B.5 Sediment Chemistry

The chemical quality of deposited sediments is important to evaluate since many pollutants adhere strongly to sediment particles and are persistent in the aquatic environment. The chemical and physical make-up of streambed sediments is largely a reflection of upstream and local geology, land use and surface run off. Some chemicals are attracted to the surface electrical charges associated with fine silts and clay suspended in the water column. Many persistent compounds are highly insoluble in water and have a high molecular weight and, therefore, settle out quickly where they will be incorporated with other settled materials, organic and inorganic in nature. The sediment - water interface is the most physically, chemically and biologically reactive layer of the streambed. It can be affected by currents, floods, sunlight, and burrowing benthic organisms. Analysis of the chemical make-up of this interface can be used to predict ecological impact.

Sediment sampling followed protocols detailed in Ohio EPA's Sediment Sampling Guide and Methodologies (Ohio EPA, 2001). Sediment samples were obtained from nine sites on Big Darby Creek and ten sites on tributary streams, four of which were from Little Darby Creek. Sediment samples were collected one time during the survey and evaluated for percent solids, total organic carbon, VOCs, BNAs, PCBs, pesticides, heavy metals, and nutrients. Not all samples received nutrient analysis.

Sediment contamination was evaluated by utilizing procedures detailed in peer reviewed literature (e.g., MacDonald, 2000; Persaud and Jaagumagi, 1994). Metal contamination was also compared with Ohio EPA statewide data (Ohio EPA 1996, 2003). The Ohio EPA Sediment Reference Values were based on data derived from ecoregional sediment reference sites. This Ohio EPA Sediment Reference Value (SRV), either ecoregion specific or a statewide value, was derived as a cutoff value, where a concentration above the SRV is considered an outlier and is judged to be elevated above the background concentration. The reference value is defined as the interquartile range (distance between the 25th and 75th percentile) multiplied by 1.5 and added to the upper quartile (75th percentile value). This value is consistent with the upper fence on a standard box plot. It is not a direct measure of toxicity. Guidelines for the Protection and Management of Aquatic Sediment in Ontario (Persaud et al., 1994) define two levels of ecotoxic effects, and are based on chronic, long-term effects of contaminants on benthic organisms. A Lowest Effect Level (LEL) is a level of sediment contamination that can be tolerated by the majority of benthic organisms. Contaminants at a Severe Effect Level (SEL) are expected to produce a significant disturbance of the sediment dwelling community. The potential for toxicity was also evaluated by the MacDonald guidelines which are consensus based using previously developed values. These guidelines predict that sediment below the threshold effect concentration (TEC) is not toxic and that concentrations greater than the probable effect concentration (PEC) in contrast are toxic.

Very few organic compounds were detected in the sediments sampled in the Big Darby Creek watershed. Only dieldrin (1 detection) and acetone (3 detections) were found (Tables B.5.1 and B.5.2). The detection of dieldrin, a pesticide, at RM 52.00 on Big Darby Creek, just downstream

from the Plain City WWTP, was sufficiently high to be greater than a threshold effect concentration (TEC, MacDonald, 2000). This concentration of dieldrin, an insecticide, may have contributed to the decline in the ICI, total EPT taxa and sensitive macroinvertebrate taxa documented downstream from Sweeney Run and the Plain City WWTP. Acetone was detected at 3 locations, RM 54.20 on Big Darby Creek, and RM 0.70 on Robinson Run, which were adjacent to and downstream from Ranco, Inc., respectively. Acetone was also found at RM 3.10, with no known source there. The acetone source(s) are unknown and did not seem to pose a threat to the stream or aquatic life.

Tributary Sediment Results

Nutrient analysis for sediments included both ammonia, total phosphorus, and total organic carbon. Ammonia concentrations were highest in Hellbranch Run near the mouth (i.e., 140 mg/kg) (Table B.5.4) and in Robinson Run (i.e., 94 mg/kg). Decreased fish community performance coincidently was observed at both of these sites. Both of these streams receive effluent from package WWTPs which may be contributing to sediment ammonia. The site with the next highest concentration (i.e., 57 mg/kg) was on Little Darby Creek at RM 15.3 (US Rt. 42) which is probably due to the Green Meadows MHP WWTP which discharges a short distance upstream to the mouth of Spring Fork. There has been a slight decrease in macroinvertebrate community quality here over time.

Total organic carbon was found in all tributary streams at concentrations above the lowest effect level (LEL, Persaud and Jaagumagi, 1993). Total organic carbon values in tributary streams (2.2 mg/kg - 5.1 mg/kg) were comparable to values documented in other ECBP tributary streams in central Ohio, such as Bokes Creek (2.5 mg/kg -3.5 mg/kg) and Olentangy River tributary streams (1.5 mg/kg - 9.4 mg/kg) (Ohio EPA 2000 and Ohio EPA 2001).

Sediment total phosphorus was evaluated at all sites (except two sites on Little Darby Creek) and all exceeded LEL concentrations. Total phosphorus concentrations in sediments were highest in Little Darby Creek (RM 15.3), Hellbranch Run at the mouth, Treacle Creek (RM 0.8), Robinson Run (RM 0.7) and Sugar Run (RM 0.7). The Green Meadows MHP WWTP is the logical source for the elevated total phosphorus value found at RM 15.30 in Little Darby Creek although NPS sources may have contributed to the problem. There has been a slight decline in macroinvertebrate community quality over time at this site. The majority of the responsibility for the Hellbranch Run value likely falls to the Timberlake WWTP which is just upstream and has experienced operational problems. A description of the problems associated with the Timberlake Subdivision WWTP is provided in the Pollution Loadings Section. Robinson Run has nonpoint source and WWTP inputs. Again, inadequate quality fish performance was observed at the Hellbranch Run and Robinson Run sites. Sugar Run and Treacle Creek sites had sedimentation, nutrient enrichment and low dissolved oxygen problems which yielded decreased biological community performance.

Mainstem Sediment Results

Nutrients found in Big Darby Creek followed the same pattern as the tributaries in most instances. Ammonia concentrations were not as elevated as some of those found in the tributaries; however, the three sites with higher concentrations have shown trends of decreasing quality. The highest concentrations were found at RM 3.10 (83 mg/kg) at RM 63.8 (68 mg/kg) and RM 53.9 (52 mg/kg) (Table B.5.3). All three areas have accumulated sediment from upstream NPS inputs (i.e., agriculture, tributaries and other sources). Sediment ammonia, along with other factors, likely contributed to decreased mussel diversity in these reaches (see Trends in Unionid Mussel Communities).

All sites exhibited total organic carbon concentrations greater than the lowest effect level (LEL, Persaud and Jaagumagi, 1993). The highest concentration was found at RM 53.9. Total organic carbon values in the Big Darby Creek mainstem (range 2.8 mg/kg - 7.2 mg/kg) compare favorably with those in other central Ohio waterbodies such as the Olentangy River (2.1 mg/kg - 9.0 mg/kg), Stillwater River (2.1 mg/kg - 9.1 mg/kg), and the middle Scioto River (1.5 mg/kg - 15.0 mg/kg) (Ohio EPA 2000 and Ohio EPA 2001).

All sites which received analysis for total phosphorus were also greater than the LEL (Ibid). Results for other ECBP streams show that the lower value of the Big Darby Creek sediment phosphorus concentration range (i.e., 971 mg/kg - 1700 mg/kg) was almost double to more than double the lower values from the Olentangy and Stillwater Rivers, respectively (Olentangy River - 527 mg/kg -1060 mg/kg, Stillwater River - 480 mg/kg - 1610 mg/kg). The upper end of the range in Big Darby Creek was 70% higher than the Olentangy River and less than 10% higher than the Stillwater River (both TSD cited). The three highest phosphorus concentrations were found at RM 3.1 (1700 mg/kg), RM 53.9 (1670 mg/kg), and RM 63.8 (1420 mg/kg). All three reaches have accumulated sediment as well as elevated sediment ammonia concentrations (see above). The elevated sediment phosphorus values at these sites likely contributed to the decreased mussel diversity in these reaches through time (see Trends in Unionid Mussel Communities).

In general, sediment nutrient values greater than the LEL indicate that the sediment is marginally to significantly polluted and that it will produce some toxicity concerns for benthic organisms living in them (Persaud and Jaagumagi, 1993). Sediment taken from an individual sampling location are chosen based on a qualitative evaluation of 2 observations. First, the material must be unconsolidated and freshly deposited, and second, the material should consist of mostly fine grained material (i.e., clays, silts, etc.) if available. The proportion of fine grained sediment in the segment will determine the magnitude of the toxicity associated with elevated concentrations of nutrients. If fines are a small proportion of the stream bed materials elevated concentrations of nutrients will not exacerbate enriched conditions in the water column. In contrast, nutrient enrichment may be a problem where substrates are dominated or embedded by fine-grained sediments.

Table B.5.1. Results of chemical/physical sediment quality sampling conducted on the Big Darby Creek mainstem during July-September, 2001. Blank spaces indicate that the compound was not detected in the sample. Parameters noted with underlining exceed the threshold effect concentration (TEC, MacDonald, 2000) and those in italics do not have data sufficient to produce an evaluation.

Big Darby Creek Mainstem Sediments										
		River Mile								
Analyte	Units	63.80	54.20	53.90	52.00	34.10	27.00	23.80	13.40	3.10
Solids	%	30.8	31.4	30.2	50.6	37.7	37.5	47.6	47.5	33.2
TOC	%	5.0	6.3	7.2	4.3	4.5	2.9	3.3	2.8	3.7
Acetone	mg/kg		*0.200*							*0.132*
Dieldrin	mg/kg				23.8					

Table B.5.2. Results of chemical/physical sediment quality sampling conducted in Big Darby Creek tributaries during July-September, 2001. **HR** = Hellbranch Run at mouth (RM 0.50), **BR** = Buck Run at mouth (RM 0.10), **TC** = Treacle Creek at mouth (RM 0.80), **PR** = Proctor Run at McMahill Road (RM 1.60), **RR** = Robinson Run at U.S. 42 (RM 0.70), **LD1** = Little Darby Creek at Allison Road (RM 41.20), **LD2** = Little Darby Creek at Rosedale-Plain City Road (RM 24.50). **LD3** = Little Darby Creek at U.S. 42 (RM 15.30), **LD4** = Little Darby Creek at Roberts Road (RM 4.10), **SR** = Sugar Run at Taylor Road (RM 7.00). Parameters noted with a ◙ are compared with the Ontario guidelines published by Persaud and Jaagumagi, 1993 (LEL = greater than the Lowest Effect Level). Blank spaces indicate that the compound was not detected in the sample. Parameters noted in italics do not have data sufficient to produce an evaluation.

Big Darby Creek Tributaries Sediments											
Analyte	Units	**HR**	**BR**	**TC**	**PR**	**RR**	**LD1**	**LD2**	**LD3**	**LD4**	**SR**
Solids	%	48.6	57.2	46.0	47.5	41.2	42.8	41.4	38.0	33.6	61.6
TOC ◙	%	3.4 LEL	3.0 LEL	3.9 LEL	3.4 LEL	4.4 LEL	3.5 LEL	3.8 LEL	5.0 LEL	2.2 LEL	5.1 LEL
Acetone	mg/kg					*0.137*					

Table B.5.3. Results of chemical/physical sediment quality sampling conducted in the Big Darby Creek study area during July-September, 2000. Parameters in *italic* have no established guideline for comparison. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. Parameters noted with a ◙ are compared with the Ontario guidelines published by Persaud and Jaagumagi, 1993 (LEL = greater than the Lowest Effect Level but less than the Severe Effect Level). Shaded boxes exceed the consensus-based threshold effect concentration (TEC) published in MacDonald, 2000. Shaded boxes with bold print exceed the consensus-based probable effect concentration (PEC) published in MacDonald, 2000. Shaded boxes with a subscript "p" have possible concentrations >TEC and/or >PEC (in bold), but were below that particular test method detection limit, so chronic effects are possible but not certain. All other parameters are compared with Ohio EPA sediment reference guidelines (Ohio EPA1996, 2003). Descriptive guidelines are as follows: Not elevated, elevated (✚).

Big Darby Creek Mainstem Sediments										
		River Mile								
Analyte	Units	**63.80**	**54.20**	**53.90**	**52.00**	**34.10**	**27.00**	**23.80**	**13.40**	**3.10**
Solids	*%*	*31.6*	*29.6*	*27.4*	*42.9*	*33.0*	*31.3*	*43.8*	*44.2*	*30.1*
NUTRIENTS										
TOC ◙	%	5.0_{LEL}	6.3_{LEL}	7.2_{LEL}	4.3_{LEL}	4.5_{LEL}	2.9_{LEL}	3.3_{LEL}	2.8_{LEL}	3.7_{LEL}
Ammonia	*mg/kg*	*68*	*NA*	*52*	*NA*	*32*	*NA*	*34*	*42*	*83*
Phosphorus ◙	mg/kg	1420_{LEL}	NA	1670_{LEL}	NA	1310_{LEL}	NA	971_{LEL}	1100_{LEL}	1700_{LEL}
METALS										
Aluminum	mg/kg	27700	28900	30800	25100	11800	17800	18500	25900	44000 ✚
Arsenic	mg/kg	11.6	11.1	9.47	12.0	7.44	11.0	7.21	10.2	14.0
Barium	mg/kg	203	188	231	175	125	189	139	135	264 ✚
Cadmium	mg/kg	0.507	0.540	0.706	0.634	0.339	0.396	0.263	0.315	0.425
Calcium	mg/kg	48900	50100	46400	26800	58800	72900	44300	45900	82000
Chromium ◙	mg/kg	36	37	41 ✚	30 LEL	31	32	25	25	36LEL
Copper	mg/kg	13.5	16.9	18.5	27.2	11.7	15.4	13.9	17.9	20.9

Continued

Big Darby Creek Mainstem Sediments										
		River Mile								
Analyte	Units	**63.80**	**54.20**	**53.90**	**52.00**	**34.10**	**27.00**	**23.80**	**13.40**	**3.10**
Iron	mg/kg	23900	23900	24400	27100	16000	22800	17100	19200	27800
Lead	mg/kg	48 ☆p	49 ☆p	55 ☆p	108	42p	43p	33	33	48 p
Magnesium	mg/kg	11400	15600	12900	10800	12700	16500	15300	18800	19400
Manganese	mg/kg	540	391	272	306	259	381	212	378	651
Nickel	mg/kg	48✚p	**49 ✚p**	**55 ✚p**	33p	42✚p	43 ✚p	33p	33p	48 ✚
Mercury	mg/kg	0.055	0.084	0.099	0.077	0.070	0.060	0.044	0.045	0.055
Potassium	mg/kg	7500	7210	9120	6520	3700	6000	6090	6050	10200
Selenium	mg/kg	2.39✚	2.46✚	2.75✚	1.58	2.09	2.13	1.66	1.64	2.37✚
Sodium	*mg/kg*	*5970*	*6140*	*6890*	*3950*	*5220*	*5320*	*4150*	*4110*	*5930*
Strontium	mg/kg	848✚	803✚	804✚	432✚	1940✚	1900✚	507✚	603✚	1640✚
Zinc	mg/kg	90.7	113	98.4	114	63.2	96.1	85.4	72.3	128

Table B.5.4. Results of chemical/physical sediment quality sampling conducted in the Big Darby Creek study area during July-September, 2000. Parameters in *italic* have no established guideline for comparison. Underlined values indicate concentrations below the method detection limit. Parameters noted with a ◙ are compared with the Ontario guidelines published by Persaud and Jaagumagi, 1993 (LEL = greater than the Lowest Effect Level). Most other parameters are compared with Ohio EPA ecoregional or statewide sediment reference guidelines (Ohio EPA 1996, 2003). Descriptive guidelines are as follows: Not elevated, elevated(✚). Shaded boxes exceed the consensus-based threshold effect concentration (TEC) published in MacDonald, 2000. Shaded boxes with bold print exceed the consensus-based probable effect concentration (PEC) published in MacDonald, 2000. Shaded boxes with a subscript "p" have a possible concentration > TEC but were below that particular method detection limit, so chronic effects are possible but not certain.

Big Darby Creek Tributaries Sediments											
Analyte	Units	**HR**	**BR**	**TC**	**PR**	**RR**	**LD1**	**LD2**	**LD3**	**LD4**	**SR**
Solids	%	*44.4*	*51.6*	*41.1*	*41.3*	*38.2*	*46.9*	*40.5*	*38.4*	*31.6*	*46.5*
NUTRIENTS											
TOC ◙	%	3.4 LEL	3.0 LEL	3.9 LEL	3.4 LEL	4.4 LEL	3.5 LEL	3.8 LEL	5.0 LEL	2.2 LEL	5.1 LEL
Ammonia	*mg/kg*	*140*	*42*	*27*	*53*	*94*	*31*	*NA*	*57*	*NA*	*24*
T. Phosphorus ◙	mg/kg	1340 LEL	834 LEL	1270 LEL	917 LEL	1250 LEL	853 LEL	NA	1520 LEL	NA	1050 LEL
METALS											
Aluminum	mg/kg	15700	16800	17200	13100	23200	15300	21800	27900	21600	27600
Arsenic	mg/kg	11.1	8.74	12.7	11.2	11.5	11.1	10.6	11.3	9.60	17.3✚
Barium	mg/kg	144	99.5	142	136	143	124	180	190	172	155
Cadmium	mg/kg	0.520	0.348	0.449	0.319	0.439	0.344	0.423	0.370	0.426	0.454
Calcium	mg/kg	43900	20100	54700	73000	46000	46800	52500	60400	70200	15300
Chromium ◙	mg/kg	24	21	25	27	27	23	25	30	36	31LEL
Copper	mg/kg	19.9	14.0	12.7	9.2	15.6	9.4	11.0	11.7	13.6	20.6
Iron	mg/kg	19500	18200	19600	15500	21600	16000	19400	19900	19400	30000 ✚
Lead	mg/kg	32	28	33	37p	36p	31	33	39p	48p	31
Magnesium	mg/kg	16200	10000	21700	19600	17600	20400	18600	18200	18500	8050
Manganese	mg/kg	329	254	452	393	213	228	412	498	412	365
Mercury	mg/kg	0.038	0.042	0.047	0.041	0.055	0.053	0.061	0.063	0.067	0.054
Nickel	mg/kg	32p	28p	33p	37p	36p	31p	33p	39p	48✚p	36
Potassium	mg/kg	5150	4510	4710	3710	6770	3970	5240	5440	5210	6560
Selenium	*mg/kg*	1.61	1.38	1.65	1.83	1.77	1.55	1.65	1.96	2.39 ✚	1.56
Sodium	*mg/kg*	*4020*	*3460*	*4120*	*4570*	*4440*	*3880*	*4120*	*4910*	*5970*	*3910*
Strontium	mg/kg	213	203	601 ✚	1840 ✚	512 ✚	204	590 ✚	703 ✚	828 ✚	121
Zinc	mg/kg	99.2	70.1	68.9	51.1	75.9	67.7	68.4	86.7	97.8	102

HR = Hellbranch Run at mouth (RM 0.50), **BR** = Buck Run at mouth (RM 0.10), **TC** = Treacle Creek at mouth (RM 0.80), **PR** = Proctor Run at McMahill Road (RM 1.60), **RR** = Robinson Run at U.S. 42 (RM 0.70), **LD1** = Little Darby Creek at Allison Road (RM 41.20), **LD2** = Little Darby Creek at Rosedale-Plain City Road (RM 24.50). **LD3** = Little Darby Creek at U.S. 42 (RM 15.30), **LD4** = Little Darby Creek at Roberts Road (RM 4.10), **SR** = Sugar Run at Taylor Road (RM 7.00)

Tributary stream sediments were also evaluated for heavy metals. The most impacted stream locale was Sugar Run at RM 7.00. Here, arsenic concentrations were elevated as were chromium and iron. Copper, nickel, and zinc concentrations were slightly elevated (Table B.5.4). This was the only tributary that exhibited detectable concentrations of chromium and nickel as well as the highest values for copper, iron, and zinc. The Hershberger Landfill may be the source of these metals.

Metals were found in sediments throughout the Big Darby Creek mainstem. There were two locations of particular concern: RM 52.00, downstream of the Plain City WWTP, and at RM 3.10 near the mouth. Sediment lead concentrations of 108 mg/kg greatly exceeded the TEC at RM 52.00 (Table B.5.3). The sediment chromium concentration exceeded the LEL. Other relatively higher concentrations of zinc (114mg/kg) and copper (27.2 mg/kg) indicated metals present in the sediments possibly from a defunct metal plating shop, the Plain City WWTP and Sweeney Run NPS inputs. Toxicity from these sediment metals could have contributed to the decrease in macroinvertebrate community ICI and diversity at this site compared to upstream.

At RM 3.1 on Big Darby Creek sediment aluminum and barium was elevated in comparison to the Ohio EPA sediment reference values. Nickel was elevated (48 mg/kg) and exceeded the TEC concentration. The zinc sediment concentration at RM 3.1 of 128 mg/kg also exceeded the TEC concentration. The sediment chromium exceeded the LEL (Table B.5.3). The elevated sediment metals and silt bedload with attached phosphorus and ammonia noted earlier likely contributed to decreased mussel diversity in this reach.

Sediment metals including nickel, lead, zinc and chromium at RM 54.2 and RM 53.9, which are in the vicinity of Ranco and US Rt. 42, may be causing toxicity. These sediment metal concentrations along with other factors (i.e., sediment total phosphorus and ammonia) could have contributed to the documented decline of mussel diversity in this reach. Although detection limits somewhat confound the lead and nickel analyses, the shaded areas in the tables document values that might exceed the TEC at sites not discussed.