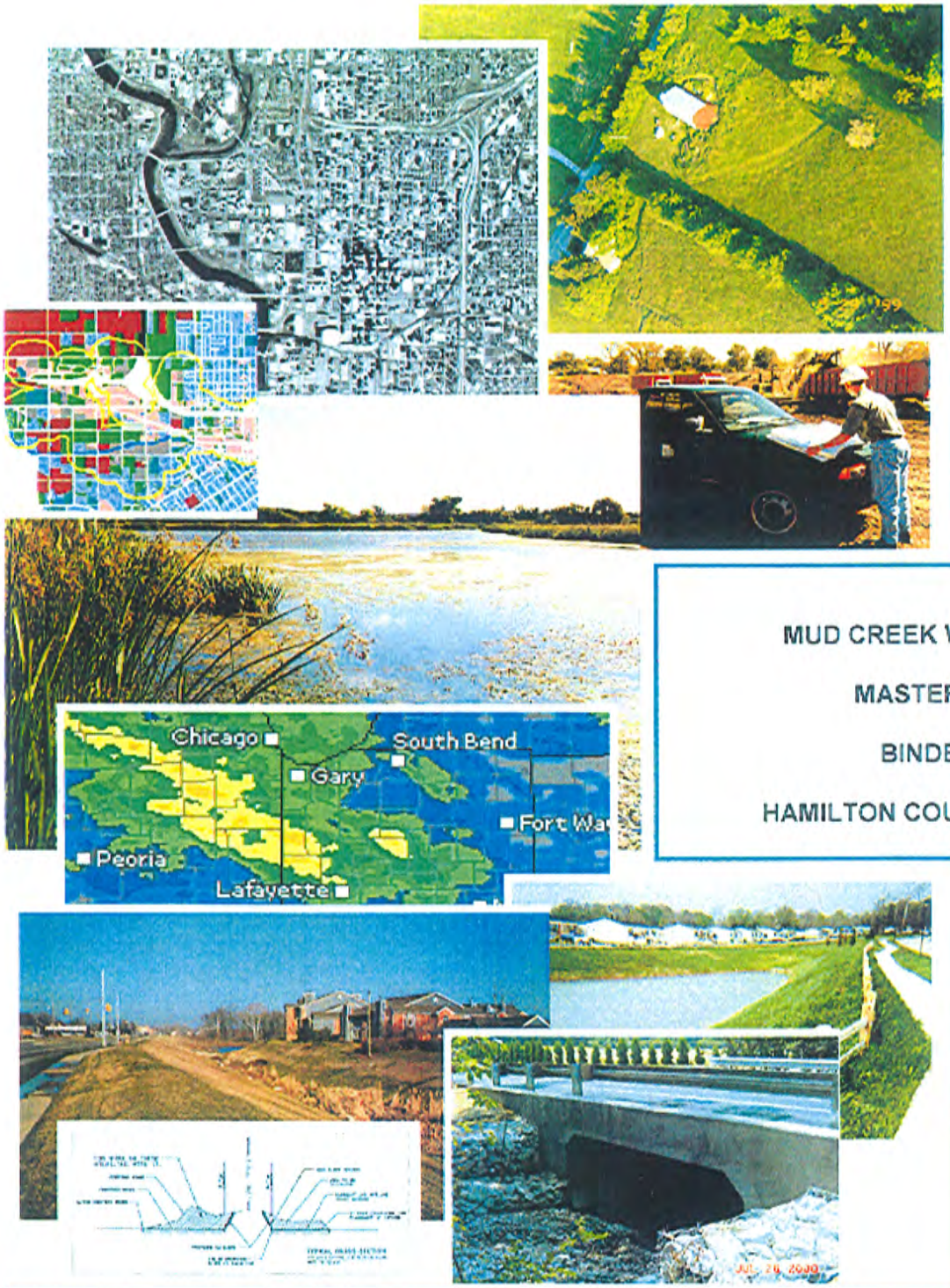

MUD CREEK WATERSHED

MASTER PLAN

BINDER #2

HAMILTON COUNTY, INDIANA

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Binder #2

Mud Creek Watershed
Master Plan

Prepared for

Hamilton County Surveyor

One Hamilton County Square
Noblesville, Indiana 46060

February 2005

Prepared by

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CBBEL Project No. 01-410A

BIOMONITORING, WATER QUALITY AND HABITAT ASSESSMENT FOR THE MUD CREEK WATERSHED, HAMILTON COUNTY, IN

By:

Claude D. Baker, Ph.D
and
August R. Nelson

Indiana University Southeast

Student Assistants: Mollie McDonough, Anthony Smith, DeLynn Rutherford and Robert Kelley

Prepared for:

CHRISTOPHER B. BURKE ENGINEERING, LTD.
Indianapolis, IN 46204
February 2004

INDIANA UNIVERSITY SOUTHEAST
Excellence Close to Home

FINAL REPORT

Biomonitoring, Water Quality and Habitat Assessment for the Mud Creek Watershed, Hamilton County, Indiana

By:

Claude D. Baker, Ph.D. and
Ms. August Nelson
Indiana University

Student Assistants: Ms. Mollie McDonough, Mr. Anthony Smith, Mr. Robert Kelley and Ms. DeLynn Rutherford

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As part of:

Mud Creek Watershed Master Plan

Indiana University Southeast
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Submitted 2003
Revised February 2004

EXECUTIVE SUMMARY

During May, June and October 2003, Dr. Claude Baker, Ms. August Nelson and field biology students from Indiana University used rapid bioassessment techniques to assess the status of Mud Creek, a warm water stream located in southern Hamilton County, Indiana. Habitat, macroinvertebrate populations and water quality were examined at six stations on Mud Creek and two stations on the major tributary, Sand Creek. Our major findings and recommendations are summarized here, and presented in more detail in the accompanying report.

Our overall conclusion is that Mud Creek is in better biological condition than either Stony Creek or White Creek in Jackson County, a cohort stream that we analyzed in 2002. One significant factor leading to this conclusion is that the stream has a number of rocky fast water habitats (riffles), both natural and artificial, that aerate the stream and provide habitats for macroinvertebrates. Despite this assessment, the stream has issues associated with rapid urban development and the flat agricultural nature of the watershed. The stormwater discharge problems will accelerate rapidly as more impervious surface is added. At present, most problems associated with rising runoff coefficients are amenable to engineering solutions that would be designed to minimize conveyance and improve the water flow characteristics and increase habitat quality.

The habitat analysis revealed that nearly all stations on Mud Creek were in the supporting range. There is ample evidence, however, of significant bank erosion and high suspended solids during storm events. Two stations, Sand Creek near the Verizon Entertainment Complex and Mud Creek in Cumberland Park, fell into the poor habitat range. The Sand Creek station (7) was impounded during our June visit, had very high bacterial counts and a low oxygen level. By October, fields in the area had been converted into construction sites. The Cumberland Park station (2) had very little rocky structure that could provide habitat and hiding places for aquatic organisms. Since this area is in a park setting, it would be a good candidate for the installation of an attractive v-shaped artificial riffle to direct the flow of water away from the bank, improve aeration and provide habitats for macroinvertebrates and fish. Major limiting factors were lack of deep pools and a variety of habitat types, insufficient cover and loss of riparian vegetation.

Bank erosion and debris field at Station 1 upstream from 96th Street. This is the most downstream station evaluated and presumably had the highest discharge during the Labor Day flood.

The Qualitative Habitat Index (QHEI), another habitat assessment, indicated that most stations were in the slightly impaired range with one station along Olio Road being non-impaired. Coincidentally, Olio Road is where we observed large numbers of fish. We are concerned that this is another area that is being rapidly urbanized. Sand Creek at the Verizon complex was judged to be a limited resource water. The ponding of water, previous channelization and bacterial contamination at Station 7 were the major limiting factors.

Water quality analyses indicated the stream had ample oxygen to support aquatic life, an acceptable pH range, moderate alkalinity and moderately high dissolved solids. Elevated nitrate and phosphate nutrients supported the growth of algae and water weeds during the base flow sampling period. The probable sources of these nutrients were tile drainage systems, animal sources, inefficient waste disposal systems such as failing septic systems and land application of animal wastes. The stream was noted to become quite muddy during high discharge events, and this is a cause for concern.

Fecal coliform bacteria counts revealed that 13 of 24 samples exceeded the water quality benchmark of 200 counts per 100 ml of water sample. Although counts were uniformly high during the base flow sampling period in June, the coliform levels exceeded water quality standards at Sand Creek Station 7 during all sampling periods and had the highest recorded level of 5696 per 100 ml. Sand Creek Station 4 near the junction with Mud Creek was high as well. These bacteriological problems will need to be addressed in the future.

The macroinvertebrate assessment revealed that all areas of Mud Creek were moderately impaired. The Sand Creek Verizon station was severely impaired. These results correlated extremely well with our habitat analyses. In areas with poor habitat and stream structure, the taxa richness of organisms was reduced. Areas with rocky structure and a variety of habitats had significantly more organisms. Mud Creek had very few organisms that one would find in a non-polluted stream, but it did have one stonefly family found at two locations. In addition, the stream had several moderately tolerant organisms like hydropsychid caddisflies and riffle beetles that we routinely find in our higher quality streams.

At the outset, our working assumption has been that Mud Creek has more problems associated with stormwater discharge and rapid development and less in the way of biological problems. Neighboring Stony Creek, in addition to flooding problems, has biological habitats that have already been marginalized.

Unlike Stony Creek, Mud Creek, as it enters Hamilton County, has flowed through mostly flat agricultural areas. Recorded fecal coliform and nutrient levels at this location were fairly low. We found live freshwater mussels at this location. Nonetheless, discharge into the county carrying with it sediments, nutrients, bacteria and debris can be significant. Judging from corn stalks and debris hung in tree branches; we estimate that a 12-foot wall of turbid, muddy water entered the county during the Labor Day flood. This water and the floodwater generated in Hamilton County had significant erosive power. Thus, lessening stormwater conveyance of floodwaters, even in agricultural areas, should be a priority.

High water mark at Station 8 on Mud Creek, the most upstream station at Atlantic Road on the county line. Note debris hanging in tree and agricultural drainage entering in the left hand corner of photograph. Cameraman was standing on bridge when this photograph was taken.

Most of the problems in Mud Creek are associated with previous channelization and high discharge events generated by point source thunderstorms or heavy downpours. Prior to pioneer settlement, storm events were buffered by the meandering nature of the stream and the wetland hardwood forests in the area.

Even now, with the flatness of the agricultural terrain, a significant quantity of water is entrained on the agricultural lands where it eventually makes its way into the tile drainage systems that discharge nutrient rich water for long periods of time. When the agricultural lands are taken for development, then the water storage capacity of the fields is lost. Retention ponds observed in the more recent developments appear to be working and provide some water storage. We looked at some of the retention ponds being constructed. Most were not designed to be wetlands, but they could be given stormwater retrofits to convert them into wetland biofilters. If wetlands are to be included in the overall picture, these retention pond wetlands should be constructed with shelves, islands and irregular topography to maximize attachment of wetland plants (1).

Particularly troubling is the distinct possibility that the stream, in several areas, may be approaching or surpassing what is becoming known as the “10% impervious surface rule.” When the amount of impervious surface exceeds 10%, water quality and habitat degradation accelerate. It appears that in this watershed the rapid construction is generating impervious surfaces that may lead to spiraling adverse impacts. The surfaces are reducing the amount of land available for infiltration, decreasing storm storage capacity, and provide areas where pollutants will be rapidly delivered to the stream (2,3).

Our experience and the studies of others have demonstrated that a significant quantity of nutrients, bacteria and undesirable sediment is contained in the *first flush* from a particular area. Thus, an engineering solution is to maximize storage and contain this initial stormwater. Solutions in agricultural areas might be different, but the intent is the same. It is possible that in agricultural areas that small-scale wetlands or storm drainage retrofits could be installed at the end of the tile drainage systems (4). These wetlands are formed by berming an area adjacent to a stream and forming a small detention basin or holding pond that intercepts tile drainage water before it enters a stream.

Conventional wisdom suggests that these should be installed at the rate of 1 acre for every 100 acres of farmland drained (5). The terrain is also amenable to the construction of instream wetlands and aeration structures using cascading “ditch blocks” (fanciful name for a low water dams), Newbury-type artificial riffles, small dams or wooden bulkheads. The in-stream wetland solutions are gaining in popularity.

In the suburban areas, larger storm drainage retrofits such as retention ponds might be considered in older neighborhoods. Small scale retrofits include swales and small catchment areas known as rain gardens. Rain gardens have a considerable following, and are being installed at various locations around the country (6). In subdivisions being planned, Low Impact Development (LID) should be considered. The basic objectives of LID are to restore the site’s hydrologic regime to mimic the natural or predevelopment condition (7).

INTRODUCTION

Mud Creek has its beginnings as a ditch in an agricultural region of Madison County, Indiana. From this point, the creek flows in a southwesterly direction through agricultural lands devoted primarily to corn and soybean production. In this region, the stream has been straightened into a ditch, and most crops approach the riparian border. Past SR 132 in Madison County, the stream receives input from Henry Ditch and Kynett Ditch. The stream enters Hamilton County north of W 650S and maintains its agricultural character until it reaches I-69 in the vicinity of Olio Road. The ease of access to this area is spurring considerable residential and retail development. A number of studies link uncontrolled stormwater runoff from areas with impervious surfaces exceeding 10 percent to a rapid decline in water quality and stream health (2).

From Olio Road, varying degrees of residential and retail development were noted until the stream entered Marion County at E 96th street. In Marion County, Mud Creek joins Fall Creek, a well-known tributary of the White River that flows through the northeast section of Indianapolis eventually delivering its flow to the White River.

The major tributary of Mud Creek is Sand Creek. Sand Creek originates in Hamilton County in drainage from corn and soybean fields. Past Highway 38, the stream is readily discernable as a tree-lined and open ditch. The agricultural character is retained until the stream enters the Verizon Entertainment Complex north of E 146th St. near I-69, Boden Road, and Greenfield Avenue. In the latter area, considerable development is occurring.

Both Mud Creek and Sand Creek deliver significant discharges during storm events. For example, the Indiana DNR storm hydrograph data reveal that a 100-year storm would discharge over 4,000 cfs of storm water at the stream's juncture with Fall Creek in Marion County. Sand Creek with a relatively small watershed would produce nearly 2000 cfs during a 100-year flood (8). Research suggests that the majority of the annual input of sediments and nutrients occurs during these events (9).

On May 14, June 27 and October 3, 2003, Professor Claude D. Baker and Ms. August Nelson of Indiana University began an assessment of the habitat, macroinvertebrates and water quality at 8 stations on Mud Creek. Six of the stations are located on Mud Creek proper, and two on Sand Creek, the major tributary. The purpose of this report is to present a summary and analysis of our findings and to present possible Best Management Practice (BMP) solutions.

BACKGROUND INFORMATION

Instruction regarding the possible future of the Mud Creek Watershed can be found in several published articles. First, land use, soils, and geology affect water resources. The USGS found that urban, agricultural, and forested land use in combination with soils and geology will result in differing degrees of water quality. Forested watersheds consistently produce the best quality water and the highest biodiversity. Significantly, urban streams actually fare worse than agricultural streams. Urban streams typically are ditched, have reduced habitats, have a decided lack of retention capacity in older areas and have a variety of contaminants including sediments and volatile chemicals entering them (10).

Agricultural streams have a differing set of problems. They receive nonpoint inputs of nutrients, sediments, pesticides and herbicides. An important finding is that streams in artificially drained areas often exceed the nitrate benchmark of 10 mg/L and have a significantly higher phosphate load. This is important in this study because the agricultural lands in the study area have a significant number of tile drains.

The loss of riparian buffers also has an effect on stream quality. Studies have shown that streams with more trees and shrubs had a better ecological integrity than those without riparian cover (11).

The soils and topographic relief are an important part of this watershed. Mud Creek lies in an area of low relief known as the Tipton Till Plain or the Central Till Plain. This plain is associated with the Wisconsin glacial boundary and extends northward covering a significant portion of central Indiana. Soils in this region developed under a dense vegetation cover in Wisconsin age loess over loamy silt (12).

The soils have a number of characteristic qualities that affect the water quality. They are often clayey resulting in slow infiltration that results in significant ponding during storm events. This ponding stores a considerable quantity of water in the agricultural areas, and delivers it eventually to the tile drain systems. Nitrogen leaching capacity is in the moderate range, and lower horizons often have a low pH. Finally, they are excellent for agriculture—provided they are drained.

In general, the slopes in the till region are mostly less than 2^0. This degree of slope suggests an inherent difficultly in removing storm water from the watershed. In presettlement times, the area was under a dense beech-maple hardwood forest with wetland components. It is likely that the floodwater spilled into the bottomland hardwoods along the flood plain or was ponded for a considerable time in shallow depressions.

For development of a productive agricultural area, the land was deforested, ditched and tile drains were installed to quickly remove storm water. Many of the

streams were straightened greatly reducing their lengths and removing a substantial portion of the available habitat.

Because of the straightening and removal of water by tile drains, streams exhibit predictable characteristics during storm events. The water rises quickly much like the beat of the heart and then tails off in a recovery period as the water recedes. Depending on the time between the storm events, considerable sediment, nutrients and bacteria are delivered to the stream system during these events. A key to solving the drainage problems is to maximize retention and minimize conveyance during the initial first flush of storm water to the stream.

METHODS

Triplicate water quality samples were taken at 8 locations. Stations are presented proceeding from the upstream station at the Hamilton-Madison County border to the station at 96th Street where the stream enters Marion County. A map showing the general location of each station is presented below. The stations evaluated were at the following locations (listed in order from upstream to downstream):

MC8 Mud Creek at Atlantic Rd, County Line with Madison County.
N40^{0} 00.654', W85^{0} 51.734'

MC7 Sand Creek upstream station at Sand Creek Drain near the Verizon Entertainment Complex E 146th St
N40^{0} 00.088' W85^{0} 56.098'

MC6 Mud Creek at Olio Rd.
N39^{0} 58.666', W85^{0} 55.122'

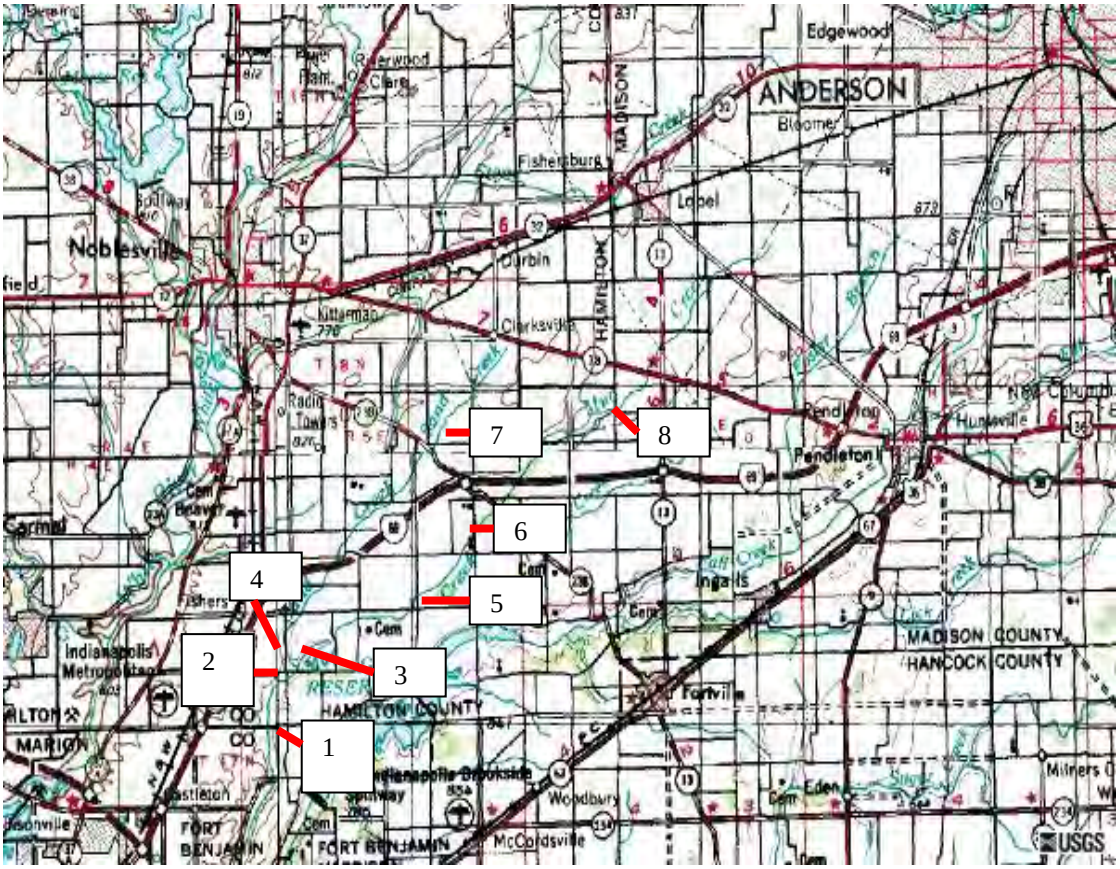
MC5 Mud Creek at Brooks School Ave.
N39^{0} 57.712', W85^{0} 56.544'

MC4 Sand Creek at merger with Mud Creek N of 106th St
N39^{0} 56.511', W85^{0} 59.482'

MC3, Mud Creek, Golf Course N of 106th St
N39^{0} 56.511', W85^{0} 59.465'

MC2, Mud Creek, Cumberland Rd at Cumberland Park
N39^{0} 56.40', W85^{0} 59.699'

MC1, Mud Creek, 96th Street, County Line with Marion County.
N39^{0} 55.635', W86^{0} 00.135'



Map of Mud Creek indicating sampling stations

Latitude and longitude coordinates for the above sites were saved into a GPS. Upstream and downstream photographs were taken at each site. Information used in preparing the Qualitative Habitat Evaluation Index (QHEI) and the EPA Habitat Assessment were tabulated in May and June. Streams that have been ditched and straightened do not fare well in these types of scoring systems when comparisons are made to a pristine stream system.

Dissolved oxygen, conductivity, and pH were measured onsite with appropriate meters. Water samples were stored in wet ice at 4^0 C until the remaining analyses could be completed later that evening using a portable spectrophotometer and *Standard Methods for the Analysis of Water and Wastewater*. One hundred ml triplicate water samples were filtered through membrane filters. The filters, placed in petri dishes with growth media, were submerged in an incubator held at a constant 44.5^0C for growth of fecal coliform bacteria.

The methodologies chosen for assessing the biological quality of the above eight sites were originally published by the Environmental Protection Agency in 1989 in the *Rapid Bioassessment Protocols for Use in Streams and Rivers; Benthic Macroinvertebrates (13)*. These protocols have been updated, and are now

available on the Internet. We used the new delineation aspects of the updated materials as an aid in understanding impairment at the stations.

As part of this study, we also developed the QHEI (Qualitative Habitat Evaluation Index) used by the Indiana Department of Natural Resources and other states. The QHEI gives an estimate of the suitability of a stream segment to meet warmwater habitat requirements for aquatic organisms. A recorded QHEI of 60 or above on a 100 point scale usually means that the stream segment is suitable for a warmwater habitat without use impairment.

The rapid bioassessment protocols described in this report are best used for detecting aquatic life impairments and assessing their relative severity. Once impairment is detected, it is often necessary to undertake specific studies to identify the causative agents and to develop mitigation procedures. When mitigation efforts are undertaken, the same procedures can be used to document *environmental recovery*. Thus, these methodologies can be very useful monitoring tools as attempts are made to improve the water quality in Mud Creek and its tributaries.

The bioassessment technique results presented in this final report focus on the evaluation of habitat and benthic macroinvertebrate community parameters. Measured water quality parameters are designed to support the bioassessment protocols. The methods and parameters used in each protocol are presented below.

Macroinvertebrate Assessment

For the macroinvertebrate analysis, we used a Rapid Bioassessment Protocol technique (RBP). This protocol focuses on the invertebrates in the riffle/run habitat, one of the most productive in a stream ecosystem, or when riffles are absent, jabs are taken in all available habitats. With our analysis, we obtained three traveling-kick net method samples in the riffles at each station. These samples, known as TKN, were taken with a triangular kick-net with a small mesh. The net is placed on the substrate and is moved upstream for 10 feet while the area in front of the net is agitated for a width of 1 foot directly in front of the net *(Standard Operating Procedures Manual, Kentucky Department for Environmental Protection, Division of Water)*. Samples taken using TKN's, jabs and a sorted qualitative sample were preserved in 40% isopropanol and taken to the laboratory where they were sorted, identified to the family taxonomic level

and counted.

Removing samples from triangular kick net following 10-foot sampling effort.

Jabbing for macroinvertebrates during base flow sampling near Verizon.

Following counting, the numbers were placed on taxonomic sheets so that the metric analyses described below could be calculated.

Taxa Richness

This metric measures the total number of families present. Generally, as habitat diversity, habitat suitability, and water quality increase, the numbers of families will increase.

Family Biotic Index

For this analysis, each taxonomic group is assigned a tolerance value from 0 to 10. Taxa with low pollution tolerance rate very low on this scale while pollution tolerant organisms are in the high range. Thus, the computed values increase as water quality decreases. This index is designed to detect organic pollution.

Ratio of Scraper and Filtering Collector Functional Feeding Groups

This metric focuses on the community food base. Scrapers are present in numbers when the rocks are covered with diatoms and other attached algae. They tend to decrease when filamentous algae and aquatic mosses increase. The algae and mosses provide good attachment sites for filtering collectors. Of course, excessive nutrient input and organic enrichment provide the fertilizer for an overabundance of algae.

Ratio of EPT Taxa (Ephemeroptera, Plecoptera, and Tricoptera) and Chironomidae Abundances

The EPT to Chironomid ratio is an indication of community balance. Mayflies (Ephemeroptera), Stoneflies (Plecoptera) and Caddisflies (Tricoptera) are organisms often associated with high quality habitats and excellent water quality. Very high numbers of midge larvae (Chironomidae) relative to the more sensitive EPT taxa may indicate environmental stress.

Percent Contribution of Dominant Family

This metric uses the dominant taxon as an indication of community balance at the family level. A community dominated by relatively few families would indicate environmental stress.

EPT Index

Scientists have determined that the EPT Index normally increases with increasing water quality. The EPT summarizes the taxa richness within the insect groups that are considered pollution sensitive.

Community Loss Index

The index measures the loss of benthic species between a reference station and the station of comparison. Values increase as the degree of dissimilarity increases.

Shredders (CPOM Sample)

Shredder macroinvertebrates are those that utilize coarse particulate organic matter (CPOM). Shredders are known to be a particularly good indicator of toxic effects since toxicants are adsorbed by the CPOM. Some toxicants such as herbicides and insecticides often are already on the CPOM when they enter the water.

After values were tallied for each metric, they were compared with those values obtained for a pristine reference location. By expressing the comparability as a percentage of the reference location, we were able to categorize each station as nonimpaired (comparable to best situation expected in this area), slightly impaired (community structure less than expected with tolerant forms increasing), or moderately impaired with fewer species present and reduction in the EPT taxa.

Habitat Assessment

The Habitat Assessment Matrix supports the macroinvertebrate biosurvey analysis and is weighted to emphasize the most biologically significant parameters. Using this analysis, all stations were rated. These ratings were then totaled and compared to a reference point that is the very best attainable situation to provide a final habitat percentage ranking.

Habitat parameters are separated into three categories--primary, secondary, and tertiary. The primary parameters are those that characterize the substrate instream habitats that have the greatest influence on community structure. These include (1) bottom substrate and available cover, (2) embeddedness and (3) flow. Secondary parameters involve an analysis of channel morphology including (1) channel alteration, (2) bottom scouring and deposition, and (3) pool to riffle ratio. Tertiary parameters are designed to measure the riparian and bank structure. Those items assessed include (1) bank stability, (2) bank vegetation and (3) streamside cover.

The actual habitat assessment involves rating the nine parameters as excellent, good, fair or poor. A field sheet serves as a guide in this process.

RESULTS

HABITAT CHARACTERIZATION DURING BASEFLOW PERIOD

As noted above, for the Habitat Assessment of Mud Creek, we used two analyses: Habitat Assessment from Chapter 5 of the Rapid Bioassessment Protocols (RBP) from the EPA (13) and the Qualitative Habitat Evaluation Index (QHEI) used in Indiana and neighboring states.

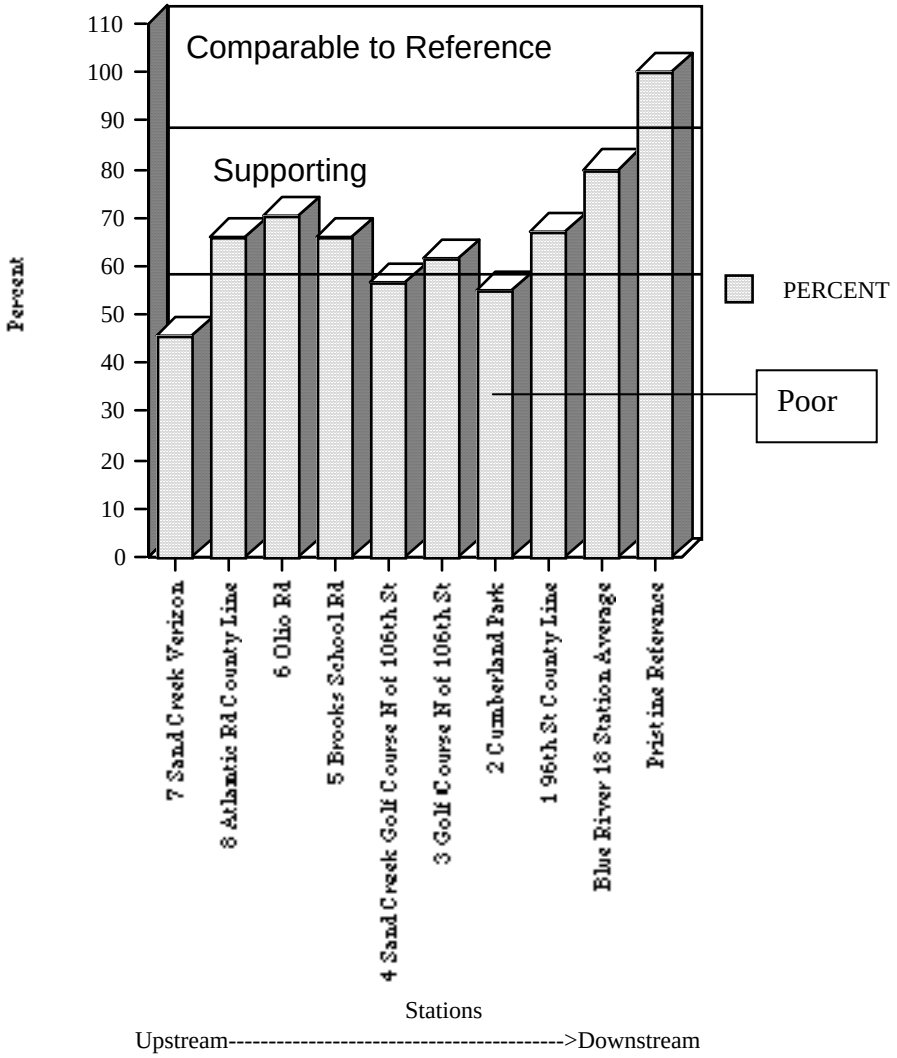
For the RBP assessment, the total score obtained for each station on Mud Creek was compared to a high quality best attainable conditions reference station and to our previous studies of the Blue River (18 station average). The ratio expressed as a percentage provides a measure for each station. The station is then classified on the basis of its similarity to expected high quality stream conditions.

In the following Figure 1, the Stations on Mud Creek proper and Sand Creek (Stations 4&7) are listed along the horizontal line while the percent comparison to a pristine, unaltered high quality reference stream is listed along the vertical scale. We set a comparison percentage of 88% as a dividing line between comparable to reference optimal habitat and supporting. We set another dividing line separating supporting from partially supporting or suboptimal. Finally, we used less than 58% to delineate those areas that are poor.

All Stations except Station 7 on Sand Creek and Station 2 on Mud Creek fell into the supporting or partially supporting range. The best habitats were found at Brooks School Road (Station 5) and Olio Road (Station 6). This is in spite of the fact that aerial photographs indicate significant land clearing in prior seasons. These were also the stations where we began to notice significant numbers of minnow and shiners. Unlike its cohort stream, Stony Creek, Mud Creek has rocks, gravel and emergent boulders in its upper reaches. This habitat structure along with aquatic plants provides a more substantial habitat and more aeration than in Stony Creek. The downstream Station 2 had a reduced habitat score because very few flat boulders and rocks were noted in these areas.

Last year, we studied White Creek, another glacial stream in Jackson County. This stream had almost no rocky structure and the habitat values fell below the 58 percentile at all stations. White Creek, however, had a number of very deep pools supporting a fairly good fish population. The deep pool habitats were lacking in Mud Creek.

Figure 1. Habitat Analysis of Mud Creek



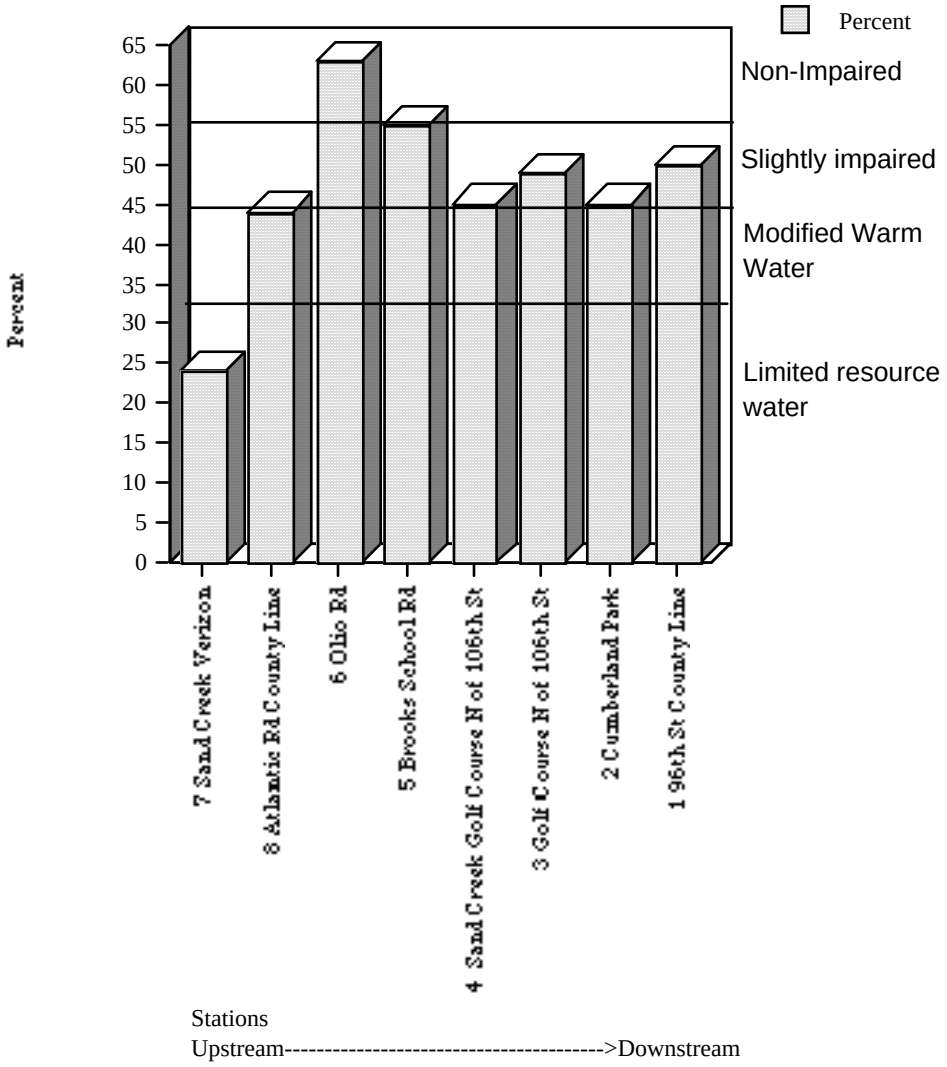
QUALITATIVE HABITAT EVALUATION OF MUD CREEK

The Qualitative Habitat Evaluation (QHEI) is designed to provide a measure of the qualitative habitat corresponding to those physical features that affect fish and invertebrate communities. Habitat variety and lack of pollution provide pollution intolerant organisms with several areas where they can find shelter, feed, grow and reproduce. Generally, these areas have several flow regimes, several substrate types, and a variety of cover possibilities. As water quality and habitat degenerate, pollution tolerant organisms will begin to become dominant occupying habitats in silt and sediment and in general, exhibiting a wide range of environmental tolerance.

The QHEI values for Mud Creek are depicted in the following Figure 2. The only unimpaired station was the upstream portion above Olio Road, but this may

change in the very near future. The area is being developed at a rapid pace. The remaining stations, except for Station 7, which was judged a limited resource water, were observed to have some level of impairment. The major limiting factors noted were silting in, lack of instream structure, insufficient cover, and loss of riparian vegetation. It is very interesting that some of the major cover in both Stony and Mud Creek is provided by an invasive exotic plant, Curly Leaf Pondweed (*Potamogeton crispus*).

Figure 2. Qualitative Habitat Evaluation Index Comparison (QHEI) for Mud Creek, 2003.

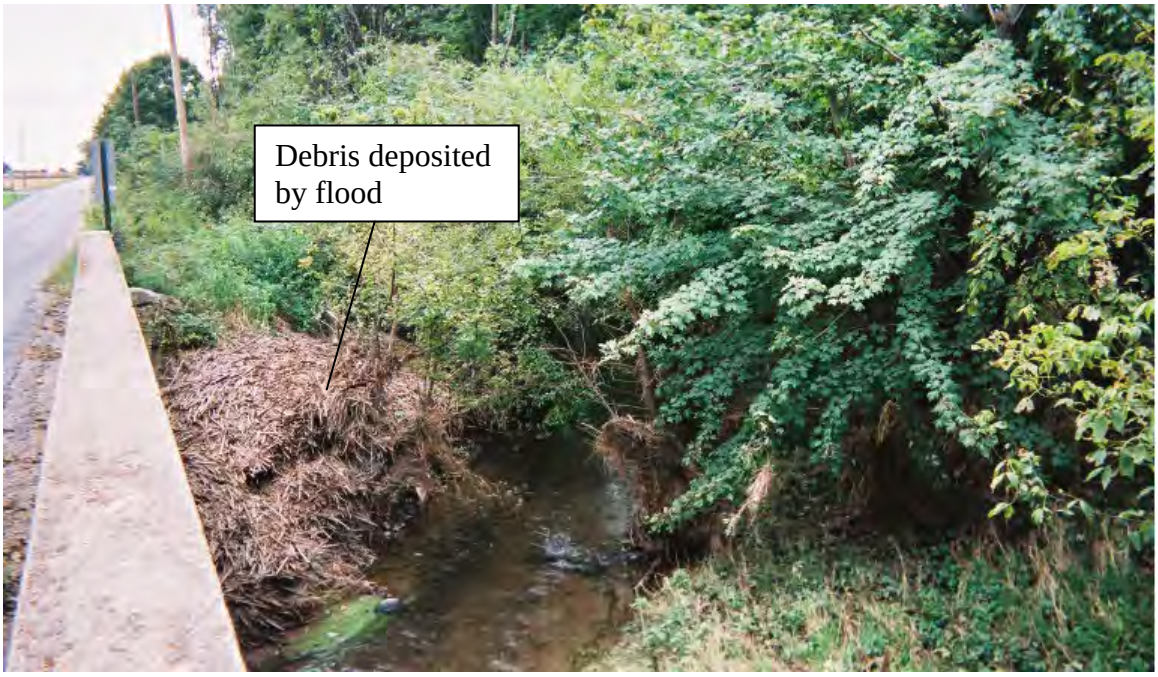


Habitat Photographic Data

Station 8. Mud Creek at Atlantic Road. Agricultural Area. Most upstream station on Hamilton-Madison County Line. Existing extensive agricultural area. The stream has some riparian vegetation cover and buffers in this area. Note flattened vegetation on downstream left photograph indicating recent flooding.

Base Flow. Note exposed boulders and rocks downstream. Stream is ditched in Madison County, but has a grass buffer.

Fall Flow Sampling following Labor Day flood.


Debris deposited
by flood

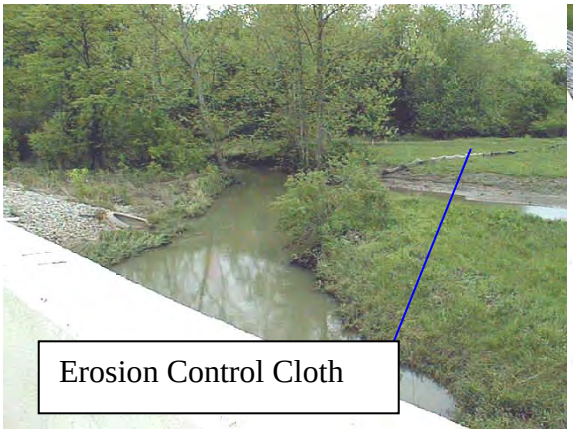
High water mark

Station 7. Sand Creek near the Verizon Entertainment Complex. Nearby farmland near I-69 was being actively developed at the time of sampling. The Verizon Complex has several ponds that may act as retention basins collecting runoff from the complex. The stream has riparian tree cover as its flows through the property.

Jabbing along bank during base flow. Algae development was significant.

Downstream obstruction removed in Fall. Water level was much lower during October.

Station 6. Mud Creek at Olio Road. Road has been expanded to four lanes. This area is undergoing rapid development. Residential and retail development was apparent at the time of collection. Riparian cover and wooded section with large pond downstream from station.



Baseflow. Note curly leaf pondweed in center of stream.

Erosion control cloth barriers had been removed or washed away during the fall flow sampling period.

Station 5. Mud Creek at Brooks School Rd., north of E116th St. New subdivision and retail stores nearby. Note residential area in background in downstream left photograph. Managed riparian grass buffer in foreground. Riparian cover upstream. Hawthorns Golf and County Club downstream.

Base flow. Note end of pipe from subdivision.

During the fall flow, large woody debris (LWD) and bank erosion were noted downstream. Note small artificial dam aerating water in sampling area upstream.

Station 4. Sand Creek upstream from juncture with Mud Creek. Both streams surrounded by Ironwood Golf Club and residential development.

Base flow. June 27, 2003. Curly leaf pondweed on bottom.

Fall flow. Most of instream vegetation is absent.

Station 3. Mud Creek at Ironwood Golf Club north of 106th street. Two impoundments noted upstream--one beside Sand Creek and one along Mud Creek.

Base flow sampling. June 27, 2003. Note artificial dam with aeration.

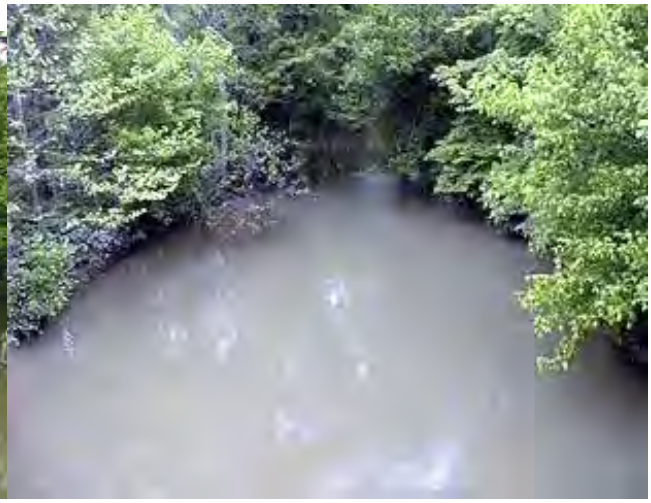
Fall flow sampling. October 3, 2003. Some algae and water weeds present.

Station 2. Mud Creek at Cumberland Park off Cumberland Road. Stream had recently overflowed banks onto road in relatively new park. This area is below combined overflows from Sand Creek and Mud Creek. Stream has riparian border, but trees are widely spaced and do not adequately shade stream. Houses are clustered with an area of green space.

Base Flow. June 27, 2003

Fall Flow October 3, 2003. New depositional area with relatively few rocks.

Station 1. Mud Creek at 96th Street. County Line with Marion County. This is the northern boundary of the Sargent Road Association. Stream has downcut into underlying glacial till in this area becoming a stream valley and is undisturbed for some distance. Storm drainage was observed entering on the left side facing upstream. A large triangular field is located upstream in the woods.



Station 1 Downstream Base Flow and Fall Flow. Note sandbar no longer exists.

Station 1. Fall flow upstream station for fall sampling period. Large woody debris and fallen trees had trapped sediment and debris.

Large woody debris on floodplain. Debris settled here during Labor Day flood.

WATER QUALITY RESULTS

The water results for three different sampling periods--flood flow, base flow and fall flow--are presented below in Table 1 and discussed below.

Table 1. Water Quality Results from Eight Stations on Mud Creek, Hamilton Co., Indiana during High Discharge, Base Flow and Fall Flow Sampling Periods in 2003

Upstream----------→Downstream

STATION NO.		8	7	6	5	4	3	2	1
Date	Flood Flow	5/14	5/14	5/14	5/14	5/14	5/14	5/14	5/14
	Base Flow	6/27	6/27	6/27	6/27	6/27	6/27	6/27	6/27
	Fall Flow	10/3	10/3	10/3	10/3	10/3	10/3	10/3	10/3
Discharge (CFS)	F	Flood	Flood	Flood	Flood	Flood	Flood	Flood	Flood
	B	5.3	Pond	12.8	19.2	21.9	34.5	53.8	60.9
	Fall	18.66	3.8	28.12	39.52	14.62	35.7	63.4	88.0
Air Temperature C	F	18.5	17.6	18.7	18.7	19.1	19.1	18.5	21.1
	B	26.5	31.4	31.7	28.4	25.6	25.6	23.5	19.3
	Fall	12.3	10.4	10.2	9.2	9.2	9.2	9.0	9.0
Water Temp C	F	13.9	14.1	13.7	14.8	14.8	15.7	15.5	15.4
	B	20.6	20.3	18.8	18.1	18.6	18.7	18.6	18.9
	Fall	12.3	10.4	10.8	10.7	9.6	11.0	10.6	10.6
Dissolved Oxygen mg/L	F	8.74	7.89	8.68	8.89	8.44	8.37	7.5	7.3
	B	15.9	4.3	10.32	10.29	8.22	6.64	6.63	7.0
	Fall	14.20	12.20	12.20	12.86	12.35	11.2	11.15	11.2
% Saturation	F	100	100	100	100	87.76	88.74	79.18	76.9
	B	100	50.08	100	100	92.56	74.92	74.65	79.3
	Fall	100	100	100	100	100	100	100	100
pH (Units)	F	7.8	7.8	7.8	7.8	7.8	7.9	7.8	7.6
	B	8.3	7.9	8.1	8.0	8.1	8.1	7.9	8.1
	Fall	8.1	7.9	8.1	8.0	8.1	8.1	8.4	8.9
Alkalinity mg/L	F	141.6	159.3	123.9	141.6	159.3	141.6	141.6	141.6
	B	247.8	283.2	318.6	283.2	283.2	265.3	283.2	283.2
	Fall	300.9	283.2	318.6	283.2	283.2	265.3	300.9	300.9
Turbidity (NTU)	F	30.0	46.8	27.0	56.1	75.1	57.6	44.0	45.1
	B	1.7	14.2	3.9	6.5	8.4	9.6	13.8	23.9
	Fall	6.6	16.7	25.5	7.9	43.8	33.4	22.6	12.0
Conductivity	F	480	520	500	480	530	480	500	500
	B	610	680	620	620	690	490	560	570
	Fall	630	680	640	640	680	620	650	630
Total Dissolved Solids mg/L (E)	F	240	260	250	240	265	240	250	250
	B	305	340	310	310	345	245	280	280
	Fall	315	340	320	320	340	310	325	315
Nitrate mg/L	F	0.13	0.10	0.11	0.09	0.12	0.08	0.17	0.18
	B	0.48	0.55	0.33	0.24	0.13	0.04	0.07	0.28
	Fall	2.0	2.3	1.2	1.7	1.4	1.8	1.6	1.8
Nitrite mg/L	F	0.046	0.045	0.041	0.049	0.041	0.036	0.043	0.042
	B	0.104	0.36	0.157	0.067	0.089	0.077	0.058	0.061
	Fall	0.019	0.14	0.094	0.041	0.048	0.037	0.023	0.045

Ammonia-N mg/L	F	0.14	0.15	0.13	0.13	0.16	0.12	0.14	0.09
	B	0.02	0.32	0.07	0.07	0.09	0.06	0.11	0.22
	Fall	0.02	0.04	0.02	0.03	0.02	0.02	0.11	0.06
Organic N mg/L	F	8.0	8.0	7.0	7.0	6.0	8.0	6.0	4.0
	B	7.2	6.9	5.4	3.6	1.7	0.9	1.4	2.1
	Fall	5.4	4.4	3.5	3.9	1.8	1.8	3.9	3.4
Ortho-Phosphate mg/L									
	F	0.12	0.37	0.25	0.56	0.65	0.59	0.53	0.51
	B	0.04	0.56	0.09	0.17	0.23	0.23	0.13	0.30
	Fall	0.17	0.20	0.10	0.14	0.12	0.16	0.09	0.15
Total Phosphate mg/L									
	F	0.59	0.86	0.75	0.73	1.01	0.89	0.95	0.63
	B	0.09	0.59	0.07	0.14	0.27	0.27	0.28	0.33
	Fall	0.26	0.74	0.68	0.22	0.27	0.46	0.44	0.28
Fecal Coliform Bacteria									
Per 100 ml	F	60	380	161	191	266	228	76	64
	B	299	5696	848	961	2821	1105	1624	1878
	Fall	47	1220	182	42	181	131	200	164

Discharge and Turbidity

The flood flow sampling was accomplished on the trailing end of the storm hydrograph. Study of flattened grass and high water marks indicated the stream had been about one to two feet higher during peak flow one or two days earlier. Mud Creek is typical of artificially manipulated streams found in agricultural areas. They rise quickly becoming extremely muddy for a day or two and then clear up as the water recedes. Accompanying the first flush of muddy water is a high load of nutrients, and depending upon the specific use of the area, bacterial contamination may also be present. The significance of these events is that most of the sediment is delivered to the stream during high water.

Turbidity is simply a measure of the cloudiness of the water. The sources of the turbidity in Mud Creek are disturbed construction areas and from fields using conventional agricultural methods. Turbid water is clouded by soil particles and organic residues suspended in the water. Brown silt laden water has high turbidity. The flood flow stream photographs clearly show that the water was cloudy or turbid. The turbidity readings for Mud Creek and Sand Creek ranged from 27 to 75.1 NTUs during storm flow. They were generally lower during base flow and fall flow monitoring periods. The recorded levels were below those considered hazardous to aquatic life.

We suspect, however, that the turbidity readings at first flush would have been above 80 NTUs. This is based upon our experience in the Blue River of southern Indiana where the stream becomes extremely muddy and then the level begins to fall almost immediately with the stream clearing in a few days. It is sometimes difficult to determine what exact effects these colloidal particles and organic matter have, but most studies suggest that muddy water is deleterious to a

variety of aquatic life. In addition, over time stones and rocks that provide habitat for aquatic invertebrates become embedded or covered by muck.

Dissolved Oxygen

Dissolved oxygen has sometimes been described as the most critical limiting factor in fresh water streams. When oxygen levels drop below 5 mg/L, organisms become stressed and may die. Oxygen enters the water by photosynthesis of aquatic plants and by the transfer of oxygen across the air-water interface in turbulent areas known as riffles. The amount of oxygen that can be held by the water depends on the water temperature. In the case of Mud Creek, oxygen levels were adequate to support aquatic life. However, they were mostly below saturation. The lowest level was noted at Station 7 near Verizon where little turbulence was observed during the base flow period. Levels below saturation suggest that the turbid water had organic enrichment and bacteria that created considerable biochemical oxygen demand.

PH

An optimal range between 7.6 and 8.9 was recorded. These conditions are ideal for the support of aquatic life.

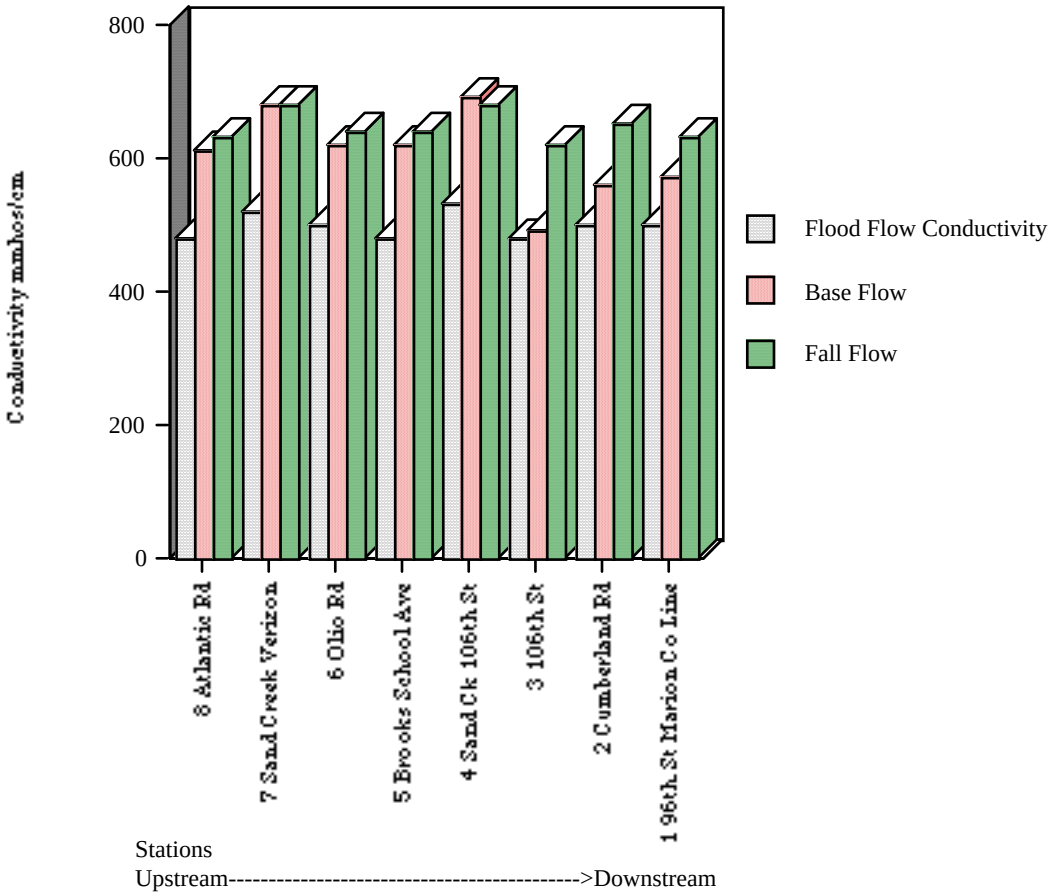
Conductivity

Conductivity is a measure of the ability of water to pass an electrical current and is therefore related to the amount of minerals dissolved in the water. In some areas where contact with the soil substrate is considerable and certain other conditions are met, minerals such as nitrates, phosphates, calcium and bicarbonates can become dissolved in the water. When this occurs, conductivities can be elevated.

The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm.

The conductivity measurements for Mud Creek were consistently between 480 and 520 micromhos/cm during flood flow indicating storm water dilution.

Figure 3. Conductivity Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003



During base flow and fall flow periods, the conductivities were between 490 and 680. This indicated the water had greater opportunity for soil to water contact. Total dissolved solids were broadly estimated to be roughly half the conductivity (as mg/L CaCO3). These levels of conductivity are well below one published standard of 800 mg/L (14).

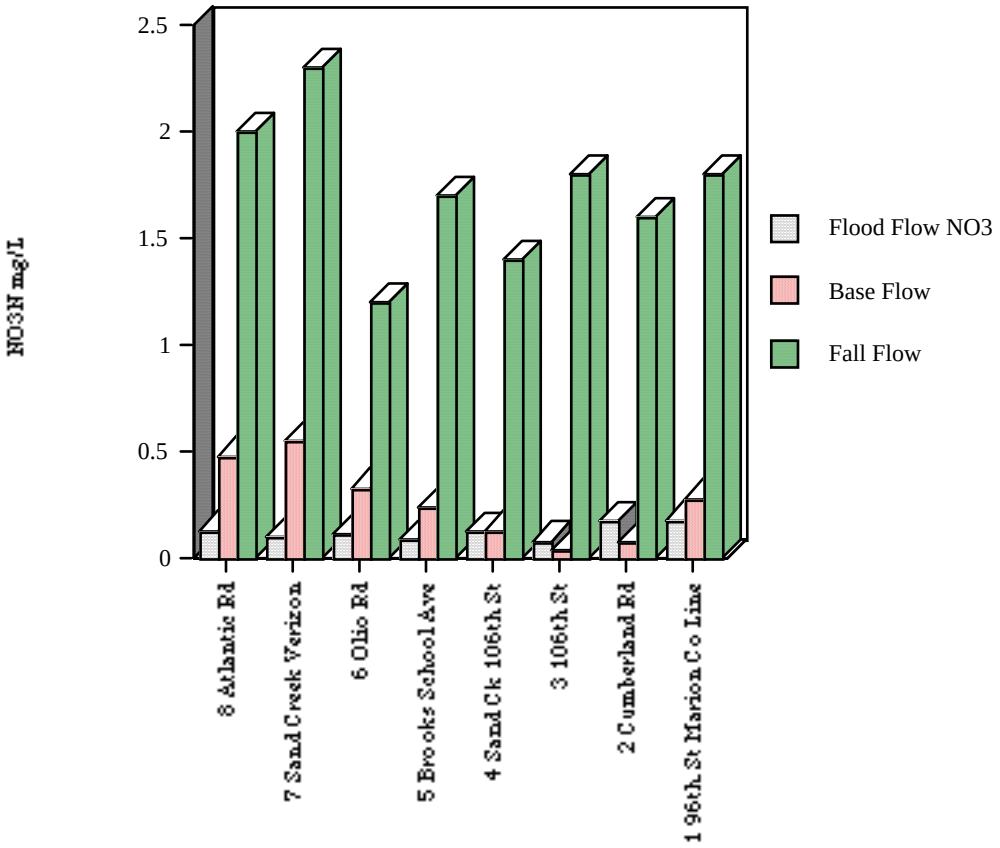
Nitrogen (Nitrates, Nitrites, Ammonia Nitrogen and Total Nitrogen)

Mud Creek water testing indicated presence of four forms or species of nitrogen. Of these, nitrate is the one found most commonly in surface waters. Ammonia is normally found in waters where oxygen is limited while Total Nitrogen is a measure of both the organic and inorganic nitrogen. The presence of nitrites in water indicates that beneficial bacteria have not converted all the nitrogen into nitrate. While not as toxic as ammonia, high levels can nonetheless affect fish and other organisms.

Nitrate is a highly mobile plant nutrient normally present in unaltered streams in small amounts. Nitrate nitrogen finds its way into Mud Creek using a variety of nonpoint sources. The most obvious source is from overland flow from primary agricultural sources. Residential and urban sources include leaky septic tanks, lawn and garden fertilizers and pet excrement.

The tile drainage system can also provide a significant input of nitrogen during storm periods. Subsurface tile drainage systems have been shown throughout the region to supply nitrogen to streams following storm events.

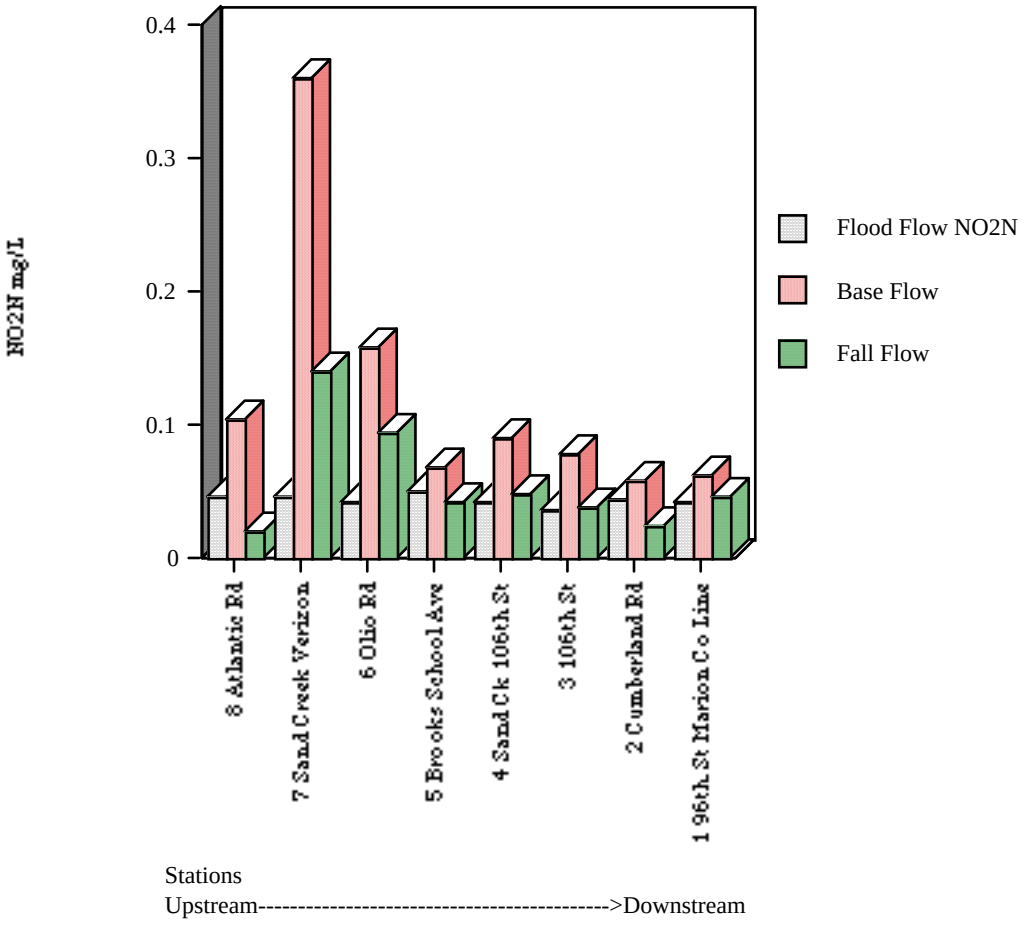
Figure 4. Nitrate Nitrogen Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003



Stations
Upstream---------->Downstream

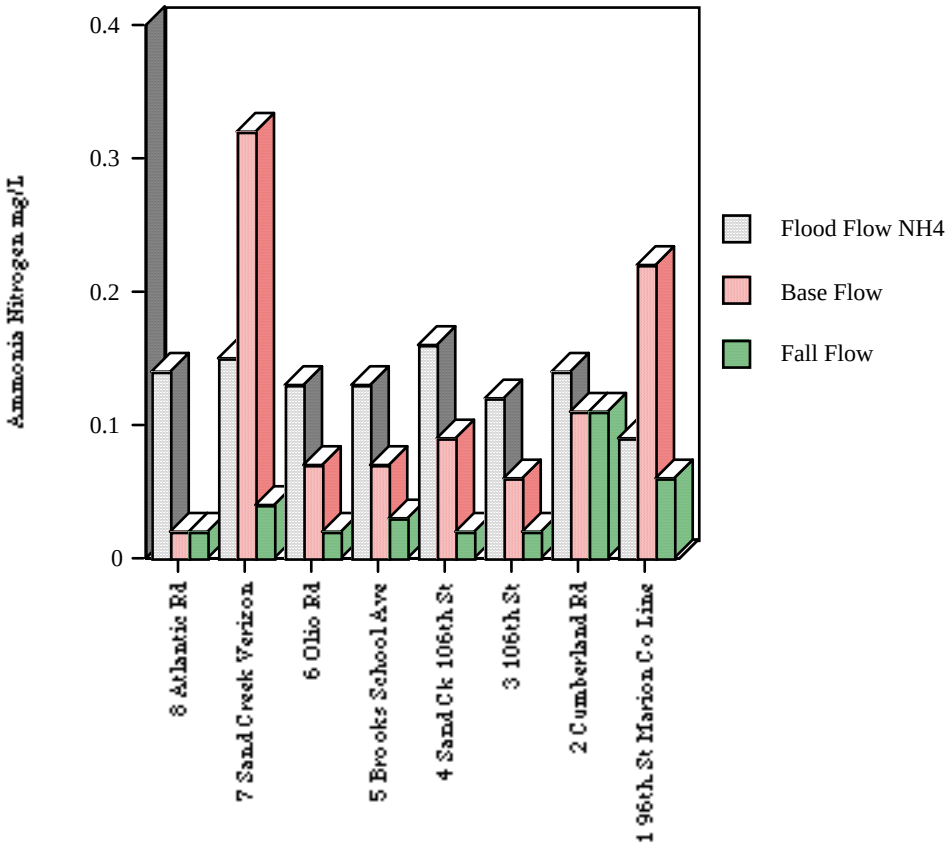
The nitrate-nitrogen standard for drinking water is 10 mg/L. None of the values in Figure 4 are above this standard. However, from the data, we can define the following trends. During flood flow, after the first flush of nutrients, the water is diluted and the levels are low. During base flow, the tile drains were mostly dry and the levels, though elevated slightly were less than 0.55 mg/L. In fall flow, the nitrates are elevated. The only possible explanations for this are leaching into the tile drains that were flowing at the time of collection and problems associated with human or animal waste systems. Nitrite and ammonia concentrations were elevated at Station 7 indicating a potential problem in that area.

Figure 5. Nitrite Nitrogen Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003



Stations
Upstream---------->Downstream

Figure 6. Ammonia Nitrogen Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003

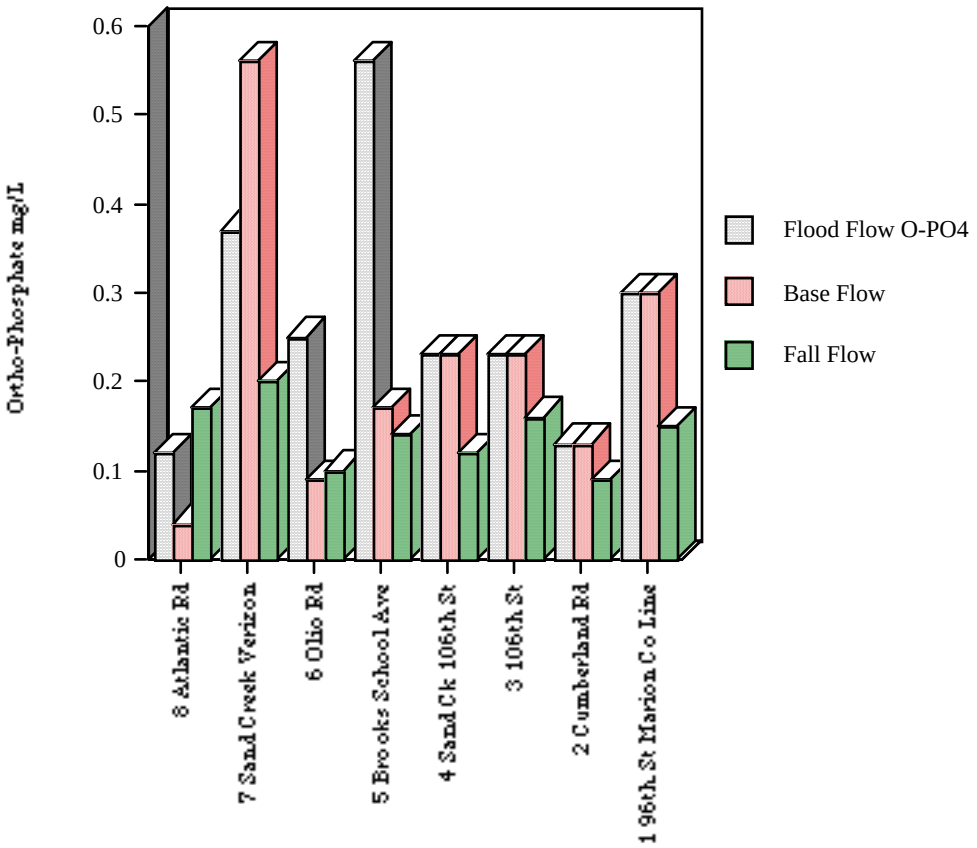


Stations
Upstream---------->Downstream

Phosphates (Dissolved and Total)

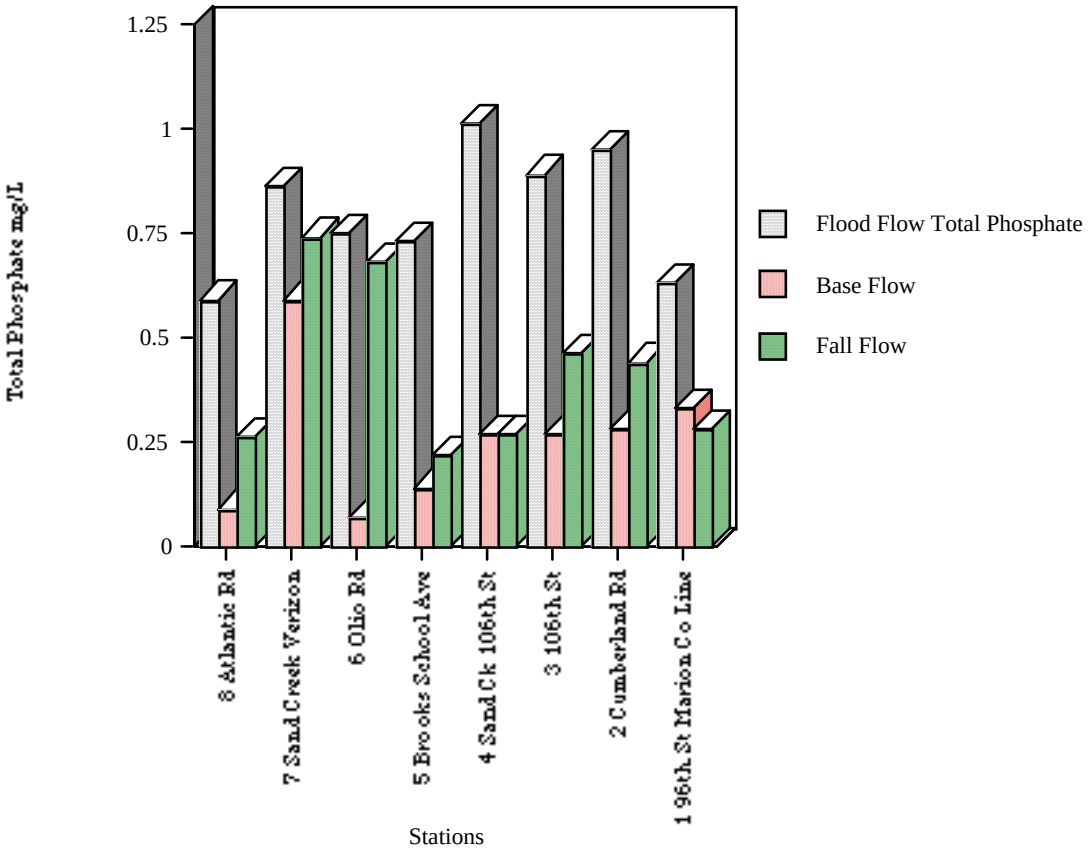
Phosphate levels for both dissolved and total phosphate were below or near 1 mg/L. The phosphate levels, while not extremely high, are a cause for concern. Nuisance algae can readily use the dissolved phosphate to produce undesirable growths. Flood flow had the highest total phosphates, and this is consistent with phosphate adhering to particulate matter.

Figure 7. Ortho-Phosphate Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003



Stations
Upstream----------->Downstream

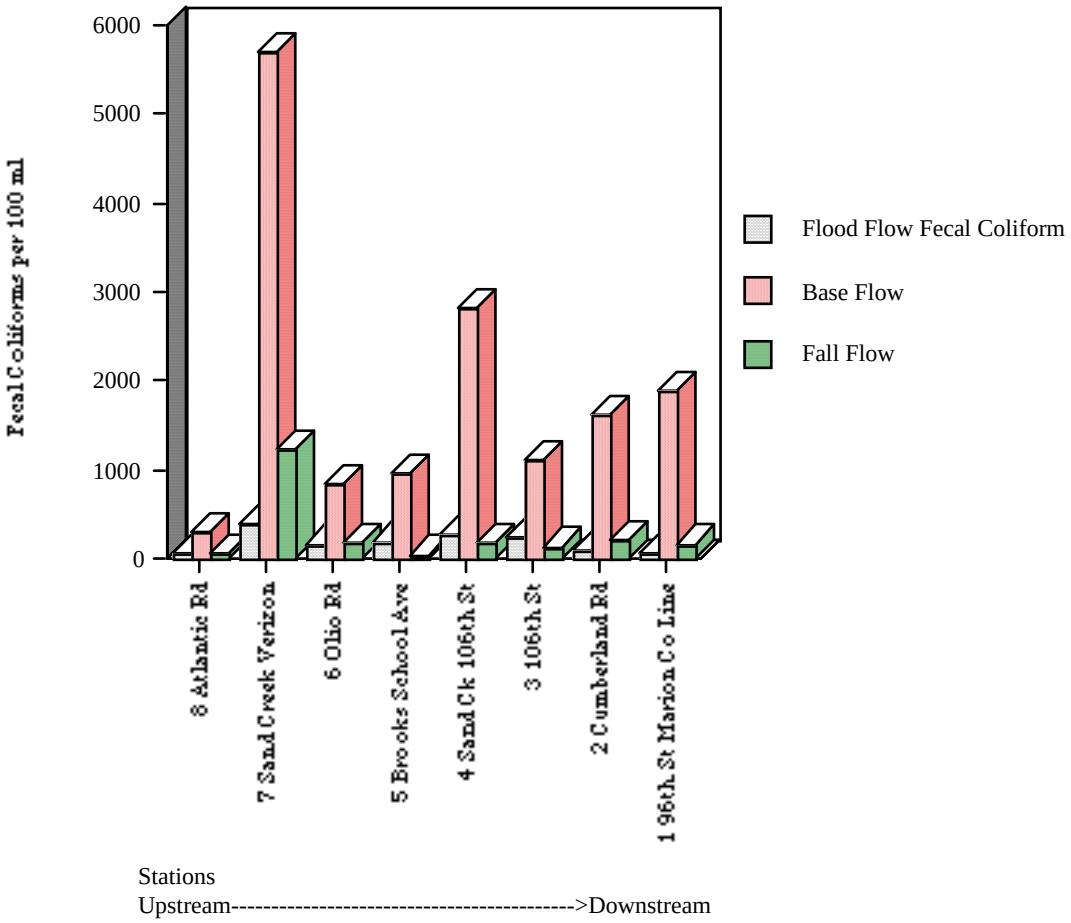
Figure 8. Total Phosphate Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003



Fecal Coliform Bacteria

All stations in Mud Creek indicated evidence of fecal coliform bacteria contamination. Values averaging 200 per 100 ml or above were found in 13 of the 24 samples analyzed. Stations 3 and 4 are in urban areas and could pick up fecal bacteria from failed septic systems and other sources. Site 7 on Sand Creek is below an entertainment complex and an existing agricultural area that may have farm animals and failed septic systems.

Figure 9. Fecal Coliform Bacteria Levels During Three Flow Regimes
Mud Creek, Hamilton County, Indiana 2003



Fecal coliforms are the coliform bacteria that originate from the intestinal tract of warm-blooded animals (e.g., humans, cattle, and dogs). They are cultured by increasing the incubation temperature to 44.5^{o} C and by using somewhat different growth media.

Typical nonpoint sources include agricultural, residential and urban areas. Agricultural sources include livestock excrement from barnyards, pastures, rangelands, feedlots, and uncontrolled manure storage areas. Land application of manure and sewage sludge can also result in water contamination.

Failed on-site septic systems in residential and rural areas or illegal connections to tile drains can contribute large numbers of coliforms and other bacteria to surface water and groundwater. Storm water runoff from residential, rural, and urban areas can transport waste material from domestic pets and wildlife into surface waters.

Bacteria-laden water either leaches into groundwater and is transported into surface waters or rises to the surface and is transported by overland flow. Bacteria in overland flow can be transported freely or within organic particles. Overland flow is the most direct route for bacteria transport to surface waters.

While most fecal coliform bacteria do not cause disease, they certainly indicate potential health problems from other waterborne pathogens. One of these pathogens is a particular type of fecal *E. coli* known as 0157:H7. This is a type of coliform found in the intestinal tracts of cattle and is known to cause bloody diarrhea, dehydration, and death in humans (http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.htm#Top).

RESULTS--MACROINVERTEBRATE ASSESSMENT

The macroinvertebrate assessments are presented in Tables 2 and 3 and summarized in Figure 10. The macroinvertebrate assessment indicated that all stations examined on Mud Creek were moderately impaired. One station on Sand Creek was moderately impaired while the stream at Station 7 was severely impaired. As part of this study, we also developed 2003 macrometric scores for Blue River in Harrison County at Rothrock's Mill, Fourteen Mile Creek in Clark County near Tunnel Mill, Laurel Fork of the Rockcastle River in Kentucky, an outstanding resource water, and for White Creek, a similar stream in Jackson County, and for a pristine reference, Mitchell River, NC.

When the Mud Creek drainage and reference streams are compared with reference stream data taken in 2003 and earlier, we find that both Blue River and Laurel Fork are comparable to a pristine reference. Fourteen Mile Creek of Clark County was only slightly impaired while White Creek was moderately impaired. White Creek is found in a highly ditched situation in Jackson County. Jackson County is pursuing remedial efforts for White Creek.

TABLE 2. Summary of Macroinvertebrate Metrics for Eight Stations on Mud Creek. June 26, 2003.

Upstream----------→Downstream

Station No.	**7**	**8**	**6**	**5**	**4**	**3**	**2**	**1**	**Ref**	**Ref**	**Reference**
Station Location	Sand	Mud	Mud	Mud	Sand	Mud	Mud	Mud	White Ck, IN	Blue River	Mitchell River, NC
Taxa Richness Families	4	22	27	15	18	18	13	16	24	20	8-21
Metric Score	0	6	6	4	6	6	4	4	6	6	6
Family Biotic Index	6.507	5.742	5.264	6.53	5.838	5.53	5.643	5.237	5.42	4.12	4.59
Metric Score	1	3	3	1	3	3	3	3	3	6	6
EPT/Chironomidae	0	1.26	0.51	0.318	0.21	0.995	0.069	1.77	0.39	1.62	9.286
Metric Score	0	0	0	0	0	0	0	0	0	0	6
CPOM Community Shredders/Total	0.012	0	0.004	0.003	0.005	0.009	0.01	0.008	0	0	6
Metric Score	0	0	0	0	0	0	0	0	0	0	6
EPT index	0	5	6	5	6	5	1	4	3	14	14-21
Metric Score	0	0	0	0	0	0	0	0	0	6	6
% Contribution Dominant Taxon	90.3	20.5	47.6	67.8	47.6	29.5	46.2	33.9	31.1	18	34
Metric Score	0	6	4	2	4	6	4	6	6	6	3
Community Loss	4.25	0.59	0.288	0.87	0.61	0.77	1.30	1.00	0.5	0	Reference
Metric Score	0	2	4	2	4	2	4	4	4	6	6
Ratio of Scrapers to Filterers	0	0.30	0.183	0.105	0.597	0.010	0.481	0.54	0.04	1.35	1.50
Metric Score	0	0	0	0	4	0	2	4	0	6	6
Total Score	1	17	17	9	21	17	17	23	19	36	45
Average	0.125	2.125	2.12	1.125	2.62	2.12	2.125	2.87	2.37	4.5	5.62

Analysis: Station 7 Poor 2.2% of Reference. Severely Impaired
Analysis: Station 8 Poor 37.7% of Reference. Moderately Impaired
Analysis: Station 6 Poor 42.2% of Reference. Moderately Impaired
Analysis: Station 5 Poor 20% of Reference. Moderately Impaired
Analysis: Station 4 Poor 46.6% of Reference. Moderately Impaired
Analysis: Station 3 Poor 37.7% of Reference. Moderately Impaired
Analysis: Station 2 Poor 37.7% of Reference. Moderately Impaired.
Analysis: Station 1 Poor 51% of Reference. Moderately Impaired

Taxa Richness=Site TR/RefTR x 100 >80%=6; 60-80=4; 40-60=2; <40=0. In subsamples, an outstanding resource water in Kentucky (Laurel Fork) had 26 families of macroinvertebrates.
FBI=Site FBI/Ref FBI x 100 >85%=6; 70-85=4; 50-70=2; <50%=0
EPT/Chironomidae=Site Ratio/Ref Ratio x 100 >75%=6; 50-75=4; 50-70=2; <50=0
Shredders/Total=>50%=6; 35-50%=4; 20-35%=2; <20%=0
EPT Index=Site/Reference x 100 >90%=6; 80-90%=4; 70-80=2; <70=0. In 100-300 organism sub samples, 14-21 EPT taxa were identified in an outstanding resource water.
% Contribution of Dominant Family or Taxon 0-35%=6; 35-50%=4; 50-75%=2; >75%=0
Scrapers/Filterers=Ratio of Site/ Ref Ratio x 100 >50%=6; 35-50=4; 20-35=2; <20%=0
Community Loss. <0.5=6, 0.5-1.5=4, 1.5-4=2, >4=0.

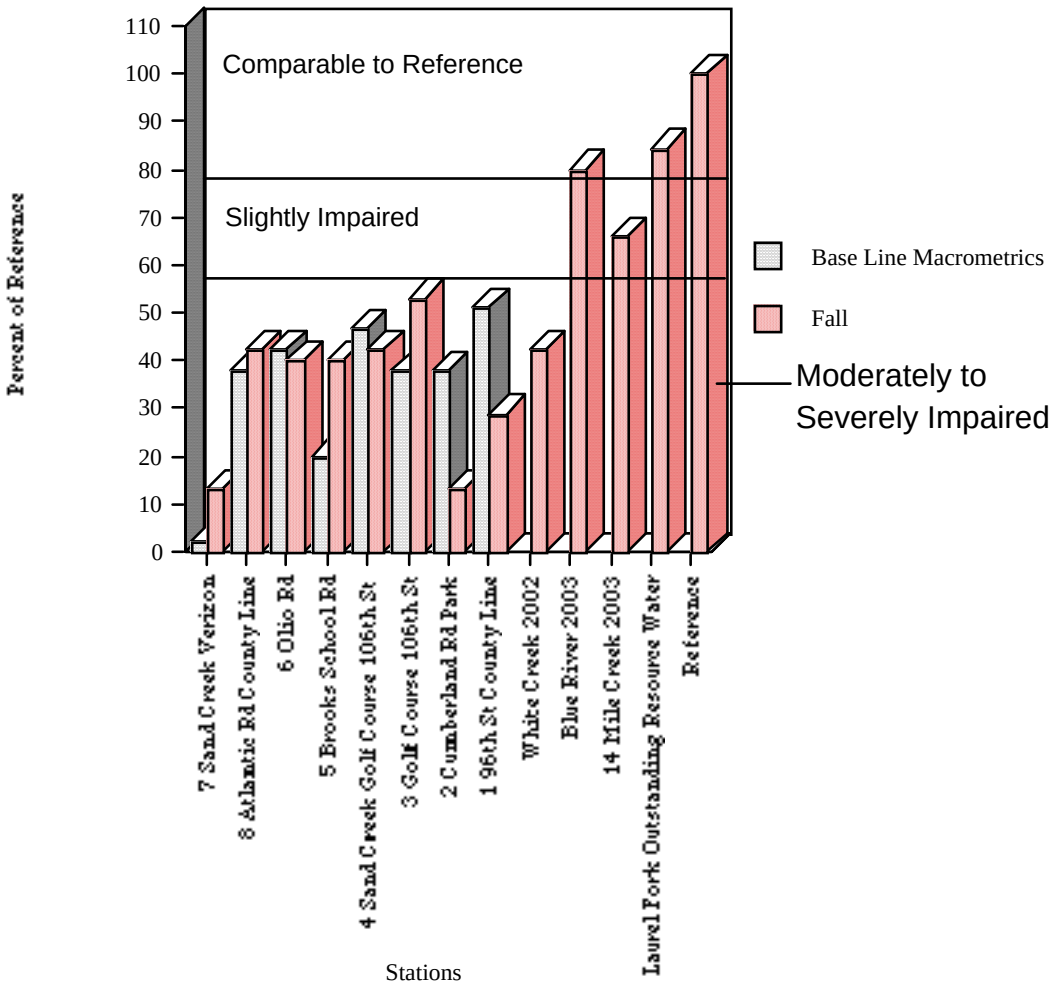
TABLE 3. Summary of Macroinvertebrate Metrics for Eight Stations on Mud Creek. October 3, 2003.

Station No.	**7**	**8**	**6**	**5**	**4**	**3**	**2**	**1**	**Ref**	**Ref**	**Reference**
Station Location	Sand	Mud	Mud	Mud	Sand	Mud	Mud	Mud	White Creek, IN	Blue River IN	Mitchell River, NC
Taxa Richness Families	8	20	16	11	13	13	7	12	24	20	8-21
Metric Score	0	6	4	2	2	2	0	2	6	6	6
Family Biotic Index	6.11	6.40	4.91	4.86	5.68	4.67	5.99	5.41	5.42	4.12	4.59
Metric Score	2	2	4	4	3	4	2	3	3	6	6
EPT/Chironomidae	0.37	2.6	1.85	1.97	1.63	18.8	0.131	0.516	0.39	1.62	9.286
Metric Score	0	0	0	0	0	6	0	0	0	0	6
CPOM Community Shredders/Total	0	0	0.017	0	0	0.01	0.019	0.006	0	0	6
Metric Score	0	0	0	0	0	0	0	0	0	0	6
EPT index	1	4	7	4	4	6	2	3	3	14	14-21
Metric Score	0	0	0	0	0	0	0	0	0	6	6
%Contribution Dominant Taxon	63.5	39	33.1	35	25.866	52.6	59.8	49.6	31.1	18	34
Metric Score	2	4	6	6	6	2	2	4	6	6	3
Community Loss	2.0	0.65	0.687	1.27	1.0	1.0	2.28	1.16	0.5	0	Reference
Metric Score	2	4	4	4	4	4	2	4	4	6	6
Ratio of Scrapers to Filterers	0	0.48	0.03	0.0	0.003	0	0	0	0.04	1.35	1.50
Metric Score	0	2	0	0	4	0	0	0	0	6	6
Total Score	6	19	18	18	19	24	6	13	19	36	45
Average	0.75	2.37	2.25	2.25	2.32	3.0	0.75	1.62	2.37	4.5	5.62

Analysis: Station 7 Poor 13.3% of Reference. Severely Impaired
Analysis: Station 8 Poor 42.2% of Reference. Moderately Impaired
Analysis: Station 6 Poor 40% of Reference. Moderately Impaired
Analysis: Station 5 Poor 40% of Reference. Moderately Impaired
Analysis: Station 4 Poor 42.2% of Reference. Moderately Impaired
Analysis: Station 3 Poor 40% of Reference. Moderately Impaired
Analysis: Station 2 Poor 13.3% of Reference. Moderately Impaired.
Analysis: Station 1 Poor 28.8% of Reference. Moderately Impaired

Taxa Richness=Site TR/RefTR x 100 >80%=6; 60-80=4; 40-60=2; <40=0. In subsamples, an outstanding resource water in Kentucky (Laurel Fork) had 26 families of macroinvertebrates.
FBI=Site FBI/Ref FBI x 100 >85%=6; 70-85=4; 50-70=2; <50%=0
EPT/Chironomidae=Site Ratio/Ref Ratio x 100 >75%=6; 50-75=4; 50-70=2; <50=0
Shredders/Total=>50%=6; 35-50%=4; 20-35%=2; <20%=0
EPT Index=Site/Reference x 100 >90%=6; 80-90%=4; 70-80=2; <70=0. In 100-300 organism sub samples, 14-21 EPT taxa were identified in an outstanding resource water.
% Contribution of Dominant Family or Taxon 0-35%=6; 35-50%=4; 50-75%=2; >75%=0
Scrapers/Filterers=Ratio of Site/ Ref Ratio x 100 >50%=6; 35-50=4; 20-35=2; <20%=0
Community Loss. <0.5=6, 0.5-1.5=4, 1.5-4=2, >4=0

Figure 10. Percent Comparison of Mud Creek and Other Cohort Stream Invertebrate Metrics to Pristine Reference Stream



Individual Macroinvertebrate Metrics

To further analyze these trends, the individual metric data in Tables 2 and 3 were evaluated and interpreted. In addition, we evaluated the ecological characteristics of individual families that were numerically dominant (autecology).

Taxa Richness

The Taxa Richness at all sites except Station 7 was moderately high to high during the base flow period. This is consistent with a stream having several available habitats. During the fall monitoring period, Station 2 joined Station 7 with depressed richness. The most like cause of this drop is the habitat alteration caused by the Labor Day flooding.

Upon careful examination, we find that nearly all the organisms identified were moderately tolerant to highly tolerant to organic pollution. The taxa missing were primarily intolerant families of mayflies, stoneflies and caddisflies. The groups comprise the Ephemeroptera, Plecoptera and Tricoptera families in the EPT index considered next.

EPT Taxa

In a non-impaired stream, we would expect to find between 8 and 24 families of pollution intolerant Ephemeroptera (mayflies), Plecoptera (stoneflies) and Tricoptera (caddisflies). In our case, we had very few EPT taxa. A few stoneflies of a single family (Perlidae) were found at two stations. Of the remaining mayfly and caddisfly larvae identified, most are known to demonstrate a moderate to strong tolerance to pollution and siltation. From the results of this metric, we conclude that pollution sensitive EPT taxa have been severely reduced in the Mud Creek watershed.

Stoneflies most often are found in clean, highly oxygenated streams. Organic enrichment and siltation can limit their occurrence. The susceptibility of stonefly larvae to sediments causes them to be one of the first organisms to disappear when a stream is impacted. It is interesting that the stonefly larvae found at Station 5 (Brooks School Road) were in an area where a small artificial dam had been constructed.

EPT/Chironomidae

The total number of specimens from the EPT group was compared with the numbers of chironomid specimens. Chironomid numbers were high leading to low ratios at nearly all sites. Chironomids are known for their pollution tolerance; thus, their elevated numbers suggest environmental stress at most stations on Mud Creek. During the fall sampling, EPT taxa outnumbered chironomids at Station 3 where artificial habitat had been placed

Percent Contribution of Dominant Family

Six of nine stations in Mud Creek had chironomid midge larvae as their dominant family during the base flow monitoring. Station 3 during this period had blackflies as the dominant family. Blackflies are collectors and gatherers of small bits of organic material floating down the stream. At Station 3 where the most blackfly larvae were found, an artificial dam and rocks provided points of attachment for the larvae. During the fall, chironomids were dominant at Stations 1 and 7 while hydropsychid caddisflies and elmid riffle beetles were dominant at the remaining stations. Basically, what we think happened is that the Labor Day flood washed away most of the algae and other plants that the chironomids and blackflies were using for attachment. The lack of algae favored the development of collector

gathering organisms like the riffle beetles and the attachment of the caddisflies to the exposed rock.

Shredders (Coarse Particulate Organic Matter Feeders)

In an unpolluted stream, many of the macroinvertebrates shred leaves as a portion of their food source. Streams supporting these type of invertebrates normally have a high woodland component with alternating riffles and pools. Canopy cover reduces light to the stream and limits algae growth. Thus the major energy source in these types of streams in fallen leaves. In the Mud Creek watershed, we did find some leaves, and in most cases these had chironomid midges attached to them. Shredders, except for the occasional tupulid cranefly larvae, were almost nonexistent.

Family Biotic Index

The Family Biotic Index (FBI) generated numbers higher than five, which suggests that fairly substantial pollution is likely.

The macroinvertebrate list was then scanned to determine if any extremely tolerant organisms were present at the stations. We found left handed snails, amphipods, bloodworms (Chironomidae), leeches, and aquatic oligochaetes, all of which have high tolerance values. The maylies and caddisflies identified were all moderately to very tolerant organisms.

Community Loss

We compared our stations with what might be expected for a high quality stream. Each station had community loss. A pristine wooded reference without development or habitat alteration would be expected to have over 20 families. Our best site was Station 6 with 27 families. However, of the 27 families, only 1 (Perlidae stoneflies) was considered pollution sensitive.

Ratio of Scrapers to Filterers

The scraper functional group was present at nearly all stations. The majority of the scrapers were snails and few water pennies (Psephenidae, beetle larvae).

Clams

Asiatic clams and fingernail clams were abundant in Mud Creek. The sandy substrate and ample food provide an ideal habitat for these species. We have found Asiatic clams in similar sandy habitats in other streams. We also found an extant population of living unionid mussels (fat mucket, *Lampsilis radiata*) at Station 8. A few pieces of relict shells were found elsewhere suggesting that at one time freshwater mussels lived in this stream.

Autecology of Dominant Families

Some instruction regarding water quality in Mud Creek is provided by study of the autecology of the dominant taxa at the various sites.

Chironomid midge larvae were dominant at most stations during the base flow period and had the highest total number during fall flow. Midge larvae are known to thrive in dense algal mats where they remove dead and decaying material. In addition, they often become very abundant in areas receiving sewage, and thus are good indicators of degraded water quality. Mud creek had an exuberant growth of algae at Station 7 where bacterial levels were very high as well. Other stations had a combination of curly leaf pondweed, algae, and other aquatic plants. The major emergent vegetation also supplying habitat for midge larvae was water willow. During the fall flow, the algae and weed population was diminished. Riffle beetles and hydropsychid caddisflies replaced the chironomids at some stations.

The caddisflies known as common netspinners, Hydropsychidae, were common in nearly all areas in both the base and fall flow sampling periods. These larvae are, during some part of their life cycle, collectors of suspended food. They are among the most abundant caddisflies in the Midwest, are considered to be one of the most tolerant species, and are resistant to sediment pollution. We have found large numbers of this family in many streams in Indiana and Kentucky. Riffle beetles are very common in many of our samples and are often the dominant organism in streams that have a moderate amount of pollution.

Siphlonuridae or primitive minnow mayflies were the most common type of mayfly observed in base flow while baetid mayflies were common during fall flow. These are highly tolerant organisms that are known to occur in the types of habitats we encountered.

Riffle beetles and blackfly larvae were also common organisms. Riffle beetles are small coleopterans that feed on algae and moss. They are common in rapid waters and indicate ample oxygen. Blackfly larvae hook onto moss or algae and filter materials from the water.

Comparison to Other Streams

We have comparative data from other streams in Indiana, Kentucky and a pristine stream located in the Mitchell River drainage in North Carolina. Our most recent bioassessment effort was in White Creek in Jackson County, Indiana. This stream, located in glacial till, is highly channelized and has very little structure. Our very best station in White Creek had 24 families of tolerant organisms found in the only good riffle system on the stream. In this stream, EPT taxa were also greatly reduced.

We have also studied Blue River of southern Indiana considered to be one of the premier streams in this state. In one comparative station in Blue River, conditions were similar to a pristine stream. The stream has abundant structure, excellent bankside vegetation, and an array of habitats. The stream had a high number of EPT taxa, and the invertebrate community was comparable to a pristine stream located in North Carolina.

In addition to the Blue River, we evaluated the invertebrates in Laurel Fork, an outstanding resource water, in Kentucky. Laurel Fork had over 20 families of invertebrates including 10 families of EPT taxa. Some of these EPT families had multiple species; so at the species level index this stream rates very high.

DISCUSSION AND SYNTHESIS

The Mud Creek watershed consists of highly channelized surface streams and ditches supported by a subsurface system of drainage tiles. The water quality data we collected suggest that storm flows quickly produce a turbid stream with elevated nutrients and bacteria. Organic contamination and bacterial action create a biochemical oxygen demand that reduces the level of dissolved oxygen. This could be a problem if storms occur in warm weather when oxygen levels are lower and bacteria can reproduce rapidly. Because of the ditching and straight channels without vegetative cover, the stream already has some of the characteristics of those found in urban environments.

According to the US EPA, polluted storm water runoff is the leading cause of impairment in 40% of our nation's streams that do not meet water quality standards. Thus, it is clear that continued vigilance and introduction of best management practices (BMPs) are required as the watershed becomes urbanized (15).

The Mud Creek watershed lies in an area of rapid conversion from a predominantly agricultural to an urban environment. Fortunately, the new residential developments have some best management practices in place. Many were observed to have connections to existing sewage systems, are often clustered, and have retention ponds for controlling storm runoff. There is also evidence of green space and trails along the stream in the 100-yr flood plain. Where feasible, older houses in the drainage with septic systems should be connected to the sewage system.
It is clear from our reading that various stakeholders are concerned about the swift urbanization and are interested in maintaining the perceived rural and undeveloped character of the Mud Creek drainage system. For example, the Mud Creek Greenway overview suggests that property owners along the stream take care to preserve it. The Sargent Road Association is an organization formed to preserve the natural beauty of Mud Creek Valley and its surroundings in Marion County. The Mud Creek Conservancy is another stakeholder that

currently holds two conservation easements protecting 10 watershed acres in Marion County (16).

Considerable information is available on cohort streams that are found in urban areas. We only have to look at the hydrology, water chemistry and biota of some streams in Marion County to develop and understanding of what conceivably could happen in Hamilton County. The results are not very encouraging. For example, Crooked Creek, a small stream located in Indianapolis, has a very exaggerated discharge pattern related to storm water input from impervious surfaces. These flows spike very quickly and fall rapidly. In dry times, streams like this either dry up or have flows that are effluent dominated. The biota of streams in Indianapolis has been examined as well. In May 1994, Fall Creek at 16th Street in Indianapolis had only 8 taxa of pollution tolerant organisms. Water quality information indicates lower dissolved oxygen and elevated nutrients in these streams.

Bank erosion in Crooked Creek drainage, Indianapolis.

Sediment deposition in Crooked Creek above Grandview, Indianapolis.

As noted above, elements of Best Management Practices (BMPs) are already in place. In the urban area, we observed retention ponds and green space along the stream. As more impervious surfaces are added, some attention should be paid to managing this water as well. Storm water retention will attenuate the flow spikes mentioned above. Grass buffers were noted in agricultural areas. These are excellent ways to prevent drainage from entering the waterways. In addition to these, an effort should be made to re-establish the riparian tree buffer along the stream. Stream invertebrates in streams like these rely on leaves as a source of energy.

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CURRICULUM VITAE

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EDUCATION

Ph.D. in Biology; University of Louisville.
Full Scholarships From National Science Foundation and National Defense Education Act.
M.S. in Zoology; University of Arkansas.
Awarded Research Assistantship From USDI, Bureau of Sport Fisheries.
B.S. in Zoology. University of Arkansas.
National Science Foundation Undergraduate Research Program Recipient.
Sabbatical—Florida Atlantic University--1985. Assisted Dr. Walt Courtenay in Comparative Anatomy Lab (unpaid assistant) and took Marine Biology from Dr. Sheldon Dobkin. Developed IU Southeast's Marine and Field Biology program with emphasis on tropical biology.
Sabbatical—Palm Beach, FL. Spring, 1992. Research on wading birds and field biology course development.
Sabbatical—Florida Atlantic University--1997-1998. Taught General Biology, A&P I Laboratory (Fall); General Biology Laboratories and A&P II Laboratories (Spring). Developed Oceanography Class for IU Southeast for Fall, 1998. Contact: GMayer@FAU.EDU (Lab Coordinator)

EXPERIENCE

Professor of Biology, Indiana University Southeast, 1976-Present
Coordinator of Biology, 1996-1997
Preprofessional Coordinator, 1995-1998
All-University President's Award for Distinguished Teaching, 1990
Grawemeyer Award for Innovative Instruction, 1990
Special Merit Award for Best Proposal, 1990
Who's Who in the Midwest, North America, Science and Industry and World 1992 - current editions
Who's Who Environmental Registry, 1992 - 1993 edition
Who's Who in American Education, 1993-current edition
Distinguished Teaching Award, 1989.
Distinguished Research/Creativity Award, 1989.
Grawemeyer Award for Innovative Instruction, 1987.
About 15 innovations used in various courses.
Courses taught--23 courses at undergraduate level.

Ecology courses taught—Marine Biology, Field Biology, Ecology, Advanced Field Biology, Fish Biology, Limnology, Environment and People, Environmental Biology

Allied Health Sciences classes taught--Medical Terminology, Histology, Anatomy, Human Biology, Anatomy and Physiology I and II, Developmental Biology, Microbiology Laboratory

Lower level classes taught--Humans and the Biological World, General Biology, Environment and People, Oceanography, General Zoology, Natural History, Botany

Evaluations mostly good or excellent.

Outstanding, innovative courses in Field Biology and Marine Biology.

Professor for Extended Studies Program in Saudi Arabia.

Extracurricular Teaching—Over 20 statewide workshops as:

Selected Speaker—Indiana Science Education Fund.
About 25 visiting scientist presentations.
Research--20+ research projects; 25+ publications; 2 book articles; 20 reports.
Many literature citations and reprint requests.

Editorial Work—Eleven reviews for journals, schools and programs.

Continuing Study Classes—Desktop Publishing, SCUBA Diving,

Aquatic Biology (High School), Project Ahead,

Summer Enrichment (Grammar School) & Scientific Writing (Teachers).

Faculty Colloquium—Devil-jack diamond fish and other creatures: An ecological history of the Ohio River Valley, 1985.

Abstracts—About 300 abstracts for Oceanic and Pollution Abstracts.

Student Success—Some 85% of graduates have been admitted to professional school.

Twenty + students have entered graduate school in my fields of study or have

attained employment in environmentally-related positions.

Service—Significant involvement with lectures, science fairs, and service to the university.
Chair—Research and Grants Committee.
Chair—Improvement of Learning Committee
Chair—Technology Task Force
Chair—Improvement of Writing Committee

Biology, Allegheny Community College; Pittsburgh, PA.

Taught in maximum security prison.
Instructed in federally-funded manpower program for
training poverty level students to be medical transcriptionists.

Environmental Biologist, D'Appolonia Engineers; Pittsburgh, PA.
Extensive experience with grant applications, project management and final reports.
Environmental considerations for proposed tourist complex in Venezuela.
Environmental considerations chapter for engineering
and design manual for coal refuse facilities.
Water quality and fishery programs for recreational lakes.
Wetlands alteration studies.
Research Assistant (Post Doctoral), University of Illinois.
Organized water chemistry laboratory.
Evaluated water quality of ponds and lakes.

Memberships and Service

Florida Academy of Science, Florida Audubon Society, Environmental Adviser for Save Our Rivers (Indiana), Board Member of Protect Our River Environment (Indiana), Board Member of Protect Our Woods (Indiana)

Hobbies

Macintosh Computers, Snorkeling and SCUBA Diving, Beachcombing, Wildflower Identification, Natural History, Writing, Genealogy

Publications, Reports and Scholarly Work in Progress

Recent Work
2003. Biomonitoring, Water Quality and Habitat Assessment for the Mud Creek Watershed, Hamilton County, IN. Mud Creek Watershed Master Plan.

2003. Biomonitoring, Water Quality and Habitat Assessment for the Stony Creek Watershed. Hamilton County, IN. Stony Creek Watershed Master Plan.

2002 and 2003. West Nile Virus Study: Light and gravid trap monitoring of mosquitoes in Clark and Floyd Counties, Indiana University Fall 2002. 60+ students and 3 interns working on this project

2003. Biomonitoring and Bioassessment for the White Creek Watershed Diagnostic Study (Jackson County, IN) Fall 2002. August Nelson, Tommy Raichel and Sandra Brown, Student Interns

The Status of Darter Populations and a Rapid Bioassessment Analysis of the Blue River, Southern Indiana, Fall 2000 and Fall 2001

Darter Population Estimates in the Blue River of Southern Indiana Following an Extensive Drought Event WEBSITE: http://homepages.ius.edu/special/darters Chris Caffrey, Webmaster Indiana University Southeast; Biology Department, 4201 Grantline Road, New Albany, IN 47150 By: The 1999 Ecology Class. Chris Caffrey and Douglas Bentfield, Student Interns Dr. C.D. Baker, Professor and Advisor Dr. Bill J. Forsyth, Professor and Advisor. Caffrey and Bentfield were Summer Interns.

Baker, Claude, Chris Caffrey Sarah Isom and Terry Huff, Student Interns. Biomonitoring and Habitat Assessment for the Indian Creek Subwatershed Diagnostic Study Completed as a Student Internship Study by: Indiana University Southeast Department of Biology 4201 Grantline Road New Albany, IN 47150 February, 1999. Submitted to Donan Engineering and Indiana Department of Natural Resources.

Water Quality Studies

Monies obtained from these projects were donated to IUS.

Baker, Claude D. 1997. Macroinvertebrate Investigation of Laurel Fork of the Rockcastle River: Cumberland River Drainage, Jackson County, Kentucky, USA. Summer Collections, 1996 Tyner 7.5 min. USGS Quadrangle For:T&T Coal Company Application No. 11828-04 P.O. Box 643 Manchester, KY 40962 By:Claude D. Baker, Ph.D.Spring, 1997. Report for Division of Surface Mining.

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Biological Assessment for Water Quality Certification Trace Branch of Cloverlick Creek Unnamed "Bee" Branch of Cloverlick Creek and Sally Huff Branch of Cloverlick Creek For Arch of Kentucky, Inc. by: Dan Weber, M.S. and Claude D. Baker, Ph.D. Associates of Robert Ray and Associates June, 1993

Biological Assessment for Water Quality Certification Lick Branch of Balls Fork of Troublesome Creek Kentucky River Drainage Perry and Knott Counties, KY For Starfire Mining Company, Inc. Permit #460-0080 Amendment #2 by: Dan Weber, M.S. and Claude D. Baker, Ph.D. Associates of Robert Ray and Associates January, 1994

Biological Assessment for Water Quality Certification Spivey Branch of Sexton Creek;Tributaries of the South Fork of the Kentucky River Owsley County and

Clay County, KY For Sturgeon Coal Company D.S.M.R.E. Permit Number #895-0121 by: Dan Weber, M.S. and Claude D. Baker, Ph.D. Associates of Robert Ray and Associates January, 1994

Biological Assessment for Water Quality Certification. Elklick Branch of Youngs Fork of Lotts Creek North Fork of the Kentucky River Drainage Knott County, KY and Right Fork of Big Branch of Troublesome Creek North Fork of the Kentucky River Drainage Knott County, KY For: Locust Grove, Inc. Permit # 860-0348 by: Dan Weber, M.S. and Claude D. Baker, Ph.D. Associates of Robert Ray and Associates March, 1994

Ecological Investigation of the Aquatic Resources of Deadening Branch of Defeated Creek and Evaluation of Habitat Which May Support Maternity Colonies of the Indiana Bat, *Myotis sodalis.* Line Fork Drainage of Kentucky River. Letcher County, KY, USA. Kentucky Processing Coal Company Application No. 867-5181. by: Dan Weber, James Kiser and Claude D. Baker, Associates of Robert Ray and Associates, Lexington, Kentucky April 20, 1995

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Herpetological Studies

The Herptofauna of Charles Spring: Washington County, Indiana. 1996. Report of Capstone Experience in Ecology and Internship Contract from the Nature Conservancy of Indiana. Terry Huff and Matthew Kingsley, Summer Interns; Claude D. Baker, Bill J. Forsyth and Teresa R. Forsyth, Ph.D.s and advisors.

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The Herptofauna of Brock-Sampson Nature Preserve: Floyd County, Indiana. 1996. Report of Capstone Experience in Ecology and Internship Contract from the Nature Conservancy of Indiana. Terry Huff and Matthew Kingsley, Summer Interns; Claude D. Baker, Bill J. Forsyth and Teresa R. Forsyth, Ph.D.s and advisors.11

RECENT GRANTS

GRANTS APPLIED FOR:

Biomonitoring and Habitat Assessment for the Stony Creek Watershed Master Plan, 2003
Biomonitoring and Habitat Assessment for the Mud Creek Watershed Master Plan, 2003
White Creek Bioassessment in Jackson County, IN 2001
Cool Creek Bioassessment in Hamilton County, IN 2001 (Not Funded)
Mud Pine Creek Watershed Diagnostic Study, IN 2000 (Not Funded)
Darter Population Estimates in Blue River in southern Indiana, 2000
Biomonitoring and Habitat Assessment for the Indian Creek Subwatershed Diagnostic Study. 1999

1997-1998 Sabbatical Year
Herptofauna Projects for Nature Conservancy, 1996

GRANTS RECEIVED:

Mosquito Monitoring Program Harrison County, Indiana, Paid directly to student
Biomonitoring and Habitat Assessment for the Stony Creek Watershed Master Plan, 2002 $7400-
Biomonitoring and Habitat Assessment for the Mud Creek Watershed Master Plan, 2003. $7400-
White Creek Bioassessment in Jackson County, IN 2002 $7400-

Darter Population Estimates in the Blue River of southern Indiana following an Extensive Drought Event, 2000. Funded by IUS Summer Intern Program $1000-
Biomonitoring and Habitat Assessment for the Indian Creek Subwatershed Diagnostic Study. Student Internship Project. 1998. Abt $7000-
Herptofauna Projects for Nature Conservancy: Mosquito Creek Woods, Martin's Glade, Three-Way Sedge Sinkhole Swamp, Brock-Sampson Nature Preserve, Charles Spring, Teeple Glade. 1996 $5000- Summer Intern Project
Funded Equipment Enhancement Proposal, 1987. About $1,000,000- in enhancement monies to Biology Department

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1. Carpenter, S.R., C.D. Baker and B.J. Forsyth. Nesting silver lampreys in the Little Blue River. Proceedings of the Indiana Academy of Science 97: 525-526; 1988. Student research project.

2. Baker, Claude D. Friends with fins: Using fish as an educational tool. Proceedings of the Indiana Academy of Science 96: 459; 1987.

3. Baker, Claude D. A pigmented northern blindfish, *Amblyopsis spelaea*, and notes on pigmentation in amblyopsid cavefishes. Proceedings of the Indiana Academy of Sciences 96: 503; 1987.

4. Christenson, Carl, Jacqueline Christenson and Claude D. Baker. Experiential training: Evaluation and grading of extended field trip courses. Proceedings of the Indiana Academy of Science 96: 459; 1987.

5. Ehringer, W.D., C.D. Baker and B.J. Forsyth. Evaluation of endangered fragile heelsplitter mussels, Potamilus ohiensis, using species/time visual census methods: Blue River, southern Indiana, Ohio River drainage, USA. Proceedings of the Indiana Academy of Science 103rd: 93; 1987. Student research project

6. Griffis, T.E., C.D. Baker and B.J. Forsyth. Population estimates of spotted darters, *Etheostoma maculatum*, in the lower Blue River, a southern Indiana tributary of the of the Ohio River. Proceedings of the Indiana Academy of Science 103rd: 92; 1987. Student research project.

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8. Baker, Claude D. A compendium of information on fishes. Indiana Academy of Science; 1986.

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14. Ainsworth, L. L., and Claude D. Baker. Effects of illumination changes on infant monkey contacts with surrogates. The Psychological Record. 32: 513-518; 1982. National Journal

15. Baker, B.M., C.D. Baker and H. T. Le. Vocal quality, articulation and audiological characteristics of children and young adults with diagnosed allergies. Annals of Otology, Rhinology & Laryngology 91: 277-280; 1982. National Journal

16. Baker, B.M., S. M. Fox, C.D. Baker and G.T. McMurry. Persistent hoarseness after surgical removal of vocal cord lesions. Archives of Otolaryngology 107: 148-151; 1981. National Journal

17. Baker, B.M. and C.D. Baker. Difficulties generated by allergies. Journal of School Health December: 583-585; 1980. National Journal

18. Baker, B.M. and C.D. Baker. Effect of language intervention techniques upon the sentence production of deaf adults. Kentucky Journal of Speech-Language Pathology and Audiology 4: 11-19; 1980. National Journal

19. Baker, B.M. and C.D. Baker. Effect of language intervention techniques upon the sentence production of deaf adults. Kentucky Journal of Speech-Language Pathology and Audiology 4: 11-19; 1980.

20. Baker, Claude D. Ecological section of Task II assignment. H.T. Spencer, ed. The Ohio River Basin Energy Study. Environmental Protection Agency ; 1977.

Scholarly Effort before Coming to Indiana University

1. Baker, C. D., et al. 1975. Engineering and Design Manual, Coal Refuse Facilities Chap VII. U. S. Department of Interior, Mining Enforcement and Safety Administration: 7.1-7.151. Chapter in Book

2. Baker, C.D. et al. Environmental survey, effects of the proposed mall on North Park, Allegheny County, Pennsylvania. Department of Parks, Recreation and Conservation. E. D'Appolonia Engineers; 1974. Report

3. Baker, C.D. et al. Investigation of the presence of carbon dioxide as it relates to tunnel operations. Metropolitan Sewerage Commission of the County of Milwaukee. E. D'Appolonia Engineers; 1974. Report

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5. Baker, C.D. et al. Environmental report for proposed casting yard facility. Corps of Engineers. E. D'Appolonia Engineers; 1974.

6. Baker, C.D. et al. Site selection and investigation for offshore nuclear power plant at Jacksonville, Florida. Dravo Corporation. E. D'Appolonia Engineers; 1974.

7. Baker, C.D. et al. Comprehensive report on water quality monitoring data; Lake Wildwood; Varna, IL: 15 pages. E. D'Appolonia Engineers; 1974.

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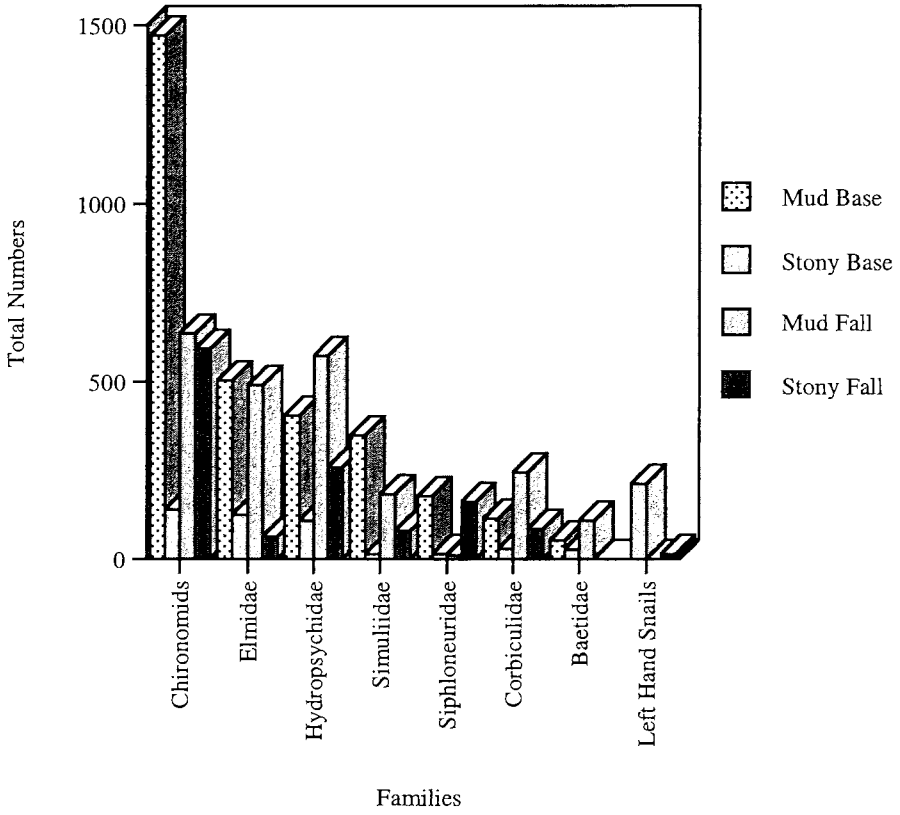
Total Numbers of Common Macroinvertebrate Families in Stony Creeek and Mud Creek during Base Flow and Fall Flow Sampling Periods, 2003



Appendix I. Aquatic Macroinvertebrate Families Taken from Mud Creek in June 2003									
Organism	Station 1	Station2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Total
Name	Three 10-foot kick net samples or 20 jabs at each station								
Phylum Platyhelmintes		1				1			2
Phylum Mollusca	Clams and Snails								
Class Gastropoda	Snails								
Fam. Lymnaeidae						2		1	3
Family Physidae						7			7
Sinistral LH		2		4	1	5		15	27
Fam. Planorbidae								10	10
Fam. Pleurocercidae	2	11			4	17		78	112
Fam. Ancylidae				12		1			13
Class Pelycypoda									
Fam. Corbiculidae	9	26	27	16	8	10		18	114
Fam. Sphaeriidae	5	1			2	10		19	31
Phylum Annelida	2				2	1	1		4
Class Hirudinea						4	1		5
Phylum Arthropoda	Crustaceans and Insects								
Class Arachnida						1		1	2
Order Isopoda	Isopods or Sowbugs								
Fam. Aseliidae				1					1
Order Amphipoda	Scuds or Sideswimmers								
Fam. Talitridae						1			1
Class Crustacea	Crustaceans								
Order Decapoda	Crayfish								
Family Astacidae	2	2		3		5		4	16

Classr Insecta	Insects								
Order Ephemeroptera	Mayflies								
Fam. Baetidae			16	3		6		28	53
Fam. Heptageniidae					1				1
Fam. Caenidae	1			6		18			25
Fam. Siphlonuridae	5	2	23	14	24	90		19	177
Fam. Leptoceridae			1						1
Order Odonata	Dragonflies and Damselflies								
Fam. Calopterygidae	1		1			1		1	4
Order Plecoptera	Stoneflies								
Fam. Perlidae					8	1			9
Order Tricoptera									
Fam. Hydropsychidae	42	1	81	2	85	100		93	404
Fam. Helicopsychidae			2			2			4
Fam. Brachycentridae	1							1	2
Fam. Hydroptilidae			6	2	3				11
Order Coleoptera	3								3
Fam. Hydrophilidae								1	1
Fam. Elmidae.	5	1	74	33	27	116		85	341
Adult	8		47	14	2	71		20	162

Fam. Psephenidae				2	2	7		6	17
Fam. Dryopidae	8	1	10			7		19	45
Fam. Haliplidae			10	3		6		1	20
Order Diptera		1							1
Fam Tipulidae.	1	1	6	10	2	6	1		27
Fam. Simuliidae	3		187	37	6	103		12	348
Fam. Chironomidae	27	43	135	152	380	547	75	112	1471
Fam. Tabanidae									
Fam. Empididae			1						1
Fam. Ceratopogonidae				1		4			5
Fam. Pryalidae			1						1
Fish eggs			3	1		27		9	40

Notes:

Numbers may not match with macroinvertebrate metrics. Some items discovered like fish eggs were not included in analysis

Appendix II. Aquatic Macroinvertebrate Families Taken from Mud Creek in October 2003

Organism	Station 1	Station2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Total
Name	Three 10-foot samples or 20 jabs were taken at each station.								
Phylum Platyhelminthes			28	2				2	32
Phylum Mollusca	Clams and Snails								
Class Gastropoda	Snails								
Fam. Lymnaeidae						1			1
Family Physidae									
Sinistral LH					1				1
Fam. Planorbidae									
Fam. Pleurocercidae								2	2
Fam. Ancylidae			9	3					12
Class Pelycypoda								4	4
Fam. Corbiculidae	2	17	78	61	5	38	6	37	244
Phylum Annelida	1								1
Class Hirudinea				2			2		4
Class Oligochaeta	1	11	1	10			12	2	37
Phylum Arthropoda	Insects and Crustaceans								
Order Isopoda	Sowbugs								
Fam. Aseliidae							1		1
Order Decapoda	Crayfish								
Family Astacidae								3	3
Classr Insecta	Insects								
Order Ephemeroptera	Mayflies								
Fam. Baetidae		3	2	25	40	38			108

Fam. Heptageniidae	5		5	25	2	11		16	64
Fam. Caenidae	2		2	3	2	2		18	29
Fam. Siphlonuridae			8			2		1	11
Fam. Isonychiidae						1			1
Order Odonata	Dragonflies and Damselflies								
Fam. Calopterygidae								5	5
Fam. Coenagrionidae								3	3
Order Hemiptera								1	1
Order Plecoptera	Stoneflies								
Fam. Perlidae					1				1
Order Tricoptera	Caddisflies								
Fam. Hydropsychidae	139	5	245	37	89	53	2	4	574
Fam. Helicopsychidae			1			17			18
Fam. Hydroptilidae								1	1
Fam. Leptoceridae			1						1
Order Coleoptera	Beetles								
Fam. Hydrophilidae						1		2	3
Fam. Elmidae.	2		60						62
Adult	2		122	82	16	130	6	70	428

Fam. Psephenidae				1				6	7
Fam. Dryopidae			1						1
Fam. Haliplidae	1			11		7	2	17	38
Order Diptera	Flies								
Fam Tipulidae.	4	61	14			7			86
Fam. Simuliidae	134	3	2		28	12		4	183
Fam. Chironomidae	302	61	14	55	68	68	54	15	637
Fam. Empididae					2	2		1	5

Notes:
Dead shells are not included in the above total
We observed several large crayfish in the stream

PHOTOGRAPHIC SUPPLEMENT
MUD CREEK

1. UPSTREAM STATION 8, ATLANTIC RD, FALL FLOW
2. UPSTREAM STATION 8, ATLANTIC RD, FALL FLOW
3. UPSTREAM STATION 8, ATLANTIC RD, FALL FLOW
4. UPSTREAM STATION 8, FALL FLOW KICK NET SAMPLING, FALL FLOW
5. STATION 8, LOOKING SOUTH, FALL FLOW
6. STATION 8, DOWNSTREAM FROM BRIDGE, DEBRIS, FALL FLOW
7. STATION 8, DOWNSTREAM, BASE FLOW
8. STATION 8, LOOKING NORTH, BASE FLOW
9. STATION 8, LOOKING AT LAWN, BASE FLOW
10. STATION 8, LOOKING AT HIGH WATER DEBRIS, FALL FLOW
11. STATION 8, DEBRIS IN TREE, FALL FLOW
12. STATION 8, DEBRIS IN BUSHES, FALL FLOW
13. STATION 8, DEBRIS IN TREE NEAR BRIDGE, FALL FLOW
14. STATION 8, DOWNSTREAM, FALL FLOW
15. STATION 8, DEBRIS DOWNSTREAM FROM BRIDGE, FALL FLOW
16. STATION 7, UPSTREAM FROM DOUBLE CULVERT, FALL FLOW
17. STATION 7, UPSTREAM FROM DOUBLE CULVERT, FALL FLOW
18. STATION 7, SAMPLING UPSTREAM FROM DOUBLE CULVERT, FALL
19. STATION 7, SAMPLING UPSTREAM FROM DOUBLE CULVERT, FALL
20. STATION 7, SAMPLING AREA IN SHALLOW WATER WITH ARTIFICIAL PLACEMENT OF ROCK, FALL
21. STATION 7, SAMPLING, FALL FLOW
22. STATION 7, JABBING ABOVE DOUBLE CULV ERTS, BASE FLOW
23. STATION 7, WALKING TO DOWNSTREAM EXIT OF DOUBLE CULVERTS, BASE FLOW
24. STATION 7, HABITAT IN TREE LINED AREA, FALL FLOW
25. STATION 7, SAMPLING, FALL FLOW
26. STATION 7, HABITAT, FALL FLOW
27. STATION 7, UPSTREAM HABITAT, FALL FLOW
28. STATION 6, UPSTREAM FACING NORTH, FALL FLOW
29. STATION 6, FACING UPSTREAM DEVELOPMENT ON RIGHT, FALL
30. STATION 6, DEVELOPMENT DOWNSTREAM, FALL
31. STATION 6, UPSTREAM, FALL
32. STATION 6, UPSTREAM, FALL
33. STATION 6, UPSTREAM, FALL
34. STATION 6, UPSTREAM, FALL
35. STATION 6, DOWNSTREAM UNDER BRIDGE, FALL
36. STATION 6, UPSTREAM, FALL
37. STATION 6, UPSTREAM, FALL
38. STATION 5, LOOKING UPSTREAM TOWARD BRIDGE FROM PARKING LOT
39. STATION 6, LOOKING DOWN AT CREEK FROM S SIDE, FALL

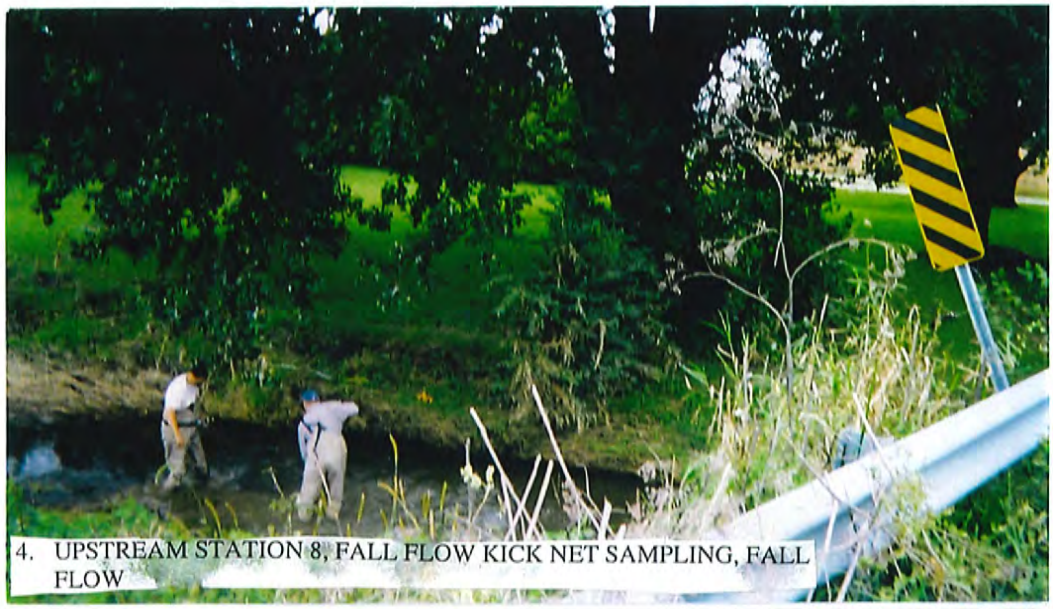
40. STATION 6, LOOK AT CREEK FROM S SIDE, FALL
41. STATION 6, LOOKING UPSTREAM TOWARD SAMPLING SITE, FALL
42. STATION 6, SAMPLING AREA WITH ARTIFICIAL DAM, FALL
43. STATION 6, END OF PIPE ON N SIDE, FALL
44. STATION 6 DOWNSTREAM FROM ARTIFICIAL RIFFLE, FALL
45. STATION 6 DOWN FROM PIPE SHOWING EROSION
46. STATION 6 DOWNSTREAM SHOWING BANK EROSION
47. STATION 6 DOWNSTREAM, FALL
48. STATION 6 DOWNSTREAM SHOWING LARGE WOODY DEBRIS, FALL
49. STATION 6 DOWNSTREAM, FALL
50. STATION 6, SAMPLING AREA, BASE FLOW
51. STATION 6, END OF PIPE, BASE FLOW
52. STATION 6, END OF PIPE BASE FLOW
53. STATIONS 3&4 GOLF CART PATH TO STATIONS FACING EAST, BASE FLOW
54. STATIONS 3&4 GOLF CART PATH TO STATIONS FACING WEST, BASE FLOW
55. STATION 3 DOWNSTREAM TOWARD BRIDGE, BASE FLOW
56. STATION 3 UPSTREAM BASE FLOW
57. STATION 3 UPSTREAM BASE FLOW
58. STATION 3, UPSTREAM TOWARD GOLF CART BRIDGE, BASE FLOW
59. STATION 3, UPSTREAM TOWARD GOLD CART BRIDGE, FALL FLOW
60. STATION 3, DOWNSTREAM TOWARD BRIDGE, FALL FLOW
61. STATION 4, UPSTREAM TOWARD NATURAL DAM
62. STATION 4, UPSTREAM TOWARD NATURAL DAM. GOLF CART PATH OVERHEAD
63. STATION 4, UPSTREAM
64. STATION 4, DOWNSTREAM TOWARD BRIDGE
65. STATION 4, DOWNSTREAM TOWARD BRIDGE
66. STATION 4, DOWNSTREAM TOWARD BRIDGE
67. STATION 4, BANK EROSION, FALL
68. STATION 4, DOWNSTREAM TOWARD BRIDGE, FALL
69. STATION 4, DOWNSTREAM TOWARD BRIDGE
70. STATION 3, UPSTREAM
71. STATION 3 DOWNSTREAM FROM CART PATH SHOWING OXYGENATION FROM ARTIFICIAL RIFFLE
72. STATION 3, DOWNSTREAM LEFT BANK
73. STATION 3, DOWNSTREAM, BASE FLOW
74. STATION 4 FACING WEST FROM CART PATH, BASE FLOW
75. STATION 4 FACING UPSTREAM, BASE FLOW
76. STATION 3??
77. STATION 4, DOWNSTREAM, BASE FLOW
78. STATION 4, BASEFLOW
79. STATION 2, DOWNSTREAM IN SAMPLING AREA, FALL FLOW
80. STATION 2, DOWNSTREAM, FALL FLOW
81. STATION 2, BANK EROSION, FALL FLOW

82. STATION 2, SAND AND MUCK DEPOSIT, FALL FLOW
83. STATION 2, PARK, BASE FLOW
84. STATION 2, PARK BASE FLOW
85. STATION 2 PARK, BASE FLOW
86. STATION 2, UPSTREAM BASE FLOW
87. STATION 2, DOWNSTREAM BASE FLOW
88. STATION 2, END OF PIPE, BASE FLOW
89. STATION 2, SUBSTRATE BASE FLOW
90. STATION 2 DOWNSTREAM BASE FLOW
91. STATION 2 MULTIFLORA ROSE BASE FLOW
92. STATION 2 UPSTREAM BASE FLOW
93. STATION 2 PARK BASE FLOW
94. STATION 2 PARK BASE FLOW
95. STATION 1 BANK EROSION FALL FLOW
96. STATION 1 MEASURING DISCHARGE FALL FLOW
97. STATION 1 DEBRIS FIELD BASE FLOW
98. STATION 1 RECORDING VELOCITY FALL FLOW
99. STATION 1 UNDER BRIDGE FALL FLOW
100. STATION 1 DOWNSTREAM FALL FLOW
101. STATION 1 DOWNSTREAM FALL FLOW
102. STATION 1 DOWNSTREAM FALL FLOW BANK EROSION
103. STATION 1 UPSTREAM BASE FLOW
104. STATION 1 DOWNSTREAM SAMPLING STATION BASE FLOW
105. STATION 1 UPSTREAM TOWARD BRIDGE BASE FLOW
106. STATION 1 DRAIN ON LEFT HAND SIDE FACING UPSTREAM
107. STATION 1 SAMPLING FROM BRIDGE BASE FLOW
108. STATION 6 FACING S CONSTRUCTION BASE FLOW
109. STATION 6 FIELD ON RIGHT UPSTREAM BASE FLOW
110. STATION 6 SAMPLING UPSTREAM BASE FLOW
111. STATION 6 FACING SOUTH CONSTRUCTION BASE FLOW
112. STATION 6 FIELD ON DOWNSTREAM SIDE FACING NORTH BASE FLOW
113. STATION 6 DOWNSTREAM CURLY LEAF POND WEED
114. STATION 6 DOWNSTREAM CURLY LEAF POND WEED
115. STATION 6 DOWNSTREAM
116. STATION 6 FACING NORTH NOTE CONSTRUCTION ON LEFT

1. UPSTREAM STATION 8, ATLANTIC RD, FALL FLOW

2. UPSTREAM STATION 8, ATLANTIC RD, FALL FLOW

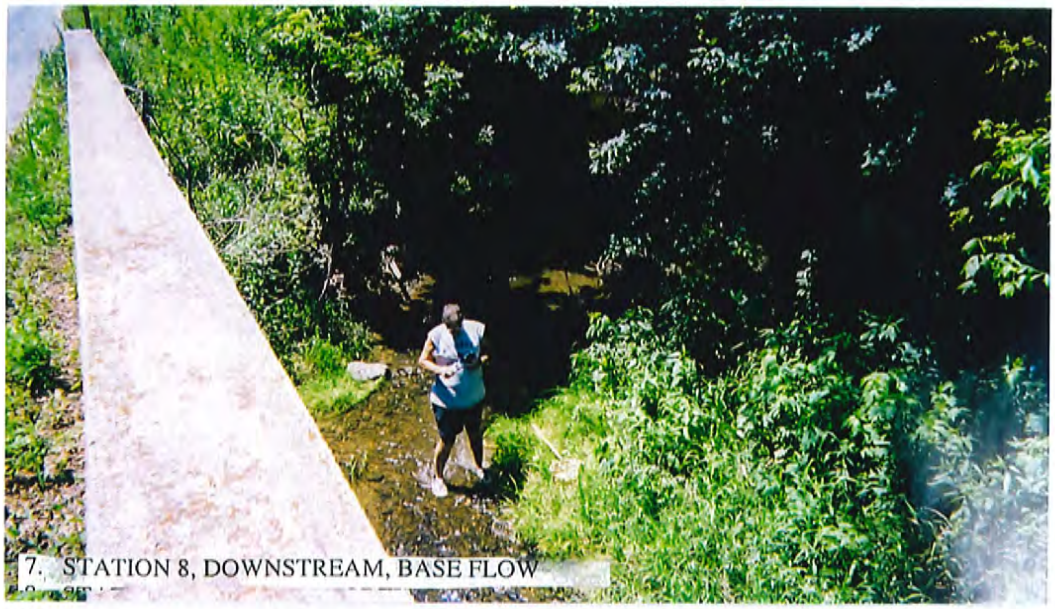
3. UPSTREAM STATION 8, ATLANTIC RD, FALL FLOW



4. UPSTREAM STATION 8, FALL FLOW KICK NET SAMPLING, FALL FLOW

5. STATION 8, LOOKING SOUTH, FALL FLOW

6. STATION 8, DOWNSTREAM FROM BRIDGE, DEBRIS, FALL FLOW



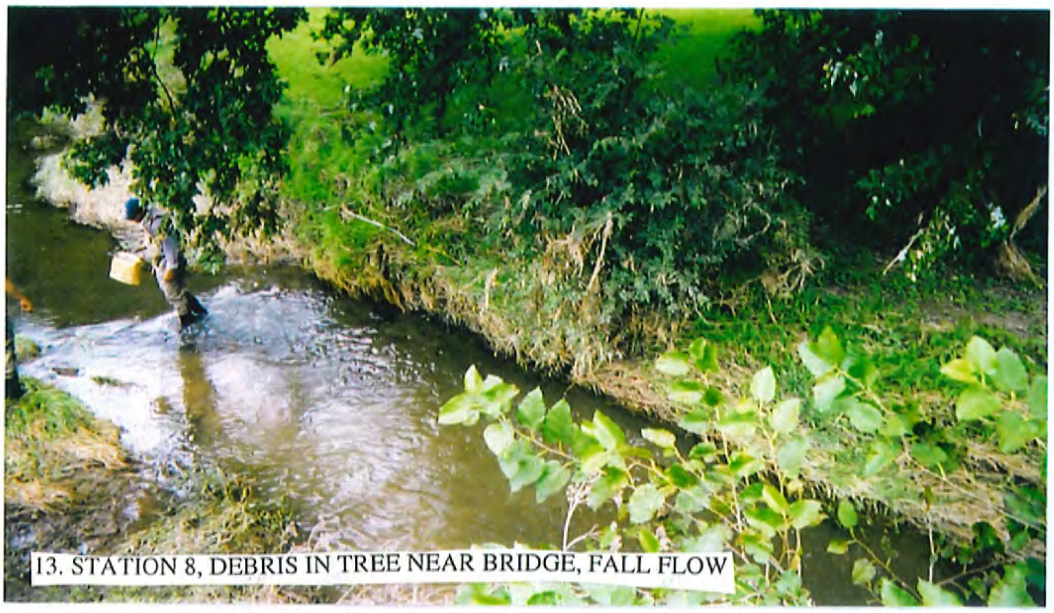
7. STATION 8, DOWNSTREAM, BASE FLOW

8. STATION 8, LOOKING NORTH, BASE FLOW

9. STATION 8, LOOKING AT LAWN, BASE FLOW

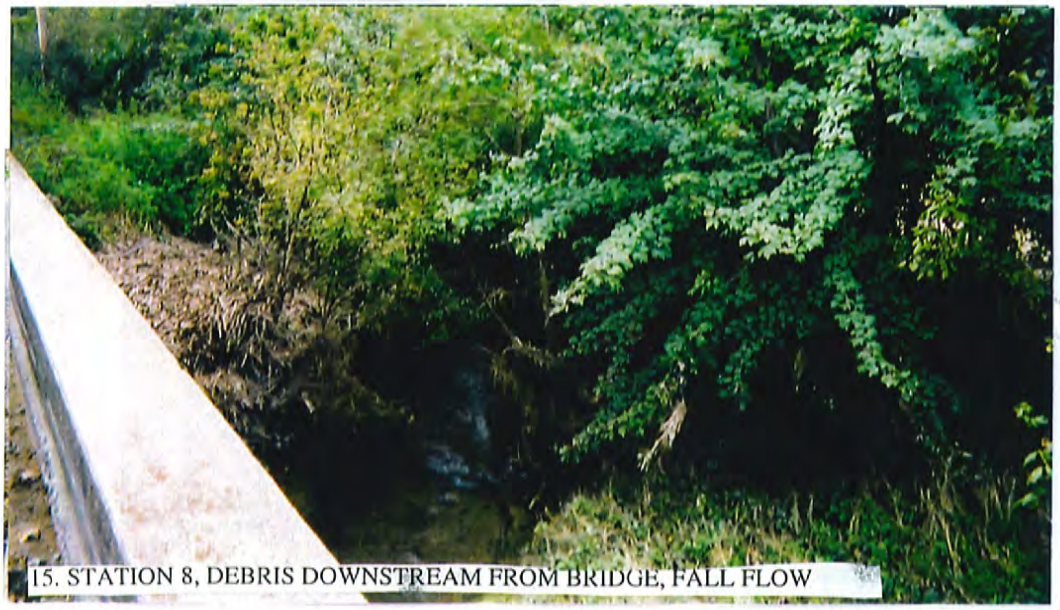
10. STATION 8, LOOKING AT HIGH WATER DEBRIS, FALL FLOW

11. STATION 8, DEBRIS IN TREE, FALL FLOW



13. STATION 8, DEBRIS IN TREE NEAR BRIDGE, FALL FLOW

14. STATION 8, DOWNSTREAM, FALL FLOW



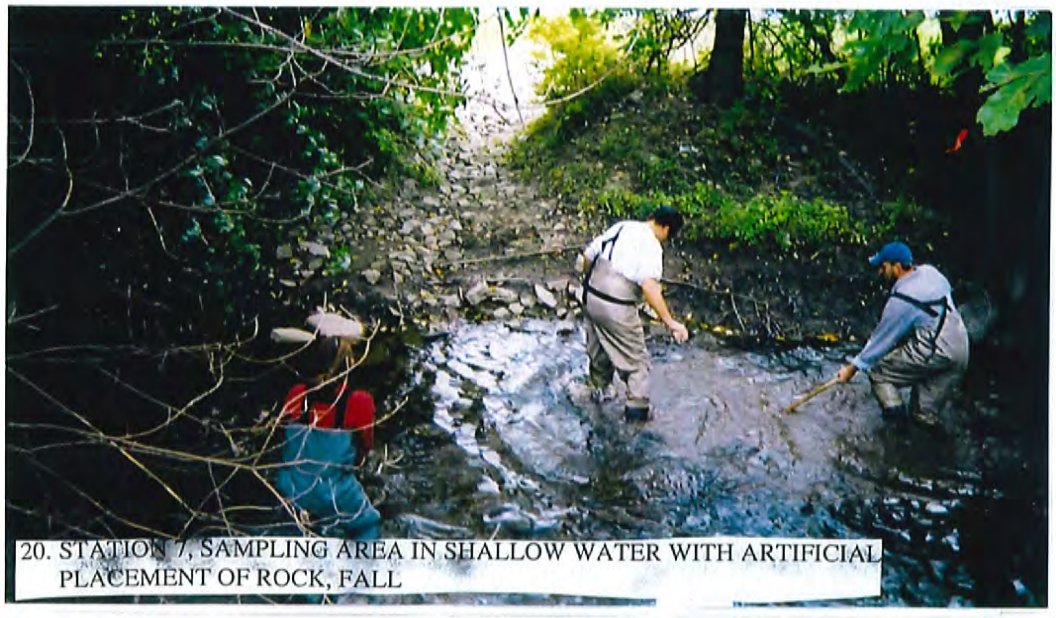
15. STATION 8, DEBRIS DOWNSTREAM FROM BRIDGE, FALL FLOW

16. STATION 7, UPSTREAM FROM DOUBLE CULVERT, FALL FLOW

17. STATION 7, UPSTREAM FROM DOUBLE CULVERT, FALL FLOW

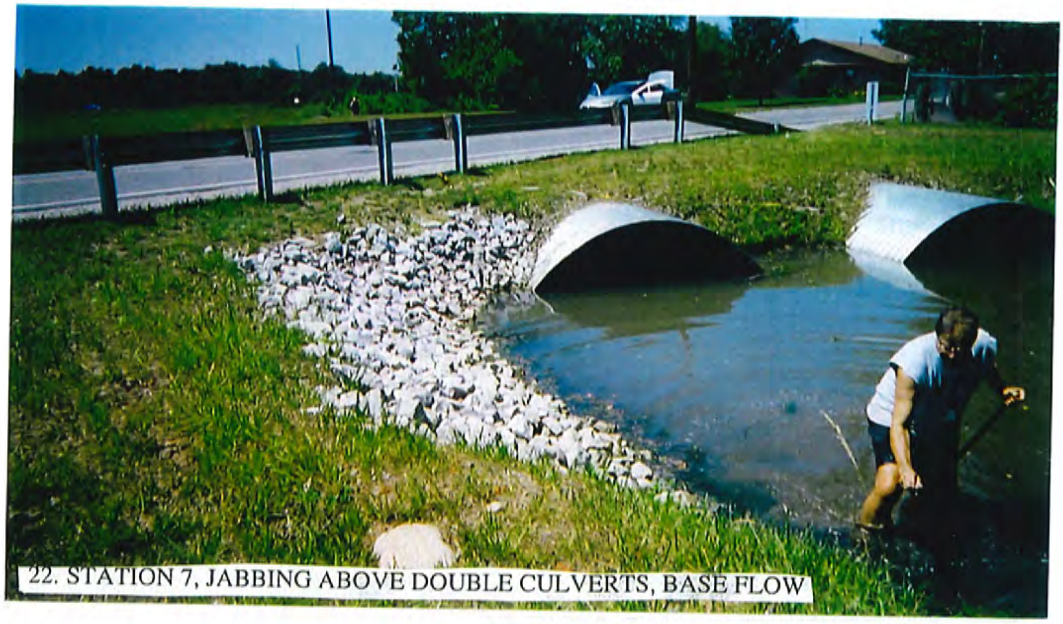
18. STATION 7, SAMPLING UPSTREAM FROM DOUBLE CULVERT, FALL

19. STATION 7, SAMPLING UPSTREAM FROM DOUBLE CULVERT, FALL



20. STATION 7, SAMPLING AREA IN SHALLOW WATER WITH ARTIFICIAL PLACEMENT OF ROCK, FALL

21. STATION 7, SAMPLING, FALL FLOW



22. STATION 7, JABBING ABOVE DOUBLE CULVERTS, BASE FLOW

23. STATION 7, WALKING TO DOWNSTREAM EXIT OF DOUBLE CULVERTS, BASE FLOW

24. STATION 7, HABITAT IN TREE LINED AREA, FALL FLOW

25. STATION 7, SAMPLING, FALL FLOW

26. STATION 7, HABITAT, FALL FLOW

27. STATION 7, UPSTREAM HABITAT, FALL FLOW

28. STATION 6, UPSTREAM FACING NORTH, FALL FLOW

29. STATION 6, FACING UPSTREAM DEVELOPMENT ON RIGHT, FALL

30. STATION 6, DEVELOPMENT DOWNSTREAM, FALL

32. STATION 6, UPSTREAM, FALL

33. STATION 6, UPSTREAM, FALL

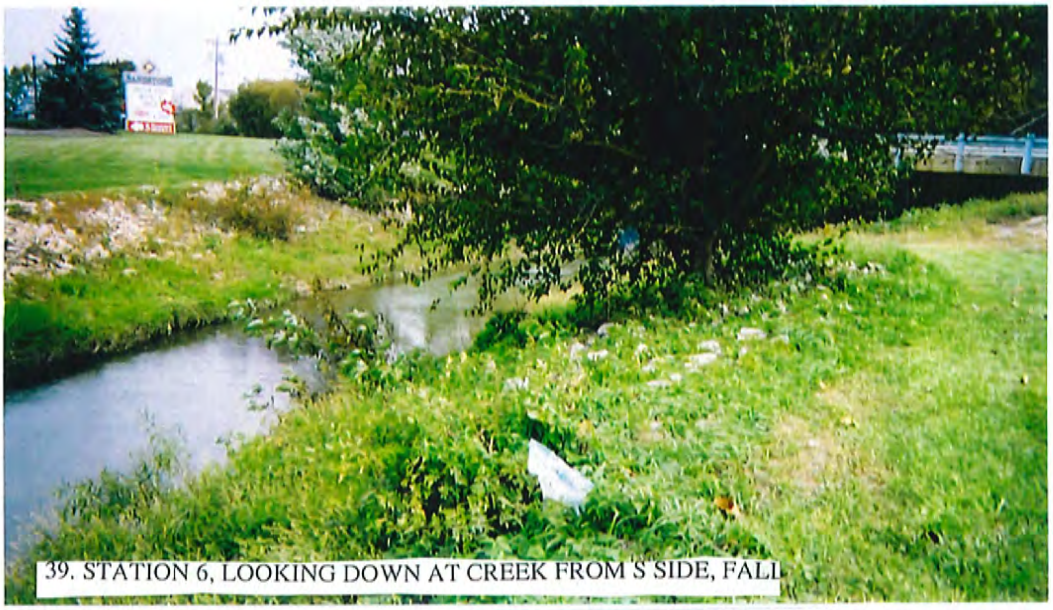
34. STATION 6, UPSTREAM, FALL

35. STATION 6, DOWNSTREAM UNDER BRIDGE, FALL

36. STATION 6, UPSTREAM, FALL

37. STATION 6, UPSTREAM

38. STATION 5, LOOKING UPSTREAM TOWARD BRIDGE FROM PARKING LOT



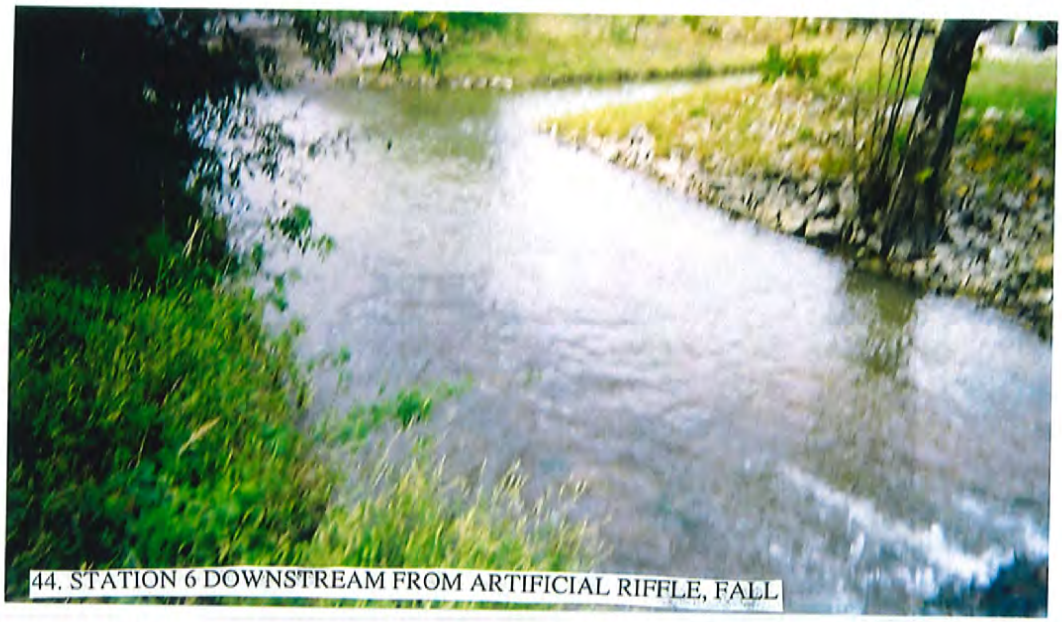
39. STATION 6, LOOKING DOWN AT CREEK FROM S SIDE, FALL

40. STATION 6, LOOK AT CREEK FROM S SIDE, FALL

41. STATION 6, LOOKING UPSTREAM TOWARD SAMPLING SITE, FALL

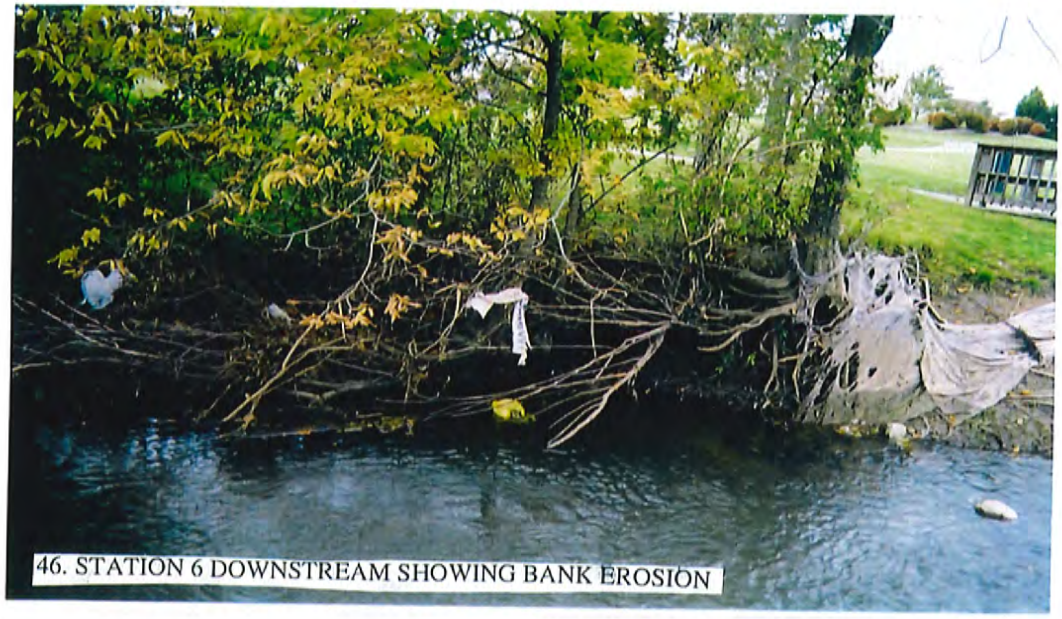
42. STATION 6, SAMPLING AREA WITH ARTIFICIAL DAM, FALL

43. STATION 6, END OF PIPE ON N SIDE, FALL



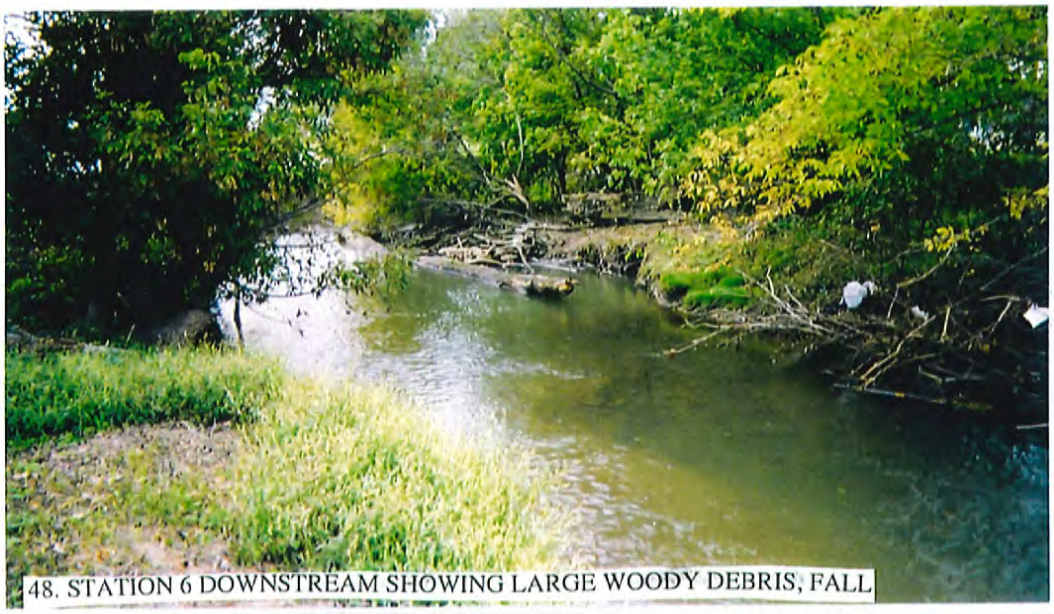
44. STATION 6 DOWNSTREAM FROM ARTIFICIAL RIFFLE, FALL

45. STATION 6 DOWN FROM PIPE SHOWING EROSION



46. STATION 6 DOWNSTREAM SHOWING BANK EROSION

47. STATION 6 DOWNSTREAM, FALL



48. STATION 6 DOWNSTREAM SHOWING LARGE WOODY DEBRIS, FALL

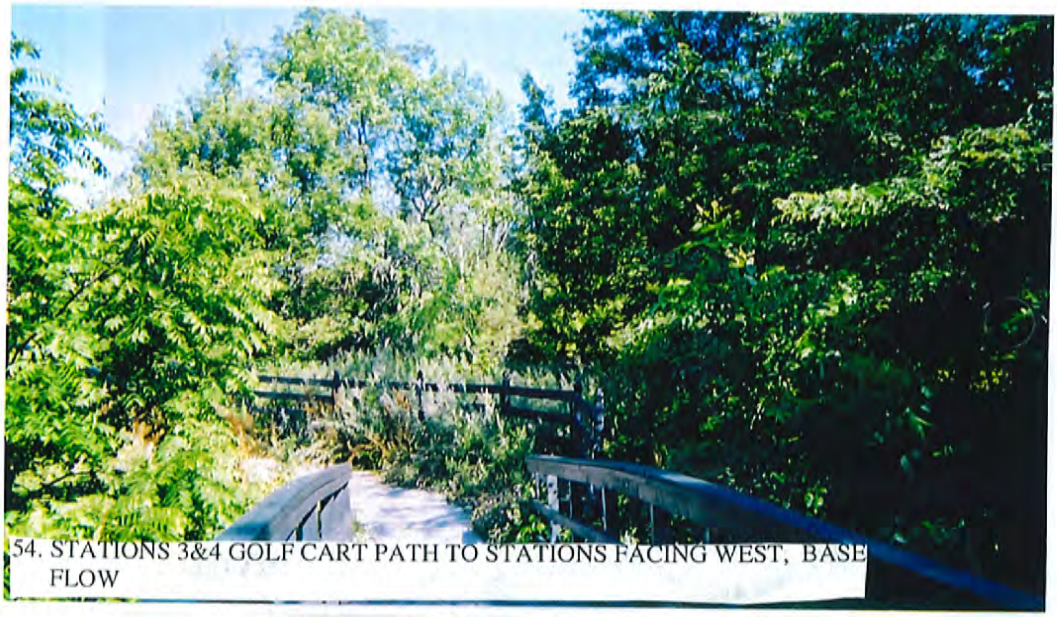
49. STATION 6 DOWNSTREAM, FALL

50. STATION 6, SAMPLING AREA, BASE FLOW

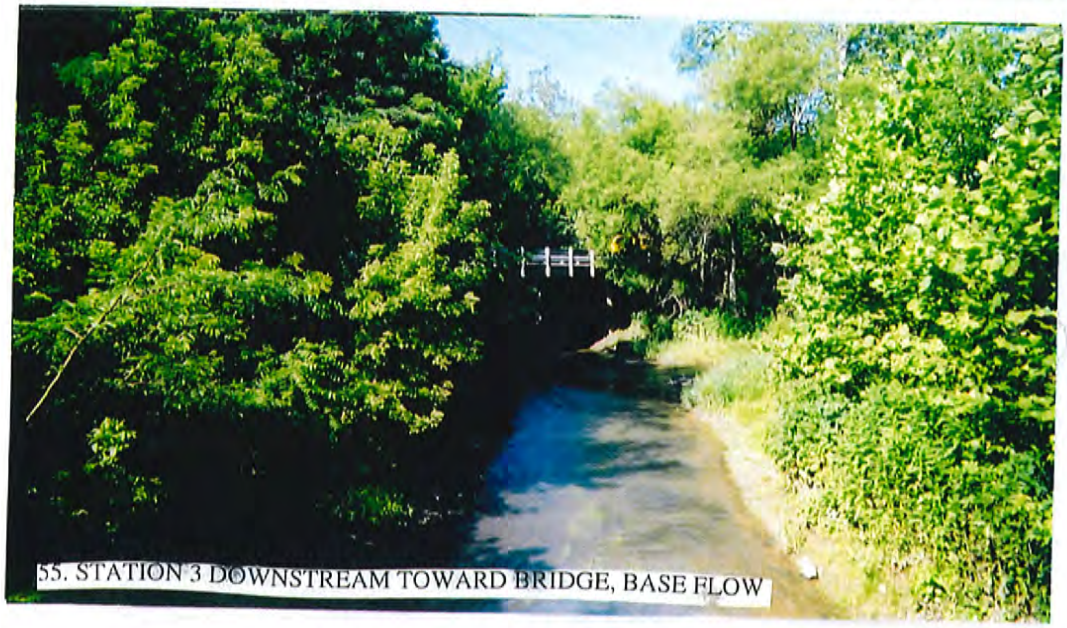
51. STATION 6, END OF PIPE, BASE FLOW

52. STATION 6, END OF PIPE BASE FLOW

53. STATIONS 3&4 GOLF CART PATH TO STATIONS FACING EAST, BASE FLOW



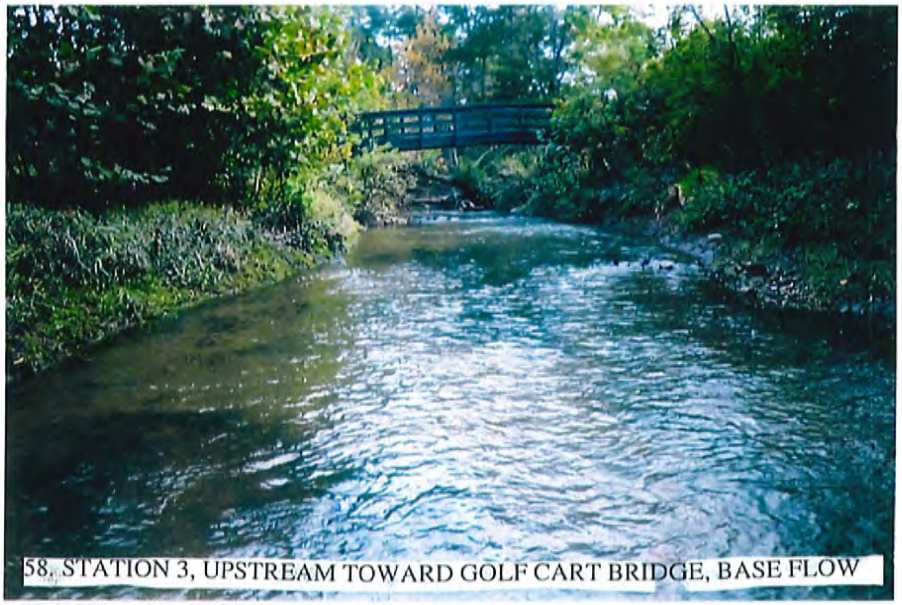
54. STATIONS 3&4 GOLF CART PATH TO STATIONS FACING WEST, BASE FLOW



55. STATION 3 DOWNSTREAM TOWARD BRIDGE, BASE FLOW

56. STATION 3 UPSTREAM BASE FLOW

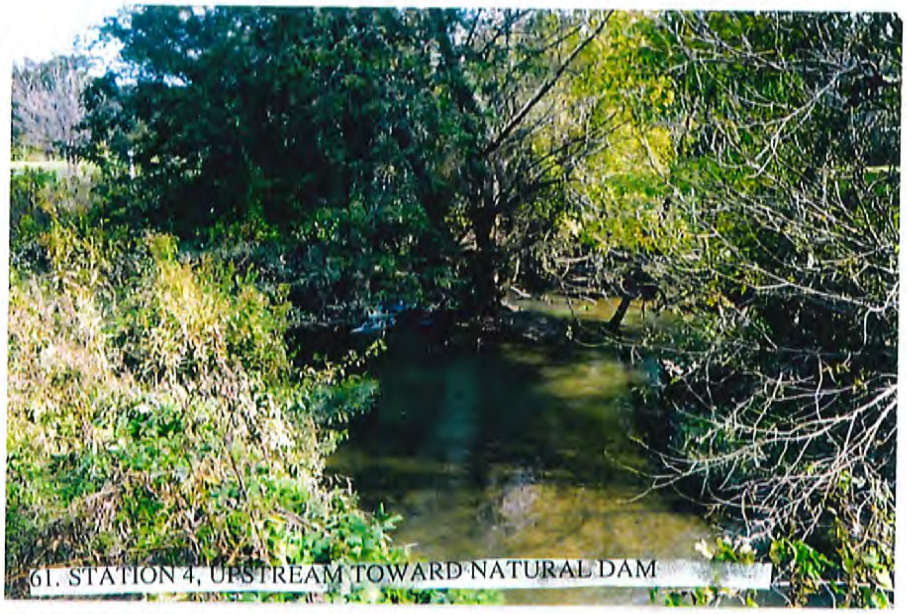
57. STATION 3 UPSTREAM BASE FLOW



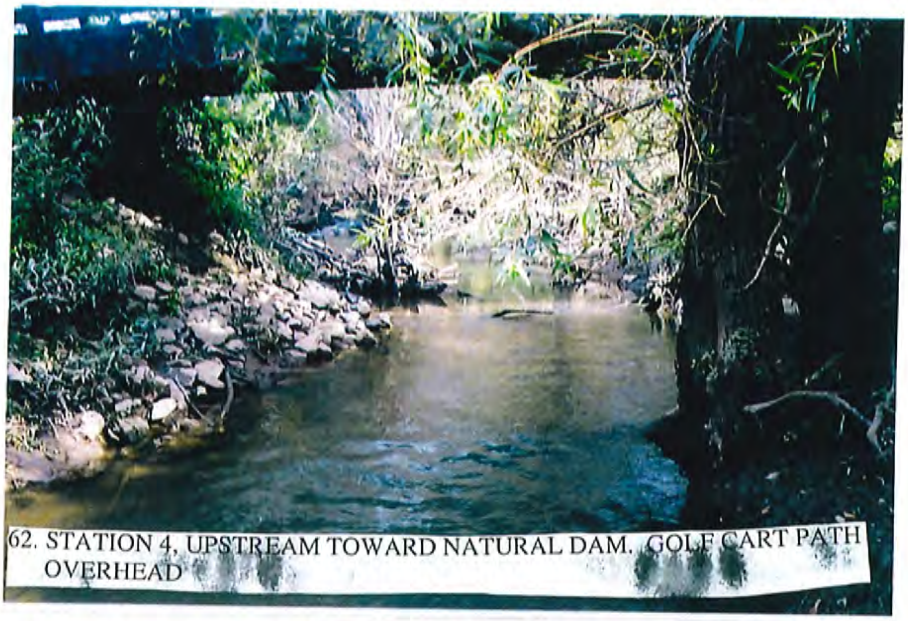
58. STATION 3, UPSTREAM TOWARD GOLF CART BRIDGE, BASE FLOW

59. STATION 3, UPSTREAM TOWARD GOLD CART BRIDGE, FALL FLOW

60. STATION 3, DOWNSTREAM TOWARD BRIDGE, FALL FLOW

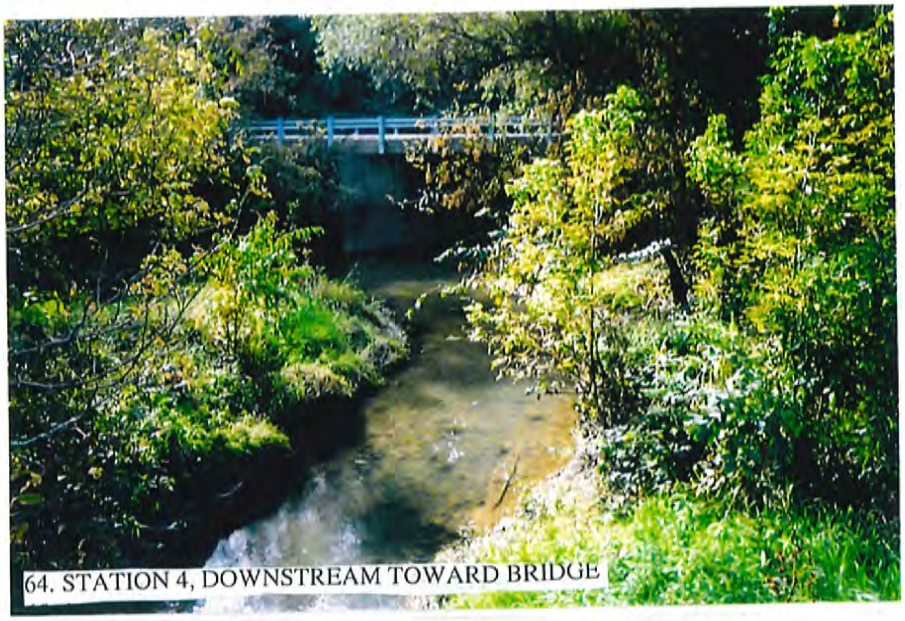


61. STATION 4, UPSTREAM TOWARD NATURAL DAM



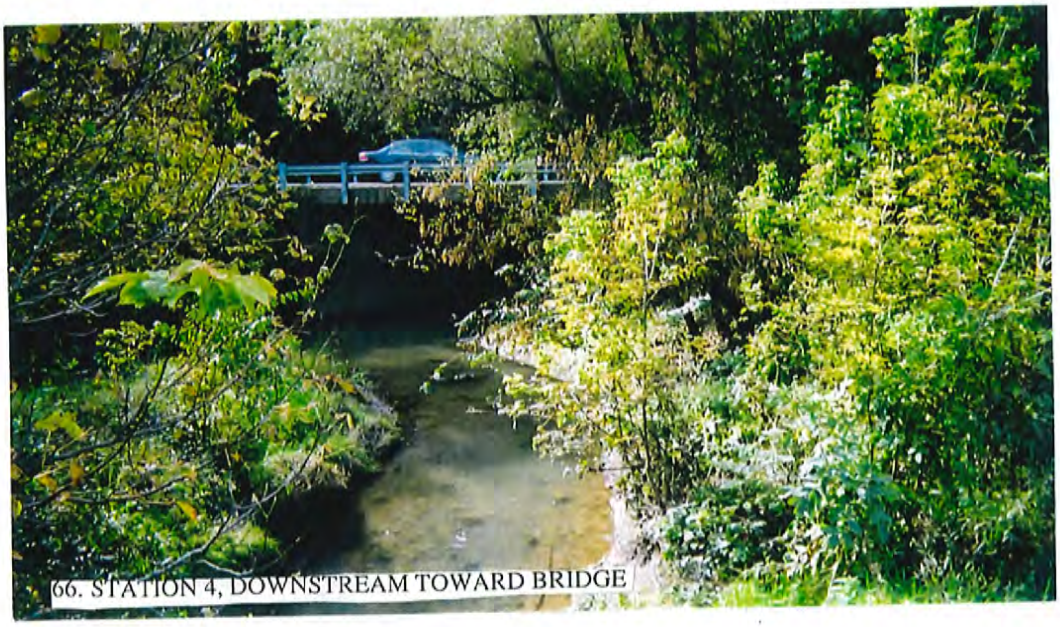
62. STATION 4, UPSTREAM TOWARD NATURAL DAM. GOLF CART PATH OVERHEAD

63. STATION 4, UPSTREAM



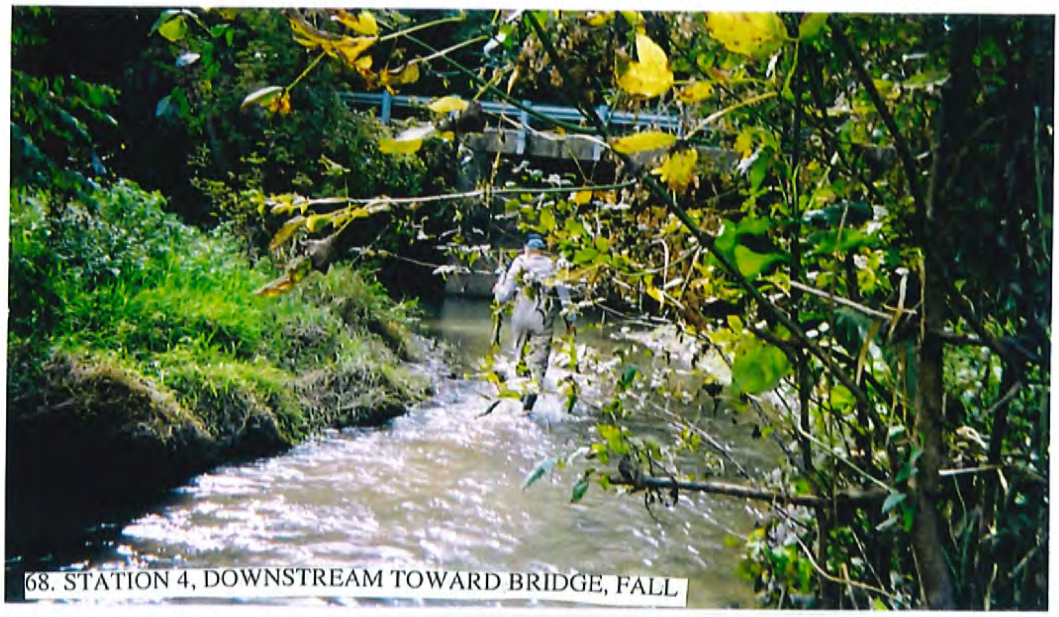
64. STATION 4, DOWNSTREAM TOWARD BRIDGE

65. STATION 4, DOWNSTREAM TOWARD BRIDGE



66. STATION 4, DOWNSTREAM TOWARD BRIDGE

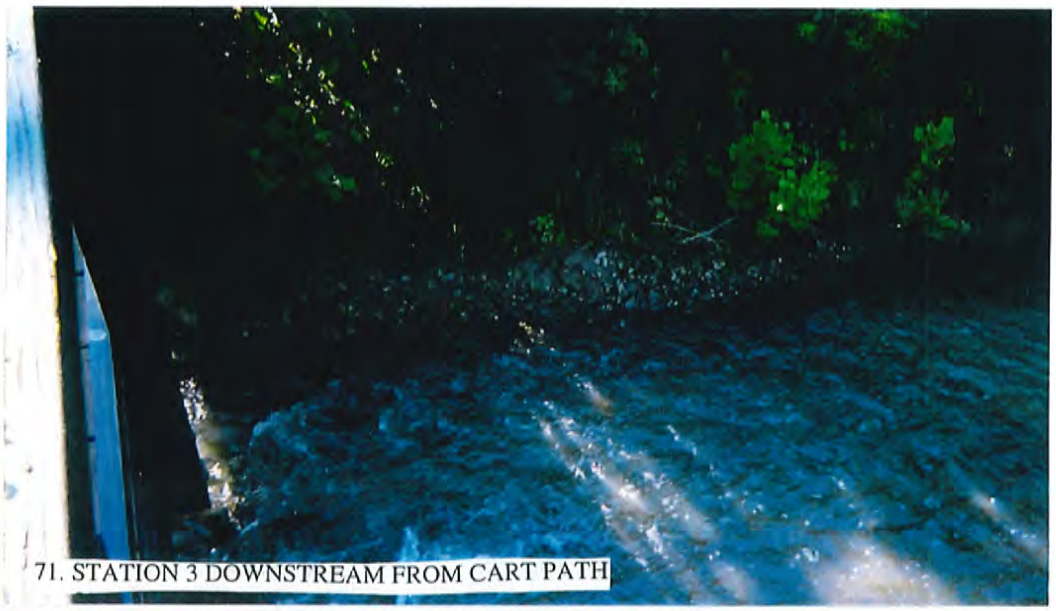
67. STATION 4, BANK EROSION, FALL



68. STATION 4, DOWNSTREAM TOWARD BRIDGE, FALL

69. STATION 4, DOWNSTREAM TOWARD BRIDGE

70. STATION 3, UPSTREAM



71. STATION 3 DOWNSTREAM FROM CART PATH

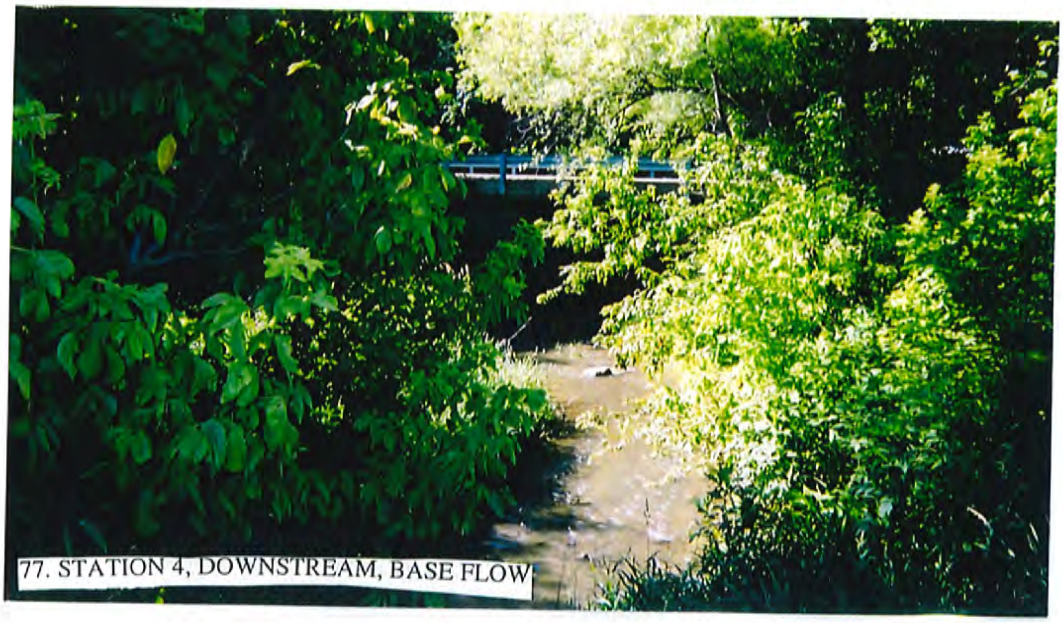
72. STATION 3, DOWNSTREAM LEFT BANK

73. STATION 3, DOWNSTREAM, BASE FLOW

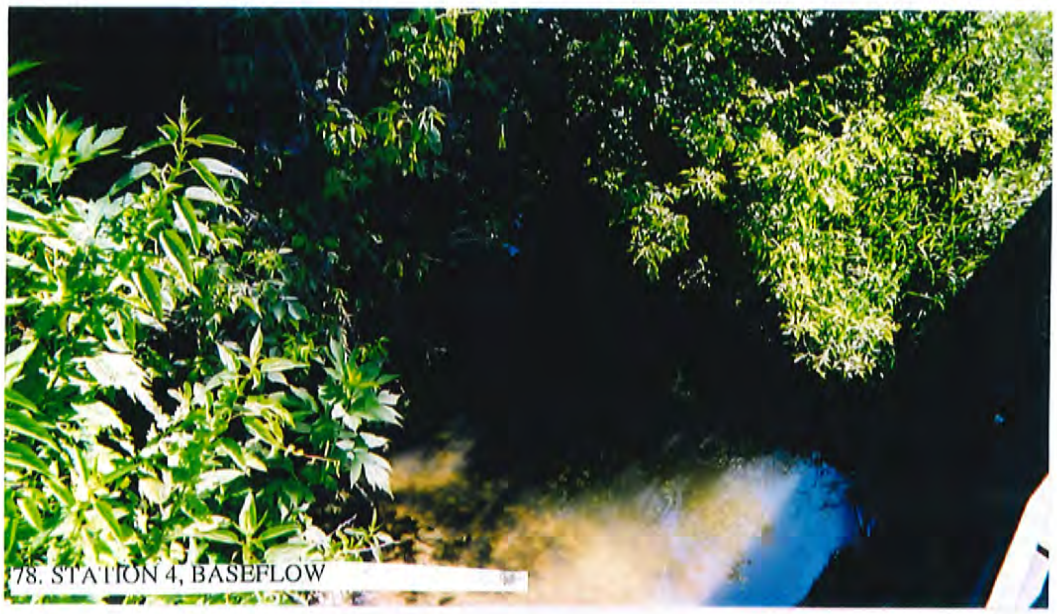
74. STATION 4 FACING WEST FROM CART PATH, BASE FLOW

75. STATION 4 FACING UPSTREAM, BASE FLOW

76. STATION 3??



77. STATION 4, DOWNSTREAM, BASE FLOW



78. STATION 4, BASEFLOW

79. STATION 2, DOWNSTREAM IN SAMPLING AREA, FALL FLOW

80. STATION 2, DOWNSTREAM, FALL FLOW

81. STATION 2, BANK EROSION, FALL FLOW

82. STATION 2, SAND AND MUCK DEPOSIT, FALL FLOW

83. STATION 2, PARK, BASE FLOW

84. STATION 2, PARK BASE FLOW

85. STATION 2 PARK, BASE FLOW

86. STATION 2, UPSTREAM BASE FLOW

87. STATION 2, DOWNSTREAM BASE FLOW

88. STATION 2, END OF PIPE, BASE FLOW

89. STATION 2, SUBSTRATE BASE FLOW

90. STATION 2 DOWNSTREAM BASE FLOW

91. STATION 2 MULTIFLORA ROSE BASE FLOW

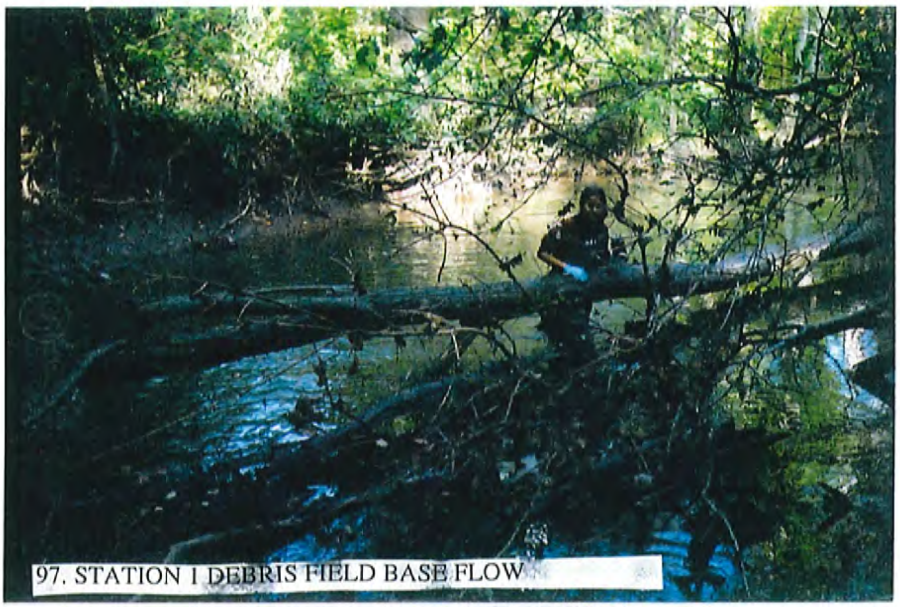
92. STATION 2 UPSTREAM BASE FLOW

93. STATION 2 PARK BASE FLOW

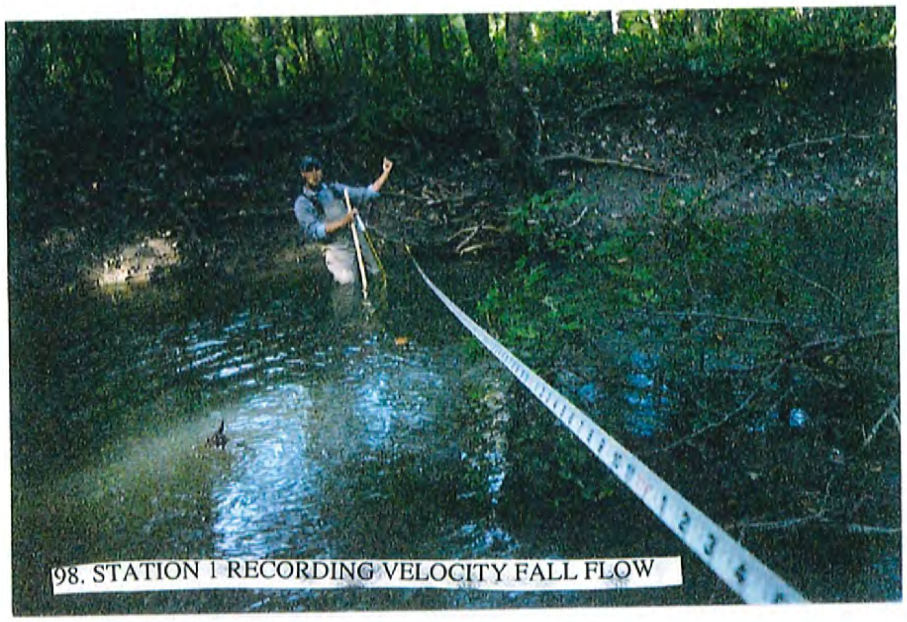
94. STATION 2 PARK BASE FLOW

95. STATION 1 BANK EROSION FALL FLOW

96. STATION 1 MEASURING DISCHARGE FALL FLOW



97. STATION 1 DEBRIS FIELD BASE FLOW

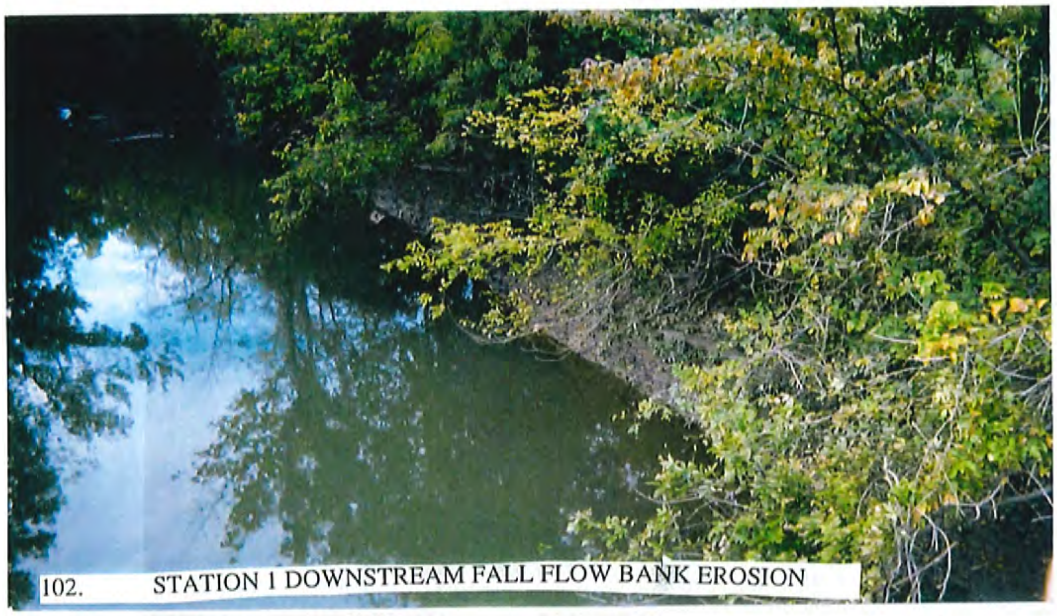


98. STATION 1 RECORDING VELOCITY FALL FLOW

99. STATION 1 UNDER BRIDGE FALL FLOW

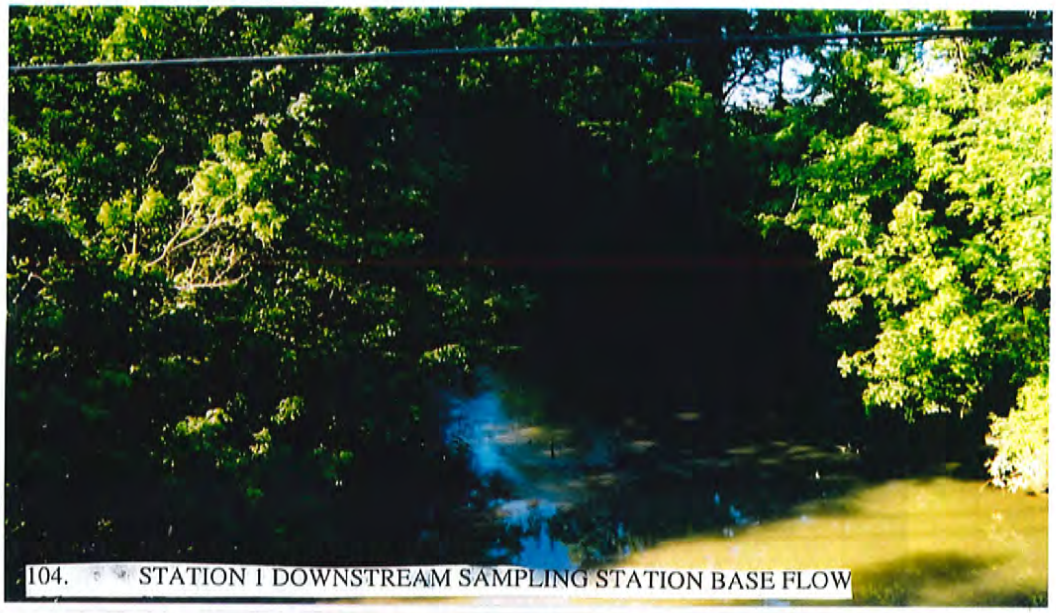
100. STATION 1 DOWNSTREAM FALL FLOW

101. STATION 1 DOWNSTREAM FALL FLOW

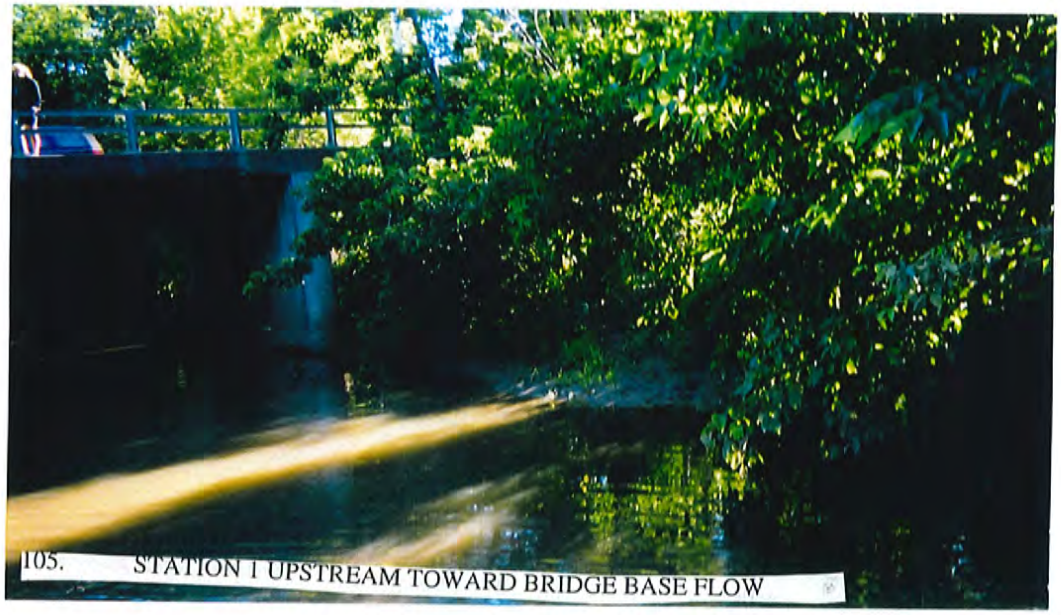


102. STATION 1 DOWNSTREAM FALL FLOW BANK EROSION

103. STATION 1 UPSTREAM BASE FLOW



104. STATION 1 DOWNSTREAM SAMPLING STATION BASE FLOW



105. STATION 1 UPSTREAM TOWARD BRIDGE BASE FLOW

106. STATION 1 DRAIN ON LEFT HAND SIDE FACING UPSTREAM

107. STATION 1 SAMPLING FROM BRIDGE BASE FLOW

108. STATION 6 FACING S CONSTRUCTION BASE FLOW

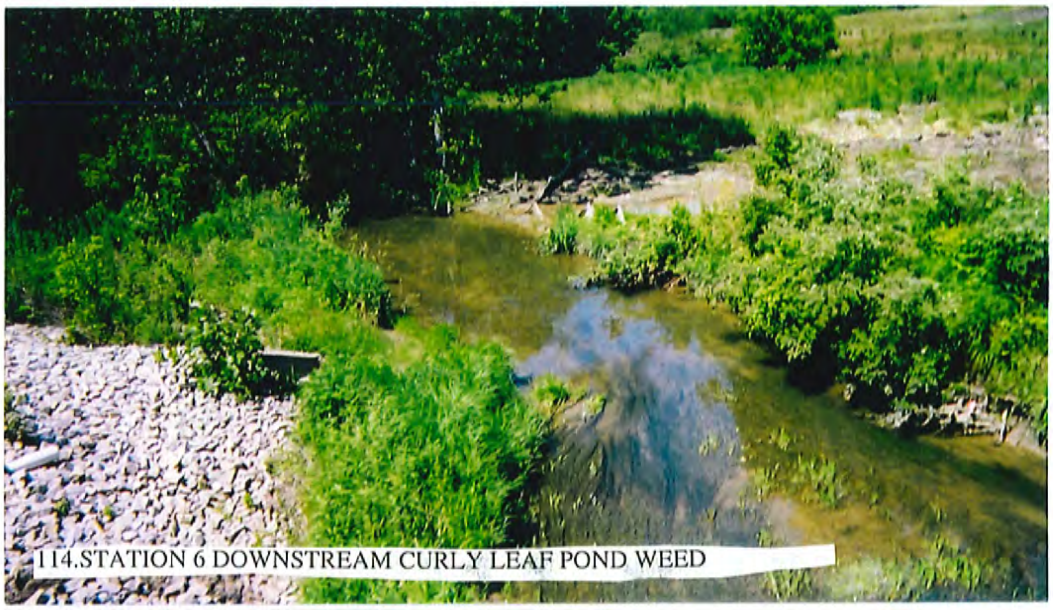
109. STATION 6 FIELD ON RIGHT UPSTREAM BASE FLOW

110. STATION 6 SAMPLING UPSTREAM BASE FLOW

111.STATION 6 FACING SOUTH CONSTRUCTION BASE FLOW

112.STATION 6 FIELD ON DOWNSTREAM SIDE FACING NORTH BASE FLOW

113.STATION 6 DOWNSTREAM CURLY LEAF POND WEED



114.STATION 6 DOWNSTREAM CURLY LEAF POND WEED

115.STATION 6 DOWNSTREAM

116.STATION 6 FACING NORTH NOTE CONSTRUCTION ON LEFT

MUD CREEK WATERSHED

SUMMARY OF WATER QUALITY STUDY AND EVALUATION OF NPDES PHASE II PERMIT ISSUES

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Mud Creek Watershed
Summary of Water Quality Study and Evaluation of NPDES Phase II Permit Issues

Prepared for

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April 2004

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CBBEL Project No. 01-410A

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1 Mud Creek Monitoring Sites

1.0 SUMMARY

In November of 2002, the Hamilton County Surveyor's Office hired Christopher B. Burke Engineering, Ltd. (CBBEL) to conduct a study of the Mud Creek Watershed in Hamilton County, Indiana. The project included both water quality and water quantity studies, of which CBBEL subcontracted water quality monitoring tasks to Dr. Claude Baker of Indiana University. Dr. Baker, of the New Albany Campus, and his students conducted water quality tasks, including chemical monitoring, habitat assessments, and bio-monitoring at eight sites within the Mud Creek watershed. Six of the sites were located on Mud Creek and two sites were located on Sand Creek, a major tributary to Mud Creek. Monitoring was conducted during the months of May, June, and October of 2003. The following is a summary of the finding from Dr. Baker's study Biomonitoring, Water Quality and Habitat Assessment for the Mud Creek Watershed, Hamilton County, Indiana, dated February 2004, and a correlation to the NPDES Phase II Stormwater permit requirements.

Mud Creek Water Quality Monitoring

Water quality samples were collected at eight sites to characterize high flow, base flow, and low flow conditions. Monitoring sites are illustrated in **Exhibit 1** and described in **Table 1**. Water quality parameters evaluated at these sites included: water and air temperature, dissolved oxygen, pH, alkalinity, turbidity, conductivity, total dissolved solids, nitrate, nitrite, ammonia-nitrogen, total nitrogen, ortho-phosphate, and fecal coliform bacteria.

Table 1
Mud Creek Monitoring Sites

Site #	Site Description
MC1	Mud Creek @ 96th Street, Marion/Hamilton County Line
MC2	Mud Creek @ Cumberland Rd (Cumberland Park)
MC3	Mud Creek @ Golf Course N of 106th St
MC4	Sand Creek @ confluence with Mud Creek, north of 106th St
MC5	Mud Creek @ Brooks School Ave.
MC6	Mud Creek @ Olio Rd.
MC7	Sand Creek at Sand Creek Drain, near the Verizon Entertainment Complex @ 146th St
MC8	Mud Creek @ Atlantic Rd, Madison/Hamilton County Line.

Monitoring results identified several pollutants at concentrations of concern in the Mud Creek watershed. Thirteen of the twenty-four samples collected were above 200 fecal coliform colonies per each 100ml sample, which may pose threats to public health via recreational contact. The Sand Creek site downstream of the Verizon Entertainment Complex, located in Hamilton County portion of the watershed, exceeded 200 colonies per 100ml sample during all sampling events. This site also had the highest coliform value of 5,696 colonies per 100ml and the lowest dissolved oxygen concentrations on average.

In addition, monitoring results identified elevated concentrations of phosphate and nitrate. These nutrients have been known to contribute to the growth of noxious algae and aquatic weeds in aquatic environments. Elevated turbidity values and visual observations also identified erosion and sedimentation problems at several locations in the watershed following storm events. Results did indicate, however, that the stream has sufficient oxygen levels and pH values to support aquatic life.

The Mud Creek Watershed Study suggests that pollutants within the watershed may originate from the following sources:

- erosion and sedimentation from constructions sites
- eroding streambanks
- runoff from impervious surfaces
- rapid urbanization of the watershed
- failed on-site septic systems or illegal septic tank connections to tile drains
- agricultural tile drainage systems
- runoff from agricultural lands

Mud Creek Habitat Assessment

Habitat assessments conducted at each of the eight sampling sites were performed using two analyses methods: EPA's Habitat Assessment from the Rapid Bioassessment Protocols (RBP) and the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI).

The RBP method found all sites to be of sufficient condition to support aquatic life, while the QHEI method identified most sites as being "moderately" impaired. Both methods found that Mud Creek has numerous natural and artificial riffles that aerate the stream and provide good macroinvertebrate habitat. However, numerous stretches of streambank along Mud Creek were identified as experiencing severe erosion. In addition, the Sand Creek site at the Verizon Complex was determined to be "limiting" for aquatic life due to previous channelization, low dissolved oxygen concentrations, and elevated bacteria levels. The report cites rapid urbanization on adjacent lands and upstream agricultural activities as the causes of impairment at this site.

Mud Creek Biomonitoring

Macroinvertebrates were collected at each of the eight sites utilizing the EPA's Rapid Bioassessment Protocol (RBP). The RBP focuses on macroinvertebrates in the riffle/run habitat. Samples were collected at each of the eight sites utilizing a traveling-kick net method.

The macroinvertebrate assessment revealed that Mud Creek is "moderately" impaired due to rapid urbanization of the watershed. In addition, the Sand Creek site, downstream of the Verizon Entertainment Complex, was considered "severely" impaired due to the rapid development occurring on the adjacent upland areas and runoff and tile discharges from upstream agricultural lands.

Recommendations Consistent with NPDES Phase II Requirements

Dr. Baker's study provided a variety of recommendations for addressing the pollutants impacting water quality in the Mud Creek watershed. **Table 2** highlights recommendations from the study that are consistent with Hamilton County's NDPES Stormwater Phase II requirements as outlined in 327 IAC 15-13; however, additional recommendations are included in the study.

Table 2
Mud Creek Watershed Study Recommendations

Recommended BMPs	BMP Benefits
• Restoration of eroded streambanks and riparian areas through vegetative practices, such as grass plantings, vegetative geogrids..	• Vegetative plantings minimize streambank erosion while serving as sediment and pollutant filters and slowing the velocity of runoff from upland areas. • Vegetative practices increase stream shading resulting in increased oxygen concentrations.
• Implementation of conservation tillage on agricultural lands, as well as nutrient management and conservation buffers croplands.	• Conservation tillage minimizes the transport of sediment and sediment bound pollutants from croplands. • Nutrient management minimizes the amount of nutrients applied to fields and reduces the risk of over application and contamination of runoff. • Buffer strips serve as sediment and pollutant filters while slowing the velocity of runoff from croplands.
• Adoption and enforcement of erosion and sediment control (ESC) practices upon construction sites.	• ESC practices minimize erosion and sedimentation that originates from developing and/or redeveloping areas.
• Utilization of post-construction BMPs, such as retention and detention basins in developing and re-developing areas.	• Retention and detention ponds, as well as other post-construction BMPs, provide for the settling out of sediment and pollutants prior to discharge to receiving streams. • Post-construction BMPs also minimize runoff volumes and velocities minimizing upland and streambank erosion.
• Utilization of rain gardens, grassy swales, and dry retention ponds on commercial and residential properties.	• These measures minimize runoff volumes of stormwater, increasing infiltration and limiting erosion and pollutant loading.

Conclusions

Implementation of the recommendations discussed in Table 2 would address multiple requirements of Hamilton County's NDPES Stormwater Phase II requirements. In addition, implementation of these recommendations would minimize the introduction of new or increased pollutant loads to streams, while also optimizing the ability of those streams to naturally process and decompose water quality pollutants. This approach would ultimately result in a healthier aquatic ecosystem for the Mud Creek watershed.

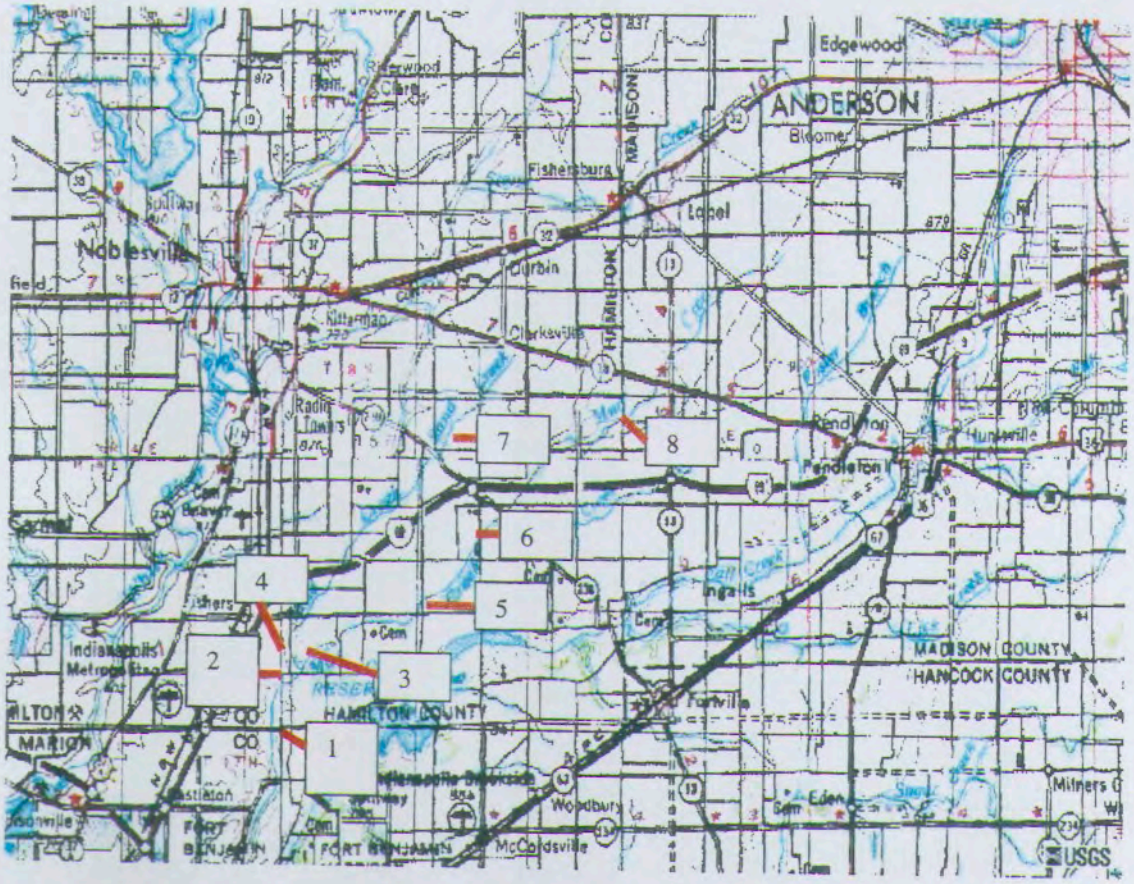
2.0 REFERENCES

Claude D. Baker, Ph.D, Indiana University Southeast. Biomonitoring, Water quality and Habitat Assessment for the Mud Creek Watershed, Hamilton County, IN, Hamilton County, Indiana, February 2004.

Indiana Department of Environmental Management. 327 IAC 15-13 Final Rule. August 2003.

Indiana Department of Environmental Management. Rule 13 Guidance Document. May 2003.

U.S. EPA – Office of Water, Stormwater Phase II Final Rule. January 2000.



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PROJECT:	PROJECT NO:	APPROX. SCALE:
Mud Creek Watershed Summary	01-410A	No Scale
TITLE: Mud Creek Monitoring Sites		DATE: 4/04
Source: Claude D. Baker, Ph.D. Indiana Univeristy Southeast. 2003		EXHIBIT 1