in 2004 samples than 2000. The number of sites with 'excellent' (4) or 'good' (4) ratings increased, and its combined proportion (29%) were higher than that (18%) of sites with 'poor' (4 sites) or 'very poor' (1 site) in 2004. However, there was only one site with 'excellent' rating in 2005 sampling. Although the number of 'good' sites (4) did not change from the 2004 sampling, numbers of 'poor' (9 sites; 32%) and 'very poor' (4 sites; 14%) were much higher than 2004. The number of 'fair' sites also decreased from 15 (2004) to 10 (2005) during the same period.

14.1.3 Fish

Four samplings were conducted in LTMN sites during the report period (2000-2007) for fish community assessment. Fish communities were collected in 20 sites in 2000, 26 sites in 2002 and 2003, and 28 sites in 2005 (Table 14-3).

Water quality combined for all LTMN sites was generally improving throughout the sampling events in 2000-2005 (Figure 14-3). In 2000, there were only 3 sites (15%) with 'excellent' or 'good' ratings and 55% of sampled sites (11) had either 'poor' or 'very poor' ratings. The proportions of this rating distribution did not change much in 2002 with 50% of sites (23) with 'poor' or 'very poor' ratings. However, the number of sites with 'excellent' (2 sites; 8%) or 'good' (5 sites; 19%) increased in 2003, while the number of sites with 'poor' rating declined to 5 (19%).

The next sampling in 2005 showed dramatic improvements in water quality ratings based on the fish IBI assessments. The number of LTMN sites with 'excellent' (6 sites; 21%) and 'good' (4 sites; 14%) quality ratings were much higher than any previous sampling events, and sites with 'poor' (5 sites; 18%) and 'very poor' (1 site; 4%) were reduced. Such a great improvement in fish IBI ratings might be due to the altered criteria from 2003 to 2005.

14.2 Recommendations for Monitoring Practices

MSD have sampled various components of stream ecosystems for water quality assessments. These include not only the basic physical and chemical parameters, but also three biological components (diatom, macroinvertebrates, and fish). As stream ecosystems in urban settings are influenced by many natural and anthropogenic factors, such comprehensive monitoring efforts should be needed to assess the current ecological status of streams and to find possible remedies.

Here are some recommendations for future stream monitoring to improve the correlation of among different variables and data interpretations.

Synchronized sampling efforts in the same year and season:

Three biological components were sampled 3-5 times in the report period: 5 samplings including summer and fall samples in 2005 for diatom, 3 samplings for macroinvertebrates, and 4 samplings for fish. In some cases, these were sampled in different years and seasons except the 2005 samplings. Synchronized sampling of all biological parameters and chemical parameters may provide better information on how the physical and chemical settings influence biotic communities in stream ecosystems. It is thus recommended that MSD consider synchronizing samplings of biological and chemical water quality assessments, when deemed beneficial and cost-effective.

Frequent water chemistry monitoring:

Water samples were collected at LTMN sites for laboratory analyses of multiple parameters (water chemistry and fecal coliform counts). MSD should be praised for their efforts to improve the water quality monitoring by expanding these chemical analyses in recent years (2006-2007). The sampling of water chemistry parameters only started back (some water chemistry data are available until 1998) in 2006 in the most LTMN sites with a very limited sampling frequency (quarterly). For example, there were only 4 water collections in the most LTMN sites other than Beargrass Creek and Mill Creek watershed. Although these 4 samples were taken in quarterly basis, 2 were taken during 'dry' period, while other 2 were considered 'wet' samples (see Chapter 1 for the definition of 'dry' and 'wet' periods). Thus a direct comparison between these samples and statistical analysis is impractical with these limited sample numbers.

It is thus recommended that MSD consider increasing the frequency of water chemistry samples to figure out the seasonal and annual water quality trends in LTMN sites, if deemed beneficial and cost-effective.

It is also recommended that MSD improve the minimum detection limits for some water chemistry parameters. Currently, the MDL is 0.05 mg/L for ammonia-nitrogen and ortho-phosphate analyses, which is higher than MDL used in most water chemistry analysis laboratories. Although impacts of these chemical parameters at close to the MDL is not well understood, it is known when ammonia levels reach 0.06 mg/L, fish can suffer gill damage. A one-half of the MDL (0.025 mg/L) was assigned as a sample value to the sample with lower than MDL concentration for this report by the agreement between MSD and UofL. However, this practice inflates the true sample concentration and makes it more difficult to quantify and comprehend the effects of these important chemical (nutrient) parameters and biological communities.

Designation of reference sites:

MSD have been monitoring water quality of up to 48 stream sites (28 LTMN sites) in Jefferson and surrounding counties. However, there have not been clear guidelines established for true reference sites that can be compared by all sites. There are a few stream sites to be used as quality reference sites: Otter Creek, Cedar Creek in Bullitt County, and Brier Creek (a Pond Creek tributary). Although Otter Creek (EOCOC001) has been considered as a reference stream thus far, its geographic location (Pennyroyal Region) is different from the majority of LTMN sites (Bluegrass Region) (see Chapter 1). Also, it should be noted that Otter Creek in Otter Creek Park (EOCOC001) is not included as a State's reference site in the recent 305(b) report.

It is thus recommended that MSD clarify the guidelines for establishing the reference sites with the state and designate 3-4 sites as reference streams, as appropriate or establish sites if existing locations do not meet the proper criteria. Overalls Creek, Wilson Creek, Harts Run, and Cedar Creek in Bullitt County are currently listed as reference reach streams of Kentucky in 2008 (2008 Integrated Report tot Congress on Water Quality in Kentucky, Volume 1, 305(b) Report).

Diatom bioassessment:

1.) The Mill Creek Cutoff at Old Cane Run Road site was dried up during most of the 2002 sampling season, and the entire 2003 and 2005 sampling seasons with respect to algal sampling. Therefore, the MSD may wish to consider eliminating this site from the sampling rotation and adding an alternative site within the Mill Creek watershed.
2.) Currently, the Muddy Fork of Beargrass Creek is sampled at one location (Mockingbird Valley Lane) while South and Middle Forks are sampled at three locations. Therefore, MSD may wish to consider adding two sampling locations on Muddy Fork as a means of balancing the sampling effort.
3.) Currently, the MSD collects diatom samples from artificial substrates (ceramic tiles). Most national and state monitoring programs prefer sampling natural substrates whenever possible to improve the ecological applicability of the information. Therefore, MSD may wish to consider during the next sampling regime collecting samples from both natural (fist-sized rocks) and artificial substrates from each stream at approximately the same location within the stream. Likely, the communities on both types of substrate will be similar thereby validating the information produced during previous artificial substrate only sampling regimes and beginning the transition to natural substrate only sampling in the future.
4.) Currently, MSD collects and processes algal samples for diatom enumeration. These same samples may be processed for whole algal community composition and carbon/silt content at a fairly minimal cost. Therefore, the MSD may wish to consider adding estimates of chlorophylls a, b, c and pheophytin as well as ash-free dry mass to the normal sample processing routine to obtain this information.
5.) Typically, MSD collects diatom samples during the late summer/early fall seasons usually to coincide with stream low flow conditions. This practice tends to eliminate certain diatom taxa from the sampling pool as they do not thrive in the warmer waters encountered during this time of year. Therefore, the MSD may wish to consider initiating a sampling regime that includes all four seasons of the year in order to obtain a truer representation of the diatom community as a whole, if deemed beneficial and cost effective. Sampling could be conducted during the mid-point of each season and should be preceded by at least 5 – 7 days of stable flow.

Table 14-1 Stream water quality changes in LTMN sites based on diatom bioassessment index during 2000-2005.

Year	Excellent	Good	Fair	Poor	No. of Sites
2001	1	10	7	4	22
2002	2	12	8	4	26
2003	5	9	7	5	26
2005	0	12	12	3	27

Table 14-2 Stream water quality changes in LTMN sites based on macroinvertebrate biotic integrity index during 2000-2005.

Year	Excellent	Good	Fair	Poor	Very Poor	No. of Sites
2000	1	1	11	6	3	22
2004	4	4	15	4	1	28
2005	1	4	10	9	4	28

Table 14-3 Stream water quality changes in LTMN sites based on fish biotic integrity index during 2000-2005.

Year	Excellent	Good	Fair	Poor	Very Poor	No. of Sites
2000	1	2	6	5	6	20
2002	1	2	10	10	3	26
2003	2	5	10	5	4	26
2005	6	4	12	5	1	28

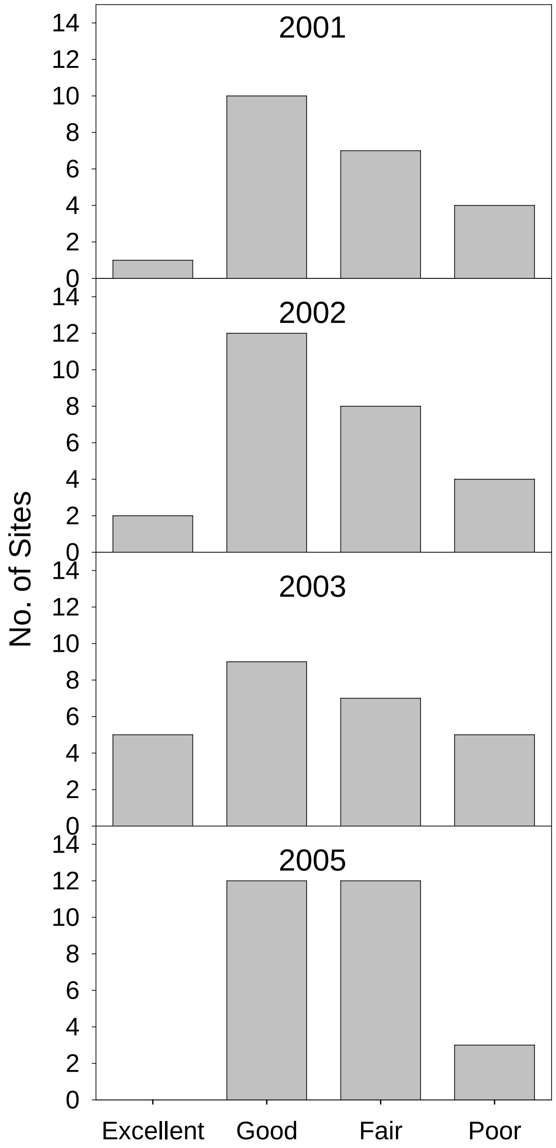

Figure 14-1 Stream water quality changes in LTMN sites based on diatom bioassessment index during 2000-2005.

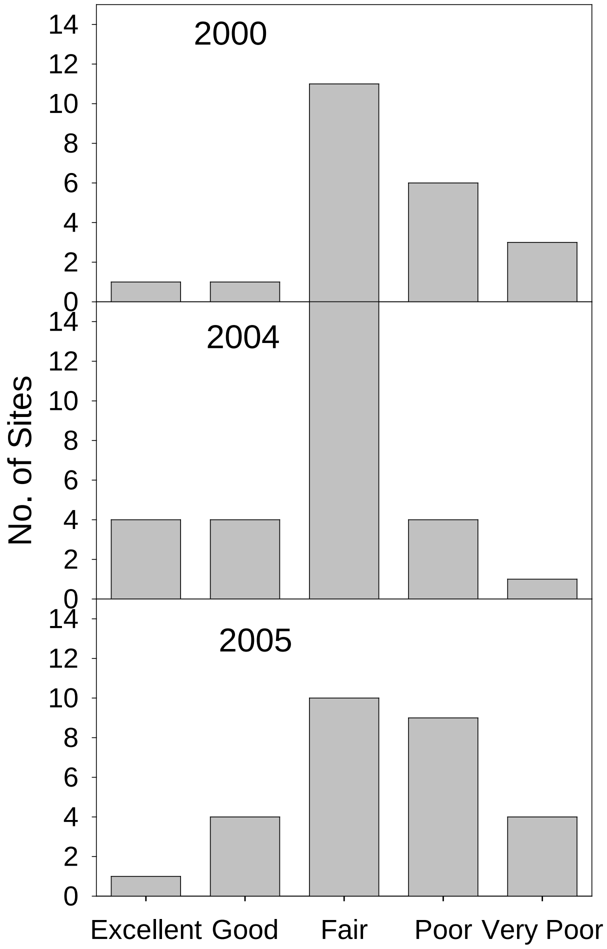

Figure 14-2 Stream water quality change in LTMN sites based on macroinvertebrate biotic integrity index during 2000-2005.

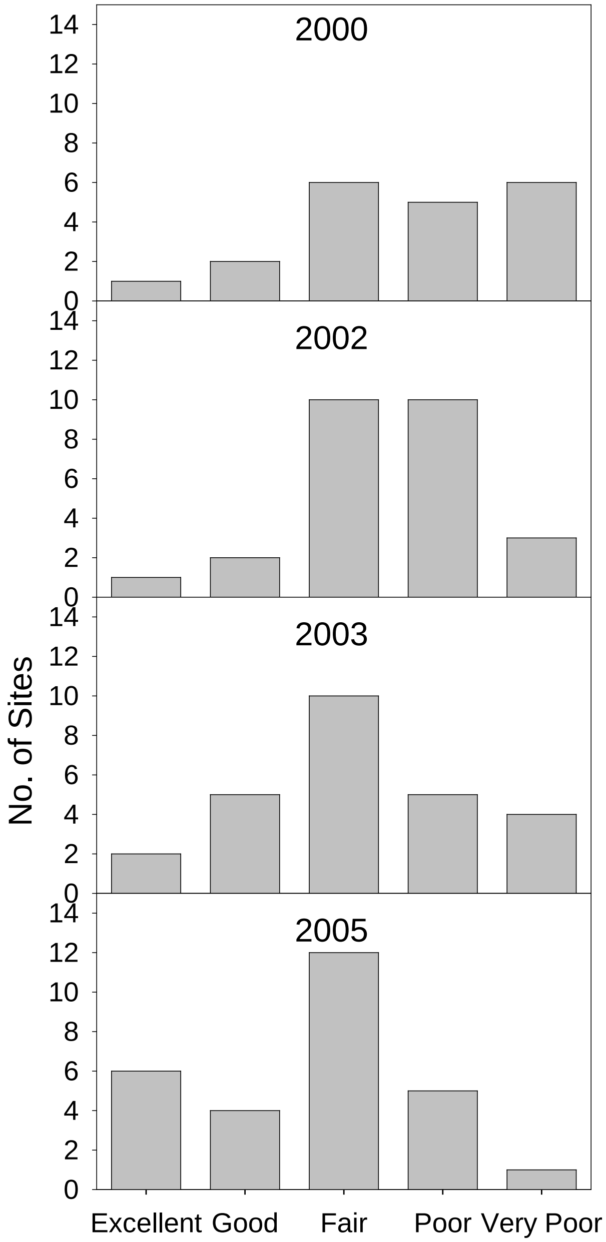

Figure 14-3 Stream water quality change in LTMN sites based on fish biotic integrity index during 2000-2005.

Running Head: Urban stream disturbance pathways

Multiple pathways propagate disturbance from catchment urbanization to stream diatom, macroinvertebrate, and fish assemblages

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Abstract

Urbanization introduces myriad stressors to stream ecosystems that ultimately affect stream biota. These stressors originate from multiple locations and form complex interactions that confound the identification of specific impairment sources. Nevertheless, identifying important impairment sources is essential for successful urban stream management and rehabilitation. In this study, path analysis was used to determine how increased catchment impervious surface area (% ISA) affects intermediate in/near-stream environmental characteristics (i.e. riparian structure, hydrology, water chemistry, benthic substrate, etc.), which, in turn, propagates disturbance to diatom, macroinvertebrate, and fish assemblages. The multi-metric Kentucky diatom bioassessment index (DBI), macroinvertebrate bioassessment index (MBI), and fish index of biotic integrity (IBI) were used as response variables in path analyses. Significant path models were created for all three biotic indices and several of their component metrics. Three general pathways were identified that propagated urban disturbances to biotic assemblages, and each biotic assemblage responded differently to these pathways. The first pathway was initiated by changes in channel structure and riparian cover. The second disturbance pathway consisted of changes in water chemistry from both non-point and point sources that ultimately affected biotic assemblages. The third pathway involves catchment % ISA altering stream hydrology, which ultimately affects stream assemblages. Diatoms and macroinvertebrates were most related to water chemistry and geomorphic/riparian properties, but the specific pathways of disturbance were different between these two assemblages. For example, macroinvertebrates responded more to in-stream habitat features compared to diatoms. Fish were most affected by hydrology and water chemistry. Due to the contrasting response of these three assemblages to the multiple stressors associated with urbanization, we conclude that all three biotic assemblages need to be monitored to more comprehensively assess all of these urbanization stressors. The resulting path models from this analysis can serve as starting points for catchment management and restoration in these highly urbanized streams.

Keywords: Urban streams, Kentucky (USA), Diatom, Macroinvertebrate, Fish, biotic integrity, disturbance, path analysis

Introduction

The future expansion of urban areas is one of the most pervasive threats to the natural environment and the services it provides. Streams, as integrators of the terrestrial ecosystems they drain, are particularly sensitive to urbanization. Catchment urbanization is commonly estimated by the relative proportion of land area represented by impervious surfaces (% ISA) such as parking lots, roads, roof tops, and other structures that do not allow water to naturally percolate into the ground (Arnold and Gibbons 1996). Extensive research has shown that urbanization and % ISA introduce numerous stressors that drastically alter stream ecosystem structure and function (Paul and Meyer 2001; Scheuler 1994; Scheuler et al 2009). Typically, % ISA increases surface runoff which drastically alters the hydrologic characteristics of the stream (Leopold 1968, Konrad and Booth 2005). Changes in hydrology also result in changes to stream channel morphology (Booth 1990), which is exacerbated by other management practices in human-altered landscapes including channelization and dredging (Urban and Rhoads 2003). Additionally, runoff from impervious surfaces can substantially increase non-point source pollution in streams (Carpenter *et al.* 1998, Duda *et al.* 1982).

Stream organisms predictably respond to the environmental stressors induced by urbanization and increased % ISA. Several studies have documented declines in richness, diversity, and ‘biological integrity’ for fish (Walton *et al.* 2007, Helms *et al.* 2009), macroinvertebrate (Walsh *et al.* 2007, Roy *et al.* 2003), and diatom (Sonnemon *et al.* 2001) assemblages. However, very rarely are studies completed that encompass the response of all three of these assemblages to increased urban intensity (Fig. 1). However, such multi-assemblage studies are needed to compare assemblage responses, and determine if the studied assemblages provide unique and complementary information to each other that is not evident in single-assemblage analyses (e.g Brown *et al*. 2009).

Despite the observation that biological integrity decreases in urban streams, very little is known about the causal mechanisms that link increased urbanization with decreased biological integrity. Most studies (i.e. Roy *et al.* 2003, Helms *et al.* 2009) rely on correlational data analyses relating biotic assemblages to land use/cover (LUC), % ISA, and/or in/near-stream environmental characteristics independently, despite the fact that all of these variables are interconnected and hierarchically linked. Urban LUC, for example, does not affect stream biota directly, but propagates disturbance by first altering in/near-stream environmental characteristics, which ultimately affect stream organisms. Recently, Burcher *et al.* (2007) proposed the land cover cascade (LCC) as a conceptual framework for assessing how changing LUC can affect in-stream biotic assemblages. In this assessment, path analysis (Shipley 2000) was used to determine the most probable pathways through which LUC change alters in/near stream abiotic characteristics (hydrology, geomorphology, sediment transport, substrate composition, *etc.*) that ultimately affect stream biota. This analysis has several benefits over previous analyses by placing the observed variables into a more representative hierarchical and causal framework (Burcher 2007). Additionally, the interaction of multiple links in the hierarchy can be modeled and represented more clearly. Ultimately, these models could be used for generating hypotheses to further investigate important and interesting links within the models for further elucidation.

In this study, we assess the effects of % ISA on diatom, macroinvertebrate, and fish assemblages in a highly urbanized environment. The urban environment, and the multiple interacting stressors found within, provides a highly complex LUC template for this analysis. The specific objectives of this research were to (1) determine the strength of % ISA as a predictor of diatom, macroinvertebrate, and fish assemblage structure, and (2) quantify the pathways leading to reduced diatom, macroinvertebrate, and fish biological integrity that are propagated from % ISA through in/near-steam environmental variables. We hypothesized that causal pathways in a highly urban environment would be very complex with multiple pathways leading from changes in urban intensity (i.e. % ISA) to ultimately affect each assemblage. We also hypothesized that different disturbance pathways would exhibit the strongest influence on each assemblage due to the very contrasting life history characteristics associated with each assemblage.

Methods

Study Area and LUC Analysis

Louisville, the largest city in Kentucky (U.S.A.) with a population of 1.2 million people in the Louisville Metropolitan Statistical Area (US Census Bureau 2009) is located in the interior plateau ecoregion of Kentucky (Omernik 1987). The natural landscape of the area consists primarily of oak-hickory forests, but much of the land area has been converted to agricultural and urban LUC. Mean annual temperature in the LMA is 13.8ºC and ranges from a low of 1.1 ºC in December to a high of 27.1 ºC in August (NCDC 2005). During this study, mean annual temperature in 2005 was 14.7 ºC (range = 3.3°C in February to 26.2°C in July). Additionally, mean annual precipitation in the study area is 121cm and is generally distributed evenly throughout the year. Total annual precipitation during this study year (2005) was 101cm.

This analysis uses data primarily collected by the Louisville Metropolitan Sewer District (LMSD) as part of their long term monitoring network (LTMN). In 1988, the LMSD and the USGS began a sampling and monitoring program to collect physical, chemical and biological samples from the surface waters in the LMA and surrounding areas. The USGS conducts stream flow monitoring and the LMSD conducts water quality sampling and biological monitoring. The LTMN developed by LMSD consists of 28 sites (Fig. 2), 24 of which are located at USGS continuous stream flow gauging sites. Physical/chemical parameters measured at the LTMN sites are collected quarterly, monthly, or continuously at 15 minute intervals. Biological assemblages (fish, macroinvertebrates, and diatoms) are scheduled to be sampled in alternating years.

Catchments for each LTMN site were delineated using a 10m spatial resolution digital elevation model (USGS 2007) for all 28 sites using ArcHydro v. 1.3 (ESRI Inc., Redlands, CA). Catchment % ISA, calculated from the 2001 National Land Cover Dataset % ISA data (Homer et al 2004), was used in this analysis as the LUC stimulus that propagates disturbance to in-stream biological communities. Initially, the percentage of other LUC classes (i.e. %Urban, %Forest, %Agriculture) were calculated at multiple spatial scales within the catchment, but further analysis failed to detect significant relationships with biotic assemblages using these LUC variables (except for catchment-scale % Urban, which is represented by catchment-scale % ISA), and therefore, only catchment % ISA was retained for further analysis.

Biotic Integrity

Fish, macroinvertebrate, and diatom data was extracted from the LTMN database for collections completed in the year 2005. Diatoms were sampled at each site between July 8 and July 19, 2005 using Kentucky Division of Water standard protocols (KOW 2002). At each site, unglazed tiles were incubated for 9 days to allow colonization. After nine days, tiles were removed from the stream and transferred to the lab for processing following standard methods (KDOW 2002). Slide-mounted diatoms were identified to the lowest determinable level, typically species, and enumerated to calculate the Kentucky diatom biotic index (DBI). The DBI was calculated as the average score for six percentile-based component metrics including total diatom richness (DIAT RICH), the Shannon-Weiner diversity index (DIAT H'), the pollution tolerance index (PTI), % Navicula, Nitzchia and Surirella (%NNS), Fragilaria group richness (FRAG RICH), and Cymbella group richness (CYMB RICH) (KDOW 2002).

Macroinvertebrates were sampled at each site between May 16 and May 24, 2005 using KDOW standard protocols (KDOW 2002). Macroinvertebrate sampling consisted of four 0.25m^2 samples collected from riffle habitats at each site using a kicknet, which were composited into a single semi-quantitative riffle sample. In addition, a qualitative multi-habitat sample was collected from each site where multiple habitats within the stream reach were systematically sampled and composited into a single qualitative sample. Invertebrates in both the semi-quantitative riffle and qualitative multi-habitat samples were identified to the lowest determinable taxonomic level, typically genus and species, and counted for abundance. This data was then used to calculate the Kentucky macroinvertebrate bioassessment index (MBI). The MBI is a multi-metric index computed by averaging the scores of six percentile-based component metrics including total taxa richness (MACRO RICH), Ephemeroptera, Plectoptera and Trichoptera richness (EPT RICH), %EPT, a modified Hilsenhoff biotic index (mHBI), % Chironomids and Oligochaetes (%CO), and % Clinger (%CLING) (KDOW 2002). Only the semi-quantitative riffle sample was used to quantify the %EPT, %CO, %CLING, and mHBI. MACRO RICH and EPT RICH were determined by summing all taxa found in both the semi-quantitative riffle sample and the qualitative multi-habitat sample.

Fish were collected at each site from September 16 to September 30, 2005. Fish collections were completed using a combination of seining and electrofishing at each site using standard protocols (KDOW 2002). Fish were identified to species in the field and enumerated to calculate the Kentucky index of biotic integrity (IBI). The IBI was calculated as the average of six percentile-based metric scores including native species richness (NAT RICH), darter, madtom, sculpin richness (DMS RICH), intolerant species richness (INT RICH), simple lithophilic spawning richness (SLS RICH), %Insectivorous (%INSECTIV), and %Tolerant individuals (%TOL) (KDOW 2002).

In/Near-Stream Environmental Characteristics

Forty-one in/near-stream environmental variables were extracted, or calculated, from the data in the LTMN database as possible in/near-stream environmental links for path analyses. These variables were grouped into five main variable classes including hydrologic, geomorphic/riparian, water chemistry, point source, and in-stream habitat variables (see Table 1 for description of variables used in path analysis; other variables not used in path analysis are described in Appendix I). Hydrologic variables were derived from data extracted from the USGS stream flow data for the 24 LTMN sites that are currently monitored for stream flow. Riparian/geomorphic variables and in-stream habitat variables were primarily collected as part of the stream physical habitat assessment during macroinvertebrate sampling. These variables were quantified following standard habitat assessment methods for Kentucky (KDOW 2002). Water chemistry variables were determined from quarterly field sampling during baseflow completed by the LMSD in 2006. The point source variables were derived from GIS data provided by the LMSD regarding municipal wastewater effluents within the LMA (i.e. waste water treatment plants, sewer overflows, etc.), and complemented by Kentucky Pollutant Discharge Elimination System (KPDES) data (KDOW 2009). The KPDES data was used to identify point sources located outside of the LMA, and was also used to identify point sources within the LMA that were not directly connected to LMSD facilities. This data was used to determine the density of point sources of pollution within the catchment (# / km^2) and the proportion of discharge at each site that is represented by effluent discharge.

Statistical Analysis

First, linear regressions were completed to assess the indirect effects of urban intensity, as measured by % ISA, on each biological variable, and compare the responses of each biotic integrity metric to the % ISA gradient. The DBI, MBI, IBI, and each component metric used in their computation was used as the dependent variable in linear regressions with catchment % ISA to determine the direction of influence (i.e. sign of regression line slope) and the strength of each relationship (i.e. r^2). Variables were transformed, as needed, to meet assumptions of normality and homogeneity of residuals. Additionally, regressions were screened for outliers, which were subsequently removed from the analysis.

Next, we created a theoretical model, based on available data, to explain how urban intensity affects in/near-stream environmental variables, which ultimately affect biotic assemblages (Fig. 3). This model included seven compartments in three main groups. The first group is the LUC stimulus which is represented by urban intensity in the model. The second group contains all of the in/near-stream environmental variable compartments that are affected by changes in urban intensity (i.e. geomorphology/riparian, hydrology, point sources of pollution, in-stream habitat, and water chemistry). Finally, the response variable, biotic integrity, is the final compartment of our theoretical model, and represents the response of the biotic assemblages to the in/near-stream disturbances associated with increasing urban intensity within the catchment. The compartments in the model were linked (i.e. connected with single-headed arrows) to depict the how compartments within the model theoretically interact and affect each other. The model was constructed based on several criteria. First, the model had to assess the direct effects of the in/near-stream environmental compartments on the biotic integrity compartment. Consequently, no direct connection was created between urban intensity and the biotic response compartments in the model. Instead, this relationship is addressed in the linear regressions of each biotic index with % ISA previously described. In the model, urban intensity is directly conncected to four of the five in/near-stream environmental compartments. Urban intensity was not connected to the in-stream habitat compartment; because it was initially hypothesized that the majority of the impact that urban intensity has on in-stream habitat is transferred indirectly through changes in the hydrology and geomorphic/riparian compartments, which are directly connected to the in-stream habitat compartment. We also expected that two compartments, point sources and urban intensity (i.e. non-point source runoff from % ISA), would affect the water chemistry compartment in the model. Finally, all of the in/near-stream environmental variable compartments were linked to the biotic integrity compartment, because all of these compartments were thought to directly affect biotic integrity in some way.

Prior to path analysis, the in/near-stream environmental variable dataset was reduced based on several criteria. First, all variables were screened for normality, and variables that did not approximate a normal distribution, or could not be transformed to meet this assumption were excluded from further analysis. Next, linear regressions were used to exclude all variables that were strongly related ($r^2 > 0.30$) to total catchment area. Differences in stream size were a confounding variable in this analysis, and this variable reduction step was used to reduce the effect of this confounding factor. Next, linear regressions were used to reduce the in/near-stream environmental variable dataset to only include variables that were significantly related ($p < 0.025$) to one of the other variables that it is directly related to in the proposed theoretical path model (i.e. connected by a single-headed arrow in Fig. 3). For example, for a variable in the in-stream habitat compartment dataset to be included in the analysis it has to be significantly related ($p < 0.025$) to a hydrologic, geomorphic/riparian, or biotic integrity variable (Fig. 3). Finally, variables in each element that meet the first three criteria were further reduced using Pearson product-moment correlations to remove highly correlated variables from each compartment. This variable reduction process reduced the in/near-stream environmental variable dataset from 41 variables to 15 variables including four geomorphic / riparian, two hydrologic, two point source, four in-stream habitat, and three water chemistry variables (Table 1). These 15 variables, along with % ISA and the 21 biotic indices, were used in path analysis.

Finally, exploratory path analysis was used to determine the pathways leading from changes in urban intensity (i.e. % ISA) through the in/near-stream environmental compartments to ultimately affect biotic assemblage metrics. Path analysis was completed using AMOS 17.0 (Arbuckle 2009), and was guided by the results of the bivariate linear regressions and correlations completed in the data reduction step. Initially, a path model was created for each biotic assemblage metric included in our analysis (21 total models including one for DBI, MBI, IBI, and all component metrics) that included all the links and the basic structure of our initial hypothesized model (Fig. 3). Next, constraints were placed on the model to remove insignificant path coefficients (PC) or links between two variables in the model by assessing the critical ratios and associated p-values for each PC. This step was completed to increase parsimony within the constructed model without sacrificing model fit to the collected sample data. Final models were evaluated based on several criteria to determine 'acceptance' of a model. First, the model had to conceptually adhere to the current understanding of stream response to urbanization. Second, the model had to explain a significant amount of variation in the biotic assemblage metric ($r^2 > 0.40$). Third the model had to fit the sample data based on the chi-square minimum discrepancy statistic ($p > 0.05$ indicates significant fit to sample data). The root-mean-square error of approximation (RMSEA; RMSEA < 0.05 indicates significant fit to sample data) and pclose, which tests the null hypothesis that the population RMSEA is no greater than 0.05 were used along with the normalized fit index (NFI; NFI > 0.90 indicates significant fit to sample data) as complementary fit indices. Finally, the model had to maximize parsimony, while not sacrificing overall fit to the sample data as measured by the chi-square minimum discrepancy test and the complementary fit indices. Only models that meet all of these selection requirements are reported hereafter.

Results

Indirect Effects of % ISA on Biological Integrity

Catchment % ISA ranged from 0.1 – 37.8% at the 28 study sites (Table 2). One diatom, six macroinvertebrate, and four fish assemblage metrics were significantly related to % ISA (Fig. 4). The DBI (mean = 46.0; range = 36.5 – 52.1) was the only diatom metric that was significantly related to % ISA ($r^2 = 0.116$; $p = 0.046$), but the CYMB RICH metric was marginally significant ($r^2 = 0.105$; $p = 0.055$). The other five diatom assemblage metrics showed no statistically significant relationships with % ISA and in one case (H') the reponse to % ISA observed in the metric was counterintuitive to what would be predicted by ecological disturbance theory.

The macroinvertebrate assemblage exhibited the strongest responses to % ISA ($p < 0.001$ for six of seven metrics) (Fig. 4). The MBI exhibited a stronger response ($r^2 = 0.663$; $p < 0.001$) than both the DBI ($r^2 = 0.116$; $p = 0.046$) and IBI ($r^2 = 0.218$; $p = 0.007$). Additionally, all of the MBI component metrics responded predictably to the % ISA gradient with the mHBI ($r^2 = 0.459$; $p < 0.001$) and %CO ($r^2 = 0.377$; $p = 0.001$) metrics positively related to % ISA and the other metrics negatively related to % ISA. Even the %CLING metric, which was not statistically significant ($r^2 = 0.058$; $p = 0.116$), exhibited the expected negative trend to the % ISA gradient (Fig. 4). EPT RICH exhibited the strongest relationship with % ISA of any macroinvertebrate metric ($r^2 = 0.734$; $p < 0.001$), which was also the strongest relationship observed for all three assemblages.

The overall IBI was negatively and significantly related to the % ISA gradient ($r^2 = 0.218$, $p= 0.007$). The NAT RICH ($r^2 = 0.637$; $p < 0.001$), DMS RICH ($r^2 = 0.418$; $p < 0.001$), and SL RICH ($r^2 = 0.457$; $p < 0.001$) component metrics were also significantly related to % ISA. The INT RICH ($r^2 = 0.086$; $p = 0.101$) and % INSECTIV metrics ($r^2 = 0.079$; $p = 0.089$) were marginally related to the % ISA gradient, and the %TOL metric was not statistically related to the % ISA gradient ($r^2 = 0.000$; $p = 0.387$). Finally, all of the fish assemblage metrics responded predictably to the % ISA gradient except for %INSECTIV, which increased along the % ISA, but should theoretically decrease with higher disturbance levels (i.e. % ISA).

Path Analysis

Twenty-five variables were included in significant path analysis models (Table 2). Elevenof the 15 variables in the reduced in/near-stream environmental variable dataset were used in at least one path model. Significant path models were created for two diatom (Fig. 5), six macroinvertebrate (Fig. 6), and five fish metrics (Fig. 7). All path coefficients leading from % ISA to in/near-stream environmental variables in all models were statistically significant ($p < 0.05$). However, two paths proposed between in/near-stream environmental compartments in our initial model (Fig. 3) were not supported by the sample data. First, the proposed path leading from the point sources compartment to the water chemistry compartment in our initial model was not significant in any of the 12 constructed path models, and, as a result, was constrained to equal zero in all path models. While there was a correlation between the point source variables (PSDEN and %EFFL) and the water chemistry variables (TN and Cl^-) (Table 3), the effect of point sources on water chemistry were masked by the strong correlation between % ISA and the water chemistry variables (Table 3). Therefore, after accounting for the effects of % ISA on water chemistry, the unique effects of point sources (i.e. not including covariation shared with % ISA) become statistically insignificant. Additionally, the link between the hydrology compartment and the habitat compartment was only significant in one of the 12 constructed path models (Fig. 5a). This also happens to be the only model where TMP MN was used as the habitat variable, which was positively related to the hydrology variable, PK/MN FLOW ($r = 0.352$; Table 3). Other path models included EMBED or SUBH' as the habitat variable, which were not significantly related to the hydrology variable in these models, despite both being marginally correlated to PK/MN FLOW (Table 3). This effect could not be separated from the strong effect of %ALT on EMBED and SUBH' in these path models because of the high correlation between the %ALT and PK/MN FLOW variables ($r = 0.491$; Table 3).

The %NNS and DBI metrics were the only two significant path models created for the diatom assemblage. The geomorphic/riparian and point source model compartments were the strongest predictors of %NNS and the DBI, and were significant in both models (Fig. 5). The strongest and most parsimonious %NNS model explained 45% of observed variation in %NNS. This model included three in/near-stream predictor variables including RIPWID (PC = -0.53, $p < 0.01$), PSDEN (PC = 0.41, $p = 0.01$), and PK/MN FLOW (PC = -0.30, $p = 0.08$) that affect %NNS (Fig. 5A). The habitat compartment (TMP MN) and water chemistry compartment (TN) were both positively correlated to %NNS (Table 3), but these effects were not significant in the path model after accounting for the stronger effects of PSDEN, RIPWID, and PK/MN FLOW. Consequently, the effects of TMP MN and TN on %NNS were constrained to equal zero in the model (Fig. 5A). The constructed DBI path model explained 56% of variation observed in the DBI (Fig. 5B). In this model, TN (PC = -0.45, $p < 0.01$), %EFFL (PC = -0.31, $p = 0.02$), and %ALT (PC = -0.27, $p = 0.06$) were all negatively correlated to the DBI. Additionally, EMBED ($r = -0.359$) and PK/MN FLOW ($r = -0.365$) were negatively correlated to the DBI (Table 3), but the effects of these variables in the path model were insignificant after accounting for the stronger effects of TN (r = -0.57), %EFFL (r = -0.47), and %ALT (r = -0.52). Therefore, the PCs leading from EMBED, and PK/MN FLOW were constrained to equal zero.

Six significant path models were created from the seven macroinvertebrate assemblage metrics (Fig. 6). The geomorphic/riparian (5 models), water chemistry (5 models), and hydrology (3 models) model compartments were the strongest predictors of macroinvertebrate assemblage metrics. Additionally, the models explaining macroinvertebrate biotic indices were very similar, and only the water chemistry and in-stream habitat compartments varied in these models. In the water chemistry compartment the Cl^- and TN variables were each used in three models, while, in the in-stream habitat compartment, the EMBED variable was used in five models and the SUBH' variable was used in the other model. The EPT RICH model was the strongest macroinvertebrate model (Fig. 6A), and also the strongest model of all three biotic assemblages explaining 77% of variation in EPT RICH. This model included three in/near-stream environmental variables as predictors of EPT RICH including Cl^- (PC = -0.43, $p < 0.01$), %ALT (PC = 0.35, $p < 0.01$), and PK/MN FLOW (PC = -0.32, $p < 0.01$). The EMBED (r = -0.580) and PSDEN (r = -0.540) variables were highly correlated to EPT RICH, but were statistically insignificant after accounting for the stronger affects of Cl^- (r = -0.73), %ALT (r = -0.68) and PK/MN FLOW (r = -0.68), and were consequently constrained to equal zero in this model. The %EPT model (Fig. 6B) was the most complex model and included four in/near-stream environmental variables including EMBED (PC = -0.29, p = 0.03), PK/MN FLOW (PC = -0.43, $p < 0.01$), PSDEN (PC = 0.34, p = 0.02), and Cl^- (PC = -0.45, $p < 0.01$). The %ALT path coefficient leading to %EPT was insignificant in the model and constrained to equal zero, but was highly correlated to %EPT (r = -0.50). The %CO (Fig. 6C) and mHBI (Fig. 6D) path models were very similar and included both the %ALT (%CO PC = 0.48, $p < 0.01$; mHBI PC = 0.45, $p < 0.01$) and TN (%CO PC = 0.38, $p < 0.01$; mHBI PC = 0.40, $p < 0.01$) variables as significant predictors of these metrics. The other path coefficients between in/near-stream environmental variables and these two biotic metrics, %CO and mHBI, were constrained to equal zero. However, the PSDEN, EMBED, and PK/MN flow variables were highly correlated to %CO and the mHBI (Table 4) The MACRO RICH model explained 43% of variation in this metric, and included %ALT (PC = -0.48, $p < 0.01$), SUBH' (PC = -0.36, p = 0.03), and Cl^- (PC = -0.35, p = 0.03) as significant predictors. The PK/MN FLOW (r = -0.39) and PSDEN (r = -0.38) variables were negatively correlated to MACRO RICH, but these effects were statistically insignificant after accounting for the effects of %ALT, SUBH', and Cl^-. The MBI path model (Fig. 6E) included %ALT (PC = -0.56, $p < 0.01$) and PK/MN FLOW (PC = -0.26, p = 0.02) as significant predictors of the overall MBI. Despite being strongly correlated to the MBI (Table 4), the TN (r = -0.547), PSDEN (r = -0.314), and EMBED (r = -0.576) path coefficients were not statistically related to the MBI in the path model and were consequently set to equal zero.

Five significant path models were created from the seven fish assemblage metrics. Significant fish path models did not explain as much variation in the biotic index response metrics (Fig. 7) as was observed for the macroinvertebrate metrics (Fig. 6). The hydrology (5 models) and point source (4 models) model compartments were the strongest predictors of fish assemblage structure. The %ALT, PSDEN, and EMBED variables were included in all fish models. However, in the hydrology compartment, TQMN was used in two models, while PK/MN FLOW was used in three models. Additionally, TN was used as the water chemistry variable in four fish metric models, while Cl^- was used in one model. The NAT RICH model (Fig. 7A) included PK/MN FLOW (PC = -0.47, $p < 0.01$) and PSDEN (PC = -0.31, p = 0.05) as significant predictor variables, with the TN, %ALT, and EMBED path coefficients leading to

NAT RICH being constrained to equal zero, despite high negative correlations with NAT RICH (Table 4). The DMS RICH model (Fig. 7B) included PSDEN (PC = -0.27, p = 0.08), TQMN (PC = 0.34, p = 0.03), and EMBED (PC = -0.34, p = 0.02) as significant predictors. As with NAT RICH, the SLS RICH model (Fig. 7C) used PK/MN FLOW (PC = -0.38, p = 0.03) and PSDEN (PC = -0.36, p = 0.03) as significant predictor variables. The %TOL (Fig. 7D) metric used PK/MN FLOW (PC = 0.71, p < 0.01) and TN (PC = -0.37, p = 0.02) as significant predictors variables. Finally, the IBI (Fig 6E) used the TQMN (PC = 0.50, p < 0.01) and PSDEN (PC = -0.38, p = 0.01) variables as significant predictors.

All path models presented in this analysis significantly fit the sample data collected in this study based on the Chi-square discrepancy test (Table 5). In support, the RMSEA was < 0.05 for all presented models, and the NFI was close to, or greater than, 0.900 for all models. The DBI (chi-square = 11.055; df = 13; p = 0.606) was the diatom assemblage model with the highest fit to the sample data. The EPT RICH (chi-square = 6.705; df = 13; p = 0.917) and %CO (chi-square = 6.412; df = 14; p = 0.955) models exhibited very close fit to the sample data (pclose and NFI > 0.900 for both models). Similarly, two fish assemblage metrics, %Tol (chi-square = 6.448; df = 14; p = 0.954) and the IBI (chi-square = 7.515; df = 14; p = 0.913), exhibited very strong fit to the sample data (pclose and NFI > 0.900 for both models). Additionally, the %NNS (Fig. 5A) and the %EPT (Fig. 6B) were the most complex models with only 12 degrees of freedom. All other models were less complex (i.e. contained more constraints) and had either 13 or 14 degrees of freedom (Table 5).

Discussion

Indirect vs Direct Effects of Urbanization Gradient

Traditionally, analyses relating stream biotic assemblages to catchment LUC have followed two general methods. The first method is to relate stream biotic assemblages to LUC without accounting for in/near stream environmental variables (e.g. Moore and Palmer 2005, Goetz and Fiske 2008). The second method is to relate stream biotic assemblages to LUC and in/near stream environmental variables, but the analysis does not explicitly place the variables into an interconnected hierarchical framework (e.g. Jones and Clark 1987, Morse et al. 2003, Roy et al. 2003). All analyses following these two analytical frameworks reveal critical information about the relationships between LUC and stream biotic assemblages, but they do not accurately describe the hierarchical and mechanistic pathways through which disturbance from LUC change is propagated in these systems.

More recent work, including this study, has been focused on establishing mechanistic links between LUC change, in/near stream environmental variables, and biotic assemblages. For example, in a study of agriculturally impacted Midwestern USA streams, Hutchens et al. (2009) completed an analysis by which they first related stream macroinvertebrates to in/near stream environmental variables, which were then mechanistically linked to catchment-scale variables. Furthermore, other attributes of stream ecosystems besides biological assemblage structure are also controlled by hierarchical pathways, and could be placed in a more representative context in this type of analysis. For example, Lewis and Grimm (2007) used path analysis to model the hierarchical catchment and climatological controls on nitrogen export in arid urban streams in Arizona (USA). From this analysis, the authors were able to determine that export of nitrogen from these streams could be reduced through management of the catchment landscape (e.g. reduce effects of catchment % ISA), despite strong climatic controls on nitrogen export. Such analyses better represent the hierarchical and interconnected nature of the multiple interacting variables and spatial scales that ultimately affect urban stream ecosystems.

The three biotic assemblages assessed in this study all varied in their response to % ISA, an integrative catchment-scale disturbance predictor variable. The macroinvertebrate assemblage showed the strongest relationship to % ISA with six of seven metrics significantly related to % ISA, while only one diatom assemblage metric was statistically related to % ISA (Fig. 1). Five of the seven fish metrics were significantly related to % ISA, but these relationships (range of significant r^2 values = 0.218 – 0.637) were not as strong as those reported for macroinvertebrates (range of significant r^2 values = 0.377 – 0.734). While studies encompassing all three of these assemblages are uncommon, several studies support our findings of the relative response of these assemblages to % ISA and urbanization. For example, Brown *et al.* (2009) found macroinvertebrate assemblages to have the strongest, and most consistent, response to catchment-scale urban intensity in a study of nine metropolitan areas across the conterminous United States. Similar to our results, they also found few clear relationships between diatom assemblages and the catchment-scale urban intensity gradient used in their study. Similarly, Sonneman *et al.* (2001) concluded that macroinvertebrate assemblages were better integrators of catchment-scale disturbances than benthic diatom assemblages. These results, and those of this study, suggest macroinvertebrate assemblages are the most consistent responders to catchment-scale urbanization.

The incorporation of in/near-stream environmental variables into this analysis greatly impacted the response of each biotic assemblage. First, despite the lack of significance when relating diatom assemblage metrics to % ISA, strong diatom path models were created for the %NNS index (r^2 = 0.45) and the DBI (r^2 = 0.56). Additionally, these models had high levels of fit to the collected sample data (Table 5). In contrast, only the DBI was significantly related to % ISA (Fig. 4), and this relationship was relatively weak (r^2 = 0.116; p = 0.046). This result indicates that diatom assemblages could be better predictors of local-scale conditions (*i.e.* habitat, water chemistry, light levels, *etc.*) than catchment-scale disturbance indicators (*i.e.* % ISA). This conclusion is supported by other studies relating diatom communities to catchment-scale LUC change. For example, despite the realization that macroinvertebrates were better integrators of catchment-scale disturbance, Sonnemon *et al.* (2001) concluded that diatom communities were more sensitive to in-stream nutrient enrichment, which complicated the interpretation of this assemblage's response to changes in urban intensity. Our path models provide further support for this conclusion, as both significant path models involving diatoms included variables associated with nutrient enrichment (i.e. TN, %EFFL, and PSDEN) as strong predictors of diatom metrics. Additionally, Gardiner *et al.* (2009), found light availability to be the primary predictor of diatom assemblages in relation to changing LUC in the southern Appalachians (USA). Our path models also support this conclusion as riparian vegetation width, a primary determinant of light availability in this study area, was also identified as the strongest predictor of the %NNS path model (Fig. 5A), and was also correlated to the DBI (r = 0.419; Table 3) despite not being used in the DBI path analysis model. Additionally, two of the four variables found to be significant in diatom path models, RIPWID and %EFFL, were only moderately related to % ISA in this analysis ($|r| < 0.400$ for both RIPWID and %EFFL comparisons with % ISA; Table 3). This indicates that the diatom assemblage is affected more by local-scale in/near stream environmental characteristics that might not necessarily be correlated with the catchment-scale urbanization occurring in these catchments.

The response of macroinvertebrate and fish metrics in path models was similar to the response observed in the regressions with % ISA (Fig. 4) based on the amount of variation explained in the biotic assemblage metrics using both analysis types. Six significant path models were constructed from the macroinvertebrate metrics (Fig. 6) and five models were constructed to the fish metrics (Fig. 7). Generally, the macroinvertebrate responses (range of r^2 values = 0.51 – 0.77) were stronger than the fish responses (range of r^2 values = 0.40 – 0.51) in path analysis. The strongest in/near-stream environmental predictors of macroinvertebrate assemblages were the geomorphic/riparian (%ALT) and water chemistry (both TN and Cl^-) compartments. In contrast, the strongest in/near-stream environmental predictor of fish assemblages was hydrology (either PK/MN FLOW or TQMN depending on the model; Fig. 7). Additionally, the water chemistry and point source compartments were secondarily selected in path models explaining fish metric responses.

Fish and macroinvertebrates are the most studied biotic assemblages in urban streams (Fig. 1). Many studies have analyzed both macroinvertebrate and fish assemblages in the same study and found that they differentially respond to environmental stressors. For example, Walters *et al.* (2009) found that macroinvertebrates were most closely linked to water chemistry and substrate composition while fish were more related to turbidity and substrate embededness. This study did not include hydrologic variables, which were found in our study to be the best predictors of fish assemblages. However, in another study of fish response to urbanization in western Georgia (USA), Helms *et al.* (2009) identified hydrology and physical/chemical water chemistry as the primary determinants of fish assemblage structure.

Management Implications

The results of this analysis are the first published results that directly imply causation as to how increased urbanization can affect stream biotic assemblages. Consequently, these results provide useful information for the management of urban streams in the LMA, as well as implications for management of urban streams in other urban metropolitan centers, particularly those within similar ecoregional and climatological regimes as this study area. Based on regressions of biotic metrics with % ISA, it appeared that the macroinvertebrate assemblage was far superior in its response to % ISA compared to fish and diatoms. However, based on path analysis, all three biotic assemblages (diatoms, macroinvertebrates, and fish) exhibited significant responses to urbanization in the LMA. Also, based on the relative strengths of disturbance paths within each biological assemblage, the three assemblages provided complementary information to each other. For example, the diatom assemblage was most affected by the geomorphic/riparian and point source compartments of the model ($P < 0.05$ for both models), and secondarily by the hydrology ($P < 0.05$ for the %NNS model) and water chemistry ($P < 0.05$ for DBI model) compartments. In contrast, the strongest disturbance path within the fish metrics was the hydrology path ($p < 0.05$ for all models), while the strongest disturbance path in the macroinvertebrate analysis was the water chemistry and geomorphic/riparian compartments ($p < 0.05$ for 5 models). Therefore, using all three assemblages allows for a better assessment of the multiple environmental stressors that are commonly observed in highly urbanized streams.

Multiple studies have found relationships between LUC quantified at multiple spatial scales and stream biotic assemblages (Burcher *et al.* 2007, Schiff and Benoit 2007, Stephenson and Morin 2008). In a preliminary analysis of our data, however, the only LUC variable that we quantified that resulted in significant path models that were comparable to those created by % ISA, based on the coefficient of determination for the final step in the model and the statistical measures of fit, was the total amount of urban LUC in the catchment, which is more or less equivalent to % ISA. This finding is most likely attributed to the overwhelming effect of urban LUC at the catchment scale constraining the effects of other LUC classes (e.g. Agriculture) and local-scale LUC (e.g. LUC patterns close to the stream or sample site) in our study area. Since urbanization, the primary source of disturbance within this study area, is a catchment-scale phenomenon, it is logical that catchment-scale LUC, particularly urban LUC, would be the best predictor of in-stream macroinvertebrate communities (Allan 2004). Because of this realization, urban stream management and restoration practices only focusing on local reach scale practices (i.e. riparian plantings, etc.) will have minimal or no effect on most aspects of the stream ecosystem because they do not address the ultimate source of the disturbance: catchment-scale urbanization. However, there is evidence from this study, and others (e.g. Brown *et al*. 2009; Sonnemon *et al* 2001), that some aspects of stream ecosystems (i.e. diatom assemblage structure in this study) might respond to local reach-scale restoration and management practices. However, despite having a few ecological parameters, including diatom assemblage structure, that respond to local reach-scale restoration and management, a catchment-scale management plan would maximize restoration and management efforts in highly urban areas (Bernhardt and Palmer 2007). However, such catchment-scale management plans would be difficult to create and enforce, particularly in urban areas where property ownership is highly dissected, which consequently, creates a large number of stakeholders within these catchments.

In this study we have created quantitative and empirically-based models to describe the pathways leading to reduced biotic integrity in urban streams. However, urban streams are commonly affected by multiple, often highly correlated, and interacting stressors. Therefore, theoretically-based models describing how the multiple stressors in urban streams interact and affect these streams are very complex (Wenger *et al.* 2009). As a result, it is logistically and applicationally impossible to include all these stressors in any type of modeling procedure with high accuracy and precision, particularly since most modeling procedures strive to achieve high levels of parsimony. Consequently, within the path models constructed in this study, it is important to understand that the variables that are included in each compartment of the model have not been definitively identified to affect the biotic assemblages by their inclusion in the model. Instead, the variable used in each compartment serves as a proxy or indicator that represents the changes that are occurring in that compartment. For example, in the %EPT model (Fig. 6B), Cl^- is identified as the strongest predictor of the %EPT metric. This does not mean that increasing Cl^- concentrations in the stream water are directly reducing the %EPT metric. Instead, this should be thought of as the changes in water chemistry associated with changes in Cl^- are a strong predictor of %EPT. As in many urban stream studies, numerous other water chemistry components are highly correlated with Cl^- (Morgan II *et al.* 2007, Appendix IIIE), each of which could be affecting the %EPT metric. Therefore, management to remove Cl^- from the water column would not necessarily increase %EPT, because there are numerous other stressors that are highly associated and correlated to Cl^-. This same explanation is also true for all other compartments within the path diagrams. As a result, management should be focused on broad-scale initiatives that focus on reducing the effects of entire compartments found to be important in structuring each biotic response instead of focusing on individual variables that are found within each compartment.

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Literature Cited

Allan, J.D. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual Review of Ecology Evolution, and Systematics 35: 257-284.

Arbuckle, J.L. 2009. Amos 17.0 User's Guide. SPSS, Inc. Chicago, Illinois, USA.

Bernhardt, W.S. and M.A. Palmer. 2007. Restoring streams in an urbanizing world. Freshwater Biology 52: 738-751.

Booth, D.B. 1990. Stream-channel incision following drainage basin urbanization. Water Resources Bulletin 26: 407-417.

Brown, L.R., T.F. Cuffney, J.F. Cles, F. Fitzpatrick, G. McMahon, J. Steuer, A.H. Bell, and J.T. May. 2009. Urban streams across the USA: lessons learned from studies in 9 metropolitan areas. Journal of the North American Benthological Society 28: 1051-1069.

Burcher, C.L., H.M. Vallett, and E.F. Benfield. 2007. The land-cover cascade: relationships coupling land and water. Ecology 88: 228-242.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8: 559-568.

Cohen, J.E. 2003. Human population: The next half century. Science 302: 1172-1175.

Duda, A.M., D.R. Lenat, and D.L. Penrose. 1982. Water quality in urban streams: what we can expect. Journal of the Water Pollution Control Federation 54: 1139 – 1147.

Folke, C., A. Jansson, J. Larsson, and R. Constanza. 1997. Ecosystem appropriation by cities. Ambio 26: 167-175.

Gardiner, E.P., A.B. Sutherland, R.J. Bixby, M.C. Scott, J.L. Meyer, G.S. Helfman, E.F. Benfield, C.M. Pringle, P.V. Bolstad, and David N. Wear. 2009. Linking stream and landscape trajectories in the southern Appalachians. Environmental Monitoring and Assessment 156: 17-36.

Goetz, S. and G. Fiske. 2008. Linking the diversity and abundance of stream biota to landscapes in the mid-Atlantic USA. Remote Sensing of the Environment 112: 4075-4085.

Helms, B.S., J.E. Schooner, and J.W. Feminella. 2009. Assessing influences of hydrology, physicochemistry, and habitat on stream fish assemblages across a changing landscape. Journal of the American Water Resources Associtio 45: 157-169.

Homer, C., C. Huang, L. Yang, B. Wylie,M. Coan. 2004. Development of a 2001 national land-cover database for the United States. Photogrammetric Engineering and Remote Sensing 70: 829-840

Hutchens Jr., J.J., J.A. Schuldt, C. Richards, L.B. Johnson, G.E. Host, and D.H. Breneman. 2009. Multi-scale mechanistic indicators of Midwestern USA stream macroinvertebrates. Ecological Indicators 9:1138-1150.

Jones, R.C. and C.C. Clark. 1987. Impact of watershed urbanization on stream insect communities. Water Resources Bulletin 23: 1047-1055.

Kentucky Division of Water (KDOW). 2002. Standard methods for assessing biological integrity of surface waters in Kentucky. Kentucky Dept. for Environmental Protection. Frankfort, KY.

Kentucky Division of Water (KDOW). 2009. Kentucky Division of Water - KPDES Permitted Facilities. Available at: http://kygeonet.ky.gov/geographicexplorer/document?id={03E8279D-56CD-443B-8617-CE7ED1DC91BB}&view=fullHtml. Accessed: December 9, 2009

Konrad, C.P., and D.B. Booth. 2005. Hydrologic changes in urban streams and their ecological significance. American Fisheries Society Symposium 47: 157-177.

Leopold, L.B. 1968. Hydrology for Urban Land Planning – A Guidebook on the Hydrological Effects of Urban Land Use. USGS Circular 554.

Lewis, D.B. and N.B. Grimm. 2007. Hierarchical regulation of nitrogen export from urban catchments: interactions of storms and landscapes. Ecological Applications 17: 2347-2364.

Moore, A.A. and M.A. Palmer. 2005. Invertebrate biodiversity in agricultural and urban headwater streams: implications for conservation and management. Ecological Applications 15: 1169-1177.

Morgan II, R.P., K.M. Kline, S.F. Cushman. 2007. Relationships among nutrients, chloride, and biological indices in urban Maryland streams. Urban Ecosystems 10: 153-166.

Morse, C.C., A.D. Huryn, and C.Cronan. 2003. Impervious surface area as a predictor of the effects of urbanization on stream insect communities in Maine, U.S.A. Environmental Monitoring and Assessment 89: 95-127.

National Climatic Data Center (NCDC). 2006. Climatological Annual Summary - Kentucky 2005. ISSN# 0145-0433. Ashville, NC.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77: 118-125.

Paul, M.J. and J.L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32: 333-365.

Roy, A.H., A.D. Rosemond, M.J. Paul, D.S. Leigh, and J.B. Wallace. 2003. Stream macroinvertebrate response to watershed urbanization (Georgia, U.S.A). Freshwater Biology 48: 329-346.

Scheuler, T. 1994. The importance of imperviousness. Watershed protection techniques 1: 100 - 111.

Scheuler, T.R., L. Fraley-McNeal, and K. Cappiella. 2009. Is impervious cover still important? Review of Recent Research. Journal of Hydrologic Engineering 14: 309 – 315.

Schiff, R. and G. Benoit. 2007. Effects of impervious cover at multiple spatial scales on coastal watershed streams. Journal of the American Water Resources Association 43: 712-730.

Shipley, B. 2000. Cause and correlation in biology. A user's guide to path analysis, structural equations, and causal inference. Cambridge University Press, Cambridge, UK.

Sonneman, J.A., C.J. Walsh, P.F. Breen, and A.K. Sharpe. 2001. Effects of urbanization on streams of the Melbourne region, Victoria. II. Benthic diatom communities. Freshwater Biology 46: 553-565.

Stephenson, J.M. and A. Morin. 2008. Covariation of stream community structure and biomass of algae, invertebrates and fish with forest cover at multiple spatial scales. Freshwater Biology doi: 10.1111/j.1365-2427.2008.02142.x.

United States Census Bureau Population Division. 2009b. Population Estimates: Metropolitan and Micropolitan Statistical Area Estimates. Available at: http://www.census.gov/popest/metro/CBSA-est2008-annual.html Accessed: October 13, 2009.

United States Geological Survey (USGS). 2007. Statewide Kentucky Single Zone 30ft DEM (FGDC) / DEM_10_METER (ISO). Available at: http://kygeonet.ky.gov/geographicexplorer/document?id={4E11424B-4D76-4CB4-9F37-736C01FF3488}&view=fullHtml. Accessed: December 20, 2009.

Urban, M.A. and B.L. Rhoads. 2003. Catastrophic human-induced change in stream-channel planform and geometry in an agricultural watershed, Illinois, USA. Annals of the Association of American Geographers. 93: 783-796.

Walton, B.M., M. Salling, J.Wyles, and J.Wolin. 2007. Biological integrity in urban streams: toward resolving multiple dimensions of urbanization. Landscape and Urban Planning 79: 110-123.

Walsh, C.J., K.A. Waller, J.Gehling, and R.M. Nally. 2007. Riverine macroinvertebrate assemblages are degraded more by watershed urbanization than by riparian deforestation. Freshwater Biology 52: 574-587.

Walters, D.M., A.H. Roy, and D.S. Leigh. 2009. Environmental indicators of macroinvertebrate and fish assemblage integrity in urbanizing watersheds. Ecological Indicators 9: 1222-1233.

Wenger, S.J., A.H. Roy, C.R. Jackson, E.S. Bernhardt, T.L. Carter, S.Filoso, C.A. Gibson, W.C. Hession, S.S. Kaushal, E. Marti, J.L. Meyer,M.A. Palmer, M.J. Paul, A.H. Purcell, A. Ramirez, A.D. Rosemond, K.A. Schofield, E.B. Sudduth, and C.J. Walsh. 2009. Twenty-six key research questions in urban stream ecology: an assessment of the state of the science. Journal of the North American Benthological Society 28: 1080-1098.

Table 1. Description of in/near-stream environmental variables in the reduced dataset that was used in path analysis. The # models column represents the number of significant path models that each variable was used (12 total models). * = variable is unitless.

Variable	# models	Description
Geo. / Rip.		
%ALT (%)	12	% of channel that is channelized or dredged in the sample reach.
RIPWID (m)	1	Mean width of riparian vegetation zone at the sample site. Values greater than 20m were recorded as 20m.
POOL (%)	0	% of reach consisting of pool habitat.
FLOSTAT (%)	0	% of channel surface area submerged in the sample reach.
Hydrologic		
PK/MN FLOW*	11	Maximum annual peak flow divided by annual mean flow.
TQMN (#)	2	Number of days that daily discharge exceeded annual mean daily discharge in 2005.
Point Sources		
PSDEN (# / km^2)	12	# of point source discharges per km^2 in the watershed.
%EFFL (%)	1	% of annual site discharge represented by effluent discharge.
Habitat Variables		
EMBED (%)	11	% Embededness (% of fine sediments surrounding larger substrate).
GRAVL (%)	0	% of benthic substrate coverage represented by gravel. (particle diameter = 2 – 64mm).
SUBH’	1	Shannon-diversity index using the % of substrate classes at each site as input (i.e. bedrock, boulder, cobble, etc.).
TMPMN (°C)	1	Mean daily temperature for the 2005 calendar year.
Water Chemistry		
Cl$^-$ (mg/l)	4	Mean of seasonal chloride samples at baseflow in 2006 (n=4).
TN (mg/l)	9	Mean of seasonal total kheldahl nitrogen samples at baseflow (n=4).
TP (mg/l)	0	Mean of seasonal total phosphorus samples at baseflow (n=4).

Table 2. Descriptive statistics for variables (units) found to be significant in at least one path model.

Variable	Min.	25th %	Median	75th %	Max.	Mean	S.D.
Land Use							
% ISA (%)	0.1	7.4	16.8	24.1	37.8	15.9	11.1
Geo. / Rip.							
%ALT	0.0	10.0	35.0	42.5	100.0	38.2	70.6
RIPWID (m)	0.0	4.0	6.5	11.5	20.0	8.1	5.8
Hydrology							
PK/MN FLOW*	2.3	24.3	49.2	84.6	968.2	115.1	207.9
TQMN	43.0	64.3	70.0	87.5	108.0	73.6	17.2
Point Sources							
PSDEN (#/km^2)	0.0	2.7	8.3	18.6	84.8	13.5	17.5
%EFFL (%)	0.0	0.1	2.4	6.9	72.0	9.8	17.7
Habitat							
EMBED (%)	5.0	12.5	27.5	45.0	85.0	31.8	77.8
SUBH’	0.0	0.8	0.9	1.2	1.4	0.9	0.3
TMPMN (°C)	13.7	14.3	14.7	15.8	16.3	14.9	0.8
Water Chemistry							
TN (mg/l)	0.5	0.7	0.8	0.9	1.3	0.8	0.2
Cl- (mg/l)	7.3	18.9	29.1	45.5	66.7	32.5	16.9
Biotic Indices							
%NNS	9.6	20.7	34.4	46.7	70.1	34.9	16.2
DBI	36.5	44.0	46.2	47.9	52.1	46.0	3.7
EPT RICH	1.0	3.5	6.5	12.5	17.0	7.7	5.3
%EPT	0.0	3.1	5.6	24.4	87.2	13.9	18.4
%CO	1.8	11.9	27.8	43.1	92.1	33.3	27.9
mHBI	3.7	5.9	6.5	7.4	8.9	6.6	1.2
MACRO RICH	27.0	35.5	39.5	48.0	65.0	41.3	9.3
MBI	12.9	34.6	44.2	52.7	70.0	42.7	16.0
NAT RICH	5.0	8.0	12.0	15.5	20.0	11.6	4.4
DMS RICH	0.0	0.0	2.0	3.0	7.0	1.9	1.8
SLS RICH	0.0	1.0	2.5	5.0	8.0	3.0	2.5
%TOL	3.4	28.7	45.9	65.1	98.0	48.6	24.3
IBI	5.5	32.0	44.8	53.7	81.0	43.1	17.4

Table 3. Pearson correlation matrix showing relationships between in/near-stream environmental variables used in path analysis. Numbers in lower left represent the Pearson correlation coefficient and the upper right portion of the matrix shows the Bonferoni-corrected p-values for each comparison in the matrix.

	%ALT	RIP WID	POOL	FLO STAT	PK/MN FLOW	TQMN	PSDEN	%EFFL	EMBED	SUBH'	GRAVL	TMP MN	Cl^-	TN
RIPWID	-0.54	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
POOL	-0.08	-0.05	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
FLO STAT	0.47	-0.37	0.25	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
PK/MN FLOW	0.49	-0.38	-0.09	0.13	1	-----	-----	-----	-----	-----	-----	-----	-----	-----
TQMN	-0.02	-0.02	-0.25	-0.33	0.03	1	-----	-----	-----	-----	-----	-----	-----	-----
PSDEN	0.44	-0.12	-0.36	0.24	0.33	-0.38	1	-----	-----	-----	-----	-----	-----	-----
%EFFL	0.34	-0.26	-0.25	0.18	0.53	0.03	0.30	1	-----	-----	-----	-----	-----	-----
EMBED	0.66	-0.50	0.00	0.23	0.33	-0.08	0.30	0.08	1	-----	-----	-----	-----	-----
SUBH'	-0.46	0.38	0.39	-0.12	-0.24	-0.02	-0.14	-0.20	-0.3	1	-----	-----	-----	-----
GRAVL	-0.31	0.06	0.36	0.01	-0.31	-0.18	-0.23	-0.35	-0.49	0.33	1	-----	-----	-----
TMPMN	0.49	-0.49	-0.04	0.35	0.35	-0.14	0.33	0.50	0.16	-0.16	0.07	1	-----	-----
Cl^-	0.41	-0.13	-0.23	0.15	0.48	-0.01	0.53	0.30	0.38	-0.28	-0.23	0.40	1	-----
TN	0.43	-0.28	-0.06	0.28	0.51	-0.57	0.34	0.37	0.39	-0.38	-0.24	0.20	0.28	1
TP	0.18	-0.08	-0.03	0.39	0.42	0.03	0.10	0.57	-0.11	0.06	-0.25	0.16	-0.19	0.20

Table 4. Pearson correlation coefficients between in/near-stream environmental variables (columns) and % ISA and biotic indices (Rows) used in path analysis.

	%ISA	%NNS	DBI	EPT RICH	%EPT	mHBI	%CO	MACRO RICH	MBI	NAT RICH	DMS RICH	SLS RICH	%TOL	IBI
%ALT	0.67	0.32	-0.52	-0.68	-0.50	0.62	0.65	-0.47	-0.72	-0.37	-0.38	-0.37	0.15	-0.23
RIPWIDTH	-0.39	-0.49	0.42	0.49	0.48	-0.58	-0.50	0.25	0.53	0.38	0.26	0.30	-0.26	0.04
POOL	-0.04	-0.03	0.14	0.09	-0.13	0.08	0.08	-0.08	-0.08	0.02	0.02	-0.12	0.15	0.01
FLOSTAT	0.39	0.52	-0.56	-0.29	-0.26	0.36	0.59	-0.22	-0.43	-0.17	0.01	-0.17	-0.24	-0.41
PK/MN FL.	0.64	0.15	-0.37	-0.68	-0.61	0.57	0.46	-0.39	-0.58	-0.54	-0.37	-0.49	0.52	0.05
TQMN	-0.45	-0.40	0.03	0.08	0.02	-0.26	-0.21	0.12	0.15	0.47	0.44	0.42	0.19	0.59
PSDEN	0.70	0.40	-0.29	-0.54	-0.13	0.29	0.24	-0.38	-0.31	-0.47	-0.48	-0.49	0.10	-0.57
%EFFL	0.38	0.28	-0.47	-0.36	-0.21	0.28	0.32	-0.21	-0.28	-0.24	0.03	-0.09	-0.04	-0.16
EMBED	0.53	0.21	-0.36	-0.58	-0.48	0.50	0.58	-0.41	-0.58	-0.44	-0.46	-0.41	0.14	-0.15
SUBH'	-0.28	-0.26	0.48	0.20	0.34	-0.39	-0.17	-0.05	0.26	0.36	0.37	0.33	-0.08	0.23
GRAVL	-0.22	0.05	0.16	0.26	0.22	-0.08	-0.26	0.11	0.13	0.17	0.20	0.13	0.11	0.10
TMPMN	0.53	0.22	-0.28	-0.55	-0.30	0.47	0.28	-0.49	-0.53	-0.25	-0.16	-0.29	0.00	-0.18
Cl^-	0.69	0.13	-0.19	-0.73	-0.59	0.49	0.29	-0.46	-0.57	-0.42	-0.32	-0.35	0.02	-0.24
TN	0.63	0.40	-0.57	-0.46	-0.45	0.60	0.59	-0.21	-0.55	-0.45	-0.39	-0.32	-0.04	-0.31
TP	0.01	0.22	-0.30	0.04	0.17	-0.06	0.23	0.06	0.05	-0.06	0.09	-0.03	0.03	-0.18

Table 5. Indices of model fit for all path models that met selection criteria.

	Chi-Square			**RMSEA**		**NFI**
Path Model	χ^2	**df**	***P***	RMSEA	PCLOSE	
Diatom						
%NNS	10.851	12	0.542	0.000	0.681	0.867
DBI	11.055	13	0.606	0.000	0.740	0.880
Macroinvertebrate						
EPT RICH	6.705	13	0.917	0.000	0.956	0.946
%EPT	6.314	12	0.899	0.000	0.944	0.943
mHBI	10.747	14	0.706	0.000	0.821	0.898
%CO	6.412	14	0.955	0.000	0.979	0.937
MACRO RICH	12.627	13	0.477	0.000	0.542	0.869
MBI	14.738	14	0.396	0.028	0.558	0.871
Fish						
NAT RICH	15.559	14	0.341	0.041	0.503	0.850
DMS RICH	15.019	13	0.306	0.048	0.460	0.841
SLS RICH	12.307	14	0.582	0.000	0.725	0.876
%TOL	6.448	14	0.954	0.000	0.978	0.930
IBI	7.515	14	0.913	0.000	0.956	0.920

Fig. 1. The number of studies, since 1970, identified in a Web of Science search completed December 18, 2009 that addressed the response to urbanization by fish, macroinvertebrate, algae, and all combinations of these assemblages. Search criteria used in this analysis were: stream AND urban OR urbanization OR impervious OR imperviousness AND fish(es) AND macroinvertebrate(s) OR invertebrate(s) AND diatom(s) OR algae.

Fig. 2. Distribution of the LTMN sites and impervious surfaces within the study area.

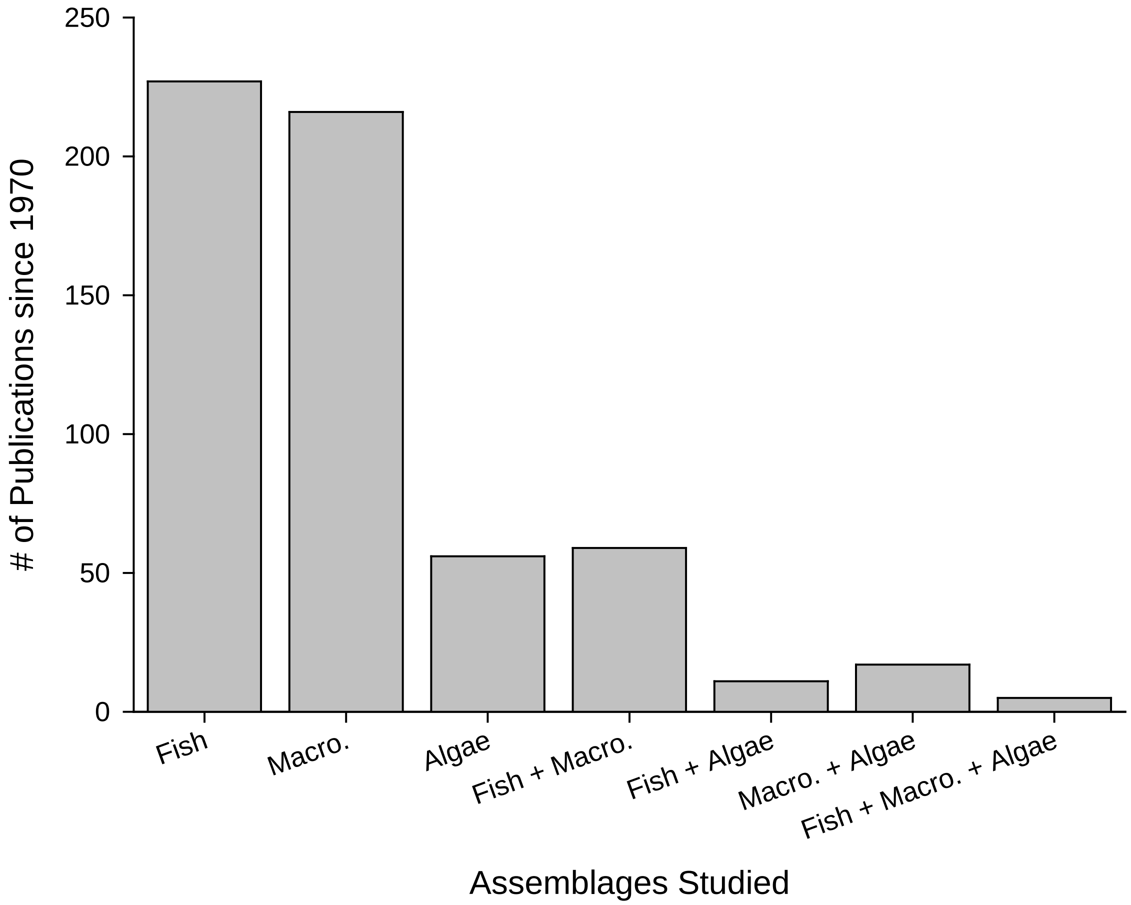
Fig. 3. Theoretical path model created to assess how urban intensity within a catchment propagates disturbance to in/near-stream environmental variables, which ultimately affect stream community biotic integrity.

Fig. 4. Linear regressions assessing the indirect effect of catchment impervious surface area (% ISA) on diatom, macroinvertebrate, and fish biotic integrity metrics used by the Kentucky Division of Water to assess surface waters in Kentucky.

Fig. 5. Significant path models describing how catchment % ISA propagates disturbance through in/near-stream environmental variables, which ultimately affect diatom assemblages. Bold numbers at the upper left corner of each in/near-stream environmental compartment of the model represent the squared multiple correlation coefficient (i.e. r^2), and quantifies the proportion of variation in that variable explained by the incoming arrows (i.e. path coefficients). Italicized numbers along arrows represent the standardized path coefficients for each link in the model ranging from -1 to 1 (* = $p < 0.05$; ** = $0.05 < p < 0.10$). The absolute value of the path coefficient equals the relative strength of each link in the model and the sign (i.e. + / -) describes whether the variables are positively or negatively related in the model. Path coefficients that are 0.00 were found to be insignificant links and were constrained, or set, to equal zero. Large numbers to the right of each biotic response metric indicate the amount of variation explained in the biotic response by the model.

Fig. 6. Significant path models describing how catchment % ISA propagates disturbance through in/near-stream environmental variables which ultimately affect macroinvertebrate communities. See Fig. 5 for detailed explanation of values.

Fig. 7. Significant path models describing how catchment % ISA propagates disturbance through in/near-stream environmental variables which ultimately affect fish communities. See Fig. 5 for detailed explanation of values



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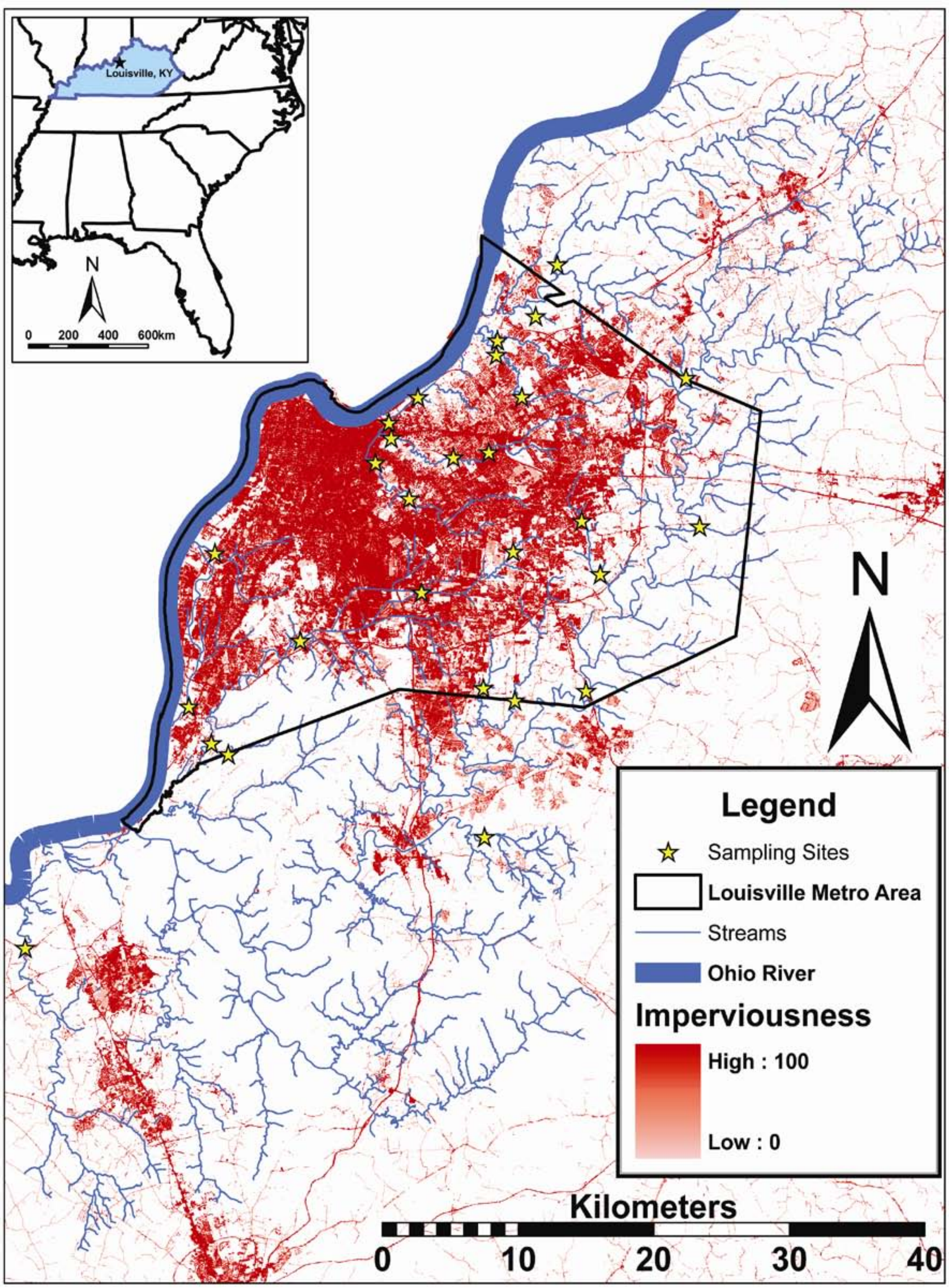

Fig. 2. Distribution of the LTMN sites and impervious surfaces within the study area.

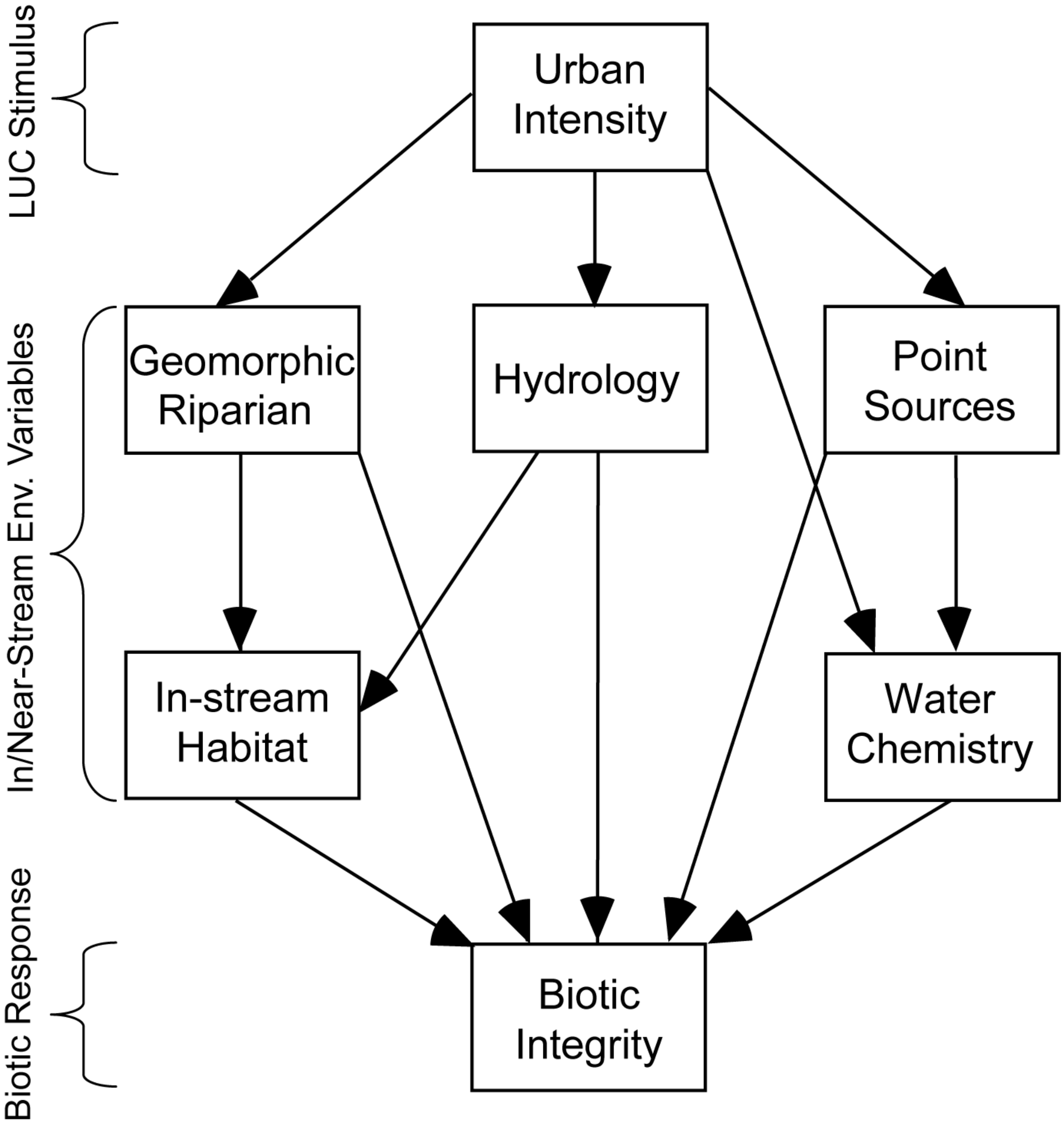

Fig. 3. Theoretical path model created to assess how urban intensity within a catchment propagates disturbance to in/near-stream environmental variables, which ultimately affect stream community biotic integrity.

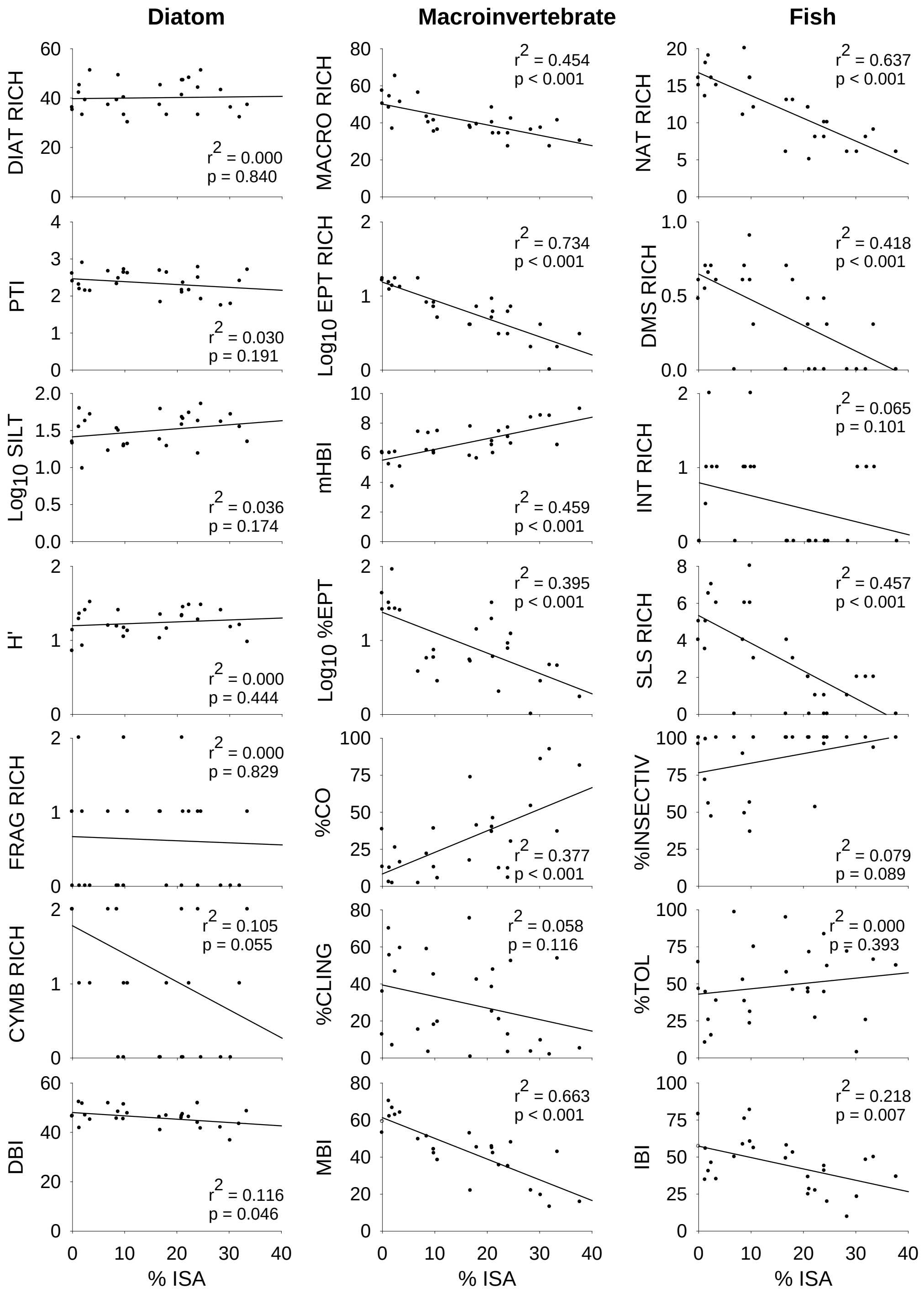

Fig. 4. Linear regressions assessing the indirect effect of catchment impervious surface area (% ISA) on diatom, macroinvertebrate, and fish biotic integrity metrics used by the Kentucky Division of Water to assess surface waters in Kentucky.

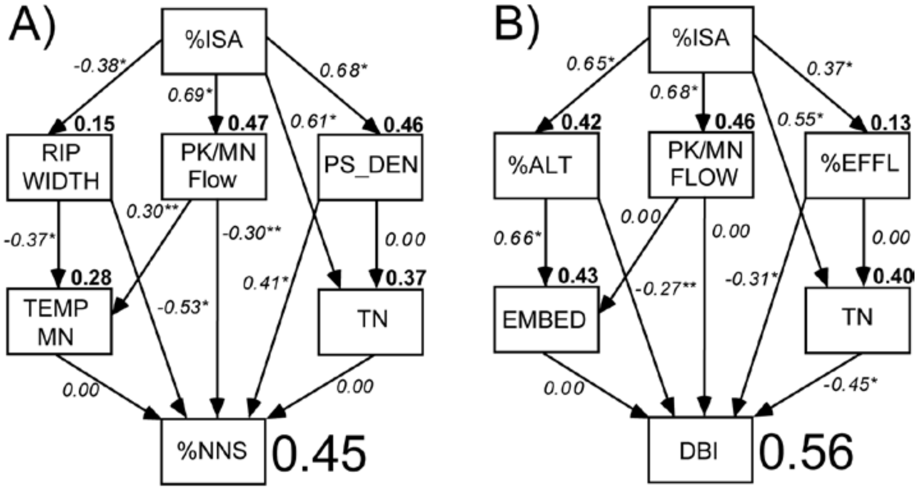

Fig. 5. Significant path models describing how catchment % ISA propagates disturbance through in/near-stream environmental variables, which ultimately affect diatom assemblages. Bold numbers at the upper left corner of each in/near-stream environmental compartment of the model represent the squared multiple correlation coefficient (i.e. r^2), and quantifies the proportion of variation in that variable explained by the incoming arrows (i.e. path coefficients). Italicized numbers along arrows represent the standardized path coefficients for each link in the model ranging from -1 to 1 (* = $p < 0.05$; ** = $0.05 < p < 0.10$). The absolute value of the path coefficient equals the relative strength of each link in the model and the sign (i.e. + / -) describes whether the variables are positively or negatively related in the model. Path coefficients that are 0.00 were found to be insignificant links and were constrained, or set, to equal zero. Large numbers to the right of each biotic response metric indicate the amount of variation explained in the biotic response by the model.

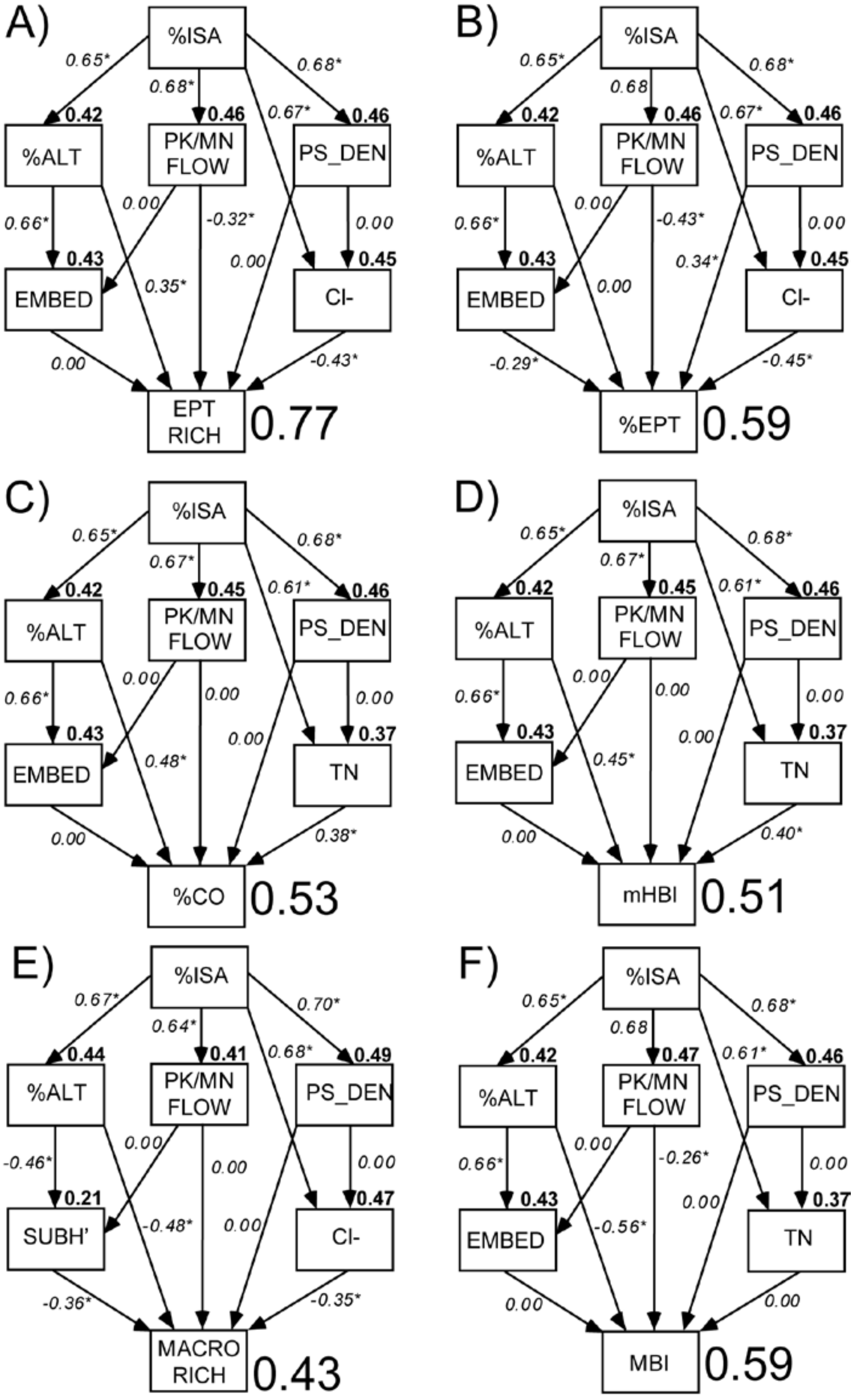

Fig. 6. Significant path models describing how catchment % ISA propagates disturbance through in/near-stream and near-stream variables which ultimately affect macroinvertebrate communities. See Fig. 5 for detailed explanation of values.

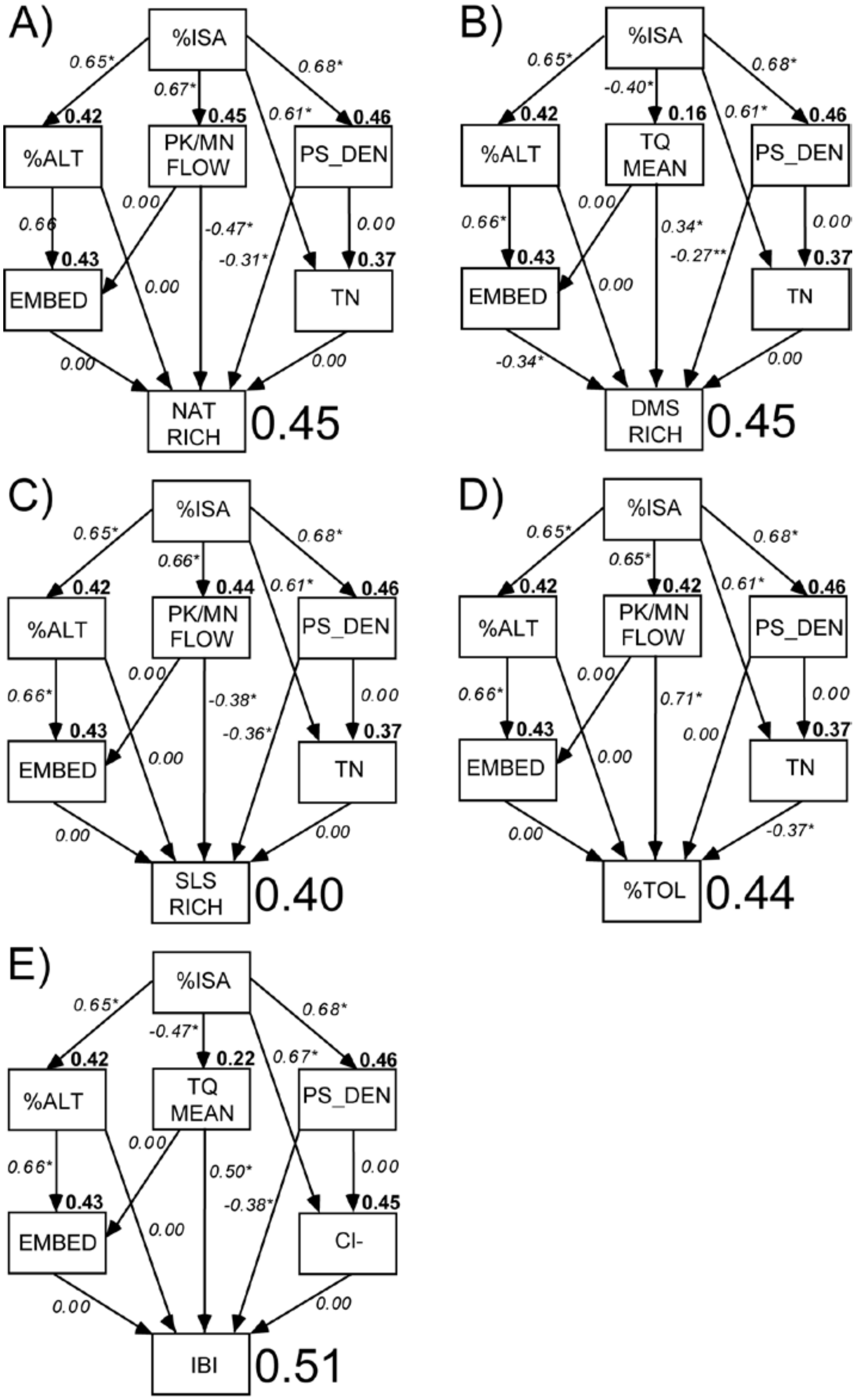

Fig. 7. Significant path models describing how catchment % ISA propagates disturbance through in/near-stream and near-stream variables which ultimately affect fish communities. See Fig. 5 for detailed explanation of values.

Appendix I. Description of in/near stream environmental variables extracted from LMSD database that were excluded from path analysis in the data reduction procedure. * = unitless

Variable	Description
Hydrologic	
LOWPULSE (# Events)	Number of flood pulses > daily mean flow during calendar year
DIS_CV*	Coefficient of variation for mean daily discharge measurements for the calendar year (2005).
HIGHPULSE (# events)	Number of flood pulses > 2x daily mean flow during calendar year
ΔDAILY (day^{-1})	Mean daily change in discharge divided by mean daily discharge.
MN RISE (day^{-1})	Mean hydrograph increase for all rising portions of annual hydrograph that increase > 10%.
MN FALL (day^{-1})	Mean hydrograph decrease for all descending portions of annual hydrograph that decrease > 10%.
Geomorphic / Riparian	
RIFFLE (%)	% of reach consisting of riffle habitat.
RUN (%)	% of reach consisting of run habitat.
RIFFREQ (*)	Ratio of distance between riffles divided by stream width
BSTAB (%)	% of bank surface area with erosional scars
VPROT (%)	% of bank surface area covered with vegetation
CHSIN (unitless)	Ratio of stream channel length to strait line distance for 1km upstream and 1km downstream of sample site.
Water Chemistry	
Fe (mg/l)	Mean of seasonal samples (n=4)
Pb (mg/l)	Mean of seasonal samples (n=4)
NO_3^- (mg/l)	Mean of seasonal samples (n=4)
SRP (mg/l)	Mean of seasonal samples (n=4)
K (mg/l)	Mean of seasonal samples (n=4)
TDS (mg/l)	Mean of seasonal samples (n=4)
TSS (mg/l)	Mean of seasonal samples (n=4)
Habitat	
BEDROCK (%)	% of substrate coverage represented by bedrock
BOULDER (%)	% of substrate coverage represented by boulder
COBBLE (%)	% of substrate coverage represented by cobble
SAND (%)	% of substrate coverage represented by sand
SILT (%)	% of substrate coverage represented by silt
SUBJ	Shannon evenness using the % of substrate classes at each site (i.e. bedrock, boulder, cobble, etc.)
TEMP MX (°C)	Mean of max. daily temperatures throughout 2005 calendar year.

Appendix II. Linear regressions completed in in/near-stream environmental variable reduction process assessing the strength of all possible direct effects (i.e. single headed arrows) associated with the initial path model.

#	Ind. Var.	Dep. Var.	Direction	r^2	*p*-value
1	% ISA	PK/MN FLOW	+	0.413	0.001
2	% ISA	RIFFLE	-	0.273	0.004
3	% ISA	%ALT	+	0.445	0.000
4	% ISA	RIFFREQ	-	0.396	0.000
5	% ISA	VPROT	-	0.235	0.009
6	% ISA	Cl^-	+	0.469	0.000
7	% ISA	TN	+	0.399	0.000
8	% ISA	PSDEN	+	0.486	0.000
9	TQMN	NAT RICH	+	0.218	0.025
10	TQMN	IBI	+	0.348	0.003
11	PK/MN FLOW	EPT RICH	-	0.465	0.000
12	PK/MN FLOW	mHBI	+	0.324	0.004
13	PK/MN FLOW	%EPT	-	0.372	0.002
14	PK/MN FLOW	%CO	+	0.208	0.025
15	PK/MN FLOW	MBI	-	0.337	0.003
16	PK/MN FLOW	NAT RICH	-	0.291	0.007
17	PK/MN FLOW	SLS RICH	-	0.242	0.015
18	PK/MN FLOW	%TOL	+	0.271	0.09
19	DIS_CV	IBI	-	0.315	0.005
20	ΔDAILY	IBI	-	0.230	0.021
21	RIFFLE	EMBED	-	0.328	0.001
22	RIFFLE	mHBI	-	0.194	0.019
23	RIFFLE	%CO	-	0.202	0.016
24	RIFFLE	IBI	+	0.246	0.007
25	POOL	%INSECTIV	+	0.279	0.004
26	FLOSTAT	%CO	+	0.349	0.001
27	FLOSTAT	DIAT RICH	+	0.230	0.011
28	FLOSTAT	PTI	-	0.416	0.000
29	FLOSTAT	%NNS	+	0.269	0.006
30	FLOSTAT	DIAT H’	+	0.198	0.020
31	FLOSTAT	CYMB RICH	-	0.309	0.003
32	FLOSTAT	DBI	-	0.308	0.003
33	%ALT	TMPMN	+	0.236	0.010
34	%ALT	EMBED	+	0.435	0.000
35	%ALT	SUBH’	-	0.210	0.014
36	%ALT	MACRO RICH	-	0.218	0.012
37	%ALT	EPT RICH	-	0.466	0.000
38	%ALT	mHBI	+	0.384	0.000
39	%ALT	%EPT	-	0.250	0.007
40	%ALT	%CO	+	0.418	0.000

Appendix II Continued

#	Ind. Var.	Dep. Var.	Direction	r^2	*p*-value
41	%ALT	%CLING	-	0.199	0.017
42	%ALT	MBI	-	0.519	0.000
43	%ALT	CYMB RICH	-	0.220	0.013
44	%ALT	DBI	-	0.273	0.005
45	RIFFREQ	TMPMN	-	0.220	0.014
46	RIFFREQ	EMBED	-	0.346	0.001
47	RIFFREQ	MACRO RICH	+	0.215	0.013
48	RIFFREQ	EPT RICH	+	0.275	0.004
49	RIFFREQ	mHBI	-	0.331	0.001
50	RIFFREQ	%CO	-	0.220	0.012
51	RIFFREQ	MBI	+	0.315	0.002
52	RIFFREQ	DMS RICH	+	0.195	0.019
53	VEGPROT	EMBED	-	0.283	0.004
54	VEGPROT	mHBI	-	0.292	0.003
55	VEGPROT	MBI	+	0.279	0.004
56	VEGPROT	%NNS	-	0.210	0.016
57	RIPWID	TMPMN	-	0.242	0.009
58	RIPWID	COBBLE	+	0.298	0.003
59	RIPWID	EMBED	-	0.248	0.007
60	RIPWID	EPT RICH	+	0.240	0.008
61	RIPWID	mHBI	-	0.341	0.001
62	RIPWID	%EPT	+	0.231	0.010
63	RIPWID	%CO	-	0.251	0.007
64	RIPWID	MBI	+	0.281	0.004
65	RIPWID	%NNS	-	0.235	0.010
66	RIPWID	CYMB RICH	+	0.246	0.009
67	PSDEN	Cl^-	+	0.289	0.004
68	PSDEN	EPT RICH	-	0.292	0.003
69	PSDEN	NAT RICH	-	0.219	0.012
70	PSDEN	DMS RICH	-	0.233	0.009
71	PSDEN	SLS RICH	-	0.240	0.008
72	PSDEN	IBI	-	0.324	0.002
73	%EFFL	K	+	0.265	0.005
74	%EFFL	TP	+	0.322	0.002
75	%EFFL	DBI	-	0.219	0.014
76	Cl^-	MACRO RICH	-	0.209	0.014
77	Cl^-	EPT RICH	-	0.527	0.000
78	Cl^-	mHBI	+	0.236	0.009
79	Cl^-	%EPT	-	0.350	0.001
80	Cl^-	MBI	-	0.325	0.002
81	Pb	%CLING	+	0.349	0.001
82	NO_3^-	EPT RICH	-	0.230	0.010

Appendix II Continued

#	Ind. Var.	Dep. Var.	Direction	r^2	*p*-value
83	NO_3^-	%INSECTIV	-	0.210	0.014
84	TDS	EPT RICH	-	0.219	0.012
85	TN	EPT RICH	-	0.212	0.014
86	TN	mHBI	+	0.354	0.001
87	TN	%EPT	-	0.206	0.015
88	TN	%CO	+	0.349	0.001
89	TN	MBI	-	0.300	0.003
90	TN	NAT RICH	-	0.199	0.017
91	TN	PTI	-	0.241	0.009
92	TN	DBI	-	0.321	0.002
93	TMPMN	MACRO RICH	-	0.244	0.009
94	TMPMN	EPT RICH	-	0.303	0.003
95	TMPMN	mHBI	+	0.222	0.013
96	TMPMN	MBI	-	0.276	0.005
97	GRAVL	%INSECTIV	+	0.217	0.012
98	EMBED	EPT RICH	-	0.336	0.001
99	EMBED	mHBI	+	0.247	0.007
100	EMBED	%EPT	-	0.232	0.010
101	EMBED	%CO	+	0.337	0.001
102	EMBED	MBI	-	0.332	0.001
103	EMBED	NAT RICH	-	0.197	0.018
104	EMBED	DMS RICH	-	0.207	0.015
105	SUB H’	DBI	+	0.233	0.011

Appendix III. Pearson's correlation matrices of variables in each in/near-stream compartment that were significantly related to variables in directly connected compartments (i.e. connected by an arrow) of the initial model (Fig. 3) in linear regressions (Appendix II). An * denotes the variable was selected for use in path analysis.

Appendix IIIA. Hydrology compartment

Hydrology	PK/MN FLOW	TQMN	DIS_CV	ΔDAILY
PK/MN FLOW*	1.000	-------	-------	-------
TQMN*	0.026	1.000	-------	-------
DIS_CV	-0.108	-0.841	1.000	-------
ΔDAILY	-0.258	-0.745	0.831	1.000

Appendix IIIB. Geomorphic/riparian compartment

Geomorphic Riparian	%ALT	RIPWID	RIFFLE	POOL	FLOSTAT	RIFFREQ	VEGPROT
%ALT*	1.000	-------	-------	-------	-------	-------	-------
RIPWID*	-0.538	1.000	-------	-------	-------	-------	-------
RIFFLE	-0.609	0.397	1.000	-------	-------	-------	-------
POOL*	-0.077	-0.049	-0.190	1.000	-------	-------	-------
FLOSTAT*	0.473	-0.365	-0.573	0.245	1.000	-------	-------
RIFFREQ	-0.755	0.481	0.704	0.036	-0.319	1.000	-------
VEGPROT	-0.555	0.519	0.591	-0.139	-0.353	0.640	1.000

Appendix IIIC. Point sources compartment

Point Sources	PSDEN	%EFFL
PSDEN*	1.000	-------
%EFFL*	0.295	1.000

Appendix IIID In-stream habitat compartment

	EMBED	SUB H'	GRAVL	TMPMN	TEMP MAX
EMBED*	1.000	-------	-------	-------	-------
SUB H'*	-0.295	1.000	-------	-------	-------
GRAVL*	-0.492	0.326	1.000	-------	-------
TMPMN*	0.158	-0.164	0.073	1.000	-------
TEMP MX*	-0.181	-0.001	0.253	0.469	1.000

Appendix IIIE Water chemistry compartment

Water Chem.	Cl^-	TN	NO_3^-	TDS	TP	K
Cl^{-*}	1.000	-------	-------	-------	-------	-------
TN*	0.283	1.000	-------	-------	-------	-------
NO_3^-	0.716	0.096	1.000	-------	-------	-------
TDS	0.824	-0.081	0.816	1.000	-------	-------
TP*	-1.87	0.0198	-0.127	-0.185	1.000	-------
K	0.077	0.292	0.210	0.054	0.614	1.000