# Mona Lake Watershed Phase I Implementation Project: Upper Black Creek

**(exclusive of soil P characterization)**

**Final Project Report**

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## Project Background and Description

The Mona Lake Watershed is approximately 200 $km^2$ (45,570 acres) in size and is located in Muskegon and Newaygo counties. The diverse land uses in the watershed include 38% developed (residential, commercial, industry), 16% agriculture, and 46% natural cover (Steinman et al. 2006). As a consequence, 54% of the land use can have a negative environmental impact on the watershed. Two tributaries in the watershed are on the 303(d) list and have TMDLs to address impaired biota due to sedimentation - Black Creek and Little Black Creek. Water quality concerns in the watershed include 1) hypereutrophic condition of Mona Lake and nuisance algal blooms resulting from high phosphorus loadings (internal and external; Steinman et al. 2009), 2) severe chemical and biological degradation of Black Creek and Little Black Creek, and 3) high levels of pathogens and toxics during storm events.

The Mona Lake Watershed Management Plan (Plan), developed by the Mona Lake Watershed Council (MLWC), identified the sources and causes of the known and suspected pollutants in the watershed and proposed systems of BMPs to address nonpoint source pollution. The proposed implementation projects were put into four “phases” based on priority need, manageability, and likelihood of funding. This project addresses the outreach and education (O&E) needs and monitoring and design needs identified in Phase I (high priority) and Phase II (moderate priority) of the Plan’s implementation phases. Specifically, this project involves 1) working with farmers in the Black Creek watershed regarding on-farm wetland restoration, nutrient management, and riparian buffers, 2) site selection and design of ~100-acres of created wetlands, 3) preconstruction monitoring, 4) NPS and stormwater runoff education, including the local phosphorus ban for lawn fertilizer application, and 5) promoting Low Impact Development (LID) criteria to all cities and townships in the watershed.

The implementation of the Phase I high-priority created wetland (“flow-through marsh”) will result in regional secondary treatment for 20 square miles of agricultural runoff. Preconstruction monitoring was conducted to facilitate wetland design development and generate baseline data to validate future in-stream water quality improvements. This work will set the stage for construction of the regional created wetland, estimated to reduce sediment to Black Creek and Mona Lake by ~6 tons/year and nutrients by ~1,005 lbs P/year.

Preconstruction monitoring began in December 2008 and continued through summer 2009. Major goals for the monitoring were to develop a baseline for evaluating water quality improvement over time and confirm soil suitability of the proposed wetland area. This was achieved through the following objectives:

- Characterize water quality during both wet and dry conditions
- Measure flow, determine rating curves, and generate a hydrograph
- Characterize the geomorphology of the stream channel
- Survey the fish community

- Describe soil chemistry and phosphorus biogeochemistry of proposed wetland area

## Methodology

**Monitoring Site Locations and Sampling Chronology:**
In November 2008 two monitoring sites were established on Black Creek to represent stream conditions upstream and downstream of the proposed wetland site. The upstream site was located west of Moorland Road immediately downstream of the confluence of Hall Drain and Black Creek (Figure 1). The downstream site was located approximately 1 km east of the Miller Road dead end and was accessed through private property on Michigan Highway 46 (Figure 1).

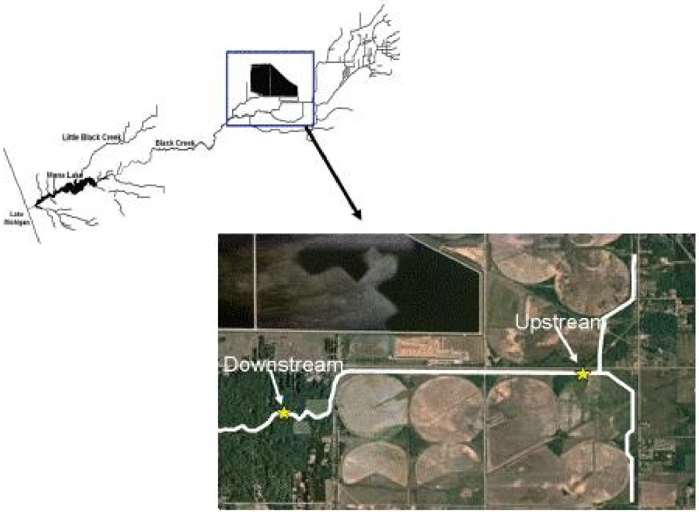

Figure 1. Map showing the upstream and downstream study sites on Black Creek.

Baseflow (i.e., dry weather) sampling was conducted bi-weekly from December 2008 to August 2009 (16 sampling events). Wet weather sampling was conducted five times during the monitoring period during and immediately following precipitation events of 0.25 inches or greater within 24 hours. Fish communities of each stream site were sampled during the winter, spring, and summer of 2009. Stream channel geomorphology was characterized in August 2009.

Soil analysis of the proposed wetland site was not conducted because of delays in identifying the wetland site location and depth of soil excavation.

**Stream Hydrographs:**
To develop stream hydrographs, pressure transducers (Hobo model U20 water level/temperature loggers) were deployed at both stream sites to measure stream stage at 10-minute intervals throughout the study period. Transducers were suspended within 1 cm of the sediment surface inside of stilling wells constructed of 5.2-cm ID perforated polyvinyl chloride pipe. An additional transducer was suspended at the top of the stilling well at the upstream site to record atmospheric pressure. Pressure and temperature data

were downloaded from each transducer and transducer clocks were synchronized during each site visit (Eastern Standard Time was used throughout the study period).

Stream stage was measured manually at both stream sites during each site visit using staff gauges attached directly to each stilling well (n=17 visual stage measurements per site). To convert pressure readings to stream stage, atmospheric pressure was first subtracted from stream pressure. Next, the 17 atmosphere-corrected stream pressure readings that corresponded with the visual stage measurements were regressed against the measured stage observations for each site. The resulting linear function was then applied to the entire record of pressure readings from each site to yield a high-frequency record of stream stage for the study period (~32,000 stage estimates).

Stream stage was converted to discharge at each site by first calculating rating curves between stage and discharge and applying these functions to the high-frequency stage records. Discharge was measured directly at each site over a range of hydrologic conditions (upper site: n=12 discharge measurements, lower site: n=11). To measure discharge, transects were established perpendicular to stream flow at both sites. Water depth and velocity were measured at twenty equally-spaced points along the transects. Water velocity was measured according to USGS protocols using a Marsh-McBirney Flow Mate 2000 flow meter attached to a top-setting wading rod. When water depth was less than 2.5 ft, velocity was measured at 0.6 x depth. When depth exceeded 2.5 ft, velocity was measured at 0.2 x and 0.8 x depth. The Windows-based hydrologic software, HYDROL-INF (Chu 2006) was used to calculate stream discharge.

Rating curves were determined by fitting quadratic equations to the stage/discharge relationship at each site. Other non-linear functions were also evaluated for representing the rating curves but quadratic functions provided the best fit for stage/discharge relationships. The rating curve functions were then applied to the high-frequency records of stream stage to yield continuous hydrographs for each site through the study period.

### Nutrient and Pathogen Monitoring:

Nutrients and *E. coli* bacteria were measured at each site 16 times (generally bi-weekly) during baseflow conditions (preceded by at least 72 hours without precipitation) and 5 times during or immediately following precipitation events of at least 0.25 inch. During baseflow sampling trips, samples were collected from each site to determine concentrations of soluble reactive phosphorus (SRP), total phosphorus (TP), ammonia ($NH_3$), nitrate ($NO_3$), and *E. coli*. During wet weather monitoring, a minimum of five grab samples were collected at regular time intervals based on the predicted duration of the storm and the estimated time for stream stage to rise and return to baseflow. For example, if a storm was predicted to last 10 hours, we planned to collect samples every 2 hours starting when the stream began to rise and ending when the stream returned to baseflow. For most precipitation events, however, the descending limb of the hydrograph was protracted out one full day or more. Therefore, we generally discontinued sampling after stream stage began to descend rather than sampling through the entire descending limb of the hydrograph. Samples collected during wet weather events were composited to represent the entire event for each site.

Nutrient samples were collected in 1-liter acid-washed polyethylene bottles in the center of the stream at mid depth and transported to the laboratory on ice. For both baseflow and wet weather monitoring, a 20-ml aliquot of each sample (composited samples for wet weather monitoring) was filtered through a 0.45 μm acid-washed membrane filter for analysis of SRP and nitrate. A 250-ml aliquot was acidified with concentrated sulfuric acid and stored at 4°C for analysis of ammonia. A 250-ml aliquot was stored at 4°C for TP analysis. During each monitoring event, three additional samples (100 ml) were collected in sterile vials at each site to culture *E. coli* bacteria. During wet weather monitoring 100-ml *E. coli* samples were collected directly from the composited sample for each site.

Specific laboratory procedures were based on previous use for water quality investigations and established ranges for accuracy/precision. Laboratory standard operating procedures (SOPs) were based on Standard Methods (APHA 1992), SW-846 (U.S. EPA 1994), or a method developed in-house. A summary of analytical methods, bottle types, and sample preservation is given in Table 1.

Table 1. Laboratory Analytical Methods

| **Parameter** | **Preparation** | **Bottle** | **Preservation** | **Holding Time** | **Methods Reference** |
|---|---|---|---|---|---|
| Soluble Reactive Phosphorus | 0.45 μm filter in field or lab | 20 mL plastic acid washed | Freeze -10°C | 28 days | 4500-P F* |
| Total Phosphorus | Persulfate digestion | 250 mL plastic acid washed | 4°C | 28 days | 4500-P B.5 and F* |
| Ammonia | - | 250 mL plastic acid washed | $H_2SO_4$, 4°C | 28 days | 4500-$NH_3$ H* |
| Nitrate | 0.45 μm filter in field or lab | 20 mL plastic acid washed | Freeze -10°C | 28 days | 4100 C* |
| *E. coli* | - | 100 mL sterile | - | 12 hours | Colilert |
| Suspended Sediment | - | 500 mL plastic | - | 28 days | 2540 D* |
| Bedload Sediment | Dry 105 °C 24 hr<br>Ash 550 °C 24 hr | Plastic bag | - | - | Beschta 1996 |

*APHA 1992
**EPA 1994

## Sediment Loads:

Bedload transport and suspended sediment concentration were determined during each baseflow and wet weather monitoring trip. Bedload subsamples (1-minute duration) were collected using a 3x3" Helley-Smith sampler at five equally-spaced points across the stream at each site (5 minute total sampling time). During wet weather monitoring, five bedload subsamples were collected each time water samples were collected. Bedload sediment was dried at 105 °C for 24 hours and weighed. Sediment was then ashed in a muffle furnace at 550 °C for 24 hours and re-weighed to determine organic content (% Loss on Ignition = %LOI). Instantaneous bedload transport rate ($Q_b$) in kg/s was calculated as:

$$Q_b = \frac{M_b}{T} \times \frac{1}{N} \times \frac{W}{0.076\ \mathrm{m}}$$

where $M_b$ is the total mass of bedload sediment in kg; T, subsample duration in s (i.e., 60); N, number of subsamples; W, wetted width of the channel in m; 0.076 m represents the width of a 3x3” Helley-Smith sampler opening.

Suspended sediment concentration (SSC) was determined for each baseflow and wet weather monitoring event. Water samples were collected in 500-ml polyethylene bottles in the center of the stream at mid depth and stored at 4°C. To determine SSC, water samples were vacuum filtered through pre-ashed glass fiber filters. Filters were then dried at 105°C and weighed to determine SSC. Filters and sediment were then ashed and weighed a final time to determine the organic content of suspended sediment.

**Nutrient and Sediment Load Calculations:**

To determine nutrient, pathogen, and suspended sediment loads carried by Black Creek, the concentration of each constituent was multiplied by stream discharge through the study period. First, the high-frequency record of discharge (10-minute frequency) was used to generate hydrographs for each site. Hydrographs were then used to identify peaks in discharge (i.e., spates) in which our wet weather nutrient, pathogen, and sediment concentrations would be applied. We favored a visual interpretation of the hydrograph rather than simply setting a threshold discharge to identify spates because baseflow discharge varied throughout the year. For example, baseflow in the spring tended to be higher than baseflow in mid-summer and spates in mid-summer peaked at discharges that were less than spring baseflow. Therefore, by identifying spates in the hydrograph visually, we ensured that the appropriate concentration data were applied across the hydrograph. After spates were identified, we determined which of our five wet weather monitoring events corresponded best with each spate in the hydrograph. In most cases, we sampled during the spate event identified in the hydrograph. However, we did not sample during a high flow event that occurred in late December/early January. Rather than ignore this important event, we used two approaches to bracket the potential contribution of this storm. We applied the sediment and nutrient concentrations measured at baseflow just prior to the storm event (providing a conservative estimate) as well as the concentrations from a February storm event (providing a liberal estimate) to the January spate. Nutrient, sediment, and pathogen concentrations were then multiplied by discharge to determine loads for each 10-minute period during spates.

For the baseflow portions of the hydrograph, we applied the nutrient, sediment, and pathogen concentrations obtained during our regular baseflow monitoring trips. The hydrograph was first divided into blocks that placed baseflow monitoring trips at their midpoints. Since baseflow sampling trips were generally bi-weekly, the hydrograph was divided into 2-week periods beginning 1 week prior to baseflow sampling events and ending 1 week after the sampling event, at which time the next period began. The nutrient, sediment, and pathogen concentrations for each period were then multiplied by discharge for each 10-minute period to determine loads.

The above calculations resulted in a loading record for each nutrient parameter, suspended sediment, and *E. coli* at a frequency of 10-minutes. By summing the records through time, total loads were determined for each site. Also, since bedload sediment transport rates were calculated for the entire streambed at each site, rates were scaled up to each 10-minute period to represent total bedload transport.

**Additional Water Quality Data:**

In addition to nutrient and sediment loads, we measured a suite of chemical and physical parameters during each sampling event using a Yellow Springs Instruments Model 6600 Sonde. Parameters included dissolved oxygen (DO, concentration and percent saturation), temperature, pH, redox potential (ORP), specific conductance, total dissolved solids (TDS), turbidity, and chlorophyll a. During baseflow monitoring trips, the sonde was submerged to one-half the water depth at the center of the stream and allowed to equilibrate before measurements were logged. For wet weather monitoring, sondes were deployed at each stream site and programmed to log data every 15 minutes throughout the event. Sondes were calibrated prior to each sampling trip according to protocols recommended by the manufacturer.

**Fish Community Monitoring:**

The fish community at each stream site was monitored three times corresponding with winter (22 January 2009), spring (2 April 2009), and summer (6 August 2009) seasons in an attempt to represent seasonal variability in fish community structure. Sampling protocols followed the Great Lakes and Environmental Assessment Section (GLEAS) Procedure #51 (MDEQ 1990). A Smith-Root-style backpack shocking unit (maximum voltage: 240, rate: 70, duty: 90) was used to sample fish in an upstream direction at each site. Sampling continued until either 100 fish were collected or 100 m of stream was covered. Total shocking time was measured using a stopwatch. All available habitats including, vegetation, bare substrate, undercut banks, and woody debris were sampled while moving upstream. After collection, fish were held in aerated tubs on the stream bank, identified to species, measured (total length), and released alive. Fish community metrics were calculated according to GLEAS Procedure #51.

**Stream Channel Geomorphology:**

Cross-sectional profiles of the stream channel were constructed at the upstream and downstream sites one time during the summer of 2009. To construct profiles, a line was stretched level across the stream to represent ‘bank full’ stage. The depth from the line to the substrate was then measured at regular intervals across the stream channel.

**Soil Characterization of Proposed Wetland Area**

This analysis was not conducted because of delays in identifying the wetland site location and depth of soil excavation. AWRI had proposed to do this work during the summer 2009 and indicated that we could still do the work as long as the sites were identified by late October. We kept the project manager involved of these constraints throughout the process. Unfortunately, the complexity of the project resulted in an inability to explicitly identify sampling locations within the needed timeline, and we believed it irresponsible to sample sites that may end up outside the footprint of the wetland site or at the wrong depths.  We still believe these data are of value, and hope the project manager will be able to retain someone to conduct these analyses.

## Results

### Hydrographs

Pressure transducers were first deployed on November 18, 2008.  However, stilling wells were dislodged by high flows requiring us to re-deploy transducers and wells on December 23.  Pressure readings indicated that water in the stilling wells froze on January 10 (pressure in the wells spiked above what was reasonable for the sites).  The downstream well was retrieved on February 5 and allowed to thaw before being re-deployed on February 17.  The upstream well was not retrieved but pressure readings from January 10 to February 17 were omitted from the analysis.  After correcting for atmospheric pressure, the relationships between stream stage and pressure were found to be linear allowing us to convert the 10-minute frequency pressure record to steam stage at both sites.  Note that since the downstream well was retrieved and re-deployed during the study period, separate pressure-stage functions were calculated for each period that the well was deployed.  The 12 discharge measurements were then plotted against stage for each site.  Quadratic functions were fitted to the curves (Figure 2) and the resulting functions were used to convert the high-frequency stage records to hydrographs for the study period (Figure 3).

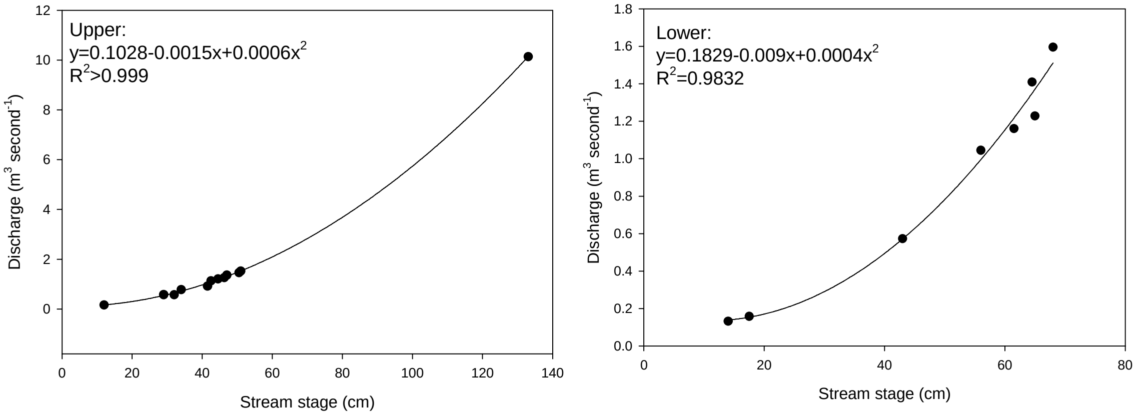

Figure 2. Relationship between stage and discharge at the upper and lower sites of Black Creek.  Note the difference in y-axis scales.  We measured stage and discharge at the upper site during a flood event but we were unable to measure flood flows at the downstream site.

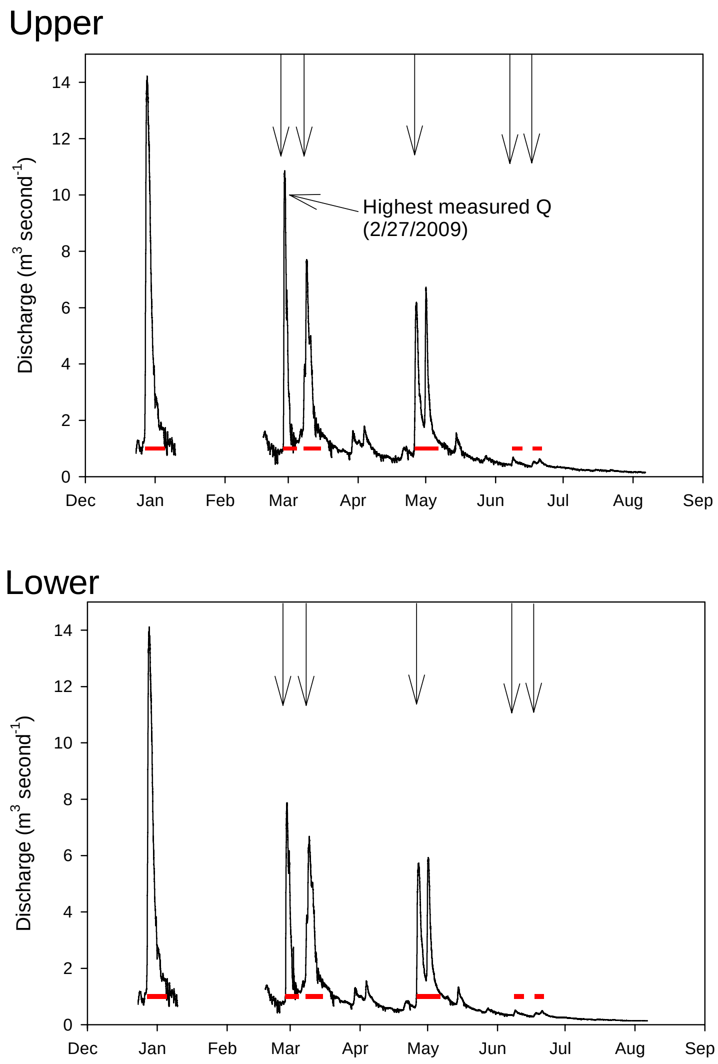

Figure 3. Hydrographs for upstream and downstream sites on Black Creek in 2009. Discharge was not measured from January 10 to February 17 because of ice buildup in stilling wells. Arrows indicate the 5 wet weather monitoring events and horizontal bars indicate the periods when wet weather monitoring data were used to calculate loads.

We identified six high-flow events in the hydrographs for each site (Figure 3). The two high-flow events in June were small compared to winter and spring spates. However, we considered these events to be important to our study since they represented the response of Black Creek to summer precipitation events that exceeded 0.25”. We also observed a number of high-flow events in which the stream overtopped its banks at the lower site. We estimated that when discharge at the lower site exceeded 4.86 $m^3$ $sec^{-1}$, water from Black Creek flowed into the floodplain at the lower site. Since our stage:discharge model does not account for flow through the floodplain, we likely underestimate flood flows at the lower site. This effect is evident in a plot of upper discharge vs. lower discharge (Figure 4) in which discharge at the lower site appears to level off after exceeding 4.86 $m^3$ $sec^{-1}$. The comparison of discharge at both sites also revealed an interesting anomaly on March 1 when discharge at the upper site was substantially higher than discharge at the lower site. The difference may have been caused by storage in the floodplain between the two sites.

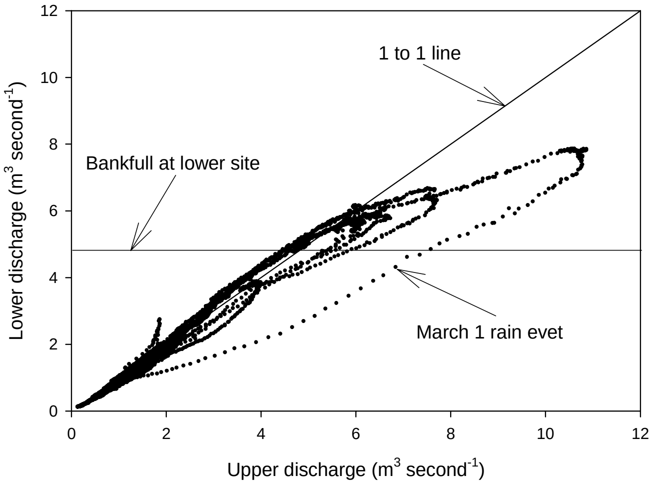

Figure 4. Relationship between discharge at the upper and lower Black Creek sites. Note the underestimation of discharge at the lower site when discharge exceeds approximately 4.86 $m^3$ $second^{-1}$.

Since channel geomorphology prevents the stream from overtopping its banks at the upstream site (i.e., Black Creek is maintained as a drain in this reach), our stage and discharge estimates are not subject to this error at the upstream site. Therefore, we recommend that loading data from the upstream site are used in the design of the constructed wetland.

## Loading estimates

The loadings associated with the late December/early January storm event (unsampled) were estimated by applying the February storm concentrations and the December baseflow concentrations (Table 2). Applying the February 26 storm concentrations to the January spate reveals that the January spate carried ~30% of the total sediment and P load, ~20% of the N, and ~25% of the pathogens for the entire project period. In contrast, applying the December 22 baseflow concentrations results in ~50% reductions in sediment and P loads, but small increases in N loads (Table 2). Results were generally similar for the upstream and downstream stations.

Table 2. Estimation of loads for late December/early January storm event (unsampled) applying concentrations from a February storm event and December baseflow conditions.

| **Parameter** | **January load based on using February storm event concentrations (% of total load carried in January event)** | **January load based on using December 23, 2008 baseflow concentrations (% of total load carried in January event)** |
|---|---|---|
| **Upstream Station** | | |
| TSS (MT) | 77 (33%) | 28 (15%) |
| Bedload (MT) | 74 (9%) | 40 (5%) |
| Total Coliforms ($10^{12}$ CFU) | 86 (25%) | 8 (3%) |
| *E. coli* ($10^{12}$ CFU) | 10 (12%) | 3 (4%) |
| SRP (kg) | 53 (34%) | 18 (15%) |
| TP (kg) | 310 (29%) | 61 (8%) |
| $NH_3$-N (kg) | 377 (20%) | 477 (24%) |
| $NO_3$-N (kg) | 3200 (13%) | 4,165 (17%) |
| **Downstream Station** | | |
| TSS (MT) | 87 (32%) | 15 (8%) |
| Bedload (MT) | 48 (4%) | 4 (0.4%) |
| Total Coliforms ($10^{12}$ CFU) | 85 (26%) | 11 (4%) |
| *E. coli* ($10^{12}$ CFU) | 0 | 4 (4%) |
| SRP (kg) | 63 (36%) | 18 (13%) |
| TP (kg) | 336 (31%) | 63 (8%) |
| $NH_3$-N (kg) | 392 (22%) | 515 (26%) |
| $NO_3$-N (kg) | 24, 106 (15%) | 4,994 (20%) |

We opted to use the February-applied concentrations to estimate the January loads; given the magnitude of the storm event (cf. Fig. 3), applying baseflow concentrations would seriously underestimate the total loads in the system. We recognize that this approach results in some uncertainty, but for the purposes of designing an appropriately sized constructed wetland, this possible overestimation should lead to a more conservatively sized design.

By applying baseflow and storm event nutrient, sediment, and pathogen concentrations across the hydrographs from each site, we calculated loading estimates for the period from December 23 to August 6, 2009 (January 10 through February 17 omitted due to ice buildup in stilling wells) (Table 3).

Table 3. Sediment, nutrient, and bacteria loads (MT per sampling period) in Black Creek at the upper and lower sampling sites. MT=metric ton (1000 kg), CFU=colony forming units.

| | Upper | Lower |
|---|---|---|
| Total Suspended Sediment (MT) | 236 | 271 |
| Bedload (MT) | 871 | 1,194 |
| Total Coliforms ($10^{12}$ CFU) | 340 | 328 |
| *E.coli* ($10^{12}$ CFU) | 86 | 121 |
| SRP (kg) | 158 | 177 |
| TP (kg) | 1,051 | 1,071 |
| Ammonia (kg) | 1,911 | 1,822 |
| Nitrate (kg) | 23,834 | 24,106 |

## Ambient Chemical/Physical Conditions

Conditions were similar between upstream and downstream sites during both baseflow and storm events (Table 4).

Table 4. Ambient chemical/physical conditions (median, range) measured during baseflow and storm events from December 2008 to August 2009 at the upstream and downstream sites on Black Creek.

| | Upstream | | Downstream | |
|---|---|---|---|---|
| | Base | Storm | Base | Storm |
| Temperature. (°C) | 10.80<br>(0.91-21.52) | 4.67<br>(-0.07-15.41) | 10.64<br>(0.00-21.26) | 5.48<br>(-0.24-15.84) |
| Spec. conductance. (mS/cm) | 0.481<br>(0.388-0.513) | 0.317<br>(0.087-0.422) | 0.509<br>(0.401-0.529) | 0.345<br>(0.096-0.496) |
| pH | 7.82<br>(7.44-8.17) | 7.52<br>(7.23-7.85) | 7.95<br>(7.70-8.25) | 7.83<br>(6.72-9.28) |
| Redox potential (mV) | 342<br>(269-463) | 323<br>(263-489) | 382<br>(270-440) | 338<br>(232-413) |
| *Dissolved* $O_2$ (% saturation) | 78.4<br>(65.2-121.1) | 77.5<br>(68.72-91.30) | 81.9<br>(64.3-104.3) | 93.4<br>(59.3-111.2) |
| Dissolved $O_2$ (mg/L) | 9.36<br>(7.20-11.01) | 10.02<br>(7.28-11.51) | 9.64<br>(7.29-11.23) | 11.75<br>(7.46-15.99) |
| Chlorophyll ( g/L) | 6.8<br>(2.7-12.8) | 8.1<br>(5.6-32.8) | 8.2<br>(4.9-12.0) | 11.0<br>(6.5-49.5) |
| Bedload (kg/min) | 1.48<br>(0.09-6.71) | 6.13<br>(0.89-9.70) | 2.08<br>(0.10-13.98) | 5.53<br>(1.94-24.65) |
| Bedload (%LOI) | 0.59<br>(0.01-2.06) | 0.67<br>(0.53-1.59) | 0.30<br>(0.00-1.79) | 0.28<br>(0.28-0.39) |
| Total colliforms (CFU/100ml) | 1810<br>(73-2420) | 2420<br>(2420) | 2340<br>(153-2420) | 2420<br>(2420) |
| *E*. coli (CFU/100 ml) | 72<br>(2-1748) | 1240<br>(117-2266) | 43<br>(2-2121) | 911<br>(272-2121) |
| Soluble reactive P (mg/L) | <0.005 | .013 | <0.005 | 0.015 |

|  |  |  |  |  |
|---|---|---|---|---|
|  | (<0.005-0.010) | (<0.005-0.020) | (<0.005-0.010) | (<0.005-0.020) |
| Total P (mg/L) | 0.02 | 0.05 | 0.02 | 0.07 |
|  | (0.01-0.07) | (0.04-0.09) | (0.01-0.06) | (0.03-0.10) |
| Ammonia (mg/L) | 0.08 | 0.11 | 0.08 | 0.11 |
|  | (0.03-0.16) | (0.09-0.13) | (0.01-0.15) | (0.07-0.18) |
| Nitrate (mg/L) | 1.14 | 0.90 | 1.27 | 1.07 |
|  | (0.48-2.96) | (0.87-1.18) | (0.43-2.98) | (0.82-1.22) |
| Sulfate (mg/L) | 67.0 | 34.3 | 72.3 | 42.2 |
|  | (40.5-133.3) | (22.8-63.8) | (35.2-142.4) | (25.9-64.9) |
| Chloride (mg/L) | 22.5 | 10.53 | 28.7 | 14.1 |
|  | (14.3-40.3) | (8.63-18.88) | (13.7-47.5) | (9.4-21.6) |
| Total suspended sed. (mg/L) | 6 | 13 | 7 | 16 |
|  | (2-18) | (9-22) | (3-14) | (10-25) |
| Total suspended sed. (%LOI) | 0.04 | 0.07 | 0.04 | 0.10 |
|  | (0.00-0.22) | (0.04-0.16) | (0.00-0.14) | (0.02-0.16) |

## Channel Geomorphology

Channel geomorphology differed substantially between the upstream and downstream sites (Figure 5). The upstream site was maintained as a drain and was straight with highly-incised banks. No floods were observed during the study period that could have overtopped the stream banks at the upstream site. Thus, Black Creek is effectively disconnected from its floodplain in this reach. This condition likely contributes to the flashiness of the hydrograph in the upper reaches of Black Creek (Figure 3). Because the stream banks were considerably higher than they would have been naturally, we estimated the bankfull level based on the highest stage observed during high flow events in 2009 (Figure 5). At the downstream site, the stream exhibited considerably more sinuosity and was connected to its floodplain during high flow events. We observed a number of occasions during the winter and spring of 2009 when the stream overtopped its banks and inundated the floodplain at the lower site. Additionally, the sinuosity at the downstream site resulted in more variability in stream habitats (e.g., undercut banks and pools) compared to the upstream site (essentially a single long run with no undercut banks).

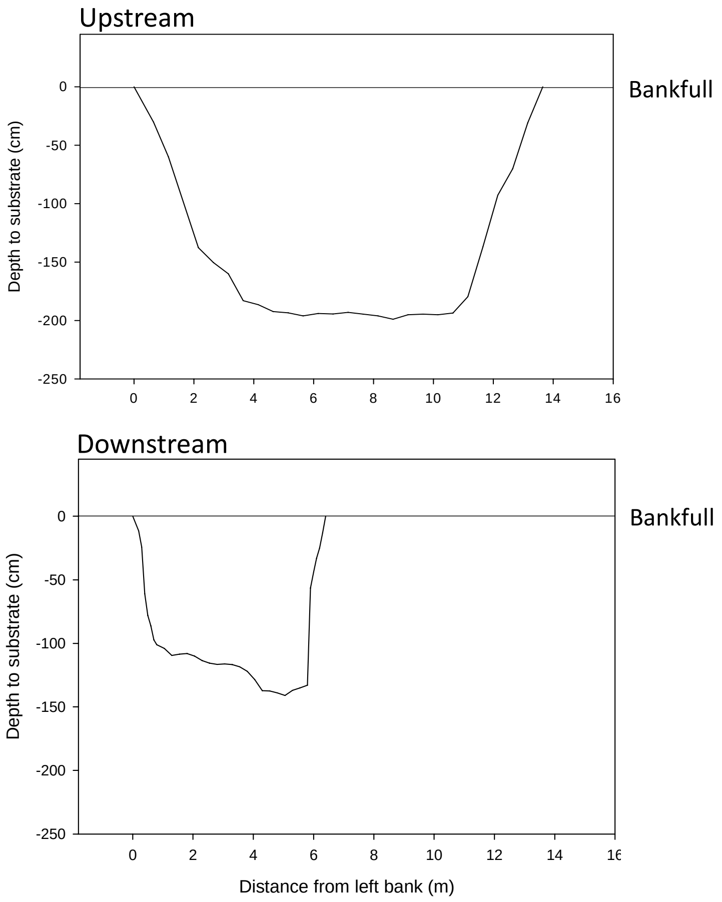

Figure 5. Channel cross-sections at the upper and lower Black Creek sites.

## Fish Communities

A total of 14 species were collected in Black Creek in the winter, spring, and summer of 2009 (Appendix A). Johnny darter (*Etheostoma nigrum*), grass pickerel (*Esox americanus vermiculatus*), central mud minnow (*Umbra limi*), and mottled sculpin (*Cottus bairdii*) were the most common species observed at the upstream site (Appendix A). Mottled sculpin, and blacknose dace (*Rhinichthys atratulus*) were the most common species at the downstream site. Two round gobies (*Neogobius melanostomus*, a non-indigenous species) were collected at the downstream site in August.

Species richness varied between 5 and 8 and was similar between the upstream and downstream sites. Values of the four Procedure 51 metrics that were based on richness of particular species groups (e.g., darters, sunfishes, suckers, and intolerant species) all tended to be low at both sites (Table 5). Only one intolerant species, a single northern brook lamprey (*Ichthyomyzon fossor*), was collected during the project. In terms of feeding ecology, the fish community at the downstream site tended to be dominated by insectivores while the upstream fish community contained more omnivores (Table 5).

Grass pickerel was the only piscivorous species collected and was more common at the upstream site than the downstream site. The low occurrence of intolerant species, piscivores, darters, sunfishes, and suckers suggests that both sites were degraded relative to other streams in the region. Furthermore, the negative aggregate Procedure 51 scores also suggest that the habitat at the two stream sites was degraded relative to other streams in the Southern Michigan/Northern Indiana Till Plains ecoregion. When Procedure 51 metrics are scored, metric values that are lower than average conditions in the ecoregion receive a negative 1, average values receive a 0 and above average values receive a positive 1. Therefore, since there are 10 metrics, the highest possible Procedure 51 score is 10 and the lowest is -10.

Table 5. Fish community metrics for the upstream (US) and downstream (DS) sites of Black Creek. Metrics were based on the Great Lakes and Environmental Assessment Section (GLEAS) Procedure #51 (MDEQ 1990). Aggregate scores are relative to other streams in the Southern Michigan/Northern Indiana Till Plains ecoregion with negative scores indicating relatively degraded conditions.

| Procedure 51 metric | Relationship of metric to status of habitat Integrity | Jan. 22 | | April 2 | | Aug. 6 | |
|---|---|---|---|---|---|---|---|
| | | US | DS | US | DS | US | DS |
| Species richness | + | 8 | 5 | 7 | 7 | 7 | 5 |
| Number of darter species | + | 2 | 2 | 1 | 2 | 2 | 1 |
| Number of sunfish species | + | 0 | 0 | 1 | 1 | 2 | 0 |
| Number of sucker species | + | 1 | 0 | 1 | 0 | 1 | 1 |
| Number of intolerant species | + | 0 | 0 | 0 | 1 | 0 | 0 |
| Rel. ab. of insectivores (%) | + | 65 | 94 | 25 | 78 | 37 | 65 |
| Rel. ab. of piscivores (%) | + | 16 | 3 | 12 | 3 | 7 | 0 |
| Rel. ab. of omnivores (%) | - | 18 | 0 | 63 | 8 | 24 | 5 |
| Rel. ab. of tolerant species (%) | - | 76 | 11 | 63 | 23 | 58 | 35 |
| Rel. ab. of lithophilic spawners (%) | - | 2 | 3 | 2 | 10 | 3 | 32 |
| Aggregate Procedure 51 score | + | -3 | -1 | -8 | -3 | -4 | -4 |

## Soil Characterization

Not conducted; see above.

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Appendix A. Fish collected at the upstream and downstream sites on Black Creek on three sampling dates. Fish were collected using backpack electro-shocking unit. TL=total length in cm.

| January 22, 2009 | | | April 2, 2009 | | | August 6, 2009 | | |
|---|---|---|---|---|---|---|---|---|
| Species | collected | TL median (range) | Species | collected | TL median (range) | Species | collected | TL median (range) |
| Upstream | | | | | | | | |
| bluntnose minnow | 12 | 6.6 (4.5-8.2) | Bluegill | 3 | 4.2 (3.9-5.8) | bluegill | 2 | 6.6 (6.0-7.1) |
| central mudminnow | 4 | 7.7 (5.5-9.6) | bluntnose minnow | 18 | 6.0 (3.6-9.2) | central mud minnow | 22 | 6.4 (3.1-10.1 |
| golden shiner | 1 | 7.0 | central mud minnow | 22 | 6.6 (5.0-11.9) | grass pickerel | 7 | 15.1 (6.5-19.0) |
| grass pickerel | 17 | 12.3 (10.0-14.6) | grass pickerel | 8 | 11.6 (6.0-13.5) | johnny darter | 35 | 5.5 (4.0-6.4) |
| johnny darter | 58 | 5.2 (2.6-7.6) | mottled sculpin | 5 | 6.9 (5.0-8.2) | mottled sculpin | 34 | 4.3 (3.2-9.0) |
| mottled sculpin | 9 | 5.7 (3.7-7.6) | pirate perch | 8 | 8.3 (6.0-10.0) | pumpkinseed | 1 | 6.6 |
| pirate perch | 1 | 10.0 | white sucker | 1 | 13.2 | white sucker | 3 | 10.6 (3.7-11.0) |
| white sucker | 2 | 7.9 (7.2-8.6) | | | | | | |
| Downstream | | | | | | | | |
| blacknose dace | 1 | 7.0 | blacknose dace | 4 | 6.8 (6.5-7.0) | blacknose dace | 18 | 7.1 (2.3-9.6) |
| grass pickerel | 1 | 14.8 | bluntnose minnow | 3 | 5.5 (5.0-6.0) | central mudminnow | 2 | 6.9 (6.2-7.6) |
| johnny darter | 3 | 6.0 (3.6-6.1) | grass pickerel | 1 | 9.2 | mottled sculpin | 37 | 5.5 (2.1-10.2) |
| mottled sculpin | 30 | 7.0 (3.6-11.0) | johnny darter | 2 | 5.2 (5.2-5.2) | round goby | 2 | 8.9 (8.4-9.4) |
| spotfin shiner | 1 | 8.0 | mottled sculpin | 28 | 6.1 (3.0-10.5) | white sucker | 1 | 3.6 |
| | | | n. brook lamprey | 1 | 16.0 | | | |
| | | | Pumpkinseed | 1 | 10.1 | | | |