Pollutant Load Analysis to Assess Sources of Sediment and Water Column Toxicity in Little Beaver Creek, Ohio

DRAFT FINAL REPORT

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1.0 INTRODUCTION

Under Contract No. 68-W9-9018, Work Assignment No. R05814, Tetra Tech EM Inc. (Tetra Tech) was tasked by the U.S. Environmental Protection Agency (USEPA) to provide background information for development of Total Maximum Daily Loads (TMDL) for metals and toxicity in the Little Beaver Creek (LBC), Alpha, Ohio.

The Ohio Environmental Protection Agency (Ohio EPA) is currently developing TMDLs for ammonia, and habitat alteration as part of studies addressing the Little Miami River watershed as a whole. Little Beaver Creek (LBC) is located within the upper Little Miami River (LMR) watershed in southwestern Ohio, covering Montgomery and Greene Counties. LBC is currently listed on Ohio's Section 303(d) List of Impaired Waters due to impairment by toxicity, metals, ammonia, pathogens, and habitat alteration. TMDL development for toxicity and metals entails a combination of chemical-specific and biocriteria/bioassessment approaches accounting for the aquatic uses of LBC, the presence of toxic organic compounds in the LBC water column, and the presence of toxic organic compounds and heavy metals in LBC sediment. Six critical pollutants were identified as posing the greatest threat to the aquatic health of LBC. These pollutants include cadmium, copper, mercury, organochlorine pesticides, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs).

1.1 OBJECTIVES

The main objective of this report is to provide background information for the development of TMDLs for metals and toxicity in LBC. Specifically, this report provides estimates of pollutant loadings from point and nonpoint sources within the watershed and assesses allowable loads to attain defined TMDL endpoints.

1.2 REPORT FORMAT

The following sections of the report present a discussion of the LBC study area; water quality standards (WQS) and aquatic life uses applicable to LBC; and load analysis. The load analysis is organized in three subsections. The first subsection addresses the level of impairment observed in the sediment in LBC and the potential sources of toxic load contributing to that impairment. The second subsection addresses the development of TMDL end points. The third subsection addresses sources of contaminants to sediments, organochlorine (OC) pesticides in the water column, and an assessment of pollutant loads to LBC.

The final section of the report summarizes the analysis of the data and presents recommendations to achieve TMDL end points. References used in the report are provided at the end of Section 5.0. The appendix to the report provides an analysis of the likely causes of sediment toxicity observed in the LBC.

2.0 ENVIRONMENTAL SETTING AND DISCHARGES OF POLLUTANTS TO LBC

This section of the report describes the general environmental setting of the study area and briefly presents the identified current and past discharges of pollutants to LBC.

2.1 ENVIRONMENTAL SETTING

LBC traverses Montgomery and Greene counties before entering Beaver Creek (BC) near Alpha, Ohio (Figure 1). BC is a tributary to the Little Miami River (LMR), which is in turn a tributary to the Ohio River. LBC is approximately 9.4 miles in length, and has a drainage area of approximately 26.4 square miles. Nine tributaries to LBC, with a total length of 16.8 miles, are visible on U.S. Geological Survey (USGS) topographic maps. The tributaries are reported to flow continuously, even during low-flow regimes (OEPA 2000a). The average gradient of LBC is 18.8 feet/mile (OEPA 2000b).

The headwaters of LBC originate in the vicinity of Kettering, Ohio (Sub-watershed J, Figure 2). LBC begins its flow in an eastward direction; at approximately river mile (RM) 7.7, LBC turns northward and receives flow from sub-watersheds H and I. At RM 4.57, LBC receives effluent discharge from the Montgomery County Eastern Regional Wastewater Treatment Plant (MCWWTP). At RM 4.52, LBC turns back to the east and maintains an easterly/southeasterly direction until its intersection with BC. Along its course from RM 4.52, LBC receives flow from sub-watersheds A through G. Sub-watershed G contributes tributary flow to LBC through the North Branch of Little Beaver Creek (North Branch). The North Branch is predominantly an artificial storm drainage channel that flows continuously (MCWWTP 2000).

2.1.1 Hydrology

The topography of the LMR watershed has been influenced by glaciation with thick deposits of silt, sand, and gravel. For most of its length, LMR flows atop a buried valley aquifer composed of highly permeable sands and gravel from past glacial events. A notable artesian area is located at the confluence of the LMR and BC near the towns of Trebein and Alpha (Norris and others 1956). The U.S. Environmental Protection Agency (EPA) (1998) and Brown and Caldwell (1999) both report that the lowest reach of LBC in the vicinity of its confluence with BC is a losing reach; that is, flow rates in the channel decrease downstream due to losses to bank storage and shallow groundwater.

Figure 1 LITTLE BEAVER CREEK WATERSHED

Figure 2 LOCATION OF SUB-WATERSHEDS IN LITTLE BEAVER CREEK AREA

Storm water runoff enters LBC through storm drains, ditches, and swales. No combined sanitary/sewer outfalls (CSO) are known to empty into LBC. Greene County Department of Public Works reports usage of silt fences, straw bales, and various forms of erosion control as means of mitigating sediment impacts of storm water flows to LBC. Other forms of storm water management in LBC have been reported to include mechanical removal of trash and woody debris.

Historic stream flow data are unavailable for LBC. However, relationships of flow per unit of drainage area were developed and are presented in Section 4.0.

2.1.2 Land Use

Land use data were obtained from the USGS Geographic Information Retrieval and Analysis System (GIRAS). GIRAS land use and land cover data are based on the Andersen Level II classification method and reside in USEPA's Spatial Data Library. According to the GIRAS data, the LBC watershed is 68.4 percent Urban or Built-Up, 30.9 percent agricultural, and 0.7 percent undeveloped. 75.8 percent of the Urban or Built-Up land is residential and 24.2 percent is Industrial, Commercial, or Other. Much of the land use data available through GIRAS were developed between the mid 1970s and early 1980s and may not accurately reflect current land uses. A review of the USGS topographic maps of the watershed suggests that the agricultural land use reported by the USGS GIRAS system is significantly overstated. OEPA (2000b) lists "Urban" as the only nonpoint source pollution category in the LBC watershed.

2.1.3 Ecoregion

LBC is located within the Eastern Corn Belt Plains (ECBP), one of five ecoregions in Ohio. This ecoregion is characterized by level to gently sloping land and relatively low gradient streams (OEPA 2000b).

2.2 DISCHARGES OF POLLUTANTS TO LBC

This section provides a brief discussion of current and past discharges of pollutants to LBC.

2.2.1 Current Discharges of Pollutants to LBC

Since 1990, three facilities permitted for the National Pollutant Discharge Elimination System (NPDES) have discharged to LBC: MCWWTP, the General Motors Delphi Chassis Systems operation (GMDC), and Beavercreek Water Treatment Plant (BCWTP). OEPA maintains Monthly Operating Report (MOR) Data Summaries for the three facilities. MCWWTP and GMDC currently discharge to LBC and MORs are available for these facilities through December 1999. MORs for BCWTP present discharge data through end of year 1998.

Effluent from MCWWTP discharges to LBC at RM 4.57 through one outfall. MCWWTP has a design flow of 13.0 million gallons per day (MGD). Approximately 15 percent of the influent to MCWWTP is waste from GMDC and Scitex Digital Printing Co. (formerly Kodak Co.) (OEPA 2000; Montgomery County 2000). A dairy processing plant that discharged industrial effluent to MCWWTP ceased operation circa 1995 (Montgomery County 2000). A summary of pollutant loads from MCWWTP is provided in Section 4.3.3.5.

GMDC discharges non-contact cooling water and storm water to LBC through the tributary represented by sub-watershed J (Figure 1). Six outfalls from GMDC discharge to LBC. Four of the six GMDC outfalls discharge non-contact cooling water. During storm events, all six outfalls discharge storm water to LBC (OEPA 2000a). The non-contact cooling water is assumed not to contribute loads of critical pollutants to LBC.

Effluent from BCWTP enters LBC through an unnamed tributary at RM 0.67 (OEPA 2000a). The plant has historically provided drinking water to communities in the vicinity of Beavercreek, Ohio. According to MORs, the plant has not discharged to LBC since December 1998.

An industrial park located within the upper watershed is occupied by various light industrial operations including metal casting, machine shops, and waste haulers. Industrial operations are also present in other areas of the watershed and include auto body shops, a nursery, a battery business, and an equipment rental operation. These facilities are all assumed to deliver storm water runoff to LBC. Some industrial and small business operations are located immediately adjacent to the LBC channel (OEPA 2000a).

2.2.2 Past Discharges of Pollutants to LBC

Environmental contamination has been documented by USEPA at the site of the Lammars Barrel Factory, located adjacent to LBC at RM 3.50. During its operation, the factory operated as a solvent recovery facility (Adrian Brown Consultants, Inc. 2000). As much as 500,000 gallons of chemical solvents including trichloromethane, tetrachloromethane (PCE), methyl ethyl ketone, and alcohol were stored above ground. In 1969, a major explosion and fire occurred at the site. Since the fire, the Lammars site has been the focus of a USEPA engineering evaluation/cost analysis report, a hydro geologic characterization study, and various soil and groundwater investigations. Significant contamination of soil and groundwater has been identified in the vicinity of the Lammars site (Adrian Brown Consultants, Inc. 2000). Samples from on-site monitoring wells have documented concentrations of benzene, toluene, ethyl-benzene, and xylene (BTEX) compounds and vinyl chloride. Volatile organic compounds (VOC), including vinyl chloride, were detected in residential wells in the vicinity of the Lammars site. USEPA funded the extension of municipal water lines to households where hazardous levels of contamination were observed. VOC, other organic compounds, and metals have been detected in sediment samples from LBC in the vicinity of RM 3.50 and have been attributed to contamination from the Lammars incident (OEPA 2000a).

Environmental remediation is currently underway at the Defense Electronics Supply Center (DESC), located within sub-watershed I (Figure 1). DESC is also known as Gentile Air Force Depot. U.S. Air Force electronic communications devices were historically repaired at DESC, but the site is no longer in operation (OEPA 2000d). According to OEPA (2000a), this site is presently under remediation for metals and PAHs. The tributary to LBC in sub-watershed I flows through the DESC site. PAH contamination of sediment was identified in the tributary. The highest concentration of PAHs observed in the tributary was 510 milligram per kilogram (mg/kg) in samples collected adjacent to an outfall receiving storm water runoff from a coal pile. The stream bed was excavated to approximately 6 feet deep or bedrock, and the contaminated sediments were replaced with clean sediment (OEPA 2000d).

Nu-Glow and Jim's Garage are two other sites of environmental contamination in the LBC watershed. At the Nu-Glo site, PCE and #2 diesel fuel spills occurred. The spilled contaminants are contained within a kettle bog and are undergoing phytoremediation. The Nu-Glo site is located in the uplands of LBC and its contaminants are assumed not to have been transported to LBC (OEPA 2000e). Jim's Garage was the site of a fire that occurred in the 1970s. Organic compounds and carbon disulfide were identified on the

site. It is assumed that any effect of Jim's Garage on water or sediment quality of LBC occurred 10 to 15 years ago (OEPA 2000e). The site is now covered by a parking lot.

3.0 OHIO WATER QUALITY STANDARDS AND AQUATIC USES

Ohio WQS consist of designated beneficial uses and measurable chemical, physical, and biological criteria. Both numerical and narrative criteria are assigned in accordance with the broad goals of each designated use. Numerical criteria include chemical criteria, biological criteria, and whole effluent toxicity levels. Narrative criteria are general water quality standards mandating that all surface waters be free from oil, sludge, color and odor materials, and nutrient concentrations causing algal blooms.

Beneficial use designations consist of two broad groups: aquatic life and non-aquatic life uses. Five different aquatic life uses are currently defined in the Ohio WQS: Warmwater Habitat, Modified Warmwater Habitat, Exceptional Warmwater Habitat, Coldwater Habitat, and Limited Resource Water. Attainment of aquatic uses is determined primarily by biological criteria assigned by Ohio EPA. Biological criteria are restricted to ambient assessments and are applicable to rivers and streams outside of mixing zones. Numerical biological criteria are multimetric indices including the Index of Biological Integrity (IBI), the modified Index of Well-Being (MIwb), and the Invertebrate Community Index (ICI). The IBI and MIwb are based on fish assemblage data, and the ICI is based on macroinvertebrate assemblage data. At any given sampling location, three attainment status outcomes are possible: full-, partial-, and non-attainment. Non-attainment status applies to a water body where all indices fail to attain aquatic uses or any one index indicates poor or very poor performance.

Non-aquatic life uses include water supply and recreation. Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). AWS and IWS uses apply, in general, to all waters in the state unless information clearly demonstrates otherwise. Typical recreation uses for rivers and streams consist of Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. Bacterial indicators such as fecal coliform and *E. coli* concentrations are used to determine attainment status for PCR and SCR uses.

4.0 POLLUTANT LOAD ANALYSES FOR TOXICITY AND METALS

This section addresses the level of impairment observed in the sediment in LBC, the development of TMDL endpoints, and an assessment of pollutant loads to LBC.

4.1 PROBLEM IDENTIFICATION

The designated aquatic life use of LBC is Warmwater Habitat (WWH), which represents the typical warmwater assemblage of aquatic organisms in Ohio rivers and streams (OEPA 2000b). This use represents the principal restoration target for the majority of water resource management efforts in Ohio (OEPA 2000b). Non-aquatic life uses of LBC are AWS, IWS, and PCR. An unnamed tributary to LBC entering at RM 6.1 is designated as WWH, AWS, and SCR. No other aquatic or non-aquatic designated uses apply to LBC or its tributaries.

OEPA (2000b) presents a detailed discussion of data collected from LBC and an unnamed tributary in 1998 and the creek's attainment status for aquatic and non-aquatic life uses. OEPA (2000b) presents the results of biological and water quality surveys conducted in the LMR watershed and its tributaries in 1998. The surveys entailed water quality sampling, sediment sampling, determination of biological indices, and habitat assessments. The 1998 study of the LMR basin is a follow-up to a 1993 study that incorporated similar sampling methods and locations. Data collection for both studies took place during the summer months (July to September) when the lowest flows in LBC typically occur.

OEPA (2000b) reports habitat index scores from LBC and its unnamed tributary entering at RM 6.1 (sub-watershed I) with respect to reference warm water habitat streams within the ECBP and states that the entire reach of LBC and its unnamed tributary do not meet WWH beneficial uses. Table 4-1 presents reported IBI, ICI, and MIwb habitat index scores for six sites on LBC and one site on the unnamed tributary that were measured in the 1998 study (OEPA 2000b). All habitat indices were rated as Poor or Very Poor or were significantly lower than applicable numerical criteria. These sub-standard scores are all at least partially caused by the presence of toxic chemicals and metals in the LBC water column and sediment.

TABLE 4-1

1998 WWH BIOCRITERIA INDEX SCORES FOR LITTLE BEAVER CREEK

RM	Site Description	IBI	MIwb	ICI
Tributary (RM 6.1)	Tributary (sub-watershed I)	–	–	P*
4.7	Upstream from MCWWTP	30*	NA	30*
4.6	MCWWTP mixing zone	24*	NA	P/VP
3.5	Downstream from. MCWWTP	29*	NA	20*
0.1	Factory Rd.	31*	6.3*	22*
	Ohio Biological Criteria for WWH	*40*	*8.3*	*36*

Notes:

* = Indicates significant departure from applicable biocriteria (≥4 IBI or ICI units, or ≥0.5 MIwb units)
-- = Data not collected
NA = MIwb not applicable to headwater site types
P/VP = Poor/Very Poor (qualitative narrative evaluation used when quantitative data are unavailable or unreliable due to current velocities less than 0.3 feet per second flowing over artificial substrates)

WQS for metals in the water column of LBC were not exceeded during the 1993 and 1998 water quality studies. However, WQS for OC pesticides were exceeded at several locations. Between July and September 1993, OEPA analyzed three samples immediately downstream from the MCWWTP (RM 4.53) for organic compounds. Between August and September 1998, OEPA analyzed two samples for organic compounds from RM 4.62, 4.40, and 0.05. RM 4.62 is upstream from the MCWWTP outfall and RM 4.40 and 0.05 are downstream from the outfall. RM 4.40 is also immediately downstream from where the North Branch enters LBC. Table 4-2 presents concentrations of pesticides observed in LBC. WQS shown represent the lowest applicable standards for aquatic life protection or drinking water use. Observed concentrations of lindane (gamma-hexachlorocyclohexane), dieldrin, endrin, and endosulfan I in water samples from LBC exceeded respective water quality standards at least once in 1993 and 1998. Two samples from LBC exceeded the standards for heptachlor in 1993.

TABLE 4-2

OBSERVED CONCENTRATIONS (µg/L) OF OC PESTICIDES EXCEEDING WQS IN 1993 AND 1998

Pesticide	WQS (µg/L)	7/27/93 RM 4.53 Dst. MC WWTP	8/10/93 RM 4.53 Dst. MC WWTP	9/7/93 RM 4.53 Dst. MC WWTP	8/5/98 RM 4.62 Ust. MC WWTP	8/5/98 RM 4.40 Dst. MC WWTP	8/5/98 RM 0.05 Factory Rd.	9/2/98 RM 4.62 Ust. MC WWTP	9/2/98 RM 4.40 Dst. MC WWTP	9/2/98 RM 0.05 Factory Rd.
Lindane	0.01[a]	0.011	0.023	--	--	--	--	--	0.015	0.012
Heptachlor	0.001[a]	0.014	--	0.016	--	--	--	--	--	--
Dieldrin	0.00076[b]	0.011	0.012	--	--	0.01	0.0074	--	--	--
Endrin	0.002[a]	0.008	0.006	--	--	0.0063	--	--	--	--
Endosulfan I	0.003[a]	--	0.006	--	--	--	--	0.0068	--	--

Notes:

dst. = Downstrean from
ust. = Upstream from
-- = Compound not detected or below detection limit

[a] Ohio Aquatic Life WQS (Outside Mixing Zone Average [OMZA])
[b] Ohio Human Health Non-drinking WQS

Contaminated sediments in LBC also contribute to biological impairment. During the 1993 water quality survey, sediments were sampled at one site upstream of MCWWTP (RM 4.62), and at one site downstream of MCWWTP (RM 4.53). No metals sampled (arsenic, copper, cadmium, chromium, iron, lead, nickel and zinc) were elevated per Kelley & Hite or per OEPA sediment guidelines. Chlordane or PCBs were not detected at either RM 4.53 or RM 4.62. PAHs were not detected at RM 4.62. However, sampling at RM 4.53 detected 2.4 mg/kg of total PAH.

During the OEPA 1998 water quality survey of LBC, organic chemicals and metals were detected in all five sediment sampling locations in LBC, including one site upstream from the MCWWTP (RM 4.62), one site downstream from the MCWWTP (RM 4.40), sites upstream and downstream from the Lammars site (RM 3.54 and RM 3.47, respectively), and one site near the mouth of LBC (RM 0.05). OEPA (2000b) reports that sediments in LBC exhibited the most significant organic contamination in the entire LMR study area. Organic chemicals present in sediment samples included PAHs, VOC., semivolatile organic compounds (SVOC), OC pesticides, and PCBs. OC pesticides included total chlordanes representing sums of alpha- and gamma-chlordane concentrations, which were not detected in LBC water column samples. Elevated concentrations of at least one of each of these toxic chemicals were detected at

every sediment sampling location in 1998. In addition, elevated concentrations of aluminum, barium, cadmium, chromium, copper, lead, mercury, and zinc were detected in LBC sediments. Urban runoff, industrial runoff, the MCWWTP, the Lammars site, and spills are listed as sources of toxic chemicals and metals in LBC sediment.

Based on methods described in Section 4.2.1, it was determined that the biocriteria index scores presented in Table 4-1 are correlated with the presence of the following sediment contaminants: cadmium, copper, mercury, total PAHs, total chlordane, and PCBs. Table 4-3 presents sediment data collected by OEPA in 1998 for these six contaminants. The letters and symbols in parentheses refer to the degree of contamination according to the classification methods employed by OEPA. All sediment concentrations are reported as dry weight.

The observed concentrations of mercury in sediment at RM 4.40 (0.222 mg/kg) and cadmium at RM 3.47 (3.09 mg/kg) are highly or extremely elevated. RM 4.40, immediately downstream from both MCWWTP and the North Branch of LBC, was the only LMR tributary site in the 1998 OEPA study of the LMR basin where the mercury level was in the "highly elevated" range. RM 3.47, immediately downstream from the Lammars Barrel Factory site, was the only site in the study where the cadmium level was in the "extremely elevated" range based on OEPA guidelines (OEPA 2000b).

TABLE 4-3

OBSERVED CONCENTRATIONS OF SIX CONTAMINANTS IN LBC SEDIMENT

RM	Site Description	Copper (mg/kg)	Mercury (mg/kg)	Cadmium (mg/kg)	Total PAHs (mg/kg)	Total Chlordane (ug/kg)	PCBs (ug/kg)
4.62	Upstream from. MCWWTP	12.3 (Aa)	<0.0397 (a)	0.254 (Aa)	6.88 (&)	BDL	BDL
4.40	Downstream from MCWWTP	28.4 (Ca)	0.222 (d)	0.401 (Aa)	36.7 (&)	57.0 (&,e)	140 (PCB-1254) (&,c)
3.54	Grange Hall Rd. (Upstream from Lammars Barrel)	27.6 (Ca)	0.0581 (a)	0.410 (Aa)	19.4 (&)	44.3 (&,e)	147 (PCB-1254) (&,c)
3.47	Grange Hall Rd. (Downstream from Lammars Barrel)	15.7 (Aa)	0.0364 (a)	3.09 (Ed)	7.31 (&)	17.7 (&,d)	109 (PCB-1248) (&) 306 (PCB-1254) (&) 415 (Total PCB) (&,d)
0.05	Factory Rd.	15.1 (Aa)	<0.0366 (a)	0.216 (Aa)	8.24 (&)	20.4 (&,d)	BDL

Notes:

BDL = Below detection limit

Ohio EPA Guidelines
A = Non-elevated
B = Slightly elevated
C = Elevated
D = Highly elevated
E = Extremely elevated

Kelly and Hite Guidelines
a = Non-elevated
b = Slightly elevated
c = Elevated
d = Highly elevated
e = Extremely elevated

Ontario Sediment Guidelines
& = greater than lowest effect level

Levels of total PAHs in LBC sediment are among the highest observed in Ohio streams. The sample from RM 4.40 contained nine different PAH compounds for a total PAH concentration of 36.7 mg/kg, the fifth highest observed PAH concentration of all streams in Southwest Ohio monitored by OEPA (OEPA 2000b). Benzo(a)pyrene, a known carcinogenic PAH compound, was observed above the "lowest effect level" according to Ontario Sediment Guidelines at all five sediment monitoring sites in LBC.

4.2 DETERMINATION OF TMDL ENDPOINTS

This section describes the methods for determining TMDL endpoints in the LBC.

4.2.1 Sediment Conditions and Water Quality Dynamics of Reference Streams

No upstream locations are available against which to establish background levels for the LBC watershed; therefore, Tetra Tech relied on sediment data from reference areas outside of the basin and Ohio established water quality standards. Rather than using data from a specific reference stream for sediment, literature data were used to establish reference levels. Ohio EPA has divided the state into five ecoregions for use in establishing sediment quality guideline for metals levels throughout the state (OEPA 1996). The sediment guideline values for streams within each ecoregion are based on chemical data and associated biocriteria, IBI, and ICI from reference streams. Each of these biocriteria provide a means to categorize a stream by its level of impairment. The categories range from very poor to exceptional. OEPA (1996) presents statistical data for sediment metal concentrations associated with each level of impairment for each ecoregion. To establish a baseline or reference for LBC, Tetra Tech reviewed these data and selected the median sediment constituent concentrations associated with the IBI score for the "good" category within the ECBP ecoregion to serve as the reference levels for this analysis. These values are presented in Table 4-4. Of the metals identified in the LBC sediments, data are only available for aluminum, barium, cadmium, chromium, copper, lead, and zinc.

TABLE 4-4

MEDIAN SEDIMENT METAL CONCENTRATIONS ASSOCIATED WITH IBI SCORE OF "GOOD" IN THE EASTERN CORN BELT PLAIN ECOREGIONS

Metal	Sediment Concentrations (mg/kg)
Aluminum	8,855
Barium	136
Cadmium	0.540
Chromium	12.0
Copper	20.4
Zinc	81.9
Mercury[a]	0.10

Note:

[a] Value from Kelly and Hite (1984)

No reference streams or ecoregion sediment data are available for mercury and organic constituents; therefore, no values specific to the ECBP ecoregion or Ohio are available. As a result, the criteria value of 0.10 mg/kg from Illinois (Kelly and Hite 1984) was used as a reference value for mercury. This value is categorized as "elevated" by Kelly and Hite (1984) and is thought to represent a level of impairment. No reference values were established for organics.

For water quality, no specific water chemistry data have been established for the ECBP ecoregion that correspond to sediment data noted above. Therefore, Tetra Tech used the Ohio WQS for WWH in the Ohio River Basin as reference values.

4.2.2 Sediment Endpoints

Tetra Tech assessed appropriate concentration endpoints for sediments by reviewing reference values for Ohio sediments (OEPA 1996), Illinois sediments (Kelly and Hite 1984), and Ontario sediments (Ontario Ministry of the Environment 1993). Ohio sediment quality guidelines are only available for metals, excluding mercury. For mercury, Tetra Tech referred to the Illinois sediment classification scheme (Kelly

and Hite 1984). For organic constituents, Tetra Tech referred to Guidelines for Aquatic Sediment Quality in Ontario (Ontario Ministry of the Environment 1993).

The appendix to this report shows a correlation between the concentrations of metals, PAHs, pesticides, and PCBs in sediments and negative impacts on the biocriteria, IBI, and ICI, indicating impact to the biological community in LBC. Because LBC is listed for sediment toxicity based on impairment of biological resources in the creek, Tetra Tech's initial evaluation of appropriate criteria considered the relationship between metals and PAH concentrations and the IBI, which uses the characteristics of fish communities as an indicator of overall ecosystem health. Tetra Tech used OEPA sediment quality guidelines for metals (OEPA 1996) to establish sediment endpoints for cadmium and copper. Since Tetra Tech used the IBI data to establish if impairment was associated with a specific constituent, it is appropriate to use the ecoregion specific IBI data to establish sediment endpoints. The endpoints chosen for these metals were the median concentrations that corresponded to the IBI values of good ecosystem health (IBI values in the range from 40 to 45). Endpoint values of 0.54 and 20.4 mg/kg were chosen for cadmium and copper, respectively. Tetra Tech then compared these values to the data compiled by OEPA (1996) that established median values and inter-quartile range values of 1, 2, 4, and 8. The median values are considered non-elevated and each quartile is associated with slightly-elevated, elevated, highly-elevated, and extremely elevated, respectively. In order to cross reference the values associated with good ecosystem health, Tetra Tech compared the concentration ranges associated with good ecosystem health (the endpoint value) with the statistical distribution described above. The copper endpoint concentration was at the low end of the slightly elevated range (20.2 to 26.4 mg/kg) and the cadmium endpoint concentration was at the high end of the non-elevated range (0 to 0.563 mg/kg). It is important to note that these ranges (non-elevated or slightly elevated) are not based on biological health but rather on a statistical distribution. Therefore, since the endpoints are based on concentrations associated with good ecosystem health, these endpoints should be protective for LBC.

Concentrations of mercury and organic contaminants could not be assessed based on biological criteria because Ohio has not evaluated sediment concentrations in relation to IBI and ICI values. Consequently, Tetra Tech referred to reference values for mercury concentrations in Illinois sediments and organic contaminants in Ontario sediments. As discussed above, the endpoints selected for copper and cadmium were chosen based on concentrations associated with good ecosystem health with an IBI of 40 to 45, these concentrations also fell with the statistical distribution identified as slightly elevated. Tetra Tech assumed that the concentration of mercury in sediments that was identified as slightly elevated concentration (less than 0.10 mg/kg) from Illinois streams would provide a similar good ecosystem health

as was seen for copper and cadmium with the Ohio sediment data. The slightly elevated categories for Ohio and Illinois were calculated using two different statistical approaches. The slightly elevated category used in the Ohio criteria corresponds to the median concentration plus 1 interquartile range value. The slightly elevated category used in the Illinois criteria corresponds to the median concentration plus one standard deviation (Kelly and Hite 1984). This endpoint is expected to be protective for LBC.

Ontario has related sediment concentrations to biological criteria. The Ontario values are based on literature surveys and are not necessarily empirically derived as Illinois and Ohio guidelines (Ontario Ministry of the Environment 1993). The category that most closely corresponds with the slightly elevated category derived statistically by Illinois and Ohio is the lowest effect level (LEL), a contaminant concentration that can be tolerated by the majority of benthic organisms. Tetra Tech used the Ontario LEL values for all organic contaminants that were detected in sediments as reported in the OEPA (2000b), which included PAHs, chlordane, and PCBs. A sediment endpoint value of 4 mg/kg was chosen for total PAHs, 0.007 mg/kg for chlordane and 0.07 mg/kg for total PCBs (Ontario Ministry of the Environment 1993). The sediment endpoints are summarized in Table 4-5.

TABLE 4-5

TMDL ENDPOINTS FOR SEDIMENT

Compound	Sediment Concentration (mg/kg)
Cadmium	0.54
Copper	20.4
Mercury	0.10
Total PAH	4.0
Total chlordane	0.007
Total PCBs	0.07

4.2.3 Water Column Endpoints

The endpoints available for water column constituents are the Ohio River Basin WQS. Because no metals, PAHs, or PCBs have been detected above their respective standards, no endpoints were identified for these chemicals. Endpoints for OC pesticides are presented in Table 4-6 and represent the lowest

standard available unless the lowest WQS concentration represents the human health drinking water standard.

TABLE 4-6

COMPARISON OF WATER COLUMN PESTICIDE DATA AND APPLICABLE OHIO WATER QUALITY STANDARDS

Chemical	River Mile	Maximum Concentration (µg/L)	Ohio River Basin Water Quality Standards (µg/L)
Dieldrin	4.40	0.010	0.00076[a]
Dieldrin	0.05	0.0074	0.00076[a]
Endosulfan I	4.62	0.0068	0.003[b]
Endrin	4.40	0.0063	0.002[b]
Lindane (gamma-Hexachlorocyclohexane)	4.40	0.015	0.01[b]
Lindane (gamma-Hexachlorocyclohexane)	0.05	0.012	0.01[b]

Notes:

[a] Ohio Human Health Non-drinking WQS (OMZA)
[b] Ohio Aquatic Life WQS (OMZA)

4.3 ASSESSMENT OF POLLUTANT LOADS TO ACHIEVE WATER QUALITY STANDARDS IN LITTLE BEAVER CREEK

The following sections discuss loads of critical pollutants in the sediments and water column of LBC. Known and potential sources of all critical pollutants are identified. Methods used in calculating ongoing loads are then presented, followed by discussion of load reductions necessary for LBC to achieve its designated WWH aquatic life use.

4.3.1 Little Beaver Creek Sediment

This section describes contaminant loads in LBC sediments and ends with a discussion of sediment pollutant load assessment.

4.3.1.1. Sources of Metal Load to Sediments

According to statistical analyses of macroinvertebrate habitat scores (ICI) and sediment metal concentrations in LBC using data collected by OEPA in 1998, mercury, copper, and cadmium pose the greatest threat to aquatic health of LBC from heavy metals. Heavy metals in LBC sediments are attributed to urban and industrial runoff and effluent from the MCWWTP. Copper and cadmium are among the four most commonly found heavy metals in urban runoff (Dennison 1996). Mercury tends to be found in urban storm water runoff in areas where inappropriate connections between sanitary and storm sewers are present. MORs from MCWWTP report loads for all three metals. Spills, including sewage, fuels and oils, and metal wastes, may also account for a substantial portion of metals in LBC sediment.

Mercury

Sources of mercury in LBC sediment include effluent discharge from MCWWTP, urban and industrial runoff, and spills. Mercury may occur on the land surface in various forms. Natural (i.e. volcanoes) and anthropogenic (i.e. coal-fired power plants) emissions are sources of mercury to the atmosphere that can reach the land surface via wet and dry deposition. In urban environments, common sources include batteries, discarded laboratory chemicals, broken thermometers, hospital waste, lawn products, and pharmaceutical products (Manahan, 1994). Industrial operations and spills are also potential sources of mercury. The only location where the level of mercury in LBC sediment exceeds the TMDL endpoint is at RM 4.40 which is immediately downstream of both the MCWWTP outfall and entry point of the North Branch tributary.

MORs provided to OEPA by MCWWTP indicate that mean annual total mercury loads in MCWWTP effluent was 67.5 lb/yr between 1990 and 1995 and 0.00 lb/yr between 1995 and 1999. Of the 10 years of MOR data, mercury was detected in MCWWTP effluent in only 2 of those years, 1990 and 1995. The mean total mercury load was 0.161 lb/yr in 1990 and was 251 lb/yr in 1995. There were no changes in treatment processes by MCWWTP or laboratory methods to account for the reduction in mercury loads from 1990 through 1995 and 1995 through 1999 (Montgomery County Sanitary Engineering Department [MCSED]2000a). Medical facilities (i.e. hospitals, dentist offices, etc.) may account for a substantial portion of mercury in the MCWWTP and that improvements to mercury disposal methods implemented by the facilities may account for the observed reduction in mercury in MCWWTP effluent from 1990 through 1995 and 1996 through 1999 (MCSED 2000b).

In cases where contaminants may have an impact on surface water and sediments even when the reported value is non-detected, it is important to consider the detection limits used in laboratory analysis. For years 1990 to 1999, the Montgomery County Environmental Laboratory (MCEL) tested for total mercury using best available technology that achieved a detection limit of 0.3 ug/L (0.3 parts per billion). Under MCWWTP's National Pollutant Discharge Elimination System (NPDES) permit, the Practical Quantification Limit is 1.0 ug/L of total mercury. The state of Ohio's human health non-drinking water quality standard for total mercury in surface waters is 0.012 ug/L. Currently, MCEL achieves a total mercury detection limit of 0.2 ug/L. In the relatively near future, the laboratory will be required to implement a detection limit on the order of nanograms per liter (parts per trillion) as part of proposed regulations by USEPA. Tetra Tech calculated average total mercury loads in MCWWTP effluent using 50th percentile flow data reported in MORs and assuming a constant concentration of 0.15 ug/L (½ the detection limit) total mercury. For years 1990 to 1999, the calculated annual average total mercury load in MCWWTP effluent was 3.9 lbs/yr. Tetra Tech used this value to represent the total mercury load from MCWWTP.

As part of an urban runoff study, USEPA (1972) observed mercury levels on street surfaces of eight urban study areas ranging between 0.019 lb/curb mile to 0.30 lb/curb mile with a weighted average of 0.073 lb/curb mile. Sediment in LBC at RM 4.40 may accumulate mercury from urban runoff that is routed to LBC via the North Branch tributary. However, if urban runoff is a substantial source of mercury to LBC, Tetra Tech would expect to see comparable mercury concentrations in other sediment monitoring sites in LBC. Spills of mercury-containing materials may have resulted in mercury contamination of LBC sediment, but no data pertaining specifically to quantities of spilled mercury in the LBC drainage is currently available. Based on the information summarized above, the mercury contamination observed at RM 4.40 is probably related to discharge from the MCWWTP or spills or illicit drainage connections occurring along the North Branch tributary drainage.

Copper

Sources of copper in LBC sediment include MCWWTP effluent, urban and industrial runoff, and spills. A combination of these sources probably accounts for copper detected in LBC sediment at RM 4.40 which was the highest concentration observed in all five LBC sediment monitoring sites. Copper is used in the electroplating industry and may be a constituent of runoff from the industrial operations in the LBC watershed.

MORs provided to OEPA by MCWWTP indicate that the mean annual copper load in MCWWTP effluent was 2,417 lb/yr of total copper between 1990 and 1995 and 342.9 lb/yr of total recoverable copper between 1996 and 1999. For copper as well as cadmium, MCWWTP's NPDES permit for years prior to 1995 required analysis and reporting of these metals as total (i.e total copper). For years 1995 to 2000, the permit required analysis and reporting of copper and cadmium as total recoverable (i.e. total recoverable copper). The difference between total and total recoverable analysis procedures involves the degree of digestion an unfiltered sample undergoes before it is analyzed by atomic absorption. Analytical procedures used to test for total recoverable metals incorporate less vigorous digestion compared to analytical procedures used to test for total metals. This change in analytical procedure may account for the reduction in effluent copper load between years 1990 through 1995 and 1996 through 1999; however, the reduction may be attributed to reductions in copper loads in industrial effluent to MCWWTP. In the early 1990s, a certain industry discharging to MCWWTP had numerous violations for levels of copper in effluent. The industry underwent operational changes and has not exceeded copper limits for approximately the last 3 years (MCSED 2000b). This may explain the dramatic reduction in copper load from MCWWTP from years 1990 through 1995 and 1996 through 1999. MCWWTP has not undergone any significant changes in waste treatment processes that would account for the reduction in copper load (MCSED 2000a). The 1996 through 1999 mean annual total recoverable copper load of 342.9 lb/yr reported in MORs data was used by Tetra Tech to represent annual loads of copper to LBC from MCWWTP.

USEPA (1972) observed copper levels on street surfaces of eight urban study areas ranging between 0.02 lb/curb mile to 0.33 lb/curb mile with a weighted average of 0.20 lb/curb mile. Spills of copper-containing materials may also have resulted in copper contamination of LBC sediment. While there is no data available pertaining specifically to quantities of spilled copper in the LBC drainage, there are reports of spills of metal waste at the General Motors Delphi Chassis (GMDC) facility. Spills in the LBC watershed are discussed further in Section 4.3.4.

Cadmium

Sources of cadmium in LBC sediment include the MCWWTP, urban and industrial runoff, releases from the Lammars Barrel Factory site, and other spills. Cadmium in urban runoff is largely a result of atmospheric deposition, however, rubber tire wear, motor oil combustion, and fertilizer applications may also contain cadmium (USEPA, 1981). Cadmium, like copper, is used in the electroplating industry and may be a constituent in runoff from the industrial operations in the LBC watershed. The highest cadmium

concentration in sediments was detected downstream from the Lammars site at RM 3.47. Section 4.3.3 discusses the Lammars site as a source of cadmium to LBC.

MORs provided to OEPA by MCWWTP indicate that the mean annual cadmium load in MCWWTP effluent was 41.1 lb/yr of total cadmium between 1990 and 1995 and 0.89 lb/yr of total recoverable cadmium between 1996 and 1999. Changes in analytical and reporting procedures (i.e. total vs. total recoverable) may account for the reduction in effluent cadmium load between years 1990 through 1995 and 1996 through 1999; however, the reduction may be attributed to reductions in cadmium loads in industrial effluent to MCWWTP. In the early 1990s, a certain industry discharged a substantial cadmium load to MCWWTP. As of 1993, the industry no longer discharged process waste to MCWWTP. This may explain the dramatic reduction in cadmium load from MCWWTP from years 1990 through 1995 and 1996 through 1999 (MCSED 2000b). MCWWTP has not undergone any significant changes in waste treatment processes that would account for the reduction in cadmium load (MCSED 2000a). The 1996 through 1999 mean annual total recoverable cadmium load of 0.89 lb/yr reported in MOR data was used by Tetra Tech to represent annual loads of cadmium to LBC from MCWWTP.

USEPA (1972) observed cadmium levels on street surfaces of three urban study areas ranging between 0.0026 lb/curb mile to 0.0033 lb/curb mile. A weighted average was not provided, however, 0.0031 lb/yr of cadmium was reported for five urban study areas using other observations. While there are no data available pertaining specifically to other cadmium spills in the LBC watershed, there are reports of spills of metal waste at the General Motors Delphi Chassis (GMDC) facility as well as fuel and oil spills which may contain cadmium. Spills in the LBC watershed are discussed further in Section 4.3.4.

4.3.1.2 Sources of Organochlorine Pesticides Load to Sediments and Water Column

In 1998, OEPA observed concentrations of OC pesticides in both sediment and water column samples collected from LBC. Chlordane compounds were detected in LBC sediment, while dieldrin, endrin, endosulfan I, and lindane were detected in the water column. These pesticides were widely used before the 1980s as soil fumigants and agricultural and household insecticides (Hoff and others 1992). Toxaphene, DDT, and aldrin were the most frequently applied OC pesticides, according to Majewski and Capel (1995). OC pesticides are extremely persistent in the environment and are resistant to environmental transformation. Because of the connection between OC pesticides in the environment and nervous disorders in wildlife and humans, OC pesticides have been banned for use in the United States since the 1970s and 1980s.

Roughly 20 years since being banned in the United States, OC pesticides continue to be detected in surface waters and sediments. Levels of OC pesticide compounds in surface waters and sediment are influenced by transport of the compounds on local, regional, and global scales through all phases of the environment. As an example of the global scale of movement of OC pesticides through the environment, the detection of DDT and other OC compounds in fish and mammals in the Arctic, Antarctic, and other remote regions is primarily attributed to atmospheric deposition (Majewski and Capel 1995). The presence of these compounds is largely due to their rapid rates of volatilization into the atmosphere. Detection of many pesticides in air and precipitation exhibit seasonal trends, even for the OC pesticides that are no longer in use. Hoff and others (1992) detected maximum concentrations of dieldrin, endrin, endosulfan, heptachlor and other pesticides in air samples during spring and summer months. The sources of airborne OC pesticides include volatilization of residues remaining in treated fields and atmospheric transport from treated areas in the United States and foreign countries where the pesticides are still heavily used (Majewski and Capel 1995).

In general, OC pesticides have very low solubilities in water. Weber (1994) reports that "chlorinated hydrocarbon" pesticides have moderate to high soil retention and short to long longevity in soils. The author also reported that soil retention of these pesticides is highly correlated with soil organic matter content. Mobility of OC pesticides through soils and into groundwater is dependent on numerous interacting factors. The detection of chlordane pesticides in LBC sediment versus detection of other OC pesticides in the water column may be a function of chlordane compounds having the lowest solubility of all OC pesticides found in LBC.

The sources of OC pesticides observed in the LBC water column and sediments include atmospheric deposition and historic local usage of pesticides by agriculture and households within the LBC watershed. A golf course close to LBC may be an additional source (OEPA 2000a). Majewski and Capel (1995) report that atmospheric transport deposition into the Great Lakes was the primary source of organic contaminants including OC pesticides. Cole and others (1984) report that four of the five OC pesticides listed in Table 4-2 were detected in urban runoff samples. Water column samples collected from other urban and urban/agricultural watersheds in the LMR basin in 1998 contained the same pesticides at levels exceeding numerical water quality standards, providing further support for atmospheric deposition and urban runoff as sources of pesticides to LBC.

4.3.1.3 Sources of PAH Load to Sediments

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds formed by incomplete combustion of other hydrocarbons (Manahan 1994). PAHs are abundant in the atmosphere and on land surfaces. Engine exhaust, wood stove smoke, cigarette smoke, and charbroiled food are sources of PAHs. In addition, coal tars and petroleum residues have high levels of PAHs (Manahan 1994). During hot, sunny days, PAHs are released from asphalt and subject to entrainment (Debo and Reese 1995). Sources of PAHs in LBC sediment include urban and industrial runoff, runoff from the Defense Electronics Supply Center (DESC), and spills. MCWWTP effluent may be a source of PAHs to LBC. PAHs have not been detected in MCWWTP effluent according to data presented in a "2C" report disclosing all pollutants in MCWWTP effluent (OEPA 2000a). Sewage sludge entering the stream due to wastewater treatment plant upsets is a known source of PAHs. A USEPA survey of forty publicly owned treatment works (POTW) with industrial contributions ranging from near-zero to more than 50 percent of total influent showed that the frequency of PAH occurrence ranged between 1 and 49 percent (USEPA 1982). Removal of PAHs was highly variable, ranging between zero and 100 percent. Manoli and Samara (1999) referenced a study by Melcer et al. (1995) that studied 8 PAH compounds in 37 sewage treatment plants in Ontario, Canada, and showed an almost constant removal percentage (79 to 80 percent) of the compounds. In a study of the occurrence and mass balance of 16 PAH compounds in an activated sludge treatment plant, Manoli and Samara (1999) found that lighter PAH compounds were effectively removed by treatment processes while heavier PAH compounds were rather resistant to treatment processes.

Based on information presented in the previous paragraph, urban runoff and MCWWTP are both potential sources of PAH loads to LBC. However, there is no available data from within the LBC watershed to confirm either as a definite source. The only PAH data specific to LBC are observed PAH concentrations in LBC sediment reported by OEPA. As shown in Table 4-3, the highest concentration of total PAHs was observed by OEPA in 1998 at RM 4.40. As stated previously, RM 4.40 is immediately downstream from both the MCWWTP effluent outfall and the confluence of LBC with the North Branch tributary. Nine PAH compounds were detected at RM 4.40. The same nine compounds were also detected downstream at RM 3.54 and 3.47, seven of the nine compounds were detected at RM 0.05, and six of the nine compounds were detected upstream from RM 4.40 at RM 4.62. Carcinogenic benzo(a)pyrene was detected at all 5 OEPA sediment sampling locations in LBC. Based on current information, Tetra Tech assumes that urban runoff is an ongoing source of PAH loads to LBC while sewage sludge from MCWWTP is a source of PAHs during plant upsets. Other potential sources are discussed in the following paragraphs.

As mentioned in Section 2.2.2, sediments in the tributary to LBC (sub-watershed I) were contaminated by runoff from a coal-pile on the DESC site. Although the contaminated sediments were removed, it is likely some of the contaminated sediments were transported downstream and remain in place. It is also important to note that sediment samples collected in the tributary upstream from DESC contained levels of total PAH ranging between 51 and 210 ppm (OEPA 2000d). Presence of total PAH upstream from the DESC site are attributed to urban runoff from the city of Kettering. Sub-watershed I is heavily commercialized and contains a substantial amount of "blacktop", which may be a source of the observed PAHs.

Spills of PAH-containing materials such as oil may account for the levels of PAHs observed in LBC sediments. Data are available regarding spills of this nature in the LBC watershed, but this data is of limited use for estimating PAH loads due to spills because of the high variability of PAH concentrations in oil.

4.3.1.4 Sources of PCB Load to Sediments

Sources of PCBs detected in LBC sediments include atmospheric deposition, urban runoff, and the Lammars Barrel site. PCBs were first produced commercially in the United States around 1929. They have been used in dielectric fluid for capacitors and transformers, as petroleum additives and lubricants, and in carbonless copy paper (Wilber and others 1992). Heavy use of PCBs resulted in widespread accumulation in the environment, and PCB production was banned in 1977. However, PCBs continue to be released due to fires, spills, landfills, and other sources. In reporting results of a study of reported spills and leaks of PCB-containing fluids in the Great Lakes states, Wilber and others (1992) cites Valaoras (1986) in stating that an average of 52,000 kg per year of PCBs are released to the environment. Section 4.3.3 discusses the Lammars Barrel Factory site as a source of PCBs to LBC.

4.3.1.5 Sediment Pollutant Load Assessment

This subsection assesses the sediment mass-balance relationships in LBC to determine whether the observed sediment pollutant concentrations are associated with past or ongoing pollutant loads. The following subsections discuss sediment mass-balance, partitioning of contaminants from surface water to sediment, and the load reductions necessary to achieve the sediment endpoints.

Sediment Mass-Balance

A detailed geomorphologic assessment of LBC is not presently possible because of data limitations. The following paragraphs discuss a conceptual model of LBC sediment mass-balance relations developed by Tetra Tech using available data.

Analysis of sediment samples reported in OEPA (2000b) from five locations in LBC demonstrate that more than 60 to 75 percent of the size fraction of sediment is coarser than 60 microns (fine sand), while the remaining 25 to 40 percent consists of silt and clay. Studies of urban runoff and contaminated sediments in lakes and estuaries have shown that most urban runoff pollutants are absorbed onto fine particles and transported as suspended sediment (Sediment Engineering 1977). Dennison (1996) reports that metals tend to be evenly distributed among particle size classes. Based on these findings, it may be concluded that a proportion of the pollutants identified in the LBC sediments may be contributed by sediment-laden runoff from the watershed that is transported downstream.

Because the sediment transport capacity along a reach is strongly influenced by its geomorphic and hydraulic characteristics, the mass balance of the pollutant load within the creek may vary from reach to reach. Profiles by the Flood Emergency Management Agency (FEMA) (1982) show that the LBC has a rather constant bed slope of about 15 feet per mile (0.0029 foot per foot) from its confluence with Beaver Creek to the headwater. If the sediment in the LBC is assumed to have a specific gravity of 2.6, the depth required to move sediment fractions coarser than 1 millimeter is about 6 inches. This result indicates that the fine sediments that contain the pollutants would be transported as suspended load. Furthermore, an estimate of the 1-year annual peak flow in LBC based on FEMA (1982) data indicates discharges of the order of 5,000 cubic feet per second (cfs) with flow depths on the order of several feet. Under such hydraulic conditions, all fractions within the streambed may be expected to move, which suggests that no reach of LBC will experience net deposition of sediment load, either as bed load or suspended load.

Using streambed widths estimated by FEMA (1982) of LBC, and USGS stream flow records of adjacent basins located in Greene County, the annual sediment transport capacities of all seven stream segments were estimated. These results suggest that LBC has the capacity to transport all sediment loads.

Stream banks are potential sources of sediment in many streams. In the case of LBC, there is no documented evidence of bank instability, undercutting, or significant erosion of the stream channel. However, public officials have indicated that stream bank erosion has been observed downgradient of the

MCWWTP. This suggests that the stream is well adjusted to the existing hydrologic conditions; that is, the sediment influx balances the sediment transported out of the stream so that no segments experience excessive deposition or degradation. As the watershed continues to urbanize, the stability of the stream may not be sustained due to concomitant increases in runoff volumes and associated pollutant loads.

Contaminant Loading to Sediments from Surface Water

Releases to surface water provides an indirect loading of metals to the sediments in LBC. Tetra Tech estimated the impact contaminated surface water has on the sediments in LBC to determine if past and current loading rates could result in metal concentrations above TMDL endpoints. Concentrations in sediment samples exceed the TMDL endpoint for copper at RM 3.54 and RM 4.40, for mercury at RM 4.40 and for cadmium at RM 3.47. The most probable source of copper and mercury at RM 4.40 is the MCWWTP, considering past and current discharges. It is assumed that the copper and mercury in the MCWWTP effluent is in the dissolved form and it is valid to estimate the partitioning from surface water to sediment at this location. The most probable source for cadmium at RM 3.47 is urban runoff or cadmium containing soils from the Lammars site. Tetra Tech assumes the cadmium introduced at RM 3.47 as a result of urban runoff or runoff from soil at the Lammars site is attached to particles; therefore, there is no further partitioning from surface water to sediment for cadmium.

Tetra Tech used available data to estimate the in-stream concentration of the copper and mercury, and to then calculate a concentration of these metals in the sediment. Tetra Tech conducted this analysis for two time periods: 1990 through 1995, and 1996 through 1999. The discharge rate, as well as the load of copper and mercury, is clearly different for these two time periods. The 1990 through 1995 time period is characterized by higher flow and loading conditions compared to the 1996 through 1999 time period. The reported 1995 mean annual mercury load of 251 lbs/yr was used to calculate the past impact to LBC sediments and a calculated average load of 3.9 lbs/yr to predict the ongoing impact to LBC sediments. Tetra Tech used the reported mean annual copper loads of 2,417 lbs/yr to calculate the past impact to LBC sediments and 342 lbs/yr to predict the ongoing impact to LBC sediments.

As shown in the Table 4-7, the historical (1990 through 1995 time period) discharges of copper and mercury from the MCWWTP result in calculated sediment concentrations that are within the same order of magnitude as the maximum observed sediment concentrations. Note that the observed sediment concentrations are from the 1998 sampling event (only set of data available immediately downstream of MCWWTP). If there was not complete scouring of sediments at the sampling location during the 1995

to 1998 time period, historical discharges from the MCWWTP could be the cause of copper and mercury exceeding the TMDL endpoint at this location.

Applying the same set of assumptions for the recent (1996 through 1999) discharges from the MCWWTP results in calculated sediment concentrations that are about an order of magnitude or more below the TMDL endpoints for copper and mercury.

There is considerable uncertainly in the analysis, such as (1) the nature of and effect of sorption/desorption kinetics in sediments is not well understood or documented in the scientific literature, (2) the partitioning coefficients (Kd values) for mercury and copper have a wide range of values depending on actual site-specific conditions, and (3) the number, temporal, and spatial variation in the sediment samples may not be sufficient to characterize the actual site conditions.

TABLE 4-7

PARTITIONING OF METALS FROM SURFACE WATER TO SEDIMENT

1990-1995 Loading Analysis									
	Flow (L/yr)	Mass (mg/yr)	Effluent Concentration (mg/L)	Dilution Factor	Instream Concentration - Calculated (mg/L)	Kd (L/kg)[a]	Calculated Sediment Concentration (mg/kg)	Maximum Observed Sediment Concentration (mg/kg)	TMDL Sediment Endpoint (mg/kg)
Copper	1.71E+10	1.10E+09	6.41E-02	0.74	4.74E-02	2.20E+01	1.04E+01	2.84E+01	2.04E+01
Mercury	1.71E+10	1.14E+08	6.67E-03	0.74	4.93E-03	1.90E+02	9.37E-01	2.20E-01	1.00E-01

1996-1999 Loading Analysis									
	Flow (L/yr)	Mass (mg/yr)	Effluent Concentration (mg/L)	Dilution Factor	Instream Concentration - Calculated (mg/L)	Kd (L/kg)	Calculated Sediment Concentration (mg/kg)	Maximum Observed Sediment Concentration (mg/kg)	TMDL Sediment Endpoint (mg/kg)
Copper	1.26E+10	1.55E+08	1.23E-02	0.67	8.24E-03	2.20E+01	1.81E-01	NA	2.04E+01
Mercury	1.26E+10	1.76E+06	3.00E-04	0.67	2.01E-04	1.90E+02	1.78E-02	NA	1.00E-01

Notes:

L/kg = Liter per kilogram
L/yr = Liter per year
mg/kg = Milligram per kilogram
mg/L = Milligram per liter
mg/yr = Milligram per year
NA = Not applicable

[a] Kd values are all in the range presented in EPA (1999) "Partitioning Coefficients for Metals in Surface Water, Soil, and Waste"

Analysis of Sediment Pollutant Load

Based on the preceding analysis, LBC sediment is likely to scour on a regular basis. Therefore, continual loading to the LBC sediments accounts for the sediment toxicity documented in Section 4.2. Table 4-8 summarizes the peak sediment concentrations for each of the six critical pollutants and the sediment TMDL endpoint associated with that pollutant. Table 4-8 demonstrates that endpoint exceedances are observed for all six contaminants.

TABLE 4-8

RELATIONSHIP BETWEEN SEDIMENT CONTAMINANT CONCENTRATIONS AND TMDL ENDPOINTS

Contaminant	Highest Observed Sediment Conc. (mg/kg)	Location (RM)	TMDL Endpoint (mg/kg)
Copper	28.4	4.40	20.4
Mercury	0.222	4.40	0.10
Cadmium	3.09	3.47	0.54
Total PAH	36.7	4.40	4.0
Total Chlordane	0.057	4.40	0.007
PCBs	0.415	3.47	0.07

The resulting percentage reductions in pollutant loads necessary to achieve endpoints are presented in Table 4-9, assuming sediment pollutant concentrations are homogenous throughout the sediment column. Loads to the LBC water column are discussed in Section 4.3.3.

TABLE 4-9

PERCENTAGE REDUCTION IN SEDIMENT LOAD TO ACHIEVE ENDPOINT

Contaminant	Percent Reduction
Copper	28
Mercury	54
Cadmium	82
Total PAH	89
Total Chlordane	88
PCBs	83

4.3.2 Organochlorine Pesticides in Water Column

This section discusses assessment of OC pesticide load to the LBC water column using water quality data collected by OEPA from LBC in 1998. OEPA collected water quality samples during the months of July, August, and September 1998 that approximate base flow conditions. The first subsection discusses methods used to estimate flows in LBC that correspond with water quality observations by OEPA. The second subsection discusses load reductions necessary to achieve endpoints.

4.3.2.1 Estimation of Flows in Little Beaver Creek

Little Beaver Creek is an ungaged stream. Flow measurements were not performed during monitoring of LBC by OEPA in 1993 nor 1998. This section discusses methods used to estimate flows to correspond with monitoring events in LBC by OEPA in 1998. Flows corresponding to the 1998 water quality sampling dates in LBC were estimated by establishing a relationship among drainage area of BC, observed flow and a rating curve for BC, and effluent discharges by the Beaver Creek Wastewater Treatment Plant (BCWWTP), MCWWTP, GMDC, and BCWTP. BCWWTP is located on BC downstream from where flow enters from LBC. BCWTP, not to be confused with BCWWTP, discharged effluent to LBC through December 1998.

On July 1998, OEPA began a series of direct flow measurements in BC below the outfall of BCWWTP. A staff gauge was installed at the site, and flow on BC was measured eight times between July 1998 and August 1999. Measured flows ranged between 27 and 87 cfs (unpublished data provided by OEPA). A rating curve was developed using the observed flow data and corresponding staff gauge levels at the BC site. For each of the 1998 sampling dates in LBC, OEPA recorded the staff gauge reading from the BC site and estimated flow in BC using the established rating curve. The flow in BC was then used to estimate flow in LBC based on the drainage area of LBC relative to the total drainage area of BC.

Flow in BC was adjusted by subtracting all point discharges in the BC watershed, which includes LBC as a sub-watershed. The point discharges that contributed to flow in BC during summer 1998 at the site of the staff gauge include BCWWTP, GMDC, MCWWTP, and BCWTP.

The following equation was used to estimate flow per unit drainage area in the Beaver Creek watershed:

$$q_{ua} = (Q_T - Q_{BCWWTP} - Q_{MCWWTP} - Q_{GMDC} - Q_{BCWTP}) / A_{BC}$$

where

q_{ua} = Unit flow per contributing drainage area of the Beaver Creek and Little Beaver Creek watersheds combined (cubic feet second per square mile [cfs/mile^2])

Q_T = Observed flow in BC below BCWWTP by OEPA (cfs)

Q_{BCWWTP} = Effluent discharge from BCWWTP (cfs)

Q_{MCWWTP} = Effluent discharge from MCWWTP (cfs)

Q_{GMDC} = Non-contact cooling water discharge from GMDC (cfs);

Q_{BCWTP} = Effluent discharge from BCWTP (cfs)

A_{BC} = Drainage area of BC watershed including LBC (49.5 square miles [mile^2]).

Q_{MCWWTP}, Q_{GMDC}, and Q_{BCWTP} were derived from their respective MORs. The 1998 summer season mean discharge rates reported for MCWWTP outfall 001 and GMDC outfalls 001, 002, 003, and 004 were used. The 1998 annual mean discharge for BCWTP outfall 001 was used to represent Q_{BCWTP}. The 50th percentile 1998 summer flows as communicated by OEPA for BCWWTP were used to represent Q_{BCWWTP}.

Once q_{ua} was determined, flow in LBC was calculated at each sampling location (RM) as a function of contributing drainage area in LBC and any upstream point discharges. This assumes that both BC and LBC watersheds maintain the same flow per unit drainage area; that both creeks are gaining streams during the late summer; and that surface water runoff was not occurring. Table 4-10 presents the q_{ua} values calculated and used in estimating 1998 flows in LBC. Data corresponding to April 29, 1999, are also included. These data are important to validation of the flow estimation method described here.

TABLE 4-10

DATA USED IN CALCULATING q_{ua}

Date	Q_T (cfs)	Q_{BCWWTP} (cfs)	Q_{MCWWTP} (cfs)	Q_{GMDC} (cfs)	Q_{BCWTP} (cfs)	q_{ua} (cfs/mile^2)
7/8/98	87.03	9.28	12.8	0.542	0.025	1.301
7/22/98	73.87	9.28	12.8	0.542	0.025	1.035
8/5/98	43.35	9.28	12.8	0.542	0.025	0.418
8/19/98	42.50	9.28	12.8	0.542	0.025	0.401
9/2/98	50.20	9.28	12.8	0.542	0.025	0.557
4/29/99	56.60	6.72	12.7	0.749	0.000	0.736

As mentioned above, this flow estimation method is based on several assumptions, including a lack of surface runoff entering LBC due to precipitation. Table 4-11 provides antecedent precipitation data reported for Dayton, Ohio. For each sampling day in 1998, precipitation in inches is noted, along with the number of days since the recent and second most recent rainfall.

TABLE 4-11

ANTECEDENT RAINFALL DATA FOR DAYTON, OHIO

Date	**Days Since Most Recent Rainfall/ Precipitation (in)**	**Days Since Second Most Recent Rainfall/ Precipitation (in)**
7/8/98	0 / 0.1	3 / trace
7/22/98	0 / 0.12	2 / 0.41
8/5/98	0 / 0.05	5 / 0.02
8/19/98	8 / 0.52	9 / 0.13
9/2/98	0 / trace	4 / 0.2
4/29/99	0 / 0.08	1 / 0.09

Table 4-12 presents calculated flows in LBC that correspond with OEPA water quality monitoring events in 1998.

TABLE 4-12

ESTIMATED FLOWS IN LBC CORRESPONDING TO 1998 OEPA MONITORING EVENTS

RM	Contributing Drainage Area ($mile^2$)	Q(cfs) 7/8/98	Q(cfs) 7/22/98	Q(cfs) 8/5/98	Q(cfs) 8/19/98	Q(cfs) 9/2/98	Q(cfs) 4/29/99
6.23	5.24	6.81	5.42	2.19	2.10	2.92	3.85
4.62	8.70	11.86	9.55	4.18	4.04	5.39	7.15
4.40	8.72	24.68	22.37	16.99	16.84	18.20	19.86
3.54	16.54	34.86	30.46	20.27	19.98	22.56	25.62
3.47	16.57	34.90	30.49	20.28	19.99	22.57	25.64
1.95	18.53	37.46	32.53	21.10	20.78	23.67	27.09
0.05	26.39	47.67	40.66	24.39	23.94	28.04	32.87

Estimated flow data for April 29, 1999, is provided as validation or support of the flow estimation method presented here. On this date, OEPA measured flow at the mouths of both BC and LBC. As presented in Table 4-10, Q_T measured in BC was 56.60 cfs. Using the flow estimation method, flow at RM 0.05 in LBC is estimated to be 32.87 cfs. Flow at LBC RM 0.05 measured by OEPA on April 29, 1999, was 30.98 cfs. The estimated and observed flows are within 10 percent of each other. This figure provides support for the flow estimation method considering that stream flow measurements can have a substantial degree of uncertainty.

It is important to note that there is information available that is contrary to the assumption that the entire reach of LBC is a gaining stream. As stated in Section 2.1.1, the lower reach of LBC has been reported to be a losing stream. The current level of information available regarding flow in LBC is insufficient in assigning any classification of LBC being permanently a gaining or losing stream. As the flow regime in LBC fluctuates on a seasonal basis, interaction between groundwater and surface water may fluctuate accordingly.

4.3.2.2 Assessment of Non-Point Loading of Organochlorine Pesticides in Water Column of Little Beaver Creek

Exceedances of numerical WQS for OC pesticides were observed in water quality samples collected by OEPA from LBC in 1998. On August 5, 1998, dieldrin exceeded its standard at RM 4.40 and RM 0.05, both downstream of where MCWWTP and the North Branch discharge to LBC. Endrin exceeded its standard at RM 4.40. On September 2, 1998, lindane exceeded its standard at RM 4.40 and 0.05. Endosulfan I exceeded its standard at RM 4.62, upstream from MCWWTP and the North Branch. Using the estimated flow values reported in Section 4.3.2.1, the observed concentrations of OC pesticides in violation of WQS were converted to loads in pounds per day (lb/day) and pounds per year (lb/yr). Using the same flow values, a load was calculated for each OC pesticide using its respective numerical concentration standard. The calculated numerical load was then subtracted from the observed load. The difference between the two represents the excess load. This information is presented in Table 4-13 for each of the four pesticides stated above.

TABLE 4-13

EXCESS LOADS OF OC PESTICIDES IN LBC

Date	RM	Conc (µg/L)	Flow (cfs)	Load (lb/day)	Load (lb/yr)
Dieldrin Loads					
8/5/98	4.40	0.01	16.99	0.000916	0.334
WQS		0.00076	16.99	0.000070	0.025
Excess Load				**0.000846**	**0.309**
8/5/98	0.05	0.0074	24.38	0.000972	0.355
WQS		0.00076	24.38	0.000100	0.036
Excess Load				**0.000316**	**0.318**
Endrin Loads					
8/5/98	4.40	0.0063	16.99	0.000577	0.211
WQS		0.002	16.99	0.000183	0.067
Excess Load				**0.000394**	**0.144**
Lindane Loads					
9/2/98	4.40	0.015	18.19	0.001471	0.537
WQS		0.010	18.19	0.000980	0.358
Excess Load				**0.000490**	**0.179**
9/2/98	0.05	0.012	28.04	0.001814	0.662
WQS		0.010	28.04	0.001511	0.552
Excess Load				**0.000302**	**0.110**
Endosulfan I Loads					
9/2/98	4.62	0.0068	5.38	0.000197	0.072
WQS		0.003	5.38	0.000087	0.032
Excess Load				**0.000110**	**0.040**

4.3.3 Pollutant Load Assessment to the Little Beaver Creek Water Column for Other Toxic Pollutants of Concern

This section addresses pollutant load to the LBC water column for the six toxic pollutants of concern identified in Section 4.2 from non-point runoff from the LBC watershed, spills, contaminated groundwater discharge, and point source discharge.

4.3.3.1 Non-Point Source Loads from Runoff

Urban runoff is a major non-point source of pollution entering LBC. The contribution of runoff to overall pollutant loads is influenced primarily by the size of the watershed, the land use patterns, and precipitation. According to USGS GIRAS land use data using the Andersen Level II classification, land use in the LBC watershed consists of 50 percent residential, 30 percent agricultural, 17 percent industrial, and about 3 percent undeveloped land. Review of the USGS topographic maps of the watershed suggest that the agricultural land use reported by the UGSG GIRAS system is significantly overstated.

To quantify the pollutant loads entering LBC through runoff from the watershed, the following procedure was used. The LBC watershed was subdivided into its tributary watersheds that drain to the LBC main stream as depicted in Figure 2. The predominant land use in each sub-watershed was determined using the USGS maps. The amount of each pollutant generated per unit area for each tributary sub-watershed was assigned by comparing the land uses with similarly urbanized areas in other parts of the United States for which data are available. Pollutant concentrations in urban runoff vary widely in different cities across the country. For the purposes of this evaluation, typical pollutant concentrations of urban runoff associated with various land uses were used. These values are based on nationwide data reported in USEPA (1972). Urban runoff typically consists of a large number of pollutants at highly variable concentrations (Manning and others 1977).

As shown in Figure 2, each sub-watershed contributes pollutants to LBC as a point load located at its confluence with LBC, which are numbered beginning from 1 (one) at the confluence with Beaver Creek to 7 representing the headwater reach. The amount of loading into LBC was calculated by multiplying the contributing area of each sub-watershed by the loading per unit area. The average daily loads were then converted to annual loads and are presented in Table 4-14. These results are representative of the average pollutant loading in urban areas with similar characteristics.

TABLE 4-14

NON-POINT SOURCE LOAD TO LITTLE BEAVER CREEK

Pollutant	Copper	Mercury	Cadmium	Total PAHs	PCBs	Chlordane
Annual Load (lbs/year)	653	0.15	123	6.7	8.7	0.30

4.3.3.2 Pollutant Loads Associated with Groundwater Discharge

The loading of contaminants to LBC includes a contribution from groundwater. Tetra Tech identified one location with groundwater contamination at a level significant enough to act as a potential source of contaminant loading to LBC. Several environmental investigations conducted at Lammars Barrel in Beavercreek, Ohio, have documented groundwater contamination. Table 4-15 summarizes loading of contaminants from the Lammars site.

TABLE 4-15

SOURCE LOAD TO LITTLE BEAVER CREEK FROM LAMMARS BARREL SITE

Contaminant	Groundwater Concentration (µg/L)	Groundwater Discharge to LBC (cfs)	Groundwater Discharge to LBC (ft^3/d)	Loading from Lammars Barrel Site (lbs/yr)
Cadmium	<1.7	0.0119	1,027	0.04
Copper	57.3	0.0119	1,027	1.34
Mercury	0.88	0.0119	1,027	0.02
Arochor-1248	<0.5	0.0119	1,027	0.01
Arochor-1254	<0.5	0.0119	1,027	0.01

The loading estimates are considered to be upper end estimates because conservative assumptions were used in the parameter selection. The groundwater concentration selected to represent site conditions is the highest concentration (USEPA 1998) detected on site or the method detection limit (MDL) if the contaminant was not detected. Furthermore, it was assumed that all groundwater beneath the Lammars site was contaminated at this elevated level. Groundwater discharge to LBC was estimated based on the average base flow for the entire watershed and prorated to the 140 feet of LBC adjacent to the site.

4.3.3.3 Loads Due to Spills

Tetra Tech attempted to quantify the contaminant load to LBC by first identifying spills in the LBC watershed and then quantifying the mass of individual constituents associated with the spills. The results of this effort are presented below.

OEPA documented reported spills within the LBC watershed according to date, material, responsible operation, and quantity in gallons (OEPA 1995 and OEPA 2000b). Between the years of 1984 and 1998, a total of 49 spills within the LBC watershed were reported, which equates to an average of roughly three spills per year. The predominant types of material spilled were wastewater/sewage, fuel/oil, and metal wastes. These are summarized below in Table 4-16. Spilled materials that are not summarized in Table 4-15 but were reported in the TSDs include "white material," "yellow material," "salt water," "Cl- water," "cooling water," and "unknown."

TABLE 4-16

SUMMARY OF SPILLS IN LBC WATERSHED REPORTED TO OEPA

Material Type	Specific Materials Reported	Operations Reported	Total Spills Total Quantity Range in Reported Quantity	Average Quantity Per Year
Wastewater/ sewage	Wastewater Sewage	GMDC MCWWTP Christopher Swim Club Greene Co. Water	19 reported spills 1,067,500 gallons* 0 - 690,000 gallons	71,167 gal/yr*
Fuel/oil	Gasoline Diesel fuel Heating oil Waste oil Hydraulic oil Motor oil Fuel oil Oil	GMDC Diconex Duncan Oil Urban Suburban Tavern Chuck's Marathon Unknown	20 reported spills 7,274 gallons 0-3,900 gallons	485 gal/yr
Metal waste	Chrome waste Chromium ZnCl plating waste Trade waste	GMDC	4 reported spills 820 gallons 66 lb 0-700 gallons 66 lb	54.7 gal/yr 4.4 lb/yr

Note:
* Number is influenced by two spills reported by MCWWTP (7/2/84 and 4/21/87) for a total of 1,065,000 gallons.

There is insufficient data to quantify the contaminant load to LBC from past spills. However, the information presented in Table 4-16 suggests that spills may be largely accountable for legacy contaminants in LBC. From the available spill data, there is great uncertainty in estimating the historic or average loading of spilled contaminants to LBC as well as the mass of individual contaminants. Within each type of specific material reported, there is inherent variation in the material's composition of contaminants of concern (metals, PAHs). In the absence of data necessary for proper risk-analysis, assumptions of composition may be incorrect or misleading and are often conservative due to lack of considerations of weathering and subsequent changes in composition (Potter and Simmons 1998). Reports of 0 (zero) gallons of a material being spilled adds even more uncertainty in estimating loads from spills. Of the 19 wastewater/sewage spills, 15 were reported as zero gallons spilled. Of the 20, fuel/oil spills, five were reported as zero gallons, and of the four metal waste spills, one was reported as zero gallons. Tetra Tech assumes that the information describing spills in the LBC watershed is

inadequate for estimation of a historic or average load of PAHs, metals, or any other contaminant of concern to LBC due to spills.

4.3.3.4 Non-Point Source Load Due to Release from Sediments and Groundwater

Contaminants adsorbed onto bottom sediments in LBC can impact water quality. There is insufficient data to reliably estimate the impact that contaminated sediments has on water quality in LBC. Conceptually contaminated sediments can impact water quality through three mechanisms:

1. Groundwater discharge to LBC may dissolve contaminants sorbed to bottom sediments and carry these contaminants into the water column
2. Sediments physically carried in the water column as a suspended fraction may contribute contaminants to the water column through desorption
3. Water flowing across the contaminated sediment surface may desorb contaminants and carry them into the water column

In addition, contaminated sediments may be resuspended in the water column. Once sediments become suspended, equilibrium partitioning and desorption kinetics will control to what degree adsorbed contaminants will desorb and contaminate the water column. Typical measured suspended solids concentrations of approximately 6 milligram per liter (mg/L) have been reported in LBC (OEPA 2000b).

4.3.3.5 Loads from MCWWTP Discharge

Tetra Tech calculated loads of critical metal pollutants (cadmium, copper, and mercury) in effluent discharged to LBC from the MCWWTP. Tetra Tech received MCWWTP MORs from OEPA covering the years 1990 to 1999. In these MORs, data pertaining to effluent flow (MGD), concentrations (mg/L), and loads (kg/d) of constituents in effluent are reported. For each year (1990 through 1999), concentrations and loads are reported as number of observations, number below detection, observed minimum, observed maximum, mean, and six percentile groups (5^{th}, 25^{th}, 50^{th}, 75^{th}, 95^{th}, and 99^{th} percentiles). MOR data also include, in this same format on an annual basis, observed concentrations of constituents in LBC samples collected by MCWWTP upstream and downstream from the MCWWTP outfall to LBC. For all constituents in both effluent and LBC, "overall" data are reported that summarize the constituents for all years on the same basis as described above (minimum, maximum, mean). Some of

the constituents in the MOR are reported on both seasonal (winter and summer) and annual bases, while others are reported only on an annual basis. Metals are reported on an annual basis.

Tetra Tech estimated annual loads of total recoverable cadmium, total recoverable copper, and total mercury from MCWWTP using the overall mean load data reported in the MOR. The overall mean loads, reported as kg/d, were converted to lb/yr by multiplying the reported load by 804.7. Tetra Tech assumed that no other critical pollutants (PAHs, chlordane, and PCBs) were present in the effluent from MCWWTP (OEPA 2000a).

4.3.3.6 Summary of Six Critical Pollutant Loads to the Little Beaver Creek Water Column

Table 4-17 summarizes the water column load analysis described above.

TABLE 4-17

TOTAL LOAD TO LBC WATER COLUMN (lbs/yr)

Source	Cadmium	Copper	Mercury	Total PAH	Total PCB	Chlordane
MCWWTP	0.88	342.9	3.9	0.0	0.0	0.0
Urban Runoff	123.0	653.0	0.15	6.7	8.7	0.30
Spills	NQ	NQ	NQ	NQ	NQ	NQ
Groundwater Discharge	0.04	1.34	0.02	0.0	0.02	0.0
Total	123.92	997.24	4.07	6.70	8.73	0.30

Note:

NQ = Not quantified

5.0 SUMMARY AND RECOMMENDATIONS

This section provides a summary of loads to LBC and recommendations to achieve TMDL endpoints. Section 5.1 summarizes the contaminant loads to the surface water and sediment in LBC, as well as the load reduction necessary for each contaminant to achieve the TMDL endpoint. Section 5.2 presents recommended best management practices (BMP) to reduce NPS loads for each contaminant to LBC.

5.1 SUMMARY OF FINAL LOAD REDUCTIONS

Past and ongoing sources of contaminant loading to LBC have impacted the quality of both surface water and sediment to the extent that TMDL endpoints have been exceeded. Contaminants in the surface water that exceed TMDL endpoints include OC pesticides such as dieldrin, endrin, lindane, and endosulfan I. Contaminants in the sediment that exceed TMDL endpoints include copper, mercury, cadmium, total PAHs, total Chlordane, and PCBs. This section presents the percent reduction of contaminants necessary to meet TMDL endpoints in each media.

5.1.1 Surface Water

The percent reductions necessary to meet the TMDL endpoints for contaminants in surface water are presented in Table 5-1. Each TMDL endpoint expressed as lbs/yr will result in a surface water concentration for that contaminant at or below the contaminant-specific endpoint, as described in Section 4.3.2.2. The source of OC pesticide loading to LBC has not been firmly established; however, non-point runoff is considered to be the largest source. In addition, it is clear that greater contaminant reductions are needed in the upper reaches of the watershed. Reducing the loading of OC pesticides in the upper reaches of the watershed will lessen the amount of load reduction necessary in the lower reaches of the watershed to meet the TMDL endpoints.

TABLE 5-1
SUMMARY OF LOAD REDUCTIONS NECESSARY TO MEET
SURFACE WATER TMDL ENDPOINTS

Contaminant	Load (lbs/yr)	Location	TMDL Endpoint (lbs/yr)	Percent Reduction
Dieldrin	0.334	RM 4.40	0.025	93
Dieldrin	0.355	RM 0.05	0.036	90
Endrin	0.211	RM 4.40	0.067	68
Lindane	0.537	RM 4.40	0.358	33
Lindane	0.662	RM 0.05	0.552	17
Endosulfan I	0.072	RM 4.62	0.032	56

5.1.2 Sediment

TMDL endpoints for sediment are expressed as mg/Kg. Achieving the TMDL endpoints for sediment will result in the creek's sediments attaining a "good ecosystem health" designation, as described in Section 4.2.2. For sediments, each TMDL endpoint is expressed as a concentration rather than a load because the contaminants are persistent once sorbed onto the sediment and a reduction in load may not result in a decrease in contaminant concentration. Therefore, achieving the TMDL endpoint must be considered in terms of past and current loads and their resultant concentrations. The load reduction necessary to meet the sediment TMDL endpoint for each contaminant is presented below in Table 5-2 and discussed in the following paragraphs.

TABLE 5-2
SUMMARY OF LOAD REDUCTIONS NECESSARY TO MEET
SEDIMENT WATER TMDL ENDPOINTS

Contaminant	Concentration (mg/Kg)	Location	TMDL Endpoint (mg/Kg)	Percent Reduction
Copper	28.4	RM 4.40	20.4	28
Mercury	0.222	RM 4.40	0.10	54
Cadmium	3.09	RM 3.54	0.54	82
Total PAHs	36.7	RM 4.40	4.0	89
Total Chlordane	0.057	RM 4.40	0.007	88
PCBs	0.415	RM 3.47	0.07	33

In the past, the two largest sources of copper to LBC were determined to be urban runoff (653 lbs/yr) and the MCWWTP (2,417 lbs/yr). The loading from urban runoff is assumed to stay at this level unless BMPs discussed in the next section are undertaken. The past copper loading of 2,417 lbs/yr from the MCWWTP by itself was enough to result in sediment concentrations above the TMDL endpoint.

However, the current loading estimate of 342 lbs/yr (an 86 percent reduction) of copper from MCWWTP to LBC results in calculated sediment concentrations an order of magnitude below the TMDL endpoint.

Similarly, the largest source of mercury to LBC in the past was determined to be the MCWWTP (251 lbs/yr). This past loading of mercury from the MCWWTP was sufficient to result in sediment concentrations above the TMDL endpoint. However, the current loading estimate of 3.9 lbs/yr (a 98 percent reduction) of mercury from MCWWTP to LBC results in calculated sediment concentrations an order of magnitude below the TMDL endpoint.

The largest source of cadmium to LBC sediments is urban runoff (123 lbs/yr). The loading from urban runoff is assumed to stay at this level unless BMPs discussed in the next section are undertaken.

PAHs have been released to LBC from hazardous waste sites and urban runoff, resulting in PAH concentrations in sediments above the TMDL endpoints. Past releases of PAHs from hazardous waste sites have been and continue to be addressed through other regulatory programs. The PAH loading from urban runoff (6.7 lbs/yr) is assumed to stay at this level unless BMPs discussed in the next section are undertaken.

The sources of OC pesticides observed in LBC include atmospheric deposition and historical local usage by agriculture and households within the LBC watershed. Water column samples collected in 1998 from other urban and urban/agriculture watersheds in the LMR Basin further support urban runoff as sources to LBC. The loading from urban runoff is assumed to stay at this level unless BMPs discussed in the next section are undertaken.

The largest source of PCBs to LBC sediment is urban runoff (8.7 lbs/yr). The loading from urban runoff is assumed to stay at this level unless BMPs discussed in the next section are undertaken.

5.2 DISCUSSION OF URBAN STORM WATER MANAGEMENT AND RECOMMENDED CONTROL GUIDELINES

While it is evident that presence of legacy contaminants combined with ongoing effluent discharge from MCWWTP impair the aquatic health of LBC, urban runoff from lands adjacent to LBC play a significant role as well in the overall degradation of LBC. USEPA has documented that there are particular storm water pollution problems common to almost any municipality (Debo and Reese, 1995). With respect to

the pollutants discussed in this report, such problems include runoff from pesticide and herbicide use, oil and grease disposal, and toxics use in products and disposal. Technical and non-technical literature describe numerous methods for controlling pollutant loads in urban storm water runoff. Methods that do not involve intense and costly mechanical treatment are labeled BMPs (Urbonas and Stahre 1993). Tetra Tech has identified management measures that have proven successful in mitigating impacts of urban runoff containing heavy metals and toxic organic contaminants such as PAHS and pesticides.

The following discussion addresses specific BMPs suitable for reducing NPS load to LBC. There is a great degree of variation in BMPs. There are two main categories of BMPs: structural and non-structural. Structural BMPs include practices designed and constructed to mitigate the adverse impact of urban runoff via physical removal, settling, infiltration, chemical reactions, or biochemical transformation (Ogden Environmental and Energy Services, Inc. 2000). Selection and use of structural BMPs depends on land use activities, existing structures, hydrology, climate, soil type, and other site-specific conditions (Dennison 1996). In addition, these practices typically require continuing operation and maintenance efforts. Non-structural BMPs are more preventative in nature and do not require construction or maintenance. These practices include various management programs, public education, zoning ordinances, and environmental permitting.

According to Dennison (1996), the basic principle of storm water controls for urban development is that it is much more cost-effective and institutionally feasible to develop controls for new development than it is to retrofit old development. The author states that structural practices (BMPs) require not only capital, but operation and maintenance costs, and are often constrained by spatial and financial limitations in core urban areas. Additionally, some structural controls can potentially destroy the resource they were designed to protect due to disruption of the hydrologic cycle. In situations where clear public concerns or ecological health impacts are evident, retrofitting of structural BMPs requiring the least amount of land can be considered (Urbonas and Stahre 1993). In contrast to structural BMPs, nonstructural practices are more suitable to urbanized areas under predominantly post-construction conditions. The most effective way to maintain clean surface waters is to eliminate the sources of pollution, not to remove pollution once it has entered the system (Debo and Reese 1995). Non-structural BMPs are critical to any storm water management program because they are designed to prevent establishment of sources of pollution in storm water.

Based on data and information discussed in this report, heavy metals and organic contaminants are transported to LBC through storm water runoff from within the watershed. Because these pollutants have

an affinity for sediment on pervious and impervious land surfaces as well as in the stream, particulates by default contribute to this contamination. These pollutants are likely to originate on all land use types represented in the watershed. It is also likely that illegal discharges to storm sewers may occur. Such discharges may be as simple as a local homeowner dumping used motor oil down a storm drain. Implementation of any type of storm water management program for the LBC watershed must include plans for identification and elimination of illegal discharges or connections to storm sewers. It is critical that such a program addresses spill prevention as well.

Protection of the aquatic health of LBC from impacts of urban runoff may necessitate both structural and non-structural control BMPs. The Internet and literature offer numerous discussions on the effectiveness of the various BMPs. It is important to note that BMPs recommended by authors and agencies or advertised by companies may have undergone limited review, that is, they have not been examined under a diverse array of urban storm conditions or municipal management settings. Debo and Reese (1995) provide thorough discussion and numerous references regarding all aspects of urban storm water management. In summarizing the general effectiveness of structural BMPs, the authors state all urban BMPs cannot provide high levels of removal of both particulate and soluble pollutants. The authors rank various control measures from the standpoints of efficiency in removing targeted pollutants , capital costs, additional land requirements, and operation and maintenance costs. Targeted pollutant categories include particulates, heavy metals, pesticides and organics (oil and grease/PAHs). Grassed channels and overland flow BMPs rank the highest in effectiveness in removing all categories of pollutants and lowest in capital costs per acre, additional land requirements, and operation and maintenance. These BMPs encompass a variety of methods utilizing landscaping, vegetation, and pervious land surfaces to filter or adsorb pollutants. Grassed swales, filter strips, and flow spreaders are specific examples of these BMPs. Grassed swales are reported to be quite effective in removal of metals and solids. Filter strips can be reliable for removal of solids but unreliable for dissolved metals.

Other BMPs assessed for LBC include infiltration systems, wetlands, and dry/wet detention basins. Infiltration systems can be highly effective in removing pollutants but some are not reliable due to poor longevity and a high level of operation and maintenance costs. In addition, infiltration systems may not be appropriate for the LBC in that they route contaminants to groundwater. Wetlands and dry/wet detention basins can be highly effective in pollutant removal as well, but they can incur medium to high levels of capital costs per acre and additional land requirements. It may be desirable to consider combinations of structural BMPs in BMP planning. Combinations of two or more of these measures may

increase operational life of the BMPs, increase pollutant removal effectiveness, and overcome site limiting factors (Debo and Reese 1995).

Several fundamental uncertainties remain unresolved regarding use of structural urban BMPs. These uncertainties include toxicity of residuals trapped by BMPs, interactions with groundwater caused by infiltration, and long-term performance (Debo and Reese 1995). There is a current trend developing in the storm water management and specifically the techniques used to mitigate impacts of urban runoff. The trend involves use of more natural features of the landscape to retain storm runoff and pollutants such as reductions in impervious areas and use of riparian buffer strips. Watershed approaches are being used to direct storm water management. Selection of measures to control storm water pollution must consider numerous factors including goals for the watershed and receiving waters, physical characteristics of the watershed, climate, potential land use changes, pollutants of concern, and the local community. In addition, realistic priorities and measurable goals must be established to ensure that solutions to critical storm water problems are feasible.

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APPENDIX

SEDIMENT ANALYSIS

(Eleven Pages)

SEDIMENT ANALYSIS

This appendix provides an analysis of the likely causes of sediment toxicity observed in Little Beaver Creek (LBC). The discussion (1) addresses the impact of sediment fines on the biological community and (2) develops a relationship between the presence of specific toxic substances and sediment impairment. The results of this analysis are used to support the development of sediment endpoints in Section 4.2.

A.1 Evaluation of the Potential Impacts of Sediment Fines on Macroinvertrebrates and Fish

To evaluate the potential impacts of sediment fines on the macroinvertebrates and fish in LBC, Tetra Tech performed a correlation analysis of Index of Biological Integrity (IBI) and Invertebrate Community Index (ICI) data and particle size distribution data from LBC. The objective of the analysis was to determine the presence or absence of a significant negative correlation between biocriteria and the silt and clay fractions of the particle size data. A negative correlation of this type would indicate that as the fraction of finer particles increased, the biocriteria or health of the stream would decrease. A significant negative correlation was defined as any negative correlation between -0.650 and -1.00. Particle size and biocriteria data were taken from the Biological and Water Quality study of the Little Miami River Basin (OEPA 2000b). The particle size data were divided into the following categories; sand, coarse silt, medium silt, fine silt, very fine silt, coarse clay, medium clay and fine clay. Table A-1 presents the correlation analytical results. A strong positive correlation was noted with the fine silt through coarse clay and fine clays and the ICI scores, indicating that higher proportions of silt and clay were associated with higher ICI scores. The only significant negative correlations were found with the medium clay when compared to the IBI and ICI data, which are -0.69 and -0.98, respectively.

The particle size data were also evaluated by combining all silt-sized fractions into one category (silt) and combining all clay-sized fractions into one category (clay) and performing the correlation analysis on the combined particle size data. Results are presented in Table A-2. No significant negative correlations were noted between particle size and the IBI and ICI results. In fact, ICI results were positively correlated with the clay size particles (0.98). It should also be noted that throughout LBC, the predominant particle size at all sampling locations was sand, never falling below 63.3 percent. Based on this data analysis, it does not appear that sediment fines have a significant impact on the biota in LBC.

TABLE A-1

CORRELATION ANALYSIS OF IBI AND ICI AND PARTICLE SIZE DATA - ALL CLASSIFICATIONS

IBI

RM	IBI	Sand	Coarse Silt	Med Silt	Fine Silt	V. Fine Silt	Coarse Clay	Med Clay	Fine Clay
4.62	30	63.5	0	1.3	14.3	5.2	6.5	0	9.1
4.4	24	63.3	3.1	18.3	6.1	1.5	0	4.6	3.1
3.54	29	72.4	0	13.1	2.9	2.9	1.5	3	4.4
3.47	29	75.6	2	5.1	7.2	4.1	1	3.2	4.1
0.05	31	66.6	4	14.7	5.3	1.3	1.3	2.6	4

	RM	IBI	Sand	Coarse Silt	Med Silt	Fine Silt	V. Fine Silt	Coarse Clay	Med Clay	Fine Clay
RM	1.000									
IBI	-0.545	1.000								
Sand	-0.101	0.282	1.000							
Coarse Silt	-0.638	-0.198	-0.189	1.000						
Med Silt	-0.337	-0.522	-0.198	0.592	1.000					
Fine Silt	0.420	0.188	-0.455	-0.343	-0.768	1.000				
V. Fine Silt	0.563	0.348	0.202	-0.765	-0.959	0.728	1.000			
Coarse Clay	0.306	0.480	-0.352	-0.627	-0.777	0.860	0.765	1.000		
Med Clay	-0.081	**-0.686**	0.231	0.551	0.789	-0.777	-0.722	-0.967	1.000	
Fine Clay	0.357	0.447	-0.335	-0.649	-0.797	0.874	0.795	0.998	-0.955	1.000

TABLE A-1 (Continued)

CORRELATION ANALYSIS OF IBI AND ICI AND PARTICLE SIZE DATA - ALL CLASSIFICATIONS

ICI

RM	ICI	Sand	Coarse Silt	Med Silt	Fine Silt	V. Fine Silt	Coarse Clay	Med Clay	Fine Clay
4.62	30	63.5	0	1.3	14.3	5.2	6.5	0	9.1
4.4	18	63.3	3.1	18.3	6.1	1.5	0	4.6	3.1
3.54	20	72.4	0	13.1	2.9	2.9	1.5	3	4.4
3.47	20	75.6	2	5.1	7.2	4.1	1	3.2	4.1
0.05	22	66.6	4	14.7	5.3	1.3	1.3	2.6	4

	RM	ICI	Sand	Coarse Silt	Med Silt	Fine Silt	V. Fine Silt	Coarse Clay	Med Clay	Fine Clay
RM	1.000									
ICI	0.155	1.000								
Sand	-0.101	-0.399	1.000							
Coarse Silt	-0.638	-0.484	-0.189	1.000						
Med Silt	-0.337	**-0.750**	-0.198	0.592	1.000					
Fine Silt	0.420	0.867	-0.455	-0.343	-0.768	1.000				
V. Fine Silt	0.563	0.688	0.202	-0.765	-0.959	0.728	1.000			
Coarse Clay	0.306	0.983	-0.352	-0.627	-0.777	0.860	0.765	1.000		
Med Clay	-0.081	**-0.979**	0.231	0.551	0.789	-0.777	-0.722	-0.967	1.000	
Fine Clay	0.357	0.974	-0.335	-0.649	-0.797	0.874	0.795	0.998	-0.955	

Notes:

IBI = Index of Biological Integrity
ICI = Invertebrate Community Index
RM = River mile

TABLE A-2

CORRELATION ANALYSIS OF IBI AND ICI AND PARTICLE SIZE ANALYSIS DATA - SAND/SILT/CLAY

IBI

RM	IBI	Sand	Silt	Clay
4.62	30	63.5	20.8	15.6
4.4	24	63.3	27.5	7.7
3.54	29	72.4	18.9	8.9
3.47	29	75.6	18.4	8.3
0.05	31	66.6	25.3	7.9

	RM	IBI	Sand	Silt	Clay
RM	1.000				
IBI	-0.545	1.000			
Sand	-0.101	0.282	1.000		
Silt	-0.254	-0.499	-0.748	1.000	
Clay	0.447	0.340	-0.391	-0.306	1.000

ICI

RM	ICI	Sand	Silt	Clay
4.62	30	63.5	20.8	15.6
4.4	18	63.3	27.5	7.7
3.54	20	72.4	18.9	8.9
3.47	20	75.6	18.4	8.3
0.05	22	66.6	25.3	7.9

	RM	ICI	Sand	Silt	Clay
RM	1.000				
ICI	0.155	1.000			
Sand	-0.101	-0.399	1.000		
Silt	-0.254	-0.241	-0.748	1.000	
Clay	0.447	0.951	-0.391	-0.306	1.000

Notes:

IBI = Index of Biological Integrity
ICI = Invertebrate Community Index
RM = River mile

A.2 Relationship Between the Sediment and Water Column Contaminants and Macroinvertebrate and Fish Populations

To determine the linkage between concentrations of contaminants in both sediment and water column and viable macroinvertebrate and fish populations, Tetra Tech used two approaches. First, Tetra Tech performed a correlation analysis with the sediment contaminant data to determine if there was a significant negative correlation between the concentrations of a specific constituent and the LBC biocriteria data, IBI and ICI. Tetra Tech defined a significant negative correlation as a value between -0.650 and -1.00. Tetra Tech performed these analyses according to the different classes of chemicals - metals, polycyclic aromatic hydrocarbons (PAH), and pesticides/polychlorinated biphenyls (PCB). In performing these analyses, several assumptions were made. If a chemical was not detected at a sampling location, a value of one-half the detection limit was used as a proxy value for that chemical. In situations where locations of biocriteria data did not correspond to locations of sediment chemistry, Tetra Tech paired the biocriteria data with the closest downstream chemical sampling location. The second approach was to compare the sediment and water column data to available Ohio criteria and standards.

Correlations between sediment metal data and the biocriteria are presented in Table A-3. For the metals, significant negative correlations were observed between copper concentrations and IBI (-0.73) and ICI (-0.72). Mercury also exhibited a significant negative correlation with IBI data (-0.98) but not with ICI data. Sediment reference values were exceeded for cadmium, chromium, copper, mercury, and zinc. It should be noted that OEPA suggested that aluminum and barium be considered elevated. Based on the correlation data and comparison to available criteria, the most significant metals are cadmium, copper, and mercury.

Correlations between sediment PAH data and biocriteria are presented in Table A-4. The IBI data showed a strong negative correlation with all the individual PAHs identified, as well as with the total PAHs value. The results ranged from -0.89 to -0.94. There was a significant negative correlation with the ICI data noted for benzo(k)fluoranthene (-0.69), indeno(1,2,3-cd) pyrene (-0.67), and benzo(g,h,i)pyrene (-0.66). No Ohio criteria currently exist for PAHs in sediment.

Tetra Tech also evaluated correlations between sediment, pesticide/PCB data, and biocriteria; these results are presented in Table A-5. The correlation analysis with the IBI data showed a significant negative relation between alpha-chlordane (-0.75), gamma-chlordane (-0.80), and total chlordane (-0.79). The correlation analysis with the ICI data showed a significant negative relation between gamma-

TABLE A-3

CORRELATION ANALYSIS OF IBI AND ICI AND SEDIMENT METAL CONCENTRATIONS LITTLE BEAVER CREEK

Sediment Metal Concentration Data

RM	Al	Ba	Cd	Cr	Cu	Mn	Hg	Pb	Zn	IBI	ICI
4.62	15800	121	0.254	**11.5**	12.3	445	**0.0199**	**15.35**	79.9	30	30
4.4	8560	101	0.401	22	28.4	200	0.222	**12.90**	108	24	18
3.54	14400	138	0.41	26	27.6	392	0.0581	**16.75**	121	29	20
3.47	11600	92.6	3.09	16.7	15.7	292	0.0364	54.90	78.9	29	20
0.05	9980	89.8	0.216	**9.8**	15.1	346	**0.0183**	**13.10**	68.8	31	22

Notes:

Data provided for all sites where at least one observation per metal was considered slightly elevated or higher

All concentrations in units of mg/kg dry weight

Metal concentration obtained from Little Miami River TSD 1998.

BOLD represents half of the detection limit

IBI versus Sediment Metal Concentrations

	RM	Al	Ba	Cd	Cr	Cu	Mn	Hg	Pb	Zn	IBI
RM	1.000										
Al	0.376	1.000									
Ba	0.485	0.762	1.000								
Cd	0.116	-0.094	-0.400	1.000							
Cr	0.472	-0.023	0.531	0.028	1.000						
Cu	0.287	-0.309	0.361	-0.240	0.911	1.000					
Mn	-0.047	0.893	0.588	-0.285	-0.322	-0.496	1.000				
Hg	0.412	-0.603	-0.087	-0.177	0.556	0.756	-0.797	1.000			
Pb	0.110	-0.009	-0.354	0.995	-0.005	0.295	0.192	-0.262	1.000		
Zn	0.501	0.079	0.676	-0.249	0.956	0.922	-0.184	0.571	-0.275	1.000	
IBI	-0.545	0.525	0.057	0.032	-0.601	**-0.731**	0.792	**-0.981**	0.114	-0.586	1.000

TABLE A-3 (Continued)

CORRELATION ANALYSIS OF IBI AND ICI AND SEDIMENT METAL CONCENTRATIONS LITTLE BEAVER CREEK

ICI versus Sediment Metal Concentrations

	RM	Al	Ba	Cd	Cr	Cu	Mn	Hg	Pb	Zn	ICI
RM	1.000										
Al	0.376	1.000									
Ba	0.485	0.762	1.000								
Cd	0.116	-0.094	-0.400	1.000							
Cr	0.472	-0.023	0.531	0.028	1.000						
Cu	0.287	-0.309	0.361	-0.240	0.911	1.000					
Mn	-0.047	0.893	0.588	-0.285	-0.322	-0.496	1.000				
Hg	0.412	-0.603	-0.087	-0.177	0.556	0.756	-0.797	1.000			
Pb	0.110	-0.009	-0.354	0.995	-0.005	-0.295	-0.192	-0.262	1.000		
Zn	0.501	0.079	0.676	-0.249	0.956	0.922	-0.184	0.571	0.275	1.000	
ICI	0.155	0.711	0.267	-0.282	-0.633	-0.716	0.787	-0.569	0.212	-0.465	1.000

Notes:

IBI = Index of Biological Integrity
Al = Aluminum
Cu = Copper
Zn = Zinc
ICI = Invertebrate Community Index
Ba = Barium
Mn = Manganese
RM = River mile
Cd = Cadmium
Hg = Mercury
Pb = Lead

TABLE A-4

CORRELATION ANALYSIS OF ICI AND IBI AND PAH CONCENTRATIONS
LITTLE BEAVER CREEK

IBI

RM	IBI	BaP	BbF	B(ghi)P	BkF	Chrysene	Fluoranthene	I(123cd)P	Phenanthrene	Pyrene	Total PAH
4.62	30	0.75	0.97	0.25	0.25	0.97	1.8	0.25	0.99	1.4	7.63
4.4	24	3	3.4	2.4	3.3	4	8.2	2.2	3.9	6.3	36.7
3.54	29	1.7	2	1.4	1.6	2.1	4.2	1.3	1.9	3.2	19.4
3.47	29	0.62	0.64	0.53	0.61	0.75	1.6	0.57	0.79	1.2	7.31
0.05	31	0.8	0.92	0.25	0.91	1	2.1	0.25	0.91	1.6	8.74

	RM	**IBI**	BaP	BbF	B(ghi)P	BkF	Chrysene	Fluoranthene	I(123cd)P	Phenanthrene	Pyrene	Total PAH
RM	1.000											
IBI	-0.545	1.000										
Bis2	0.374	**-0.934**										
BaP	0.376	**-0.912**	1.000									
BbF	0.392	**-0.896**	0.998	1.000								
B(ghi)P	0.436	**-0.927**	0.979	0.971	1.000							
BkF	0.231	**-0.903**	0.980	0.968	0.965	1.000						
Chrysene	0.381	**-0.921**	0.999	0.997	0.973	0.979	1.000					
Fluoranthene	0.359	**-0.925**	0.998	0.994	0.974	0.986	0.999	1.000				
I(123cd)P	0.443	**-0.931**	0.973	0.963	0.999	0.961	0.967	0.968	1.000			
Phenanthrene	0.409	**-0.941**	0.995	0.991	0.969	0.974	0.998	0.997	0.963	1.000		
Pyrene	0.361	**-0.925**	0.998	0.994	0.973	0.985	0.999	1.000	0.967	0.998	1.000	
Total PAH	0.372	**-0.926**	0.999	0.994	0.982	0.986	0.999	0.999	0.976	0.996	0.999	1.000

TABLE A-4 (Continued)

CORRELATION ANALYSIS OF ICI AND IBI AND PAH CONCENTRATIONS
LITTLE BEAVER CREEK

ICI

RM	ICI	BaP	BbF	B(ghi)P	BkF	Chrysene	Fluoranthene	I(123cd)P	Phenanthrene	Pyrene	Total PAH
4.62	30	0.75	0.97	0.25	0.25	0.97	1.8	0.25	0.99	1.4	7.63
4.4	18	3	3.4	2.4	3.3	4	8.2	2.2	3.9	6.3	36.7
3.54	20	1.7	2	1.4	1.6	2.1	4.2	1.3	1.9	3.2	19.4
3.47	20	0.62	0.64	0.53	0.61	0.75	1.6	0.57	0.79	1.2	7.31
0.05	22	0.8	0.92	0.25	0.91	1	2.1	0.25	0.91	1.6	8.74

	RM	ICI	BaP	BbF	B(ghi)P	BkF	Chrysene	Fluoranthene	I(123cd)P	Phenanthrene	Pyrene	Total PAH
RM	1.000											
ICI	0.155	1.000										
Bis2	0.374	-0.548										
BaP	0.376	-0.564	1.000									
BbF	0.392	-0.521	0.998	1.000								
B(ghi)P	0.436	**-0.657**	0.979	0.971	1.000							
BkF	0.231	**-0.691**	0.980	0.968	0.965	1.000						
Chrysene	0.381	-0.548	0.999	0.997	0.973	0.979	1.000					
Fluoranthene	0.359	-0.574	0.998	0.994	0.974	0.986	0.999	1.000				
I(123cd)P	0.443	**-0.671**	0.973	0.963	0.999	0.961	0.967	0.968	1.000			
Phenanthrene	0.409	-0.532	0.995	0.991	0.969	0.974	0.998	0.997	0.963	1.000		
Pyrene	0.361	-0.567	0.998	0.994	0.973	0.985	0.999	1.000	0.967	0.998	1.000	
Total PAH	0.372	-0.587	0.999	0.994	0.982	0.986	0.999	0.999	0.976	0.996	0.999	1.000

Notes:

If no detections were reported assumed a PAH concentration of 0.25 mg/kg for each constituent.

RM = River mile
IBI = Index of Biological Integrity
ICI = Invertebrate Community Index
BaP = benzo(a)pyrene
B(ghi)P = Benzo(g,h,i)perylene
BkF = Benzo(k)fluoranthene
I(123cd)P = Indeno(1,2,3-cd)pyrene
BbF = Benzo(b)fluoranthene

TABLE A-5

CORRELATION ANALYSIS OF PESTICIDES/PCBS AND ICI AND IBI

IBI

RM	IBI	Alpha-Chlordane	Gamma - Chlordane	Total - Chlordane	PCB-1248	PCB-1254
4.62	30	3.5	3.5	3.5	17.6	17.6
4.4	24	25.2	31.8	57	23.5	140
3.54	29	18.7	25.6	44.3	16.85	147
3.47	29	2.46	17.7	17.7	109	306
0.05	31	9.5	10.9	20.4	17.85	17.85

	RM	IBI	Alpha-Chlordane	Gamma - Chlordane	Total - Chlordane	PCB-1248	PCB-1254
RM	1						
IBI	-0.545	1.000					
Alpha-Chlordane	0.156	**-0.749**	1.000				
Gamma - Chlordane	0.251	**-0.803**	0.848	1.000			
Total - Chlordane	0.167	**-0.786**	0.960	0.960	1.000		
PCB-1248	0.098	0.022	-0.495	0.031	-0.241	1.000	
PCB-1254	0.296	-0.308	-0.043	0.492	0.231	0.861	1.000

ICI

RM	ICI	Alpha-Chlordane	Gamma - Chlordane	Total - Chlordane	PCB-1248	PCB-1254
4.62	30	3.5	3.5	3.5	17.6	17.6
4.4	18	25.2	31.8	57	23.5	140
3.54	20	18.7	25.6	44.3	16.85	147
3.47	20	2.46	17.7	17.7	109	306
0.05	22	9.5	10.9	20.4	17.85	17.85

	RM	ICI	Alpha-Chlordane	Gamma - Chlordane	Total - Chlordane	PCB-1248	PCB-1254
RM	1.000						
ICI	0.155	1.000					
Alpha-Chlordane	0.156	-0.623	1.000				
Gamma - Chlordane	0.251	**-0.878**	0.848	1.000			
Total - Chlordane	0.167	**-0.799**	0.960	0.960	1.000		
PCB-1248	0.098	-0.271	-0.495	0.031	-0.241	1.000	
PCB-1254	0.296	-0.594	-0.043	0.492	0.231	0.861	1.000

Notes:

IBI = Index of Biological Integrity
ICI = Invertebrate Community Index
RM = River mile
PCB = Polychlorinated biphenyls

chlordane (-0.70) and the PCB Aroclor-1254 (-0.64). There are no current Ohio standards or criteria for pesticides or PCBs in sediment.

Tetra Tech evaluated potential impacts of water quality on the macroinvertebrates and fish populations by first comparing the concentrations of the various constituents to the Ohio River basin water quality standards that apply to LBC. Water samples were obtained from seven locations, compared to the five sediment sampling locations. All water metal concentrations (reported as total) were found to be below the Ohio standards applicable to LBC. No PAH or PCBs were detected in any of the water samples.