Shaping the Future

Duck and Otter Creeks Great Lakes Legacy Act Data Gap Investigation Report

April 25, 2012

Project No. 72606001

Prepared For

Duck and Otter Creek Industrial Partners

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Great Lakes Legacy Act Report

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Cardno ENTRIX Project No. 72606001

Prepared for
Duck and Otter Creek Industrial Partners

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Acronyms

AOC	Area of Concern
AVS	acid volatile sulfide
BSAF	sediment to biota accumulation factor
DOCIP	Duck and Otter Creek Industrial Partners
EqP	equilibrium partitioning
foc	organic carbon fraction
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
IBI	Index of Biotic Integrity
IVG	simulated *in vivo* gastrointestinal fluid
Koc	organic carbon partitioning coefficient
OEPA	Ohio Environmental Protection Agency
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
QHEI	Qualitative Habitat Evaluation Index
RBP	rapid bioassessment protocol
SEM	simultaneously extracted metals
SVOC	semivolatile organic compounds
TBD	to be determined
TOC	total organic carbon
USEPA	United States Environmental Protection Agency

Executive Summary

Duck and Otter Creeks are located within the Maumee River Area of Concern (AOC). An AOC is an area where the International Joint Commission (IJC) has identified beneficial use impairments (BUIs) as described by the 1987 Annex to the Great Lakes Water Quality Agreement of 1978. A full discussion of the Maumee AOC is located in the Maumee River Remedial Action Plan (RAP) [Maumee RAP, TMACOG and Ohio Environmental Protection Agency (2006)] The Maumee AOC is approximately 775 square miles in size and includes Swan Creek, Ottawa River (Ten Mile Creek), Duck Creek, Otter Creek, Grassy Creek, Cedar Creek, and Crane Creek. In 1992, the AOC area was extended to the east to include Turtle Creek, Packer Creek, and the Toussaint River (Maumee RAP and Duck & Otter Creeks Partnership, Inc. 2006).

In the late Nineteenth Century, these streams and others in the region were modified when a large forested wetland complex called the “Great Black Swamp” was drained. The drainage process facilitated new land uses by settlers, and began a complex history of urban, industrial and residential land uses (TMACOG 1991) on the watersheds of Duck and Otter Creeks. Previous investigations determined that several chemical constituents are present in the sediments of these streams at concentrations that exceed benchmarks for aquatic life. The biological communities of Duck and Otter Creeks have been identified as impaired. For the Duck and Otter Creek watersheds, the beneficial use impairments include the loss of habitat and adverse impacts to fish, wildlife, benthic invertebrates and overall aesthetics of the watershed (Maumee RAP, TMACOG and OEPA 2006).

Prior to 2009 several studies had been conducted on the Duck and Otter Creeks; however, there was still a need for crucial information to understand the degree of impairment and potential causes of the impairment. These “data gaps” needed to be “filled” to support future environmental decisions. The Duck and Otter Creek Industrial Partners (DOCIP) and the U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO) identified several data gaps for these creeks and entered into a Project Agreement under the Great Lakes Legacy Act (GLLA) to conduct an investigation to address the data gaps in 2010. This document includes the results from that 2010 investigation.

Study Design

The 2010 investigation was designed to address the data gaps that were not completely addressed during previous studies. The data gaps that were addressed included:

- Measurements of the bioavailability of contaminants;
- Characterization of subsurface and surface sediment chemistry;
- Evaluation of habitat resources;
- Performance of more rigorous sediment toxicity testing; and,

- Investigation of conditions in urbanized, nonnon-industrial streams in the region.

Samples were collected from selected locations in Duck Creek, Otter Creek, and two nearby streams in urbanized but non-industrialized areas. Grassy Creek in Perrysburg, OH and Amlosch Ditch in Oregon, OH were identified as urban streams most similar to Duck and Otter Creeks. Samples were collected near the headwaters of both of these urban comparison streams, and the same suite of measurements as those used for Duck and Otter Creeks were completed.

Study Methods

There were three main components of the 2010 data gap investigation:

- Bulk sediment chemistry, sediment toxicity, and the community of sediment-dwelling animals, along with a qualitative evaluation of habitat were assessed in the surface layer (0-6 inches depth). In addition, the bioavailable fractions of surface sediment chemicals were measured;

- Tissue samples from fish and sediment-dwelling (benthic) invertebrates were analyzed chemically; and,

- Subsurface sediment chemistry was measured in sediment cores from selected locations.

Study Results

Each component of the data gap investigation is summarized below.

Field Observations & Measurements of Physical Sediment Characteristics

- During sample collection, field crews recorded observations of visible sheens and odors that were believed to be petroleum in several sampling locations. Neither sheens nor petroleum odors were reported in Duck Creek, Grassy Creek or Amlosch Ditch. Field observations varied in Otter Creek. Sheens and petroleum odors were reported for most of the sample locations in Otter Creek in the section downstream of Millard Avenue. Sheen and odor were infrequently observed in the middle and upstream reaches of Otter Creek: both sheen and odor were reported at a single location between Yarrow and Consaul Streets. Slight sheens without odor were reported at one upstream location downstream of Oakdale Avenue, and another upstream of Broadway Street.

- Surficial stream sediments were generally fine-grained, and were typically dominated by either silt or sand; gravel was common at two locations in Otter Creek near the Toledo Water Department works, and at one location near Ravine Park in Duck Creek. The total organic carbon content of stream sediments were generally in the range of 3% to 5% on a dry weight basis, with several locations in Duck Creek measured at concentrations greater than 6%.

Chemistry – Multiple Lines of Evidence

Multiple lines of evidence (e.g. bulk sediment, pore water, tissue) were examined to evaluate each class of sediment contaminants, and current theories and measurements were utilized to assess whether the contaminants are available to the biological species that inhabit theses streams. Chemical classes that had been identified as potential risk drivers in previous investigations included petroleum hydrocarbons, specifically the polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and metals. A brief discussion of each of the chemical classes is below.

Bulk Sediment Chemistry

- Total Petroleum Hydrocarbons (TPH) were measured at elevated concentrations in several sediment samples, and were generally greater in Otter Creek, than in the other streams. Gasoline-range organic (TPH-GRO) hydrocarbons were not detected sediment samples from Duck and Grassy Creeks. In Otter Creek, GRO hydrocarbons were detected in most samples that were collected from lower Otter Creek (north of Millard Avenue), one location between Millard Ave and York St., and the location between Consaul and Yarrow Streets. Gasoline range hydrocarbons were also detected in the Amlosch Ditch location. Diesel-range and residual range organic hydrocarbons (TPH-DRO and TPH-RRO respectively) were commonly detected in sediment samples from Duck and Otter Creeks, and both urban comparison streams.

- Polycyclic aromatic hydrocarbons (PAHs), which represent the components of petroleum that are generally most closely associated with adverse effects to aquatic organisms, were also measured in bulk sediment. The concentrations of the 16 priority pollutant PAHs in bulk sediments exceeded the probable effects concentration in Amlosch Ditch, at several locations in Otter Creek between Oakdale Avenue and Wheeling Street, and in the sample in Otter Creek located between Yarrow and Consaul Streets. The bulk sediment benchmark for PAHs was not exceeded in either Duck or Grassy Creek samples.

- Polychlorinated biphenyls (PCBs), and semivolatile organic compounds (SVOCs) other than PAHs, were not detected at concentrations that exceeded conservative benchmarks for bulk sediments in any of the 2010 data gap investigation samples.

- As was observed in previous studies, the concentrations of some metals in some sediment samples from Duck and Otter Creeks exceeded conservative benchmarks. Many metals are a natural component of soil and sediment due to the weathering of materials that comprise the Earth’s crust (i.e., naturally-occurring background) and as the result of human activities such as the combustion of fossil fuels and use of pesticides (i.e., anthropogenic background). Although this study did not define a numerical background concentration for each of the metals that were evaluated, it is important to note that background concentrations of metals unrelated to specific contributions from a potential industrial source frequently exceed conservative screening levels in urban streams in Northwest Ohio.

Bioavailable Fraction Chemistry

In addition to measurements of bulk sediment chemistry, the bioavailable fraction of sediment contaminants was measured using specific extractions that mimic biological exposures and calculations that estimate the portion of the chemicals that can be available for absorption by sediment-dwelling animals. These measurements are summarized below:

- The bioavailability of organic compounds was evaluated using equilibrium partitioning (EqP) theory which is based on a knowledge that contaminants in sediment pore water represent the fraction that is most available to sediment-dwelling organisms and can be used to most accurately predict adverse effects, and that the organic carbon content of sediments determines the pore water concentrations of organic contaminants at equilibrium. The calculations used to for EqP-based evaluations are commonly referred to as "TOC normalization." EqP-based sediment benchmark for discrete fractions of petroleum hydrocarbons have been developed; however, the eight fractions for which benchmarks are available do not coincide with the TPH-GRO, TPH-DRO and TPH RRO analyses that were conducted for this data gap investigation. There is no accurate method for calculating eight fractions of hydrocarbons from the three ranges of TPH that are available, so is was not possible to use the petroleum hydrocarbon benchmarks to quantitatively interpret the bioavailable component of the TPH ranges in Duck and Otter Creeks data set.

- Other petroleum components may contribute to petroleum toxicity, but, for the DGI data set, quantitative methods are only available for the PAHs. The TOC-normalized PEC for 16 priority pollutant PAHs was exceeded only in the surface sediment sample from Amlosch Ditch. The TOC-normalized PEC for 16 priority pollutant PAHs was not exceeded in any of the other samples from Duck, Otter or Grassy Creeks. EqP-based ecological screening benchmarks (ESBs) were not exceeded in any of the sediment samples collected in 2010. An evaluation of PAH concentrations measured in sediment pore waters, which are believed to represent the primary route of exposure to sediment-dwelling organisms, were greater than pore water-based benchmarks at three locations in lower Otter Creek. Pore water PAH concentrations were also significantly correlated with lethality in the toxicity test organisms. PAH concentrations were greater than benchmarks only in the tissue sample of sediment-dwelling invertebrates from Amlosch Ditch. PAH concentrations in fish and invertebrate tissue samples from Duck, Otter and Grassy Creeks did not exceed benchmark concentrations.

- PCBs were not detected at concentrations that exceeded EqP-based sediment benchmarks (e.g. are normalized to the content of sediment TOC). PCB concentrations in tissue samples of fish and sediment – dwelling invertebrates were low, and did not exceed benchmark concentrations.

- The bioavailability of metals in sediments was assessed using the EqP approach, which involves comparing the relative concentrations of volatile sulfides and metals that are simultaneously extracted by cold acid and the fraction of organic carbon [(SEM-AVS)/foc]. These values for all sediment samples were less than the sediment quality benchmark.

- The concentrations of metals in sediment pore water, which is generally accepted as the biologically-available fraction, and a primary route of exposure for sediment-dwelling organisms, did not exceed the respective ambient water quality criteria.

Arsenic bioaccessibility was measured using an in-vitro gastrointestinal (IV-G) method that simulates the human digestive system. Arsenic bioaccessibility in sediment samples from Duck and Otter Creek ranged from 29.8% to 57.6 %.

Sediment Toxicity

Sediment toxicity was measured by exposing larvae of the midge (*Chironomus dilutus*) to field-collected sediments for 10 days. Midge survival was significantly less than the laboratory controls at one location near the mouth of Otter Creek. Midge growth was less than laboratory controls at three locations in lower Otter Creek. When only the study locations within Amlosch Ditch and Duck, Otter and Grassy Creeks were evaluated, midge growth was significantly less at only two locations in lowest reach (Segment A) of Otter Creek. There was a significant negative correlation between the sum of PAH toxic units in sediment pore water and growth (biomass) of the midge *C. dilutus* larvae.

Based on a lack of relationships between bulk sediment chemistry and toxicity test results in a previous study, two classes of chemicals that had not previously been assessed were measured for the 2010 data gap investigation.

- Pyrethroid pesticides, which have been observed to result in sediment toxicity in other water bodies, were detected at trace concentrations in a few sediment sampling locations, but did not exceed benchmarks associated with toxicity to sediment-dwelling organisms.

- Ammonia concentrations in sediment pore water samples were greater than the associated surface water quality criteria; ammonia concentrations in the overlying water of the sediment toxicity testing chambers remained low throughout the test. Ammonia concentrations in pore water were not correlated with lethality or growth inhibition of the test organisms.

Benthic Macroinvertebrate Communities

The structure of the benthic macroinvertebrate community, which includes those insects, crustaceans, and other small animals that live in association with stream sediments, was evaluated by three metrics. The total number of taxa, which is a measure of biodiversity, ranged from 2 to 12. The lowest diversity was observed in Otter Creek near the Millard Avenue Bridge (approximately 2 miles upstream from the bay), while the greatest diversity was observed in upper Otter Creek, upstream of Broadway Road (approximately 7.8 miles upstream from the bay). The number of taxa in Duck Creek ranged from 7 to 9; and the same range was observed in the urban comparison streams. Invertebrate taxa that are considered to be sensitive to pollution and disturbance were present in about half of the sample locations. Sensitive taxa comprised more than 60% of the benthic community in Amlosch Ditch, but were absent from Grassy Creek. Sensitive taxa represented about one-fifth of the community in Duck Creek, and were present in four of the eight locations in Otter Creek. Tolerant invertebrate taxa were present in all sample locations, and dominated the benthic community in 10 of 13 locations, including the Grassy Creek location.

Qualitative Habitat Evaluations

The habitat evaluation involved two qualitative assessments; one assessment was conducted within the stream channels, and the other evaluated land use characteristics of the stream watersheds. The results of these evaluations are summarized below:

- The Qualitative Habitat Evaluation Index (QHEI) scores for Duck, Otter and Grassy Creeks and Amlosch Ditch ranged from 23 to 42 of a maximum possible score of 100. In-stream habitat evaluation indicated that physical stressors associated with: siltation; low gradient; lack of natural, in-stream structures; lack of riparian vegetation; and channelization appear to be factors that could limit the structure of the biological communities.

- The watershed land use evaluation indicated that hydraulic alterations resulting from conversion of the majority of the watershed to more than 20% impervious surface could be decreasing base flow and increasing stormwater runoff. There are a large number of storm sewer outfalls (51) in the Segments C and D of Otter Creek between Oakdale Avenue and Consaul Street/Corduroy Road that may deliver scouring flows during precipitation events that could adversely affect biological communities. The storm sewer outfalls could also deliver contaminants from the watershed that make source identification for sediment-associated chemicals difficult.

Conclusions

- The highest PAH concentrations in sediment pore waters occurred at the same locations where the growth of the midge *C. dilutus* was inhibited in the sediment toxicity test. The data from this study suggest that PAHs in sediment pore water could be contributing to the observed sediment toxicity in lower Otter Creek. The poor benthic community structure in lower Otter Creek is generally consistent with the results of the sediment toxicity test.

- PCBs, metals, pyrethroid pesticides, and non-PAH SVOCs can be ruled out as sources of toxicity in the 2010 Data Gap Investigation data set because these classes of contaminants generally are not elevated in sediments, or are not bioavailable. Ammonia concentrations are at levels of concern in the pore water of several sediment samples; however, sediments at many of those locations were not toxic to midge larvae so the available site data suggest that sediment-associated ammonia is not affecting the benthic community structure or contributing to sediment toxicity in the laboratory.

- The in-stream habitat quality ranged from very poor to poor, which implies the biological communities in these creeks are likely to include species that are tolerant of poor habitat quality. Tolerant species dominated the biological communities at the majority of the 2010 sample locations, which is consistent with the poor habitat quality that was observed.

- The section “Segment A” of Otter Creek that is downstream (North) of Millard Avenue differed from the other stream reaches of Otter Creek, the Duck Creek segments, and the urban comparison streams Grassy Creek and Amlosch Ditch. The observed differences in the lowest reach of Otter Creek include: reductions in the survival and growth of midge larvae in the sediment toxicity test; the presence of elevated PAH concentrations in sediment pore waters; the frequent observation of petroleum odor and sheen during field sampling; and the presence of elevated hydrocarbon concentrations in sediment core samples (0-48 inches) relative to surface (0-6 inches) grab samples.

- The 2010 data do not indicate there are sediment contamination or toxicity issues within Duck Creek or the upper segments of Otter Creek.

Recommendations

- Further evaluate potential remedies for Segment A of Otter Creek in a subsequent phase of the project;

- Further evaluate the combined 2007 and 2010 data sets for the remaining stream sections in a subsequent phase of the project.

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Chapter 1

Introduction

Duck and Otter Creeks are located within the Maumee River Area of Concern (AOC). An AOC is an area where there are known beneficial use impairments (BUIs) of water bodies located within the watershed(s). A full discussion of the Maumee AOC is located in the Maumee River Remedial Action Plan (RAP) [Maumee RAP, TMACOG and OEPA, 2006]. The Maumee AOC is approximately 775 square miles and includes Swan Creek, Ottawa River (Ten Mile Creek), Duck Creek, Otter Creek, Grassy Creek, Cedar Creek, and Crane Creek. In 1992, this area was extended to the east to include Turtle Creek, Packer Creek, and the Toussaint River (Maumee RAP, TMACOG and OEPA 2006).

In the late Nineteenth Century, these streams and others in the region were modified when the Great Black Swamp was drained. They have had a complex history of urban, industrial, oil production and residential land uses. Previous investigations determined that several chemical constituents are present in the sediments of these streams at concentrations that exceed conservative benchmarks for the protection of aquatic life. The biological communities of Duck and Otter Creeks have been identified as impaired. For the Duck and Otter Creek watersheds, the beneficial use impairments include the loss of habitat and adverse impacts to fish, wildlife, benthic invertebrates and overall aesthetics of the watershed (Maumee RAP, TMACOG and OEPA 2006).

Although several previous studies had been conducted on the Duck and Otter Creeks, crucial information necessary to understand the degree of impairment and potential causes of the impairment was not available. These data gaps needed to be filled to support future environmental decisions. The Duck and Otter Creek Industrial Partners (DOCIP) and the U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO) identified several data gaps for these creeks and entered into a Project Agreement under the Great Lakes Legacy Act (GLLA) to conduct an investigation to address the data gaps.

1.1 Objectives

One of the purposes of a GLLA project is to determine, based on the degree and possible sources of impacts, if sediment and/or habitat management is warranted. Specific Project Objectives relating to this purpose were identified in the Project Agreement. These objectives are inputs that are needed to address data gaps that have been identified by GLNPO and the DOCIP, and will allow decisions to be made for these streams. The project objectives identified for the GLLA investigation include:

- Determining the extent of contamination in both surface and subsurface sediments;
- Verifying sediment toxicity and identify cause(s), to the extent practicable within the constraints of this data gap investigation;
- Evaluating whether sediment contaminants are bioaccumulating in benthic invertebrates and fish at levels likely to contribute significantly to the degradation of benthos and fish populations;

- Evaluating habitat resources; and
- Collecting data to support development of a feasibility study (evaluation of remedial and restoration options to protect human health and the environment and to advance progress toward delisting of beneficial use impairments), if one is determined to be necessary.

1.2 Conceptual Model

The biological communities of Duck and Otter Creeks exhibit impairment as reflected by low biological criteria scores, as identified in the Maumee River AOC. The source of these impairments has been unclear because there are multiple physical and chemical stressors. Because the sediments of these streams contain concentrations of chemicals that exceed benchmarks used for screening level sediment quality assessments, this investigation was conducted to determine if sediment contamination may be contributing to the impaired state of the aquatic communities.

1.2.1 Physical Environment of Streams and Watersheds

Duck and Otter Creeks flow through an urban and industrial area that was historically within the Great Black Swamp on the western end of Lake Erie. Streams that flowed through the Great Black Swamp were channelized in the late Nineteenth Century to enhance drainage and support agricultural, urban and industrial land uses. Both streams remain highly-modified drainage ditches with numerous utility crossings. Portions of each stream flow through subsurface culverts. During previous investigations, SulTRAC divided each stream into five sections for sampling in 2007 (Figure 1-1 and Tables 1-1 and 1-2). These segments designations are a useful tool to summarize and evaluate data and were retained for the purpose of this report.

1.2.2 Physical Stressors

Historically, the watersheds of Duck and Otter Creeks were included in a large forested wetland that European settlers called the Great Black Swamp because the tree canopy was so complete that the interior of the forest was shaded even during the day. The Great Black Swamp was clear-cut and drained to support agricultural and industrial land uses during the late Nineteenth Century. There are no obvious remnants of the historic habitat in the watershed of Duck and Otter Creeks. Duck and Otter Creeks, like most streams within the former Great Black Swamp, were converted to storm water utilities more than a century ago and the quality of the streams as aquatic habitat is generally poor: Both streams lack the riffle-pool sequences of natural streams; meanders have been removed as channels have been straightened to improve drainage; and riparian canopy is limited.

- Duck Creek is about 3.6 miles (19,000 feet) long, with approximately 1,000 feet of (Hecklinger) pond, 3,000 feet of emergent wetland[1] (Ravine Park,) and 3,000 feet of meandering channel with partial riparian forest (Table 1-1).
- The main channel of Otter Creek is about 9.5 miles (50,300 feet) long. Approximately 16,000 feet of meandering channel has a partial riparian forest. At least 2,100 feet (4%) of Otter Creek flows through underground culverts (Table 1-2).

[1] An emergent wetland is characterized by erect, rooted herbaceous wetland hydrophytes, usually perennials, that are generally present for most of the growing season.

Stream ecosystems have common structural features that perform essential functions. Many of these structural features are rare in Duck and Otter Creeks, the absence of which is likely contributing to the impairment of aquatic communities because the essential ecological functions are not being provided. A very brief overview of common stream features is provided below:

The stream channel is the area that transmits water and provides living space for aquatic species during "normal" flow periods. Flowing waters represent kinetic energy that affects the landscape, and natural stream channels have common features to which stream communities are adapted, including:

- **Riffles** are areas where the water flows quickly over a rough (rocky) stream bed. Riffles add oxygen to the water, and the spaces beneath and between rocks are important living spaces for invertebrates. Benthic macroinvertebrate community indices such as the Index of Community Integrity (ICI) are largely influenced by the diverse communities of invertebrates that inhabit riffle areas. Riffles are rare in Duck and Otter Creeks and may not have been common historically because the area was a large forested wetland (swamp).
- **Glides** (sometimes called "Runs") areas within a stream where the water flows quickly, but smoothly. The stream bed may be smooth; or, if the water depth is sufficient, fast-moving water can flow smoothly over a rough bottom. Glides are usually located between riffles and pools, and inhabited by organisms that are adapted to currents, or seek refuge downstream of structures that provide shelter from the force of flowing water. **Pools** are areas of deeper, slower moving water. Pools provide refuge from currents, and living space for fish. Sediment also deposits in pools where it is available for burrowing invertebrates. Fish community indices such as the Index of Biological Integrity (IBI) are largely influenced by the diverse fish communities that inhabit pools and glides/runs which are intermediate between riffles and pools. Stream pools are rare in Duck and Otter Creeks, but may have been more common when the area was a swamp.
- **Meanders** are areas where stream channels curve as sediments are eroded and deposited over time. The concave sides of meanders provide rough substrates that are used for breeding by some aquatic species. The convex sides of meanders provide refuge from currents, and allow suspended sediments to settle. Meanders are rare in Duck and Otter Creeks, but were likely common when the area was a swamp.
- The **floodplain** is the land area between the stream channel and the "bank" that occurs along the high water mark. Floodplains function as a secondary stream channel that transmits high flows, or floods. Floodplains also provide ecological linkages between the stream and the watershed; for example, plant communities on the floodplain stabilize the soils and prevent erosion during floods. Important floodplain features include:
- In a forested area, the **riparian** (streamside) **canopy** shades the stream which allows the water to contain more oxygen. Warm water is stressful for many aquatic species so stream segments without trees can have impaired aquatic communities. Headwater stream ecosystems are adapted to the leaves that are deposited into the stream in the fall, so some invertebrates species that shred leaves are absent in streams without riparian forests, which will decrease overall diversity and can result in lower ICI and IBI scores. Riparian forests occur in about one-third of Duck and Otter Creeks, but likely were very common historically. Emergent wetlands or

marshes, which provide some of the functions as riparian forests exist along some portions of Duck and Otter Creeks.

- **Oxbows** are sections of historic stream channels that remain after the channel moves. Oxbows that contain open water are often important breeding and nursery habitats for fish, amphibians and burrowing invertebrates. Oxbows that contain wetlands are often important habitats for invertebrates and wildlife such as birds. Oxbows are very rare in Duck and Otter Creeks; however, some reaches of the streams have wetlands along the edges of the stream channel and along the floodplain.

The stream channels and floodplains of Duck and Otter Creeks were modified a century ago. The channels were straightened, the riparian trees were removed and structures were built on the floodplains. These land use modifications likely are contributing to low biological community scores in Duck and Otter Creeks.

1.2.3 Chemical Stressors

In addition to the physical habitat modifications of Duck and Otter Creeks, extensive industrial and urban development has resulted in chemical contamination of the creek sediments. Also, some of the chemicals in creek sediments are a natural component of soil and sediment due to weathering of materials that comprise the Earth's crust (i.e., naturally-occurring background) and as the result of human activities such as the combustion of fossil fuels and use of pesticides (i.e., anthropogenic background). Excessive concentrations of chemicals in surface water and/or sediments can stress aquatic life and result in impaired biological communities. Sediment contamination has been the focus of several previous investigations of Duck and Otter Creeks, as well as other streams within the Maumee River AOC. Previous investigations have measured a variety of chemicals in bulk sediment samples and determined that concentrations of some chemicals exceed conservative benchmarks that are used for assessing sediment quality.

However, potential adverse affects posed to benthic macroinvertebrates in Duck and Otter Creeks may not be predicted solely on the basis of the bulk sediment chemistry data. Many contaminants bind to particulate matter that is suspended in the water column and settle into sediments when the particles are deposited. Some of those chemical contaminants persist in the sediments, and it is only when present in a bioavailable form, that these chemicals may adversely affect aquatic life. Therefore, evaluation of the bulk chemistry data alone may not be sufficient to identify key chemical stressors, if any, that may be contributing to generally poor benthic community structure. In addition, evaluation of the bulk chemistry data without weighing the potential contribution of physical modifications of the steam habitat to potential degradation of the benthic community may lead to an incorrect identification of a causative factor.

Sediment toxicity tests were conducted by SulTRAC in 2007 and survival of midge larvae was impaired in some samples from Duck Creek and most samples from Otter Creek. However, a relationship between contaminant concentrations measured in the sediments and the mortalities observed during the 2007 toxicity tests could not be developed from the data. The lack of a relationship between chemical concentrations and toxicity limited inferences regarding the potential for chemicals at other locations within the streams to adversely affect aquatic communities.

Previous investigations of sediment chemistry have focused on the surface layer of sediments. The surface layer is the layer that is inhabited by benthic organisms, so evaluation of chemical contamination in the surface layer is important for understanding if and how chemical stressors in sediments are affecting biological communities. Because there was about a century of wastewater discharge to the streams prior to the Clean Water Act, there may be chemical contamination in the subsurface sediments as well. Chemicals in subsurface sediments could be exposed and/or transported downstream if erosion occurs in the stream or may move during flood events and sieches; therefore the lack of subsurface sediment data represented a data gap.

Table 1-1 Summary Description of Duck Creek.

Name	Length (a)	Landmarks	Description
Headwaters	Approximately 479 feet from aerial photos	Ravine Park on southwest side of I-280; long basin adjacent to Seaman Road	All that remains of this segment is a narrow basin with no identified connection to downstream. The upstream end of the culvert entering Hecklinger Pond is not visible.
DC-E	Approximately 1,000 feet (length of Hecklinger Pond)	Culvert beneath I-280 to shore of Hecklinger Pond at Burger Street.	An improvement project was undertaken in Hecklinger Pond in July 2007. The water was pumped out; abandoned cars bicycles, tires and other trash were removed; fish were removed and new fish were stocked.
DC-D	4,710 feet	Ravine Park; Toledo water treatment impoundment on East bank. Burger Street to Consaul Street.	Approx. 3,000 ft of cattail wetland; former Consaul landfill cover soil placement in April 2007 approx 1,500 feet of residential property on West bank
DC-C	2,804 feet	Golf Course and Toledo water plant to East. Consaul Street to York Street.	Ditch with several large culverts through a golf course.
DC-B	4,385 feet	Former Refinery, railroad tracks, and landfills. York Street to Millard Avenue.	Channelized, with riparian vegetation
DC-A	5,631 feet	Millard Ave overpass to mouth at Maumee River; Port of Toledo.	Approx. 3,131 feet has meanders and riparian wetlands, and approx. 2,500 feet is a ditch along the East side of Port Authority access road. Lacustrine area influenced by seiches.

(a) SulTRAC 2007 Duck and Otter Creeks Sediment Sampling Report

Table 1-2 Summary Description of Otter Creek.

Name	Length (a)	Landmarks	Description
Headwaters	7,800 feet	Walbridge Road to Wales Road	Ditch along the west side of Tracy Road. Agricultural and industrial land uses on watershed.
OC-E	10,255 feet	Tracy & Wales Roads to Oakdale Ave.; large storm culvert enters at Oakdale Ave.; Railroad crossings (2), Pilkington former plant site ; WMI landfill south of Wales Road	Underground culverts – RR between Tracy RD and Broadway RD.; Broadway RD. to N. of RR ; open ditch south half; mix of undeveloped land and meander creek in north half; tributary from large commercial area joins from southeast.
OC-D	6,188 feet	Woodville Road crossing –Cemetery – Sunoco Refinery	Flows through underground culverts: approx 575 ft from Woodville Rd to Maginnis Road; approximately 1,500 feet beneath Sunoco Refinery; ditch through commercial area from Sunoco Refinery to I-280
OC-C	10,648 feet	I-280 –to Consaul Street/ Corduroy Road.	Stream flows through an underground culvert under I-280; primarily residential land use with some meanders and areas with riparian vegetation.
OC-B	4,693 feet	Toledo Water Plant impoundments; closed Landfills; former Chevron Refinery; Buckeye Pipeline	Linear ditch with steep banks; and some riparian vegetation
OC-A	10,722 feet	Millard Ave overpass to mouth at Maumee Bay; CSX rail yard on West Bank and to east (setback approx. 400 feet); BP Husky Refinery east of CSX rail yard and Otter Creek Road.	Channelized area with riparian vegetation. Lacustrine area influenced by seiches.

(a) SulTRAC 2007 Duck and Otter Creeks Sediment Sampling Report; headwaters length estimated from aerial photographs

1.3 Technical Approach to GLLA Data Gap Investigation

Five specific objectives were identified in the Statement of Work for Great Lakes Legacy Act Data Gap Investigation for Duck and Otter creeks in the Maumee River Area of Concern, Ohio. These objectives formed the basis of the technical approach for this Data Gap Investigation (DGI).

1.3.1 Determining the extent of contamination in both surface and subsurface sediments

Sediment core samples were collected from selected locations and chemical analyses were conducted on 0 to 24-inch, 24 to 48-inch and 48 to 60-inch intervals, depending on availability of depositional material. Surficial sediment chemistry from previous investigations and sediment probing information was used to guide the selection of locations. Some cores were archived for potential future fine sectioning and/or additional chemical analyses.

The list of chemical analyses for subsurface sediments is summarized in Table 1-3, and includes: metals; semivolatile organic compounds (SVOCs); PCBs (i.e., Aroclors); total petroleum hydrocarbons in the gasoline range (C_8-C_{12}), diesel range (C_{10}-C_{28}), and residual range (C_{25}-C_{36}) organics (GRO/DRO/RRO); total organic carbon (TOC); and moisture.

Table 1-3 Summary of Chemical Analyses for Subsurface Sediment Samples.

Analysis	Method	Rationale
Metals	ILM05.4 with Hg, Ca, Mg	Metals exceed conservative benchmarks in surface samples; data are needed to determine vertical extent of contamination.
SVOCs	SOM01.2	SVOCs exceed conservative benchmarks in surface samples; data are needed to determine vertical extent of contamination.
Aroclors	SOM01.2	PCBs exceed conservative benchmarks in surface samples; data are needed to determine vertical extent of contamination.
TPH GRO/DRO/RRO	SW846-8015	Oil and grease have been measured in surface samples; hydrocarbon data are needed to determine vertical extent of contamination.
TOC	SW846 9060	TOC binds organic contaminants; data are used to “normalize” contaminant concentrations.
Moisture		Data are needed to compare these results with other studies.

Surface grab samples were collected from selected locations for chemical analysis. Sample locations were selected based on data from previous investigations to fill identified data gaps. The list of chemical analyses for surface sediments is summarized in Table 1-4, and includes: metals; SVOCs; the 16 priority pollutant Polycyclic Aromatic Hydrocarbons plus 18 alkylated homologues (PAH_{34}); PCBs (Aroclors); GRO/DRO/RRO; acid-volatile sulfide/simultaneously extracted metals (AVS-SEM/foc); TOC; particle size; and moisture. The suite of chemical analyses for the surface sediment grab samples was closely matched with the chemical analyses for the Sediment Quality Triad samples so that relationships developed from the Triad data set can be applied to additional reaches of Duck and Otter Creeks.

Table1-4 Summary of Chemical Analyses for Surficial Sediment Samples from Duck and Otter Creeks.

Analysis	Method	Rationale
Metals	ILM05.4 with Hg, Ca, Mg	Metals exceed conservative benchmarks in surface samples; data are needed to determine vertical extent of contamination.
AVS/SEM	SW846 9071B	This is the bioavailable fraction of divalent metals in sediments; data are needed to apply toxicity test results to additional samples.
SVOCs	SOM01.2	SVOCs exceed conservative benchmarks in surface samples; data are needed to determine vertical extent of contamination.
PAH_{34}	1734.2	PAH concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to apply toxicity test results to additional samples.
Aroclors	SOM01.2	PCBs exceed conservative benchmarks in surface samples; data are needed to determine vertical extent of contamination.
TPH GRO/DRO/RRO	SW846-8015	Oil and grease have been measured in surface samples; hydrocarbon data are needed to determine vertical extent of contamination.
TOC	sw846 9060	TOC binds organic contaminants; data are used to “normalize” contaminant concentrations.
Particle size	ASTM D421/D422	TOC binds organic molecules in sediments; data are needed to apply toxicity test results to additional samples.
Moisture		Data are needed to compare these results with other studies.

1.3.2 Verifying sediment toxicity and identify cause(s), to the extent practicable within the constraints of this data gap investigation

The Sediment Quality Triad (Triad) concept was used as a general framework for the technical approach to verifying toxicity and identifying potential causes of toxicity. The traditional elements of the Triad are sediment chemistry, toxicity, and benthic macroinvertebrate community structure. These combined lines of evidence are used to evaluate the relationship, if any, between chemical stressors, adverse effects in a controlled setting (toxicity), and the quality of the biological communities in the field setting. Bioavailability assessments and habitat quality are also lines of evidence that can be included in a Triad approach. All available lines of evidence are evaluated jointly to determine whether sediment management is likely to improve the biological communities and make progress toward restoring beneficial uses.

For the ‘toxicity’ line of evidence, laboratory bioassays were conducted to determine whether contaminants in sediments from Duck and Otter Creeks are toxic to a standard laboratory test organism. Ten-day exposures with *Chironomus dilutus* were conducted on bulk sediments to determine if exposure affected survival or growth of the organisms. *C. dilutus* is a standard test organism that was sensitive to some sediment samples from Duck and Otter Creeks in the SulTRAC 2007 study.

In addition, for the ‘chemistry’ line of evidence, selected chemicals and physical parameters were measured in bulk sediments and/or pore water extracted from sediments at all toxicity test locations. The list of chemical analyses for surface sediments (where aquatic communities would be exposed to sediments) at Triad locations is summarized in Table 1-6 and includes: metals;

SVOCs; PAH_{34}; PCBs (Aroclors); GRO/DRO/RRO; AVS/SEM; TOC; dissolved organic carbon (DOC); particle size; and moisture.

Based on the lack of a discernable relationship between bulk sediment chemistry and toxicity test results in the SulTRAC 2007 study (Tetra Tech EMI 2008b), analyses of ammonia (in pore water) and pyrethroid pesticides (in bulk sediment) were conducted in the 2010 investigation. If present at sufficient concentrations in sediment, either of these classes of compounds can result in toxicity. Recently, pyrethroid pesticides have been found to be responsible for toxicity of sediments in non-industrialized urban and suburban water bodies around the country (Weston et al. 2005; Amweg et al. 2006; Holmes et al. 2008), and it was plausible that these pesticides might be responsible for toxicity in Duck and/or Otter Creeks.

Analyses of both bulk sediments and pore water were needed for the following reasons:

- Bulk sediment chemistry – As discussed in the Conceptual Site Model (CSM), contaminants that have been discharged into water bodies often bind to suspended particles and are deposited onto the sediments. If sufficient quantities of bioavailable contaminants are present, aquatic life can be harmed, and removal of contaminated sediments may contribute to improvements in biological communities. Bulk sediments have been characterized chemically in previous studies, but significant correlations with toxicity were not found.
- Pore water chemistry - Sediment is a complex matrix that can effectively bind contaminants. Bulk sediment chemistry analyses do not separate the labile component (i.e., the fraction of the chemical in pore water) that can harm biological organisms from the component of contaminants that is not available to cause harm. The labile component of sediment contaminants can be measured by extracting and analyzing pore water from sediment samples. Measurement of contaminant concentrations in pore water represents one of the best possible methods for establishing a relationship between chemical concentrations and adverse effects to aquatic life that can be used for interpretation and decision-making. Water quality criteria for the protection of aquatic life can be used as a screening tool to evaluate pore water chemistry for many contaminants, which may assist in identification of the contaminants, if any, that are contributing to adverse effects.

Representing the ‘benthic community’ line of evidence in the Triad, biological community metrics were used to evaluate the quality of the benthic macroinvertebrate communities. Macroinvertebrate community quality was evaluated using tolerance and diversity metrics that are applied in the USEPA Rapid Bioassessment Protocol (RBP). The macroinvertebrate community sampling methods applied in this data gap investigation were based on the qualitative OEPA methods (OEPA 2010a); but multiple transects and consistent sampling efforts for each transect were used to provide a more quantitative assessment than is typically conducted with kick nets and D-nets.

Table 1-5 Summary Table of Surface Sample Chemical Analyses for Sediment Quality Triad Locations.

Analysis	Bulk sediment	Pore water	Rationale
Metals	√	√	Metals concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to interpret toxicity test results. Bulk sediment analyses are needed to apply Sediment Quality Triad results to sample locations where only bulk sediment chemistry has been measured.
AVS/SEM	√	-	This is the bioavailable fraction of divalent metals in sediments; data are critical for toxicity test interpretation (USEPA 2005).
SVOCs	√	-	SVOC concentrations in sediments exceed conservative screening benchmarks (ChemRisk 1999). SVOC results will be interpreted using equilibrium partitioning methods (USEPA 2008).
PAH_{34}	√	√	PAH concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to interpret toxicity test results (USEPA 2003, Hawthorne et al. 2005). Bulk sediment analyses are needed to apply Sediment Quality Triad results to sample locations where only bulk sediment chemistry has been measured.
Aroclors	√	-	PCB concentrations in sediments exceed conservative screening benchmarks; data are needed to interpret toxicity test results. Aroclor results will be interpreted using equilibrium partitioning methods (Fuchsman et al. 2006, USEPA 2008).
GRO/DRO/RRO	√	-	More informative for source identification than “Oil and Grease” analyses conducted in previous investigations. Information from USEPA may be useful for interpreting toxicity results (Mount et al. 2009)
TOC	√	-	TOC binds organic molecules in sediments; data are needed to interpret toxicity test results.
DOC	-	√	DOC binds metals and some organics in pore water; data are needed to interpret toxicity test results.
Hardness	-	√	Hardness competes with metals for uptake channels in gills; data are needed to interpret toxicity test results.
pH	-	√	pH controls metals solubility and precipitation and ammonia ionization; data are needed to interpret toxicity tests
Ammonia	-	√	Ammonia can be a source of toxicity in sediments; data are needed to interpret toxicity test results.
Particle size	√	-	Particle size can affect contaminant bioavailability and invertebrate survival; data needed for toxicity test interpretation.
Moisture	√	-	Used to compare data on a dry weight basis. Moisture can also be used interpret the bioavailability of less-hydrophobic organic compounds such as methylphenols (Fuchsman 2003, USEPA 2008).
Pyrethroid pesticides	√	-	Pyrethroid pesticides have been identified as a significant sediment toxicant in urban areas (Holmes et al. 2008).

1.3.3 Evaluating whether sediment contaminants are bioaccumulating in benthic invertebrates and fish at levels likely to contribute significantly to the degradation of benthos and fish populations

As a direct measure of bioaccumulation, chemical analyses of whole fish and benthic macroinvertebrates were conducted to quantify the bioaccumulation of contaminants in the aquatic biota of Duck and Otter Creeks. These tissue data were needed to verify the validity of the 2008 Tetra Tech Ecological Risk Assessment (2008b) which used sediment-to-biota accumulation factors (BSAFs) from other studies to estimate the concentrations of chemicals in the biota of Duck and Otter Creeks. Site-specific tissue data are necessary for a more accurate evaluation of the potential for contaminants to adversely affect the organisms or their predators. Fish and benthic macroinvertebrates were collected from selected locations in Duck and Otter Creeks and analyzed for: metals, PCBs (Aroclors), PAH_{34} and lipid content (Table 1-6).

Because not all contaminants that may affect biota accumulate in tissue, it is important that assessments of effects on biota consider bioavailability in addition to bioaccumulation. Contaminant bioavailability was estimated using chemical extractions of sediments (e.g. pore water, SEM/AVS) that may provide better estimates of biological dose than either tissue chemistry or bulk sediment chemistry. As discussed above in the Triad section, pore water is considered to be the primary route of toxicological exposure for several classes of chemical stressors, including: metals (Di Toro et al. 2005), PAH_{34} (Di Toro et al. 2000a; USEPA 2003; Hawthorne et al. 2005), SVOCs (Di Toro et al. 2000b; USEPA 2004), and pyrethroid pesticides (Holmes et al. 2008). Therefore, the concentration of chemicals in sediment pore water may be a better surrogate of the concentration at the site of action (i.e., the dose to which the organism is exposed).

Table 1-6 Summary of Chemical Analyses for biota tissue samples that will be used to determine site-specific bioaccumulation.

Analysis	Method	Rationale
Metals	ILM05.4 - with Hg	Some metals in sediments can be accumulated by biota Tissue data can be interpreted based on residue-effects information from the literature to estimate the likelihood of adverse effects on fish and invertebrates. In addition, tissue data could support future evaluations of wildlife and potential human exposures.
PAH_{34}	1734.2	PAHs are organic molecules that can be accumulated and metabolized by aquatic life. Tissue data can be interpreted based on residue-effects information from the literature to estimate the likelihood of adverse effects on fish and invertebrates. In addition, tissue data could support future evaluations of wildlife and potential human exposures.
Aroclors	SOM01.2	PCBs are persistent organic compounds that can biomagnify in aquatic ecosystems. Tissue data can be interpreted based on residue-effects information from the literature to estimate the likelihood of adverse effects on fish and invertebrates. In addition, tissue data could support future evaluations of wildlife and potential human exposures.
Lipid content	Gravimetric	Organic molecules tend to partition into, and can be transferred through the food web with lipids. Lipid content can also be useful for estimating accumulation factors for other species or stream areas.

Arsenic was identified as a risk driver by Tetra Tech EMI (2008) for adult and child exposure to sediments in both Duck and Otter Creeks, based on an assumption that 100% of the arsenic in the sediment was bioavailable. However, bioavailability of arsenic from incidentally ingested sediment is highly dependent upon the solid matrix and, therefore can vary widely from site to site. An accurate evaluation of the sediment ingestion pathway requires a determination of how much of the contaminants are available for absorption from the human gastrointestinal tract into systemic circulation (e.g., blood). Traditionally, this absorption has been achieved using an *in vivo* method such as a swine feeding trial. However, an *in-vitro* method using simulated gastrointestinal fluids (IVG) has been developed to estimate the potentially bioavailable arsenic by quantifying the fraction of the ingested arsenic released from the environmental matrix that is available for absorption in the human gastrointestinal (GI) tract (i.e., the fraction defined as 'bioaccessible"). The IVG analysis (Rodriguez et al 1999) is analogous to the evaluation that will be conducted to estimate the contaminants that are available to biological organisms in which the pore water concentrations of contaminants are used to estimate the labile component of contaminants that may cause adverse effects to aquatic life.

1.3.4 Evaluating habitat resources

As discussed in the CSM, Duck and Otter Creeks were greatly modified a century ago by the conversion to ditches to drain the Great Black Swamp. Habitat quality has been evaluated at two scales of analysis:

- In-stream habitat quality was evaluated at each of the Triad sampling locations using measurements and metrics consistent with the Ohio Qualitative Habitat Evaluation Index (QHEI) methodology.
- Watershed quality was evaluated by reviewing land cover and land use information, surface permeability, the presence of storm water outfalls, aerial photo review, field notes and other sources of information.

1.3.5 Collecting data to support development of a feasibility study (evaluation of remedial and restoration options to protect human health and the environment), if one is found to be necessary, and to advance progress toward delisting of beneficial use impairments.

- The Triad (chemistry, toxicity, community structure) and QHEI data were collected at the same locations to facilitate the evaluation of whether sediment contamination and/or habitat modification are key factors that contribute to impaired aquatic communities.
- Comparisons regarding the structure of biological communities, chemical concentrations in sediment and pore water, and habitat quality were made between study streams and urban comparison streams. These comparisons provide supplemental information for evaluating impacts of urban conditions in the area. The process that was used to select Amlosch Ditch and Grassy Creek as the urban comparison streams for this study is recorded in Appendix A.
- Measures of the bioavailability (e.g. AVS/SEM/foc, pore water, equilibrium partitioning, tissue chemistry, IVG, etc.) were used to identify which contaminants are biologically available.
- Arsenic bioaccessibility measurements were used to support evaluation of exposure pathways, if any, for local residents, in the event that remedial approaches are evaluated that involve leaving sediments in place.
- Supplemental core samples were collected from several of the DGI locations and have been archived for possible additional future analyses.

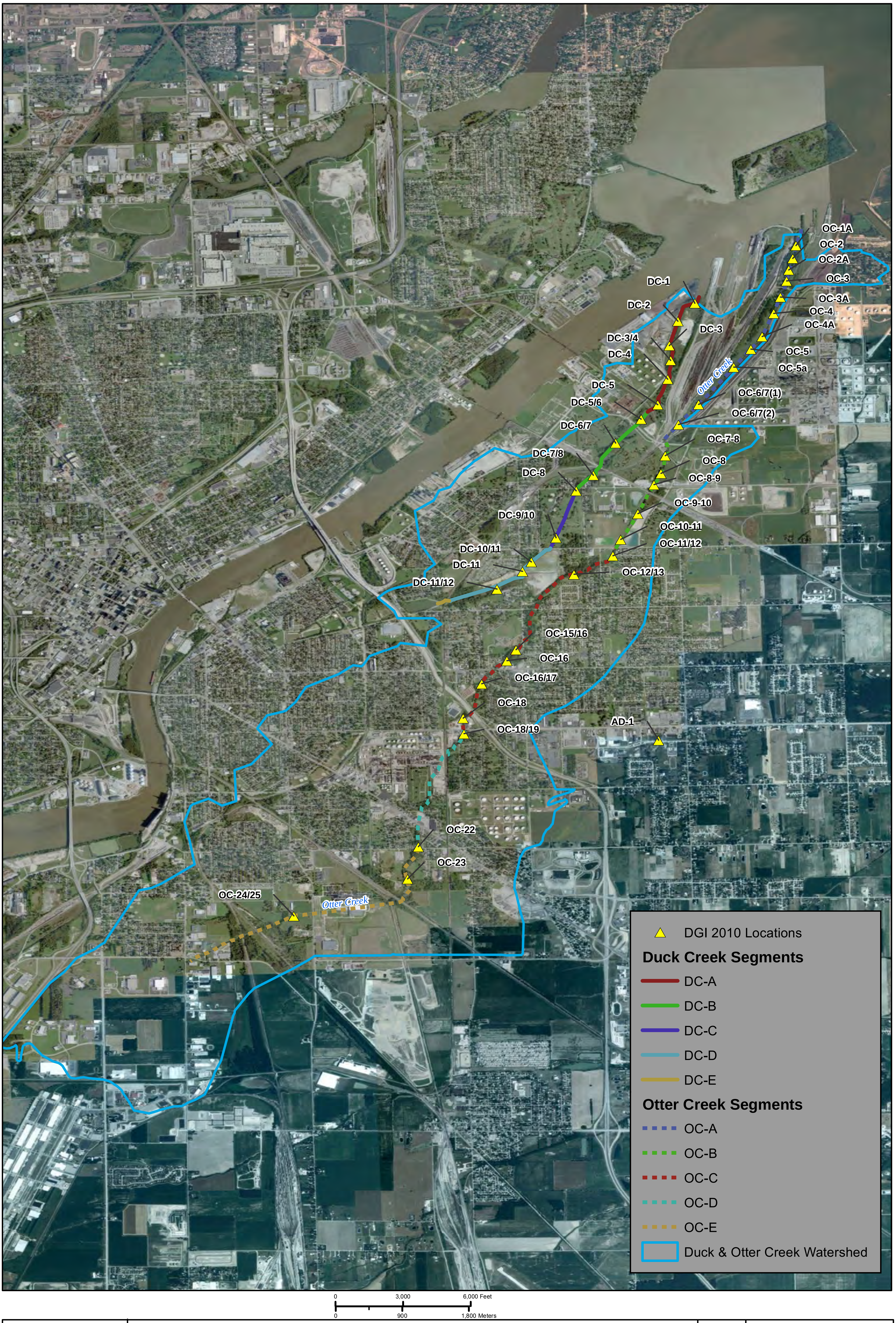

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Figure 1-1 Duck and Otter Creeks Study Area

Duck and Otter Creek
Lucas County, Ohio

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Figure 1-2 Duck Creek Segment A

Duck & Otter Creek
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Figure 1-3 Duck Creek Segment B

Duck & Otter Creek
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Figure 1-4 Duck Creek Segment C

Duck & Otter Creek
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Figure 1-5 Duck Creek Segment D & E

Duck & Otter Creek
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Figure 1-6 Otter Creek Segment A

Duck & Otter Creek
Lucas County, Ohio

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Figure 1-7 Otter Creek Segment B

Duck & Otter Creek
Lucas County, Ohio

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Figure 1-8 Otter Creek Segment C

Duck & Otter Creek
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Figure 1-9 Otter Creek Segment D

Duck & Otter Creek
Lucas County, Ohio

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Figure 1-10 Otter Creek Segment E

Duck & Otter Creek
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Chapter 2

Methods

A complete description of the methods for this DGI is presented in the *Quality Assurance Project Plan, Duck & Otter Creeks 2010 Data Gap Investigation, Wood and Lucas Counties, Ohio* (Weston Solutions 2010). Summaries of the main elements of the DGI are presented in this section.

2.1 Sample Locations

A summary of the 2010 data gap investigation sample locations and analyses for Duck and Otter Creeks and the urban comparison streams is presented in Table 2-1.

2.2 Sediment Sample Collection

Sediment core samples were collected using Lexan tubing, driven to the depth of refusal or five feet (whichever was encountered first) by delivering surface blows. Sampling was conducted from downstream to upstream. Samples were collected within the clear plastic tube liners, retrieved, and capped with plastic end caps. The field procedure was as follows:

- Sample points were located with the GPS and the water depth was measured using an echo-sounder or specialized measuring tape.
- A sediment probe was used to determine the depth of penetrable sediments.
- Sediment samples were collected at intervals stated in the plan, when the available sediment thickness permitted.
- Sediment cores were processed and sub-sampled in accordance with the sampling and analysis program outlined in Sections 2 and 7 of the Field Sampling Plan (Weston 2010). Qualitative sediment information such as sediment type, color, etc. was recorded on the appropriate field log. Sediments from the cores were transferred to a stainless steel pan, homogenized, and transferred to the appropriate sample jar. Homogenizing samples by hand mixing was accomplished by dividing the sample into quarters, mixing opposite quarters, and then mixing the remaining halves.
- Excess sediment was returned to the water body at the point of collection.
- All reusable sampling equipment was decontaminated between each sample in accordance with procedures outlined in Subsection 3.4.
- Duplicate samples were collected at a 10% frequency following the procedures outlined in Section 4.1 and Section 4.2. of the Quality Assurance Project Plan (QAPP) (Weston 2010).
- All samples were placed immediately in a cooler on wet ice (frozen water).

					Sediment Quality Triad Analyses										
river segment	river mile	**2010 DGI Sample Location**	x coord	y coord	QHEI	sediment toxicity	benthic invertebrate community	pore water chemistry	(SEM-AVS)/foc	chemistry on surface sediment "grab" sample	invertebrate tissue chemistry	fish tissue chemistry	As bioaccessibility	particle size distribution	chemistry on sediment core samples
DC-A	0.07	**DC-1**	-83.466109	41.688459											X
DC-A	0.30	**DC-2**	-83.468171	41.686288									X		X
DC-A	0.51	**DC-3**	-83.469238	41.683313	X	X	X	X	X	X		X		X	X
DC-A	0.66	**DC-3/4**	-83.469064	41.681534					X	X				X	X
DC-A	0.85	**DC-4**	-83.469430	41.679240					X	X				X	X
DC-A	1.09	**DC-5**	-83.470627	41.676134	X	X	X	X	X	X	X			X	X
DC-B	1.27	**DC-5/6**	-83.472656	41.674362					X	X				X	
DC-B	1.63	**DC-6/7**	-83.475763	41.671482	X	X	X	X	X	X				X	
DC-B	1.97	**DC-7/8**	-83.478443	41.667542					X	X				X	
DC-C	2.14	**DC-8**	-83.480536	41.665667											X
DC-C	2.53	**DC-9/10**	-83.483001	41.659964					X	X				X	
DC-D	2.85	**DC-10/11**	-83.485999	41.657027					X	X				X	
DC-D	2.97	**DC-11**	-83.487066	41.655887								X	X		X
DC-D	3.23	**DC-11/12**	-83.490185	41.653709		X		X	X	X	X			X	
OC-A	0.15	**OC-1A**	-83.453813	41.695493					X	X				X	X
OC-A	0.21	**OC-2**	-83.454218	41.693934									X		X
OC-A	0.38	**OC-2A**	-83.454716	41.692516					X	X				X	X
OC-A	0.42	**OC-3**	-83.454962	41.691196											X
OC-A	0.57	**OC-3A**	-83.455704	41.689224					X	X				X	X
OC-A	0.73	**OC-4**	-83.456536	41.687237	X	X	X	X	X	X	X	X		X	X
OC-A	1.00	**OC-4A**	-83.457932	41.684414					X	X				X	X
OC-A	1.15	**OC-5**	-83.459289	41.682876											X
OC-A	1.35	**OC-5A**	-83.461392	41.680692		X	X	X	X	X	X			X	X
OC-A	1.80	**OC-6/7(1)**	-83.465650	41.676172					X	X				X	X
OC-A	2.04	**OC-6/7(2)**	-83.468122	41.673738	X	X	X	X	X	X				X	X
OC-B	2.44	**OC-7-8**	-83.469713	41.669945					X	X				X	
OC-B	2.55	**OC-8**	-83.470243	41.667770											X
OC-B	2.66	**OC-8-9**	-83.471089	41.666426					X	X				X	
OC-B	2.96	**OC-9-10**	-83.473031	41.662890	X	X	X	X	X	X				X	
OC-B	3.22	**OC-10-11**	-83.475116	41.659771					X	X				X	
OC-C	3.37	**OC-11/12**	-83.476080	41.657779					X	X				X	
OC-C	3.76	**OC-12/13**	-83.480800	41.655507	X	X	X	X	X	X	X			X	
OC-C	4.57	**OC-15/16**	-83.487861	41.646351					X	X		X	X	X	
OC-C	4.69	**OC-16**	-83.488978	41.645025	X	X	X	X	X	X	X		X	X	
OC-C	4.96	**OC-16/17**	-83.492021	41.642215					X	X				X	
OC-C	5.34	**OC-18**	-83.494297	41.638041											X
OC-D	5.44	**OC-18/19**	-83.494194	41.636138					X	X				X	
OC-D	6.60	**OC-22**	-83.499739	41.622397	X	X	X	X	X	X			X	X	
OC-E	6.90	**OC-23**	-83.501048	41.618468											X
OC-E	7.82	**OC-24/25**	-83.514857	41.613992	X	X	X	X	X	X			X	X	
Amlosch	5.00	**AD-1**	-83.470517	41.635336	X	X	X	X	X	X	X			X	
Grassy	8.20	**GC-1**	-83.621853	41.552728	X	X	X	X	X	X	X			X	

2.3 Sediment Pore Water Generation

Sediment pore water was collected for chemical analysis on a subset of the sediment samples (see Section 2.2 above for sampling methods) as part of the Sediment Quality Triad. A total of 14 samples were collected (see Tables 2-1 through 2-3) as sediment, centrifuged at the laboratory, and analyzed for metals, 34 PAH (following alum treatment to precipitate colloids and adsorption onto a solid-phase microextraction (SPME) column), DOC, hardness, pH, and ammonia.

2.4 Benthic Macroinvertebrate Community Structure

To allow verification and future monitoring studies, the coordinates of each cross-creek transect were recorded at the West bank of the creek (unless otherwise noted) using a Trimble ProXRS, sub-meter accurate GPS.

Qualitative sampling

Qualitative sampling was used to develop a general understanding of the invertebrate community that exists within the vicinity of each of the 13 stations. Qualitative sampling was conducted utilizing methods described in the USEPA's Rapid Bioassessment Protocols. Using the USEPA's Multi-habitat Approach, benthic macroinvertebrates were collected by an aquatic entomologist from all available instream habitats along a 50 meter sampling reach, by "kicking" or "jabbing" the substrate with a pole mounted D-frame dip net (12" wide; 500µ mesh).

Semi-quantitative Sampling

Semi-quantitative sampling was used to develop specific benthic metric data of the invertebrate community that exists at each of the 13 sample stations. At each of the 13 sampling sites (see Tables 2-1 through 2-3), collection of the invertebrates was conducted at 4 cross-creek transects located at 5 meter intervals, with one transect approximately coinciding with the location of the sediment sampling site. The combination of 4 transverse and one longitudinal sampling transects ensured that all available instream habitat features were represented, and that aggregated data from these 5 transects accurately represented the benthic macroinvertebrate community.

Collection Sorting

After collection, the benthic macroinvertebrate samples were "sorted" to remove debris and sediments. Sorting of the collected samples was performed by an aquatic technician under the direct supervision of an aquatic entomologist. The sorted sample was transferred to a clean sample container and preserved in a sufficient amount of 95% ethanol to cover the sample. Sample containers were labeled (with labels both inside and outside) to provide sample identification code number, date, stream name, sampling location, collector name, and the words "preserved in 95% ethanol."

Benthic Macroinvertebrate Identification

The aquatic entomologist performed the identification of the collected benthic macroinvertebrates to taxonomic levels in accordance with recognized protocols and consistent with selected Ohio EPA published metrics. The minimum levels of taxonomic identification for the collected benthic macroinvertebrates are summarized in Table 2-2.

Table 2-2 Taxonomic resolution used to characterize the benthic macroinvertebrate communities in Duck Otter and Grassy Creeks and Amlosch Ditch.

Phylum	Class	Order	Family	Genus
Arthropoda	Insecta	Ephemeroptera	X	X
		Trichoptera	X	
		Plecoptera	X	
		Coleoptera	X	
		Diptera	X	
		Odonata	X	
		Hemiptera	X	
		Megaloptera	X	
	Crustacea	Decapoda		
		Amphipoda		
		Isopoda		
Annelida	Oligochaeta			
Mollusca	Gastropoda			
	Pelecypoda			

Taxonomic identification of the collected invertebrates was performed utilizing dissecting and compound microscopes, as well as recognized taxonomic “keys”. Each taxon found in the samples was recorded and enumerated in a laboratory bench notebook and then transcribed to the laboratory bench sheet for subsequent reports. Labels with specific taxa names (initialed by the taxonomist) were added to the vials of specimens by the taxonomist. The identity and number of organisms were recorded on the Laboratory Bench Sheet. Either a tally counter or “slash” marks on the bench sheet were used to keep track of the cumulative count. Also, the life stage of the organisms, the taxonomist’s initials, and the Taxonomic Certainty Rating (TCR) as a measure of confidence were recorded.

For archiving samples, specimen vials (grouped by sampling station and date) were placed in jars with a small amount of denatured 70% ethanol and tightly capped. The ethanol level in these jars was examined periodically and replenished as needed. A stick-on label was placed on the outside of the jar indicating sample identifier, date, and preservative (denatured 70% ethanol).

Quality Control Specimen Vouchers

In accordance with USEPA’s *Rapid Bioassessment Protocols*, a *voucher collection of all samples and subsamples* were *maintained. These specimens* have been *labeled, preserved, and stored in the laboratory for future reference.*

2.5 Habitat Quality

For the in-stream evaluation of aquatic habitats, Cardno ENTRIX field biologists utilized the OEPA QHEI procedure (OEPA 2006) to determine habitat quality scores at three locations on Duck Creek, seven locations on Otter Creek and one locations on each local urban comparison stream (Amlosch Ditch and Grassy Creek) located in non-industrial areas. Specifically, QHEI scoring was performed at each location where the sediment quality triad assessment (benthic invertebrate community assessment, sediment toxicity testing and sediment chemistry analyses) was conducted pursuant to the GLLA Data Gap Investigation Work Plan (Weston 2010).

The standardized QHEI procedure (OEPA 2006) was used to ensure that habitat evaluations were consistent among sample stations. A single team of experienced stream ecologists conducted all of the QHEI assessments to avoid differences in the application of the procedure, and ensure consistency among the sample stations.

The QHEI is composed of 6 principal metrics, each of which is described below. The maximum possible QHEI score for a station is 100. Each of the metrics is scored individually and then the scores for all metrics are summed to provide the total QHEI station score. Standardized definitions for pool, run, and riffle habitats, for which a variety of existing definitions and perceptions exist, was essential for accurately using the QHEI. For consistency, pool, run, and riffle definitions were each taken from Platts et al. (1983). When accessible, the assessment was conducted over a 200 meter reach of stream. At two stations, access to the stream channel was limited, so shorter reaches (195 m and 125 m) were evaluated. The QHEI assessments were conducted from September 27, 2010 through September 30, 2010. The six metrics evaluated in the QHEI include:

- <u>Metric 1 Substrate</u>: This metric has three components, including: substrate type, substrate origin, and substrate quality;
- <u>Metric 2 Instream Cover</u>: This metric evaluates the presence of instream cover types and amount of overall cover within the stream channel for use by fish and aquatic macroinvertebrate species;
- <u>Metric 3 Channel Morphology</u>: This metric emphasizes the quality of the stream channel that relates to the creation and stability of macrohabitat. It includes channel sinuosity (i.e. the degree to which the stream meanders), channel development, channelization, and channel stability;
- <u>Metric 4 Bank Erosion and Riparian Zone</u>: This metric emphasizes the quality of the riparian buffer zone and quality of the floodplain vegetation. This metric includes riparian zone width, floodplain quality, and the extent of bank erosion;
- <u>Metric 5 Pool/Glide and Riffle/Run Quality</u>: This metric emphasizes the quality of the pool, glide and/or riffle/run. The following are definitions for “pool,” “glide,” “riffle,” and “run” taken from Platts et al. (1983). This also includes maximum pool depth, overall diversity of current velocities (in pools and riffles), channel width, riffle-run depth, riffle-run substrate quality, and riffle-run substrate embeddedness.

- Pool: an area of a stream with slow current velocity and a depth greater than riffle and run areas; the stream bed is often concave and stream width frequently is the greatest; the water surface slope is nearly zero.
- Glide: this is an area common to most modified stream channels that do not have distinguishable pool, run, and riffle habitats; the current and flow is similar to that of a canal; the water surface gradient is nearly zero.
- Riffle: areas of a stream with fast current velocity and shallow depth; the water surface is visibly broken.
- Run: areas of a stream that have a rapid, non-turbulent flow; runs are deeper than riffles with a faster current velocity than pools and are generally located downstream from riffles where the stream narrows; the stream bed is often flat beneath a run and the water surface is not visibly broken.

- Metric 6 Map Gradient and Drainage Area: Local or map gradient is calculated from United States Geological Survey (USGS) 7.5 minute topographic maps by measuring the elevation drop through the sampling area. This gradient calculation is conducted by measuring the stream length between the first contour line upstream and the first contour line downstream of the sampling site and dividing the distance by the height of the contour interval.

General narrative ranges were assigned to final QHEI scores consistent with OEPA guidance (OEPA 2006). Ranges vary slightly in headwater streams (< 20 sq mi) as compared with larger streams and rivers (Table 2-3). The streams evaluated in the GLLA data gap investigation were all headwater streams with small watersheds, so the headwater scores apply to this document.

Table 2-3 Range of possible QHEI scores and associated narrative descriptions.

Narrative Description of Stream Habitat Quality	Headwater Stream Scores	Larger Stream Scores
Excellent	≥ 70	≥ 75
Good	55 to 69	60 to 74
Fair	43 to 54	45 to 59
Poor	30 to 42	30 to 44
Very Poor	≤ 29	≤ 29

In addition to the in-stream habitat evaluation, Cardno ENTRIX conducted a geographic analysis of the riparian zones and watershed of Duck and Otter Creeks. The watershed analysis was conducted using a geographic information system (GIS), and included an evaluation of three categories of spatial data:

- Stormwater utility information was obtained from the City of Oregon, Ohio to determine the locations of stormwater outfalls to Duck and Otter Creeks. Stormwater outfalls have the potential to transport contaminants from sources that are somewhat remote from the riparian zone. Stormwater outfalls can also deliver large volumes of water that dramatically alter the hydrology of the stream and affect the quality of the stream habitat, sediments and biological communities.

- The National Land Cover (NCLD) Dataset from 2006 was acquired for Lucas and Wood Counties. Land use in the riparian zone was tabulated at three different scales: 5 meters, 100 meters, and 250 meters to evaluate land uses adjacent to the stream banks. Land use was also tabulated for the combined topographic watershed of Duck and Otter Creeks. Land use affects stream ecology by affecting nutrient inputs, hydrology and thermal regimens. Some land uses also can contribute eroded soils and chemical contaminants to streams.
- The amount of impervious surface was provided by the 2006 NCLD. The USGS developed the imperviousness algorithms in 2001 using imperviousness threshold values of: developed open space (imperviousness < 20%); low-intensity developed (imperviousness from 20 - 49%); medium intensity developed (imperviousness from 50 -79%); and, high-intensity developed (imperviousness > 79%), and re-tested the national map with the NCLD 2006 dataset. The amount of impervious surface on the watershed and within the riparian zone can dramatically affect stream hydrology. Large amounts of impervious surface will decrease infiltration and can decrease base flows in the stream. During rain events, impervious surfaces transmit water to streams, especially in landscapes such as Lucas and Wood Counties where stormwater drains are abundant, and increase peak flows, which can result in erosion, scouring and displacement of aquatic biota.

2.6 Benthic Macroinvertebrate Tissue Sample Collection

A total of eight benthic macroinvertebrate samples (four from Otter Creek, two from Duck Creek, and one from each comparison stream) were collected for the project. The specific species that were collected for tissue analysis was not recorded. However, the list of species that were identified at each station as part of the (separate) benthic invertebrate community analysis is documented in Appendix B. Chemical analyses of tissues (summarized above in Table 1-6) were conducted to determine if and how much of the sediment contaminants in Duck and Otter Creek are present in the aquatic organisms that live in these streams.

2.7 Fish Tissue Sample Collection

Fish tissue sample data collected by U.S. Fish and Wildlife Service on Duck and Otter Creeks was provided to the GLNPO and the Industrial Partners for use in evaluating bioaccumulation of contaminants. The Industrial Partners also split fish tissue samples and obtained their own fish tissue data. The fish collection effort and the selection of samples for chemical analyses were documented in a memorandum (Kubitz and Matousek 2010, Appendix N) and are summarized as follows. Fish were collected August 24-25, 2010 from Duck and Otter Creeks by the USFWS and Cardno ENTRIX using boat electroshocking and trap nets through entire stream segments (see Figures 1-1 through 1-10). Fish were sorted by species and size to obtain the most consistent samples possible. Four samples of small whole fish were selected by Cardno ENTRIX for tissue analyses. Small fish tend to have smaller home ranges than large fish, which gives them greater fidelity for a particular location. This high site fidelity of small fish was desirable for assessing the uptake of contaminants from sediments such as metals, PCBs, and PAHs. The four fish tissue samples selected for the DGI were:

- A composite sample of whole log perch (FWS1626-OCA-LP1-C) from Otter Creek segment A;
- A composite sample of whole log perch (FWS1632-DCA-LP-1-C93) from Duck Creek segment A;
- A composite sample of whole creek chubs (FWS1626-OCC-CCH2-C8) from Otter Creek segment C; and
- A composite sample of whole creek chubs (FWS1590-DCD-CCH1-C) from Duck Creek segment D.

2.8 Sediment Toxicity Tests

Sediment samples collected as part of the Sediment Quality Triad were also subjected to 10-day bulk sediment toxicity testing using *Chironomus dilutus*. The U.S. Army Corp of Engineers (USACE) Engineering Research and Development Center (ERDC) located in Vicksburg, Mississippi performed the 10-day whole sediment toxicity testing using Method 100.4 and 100.2 as detailed in *Methods for Measuring Toxicity and Bioaccumulation of Associated Contaminants in Freshwater Invertebrates* (USEPA 2000).

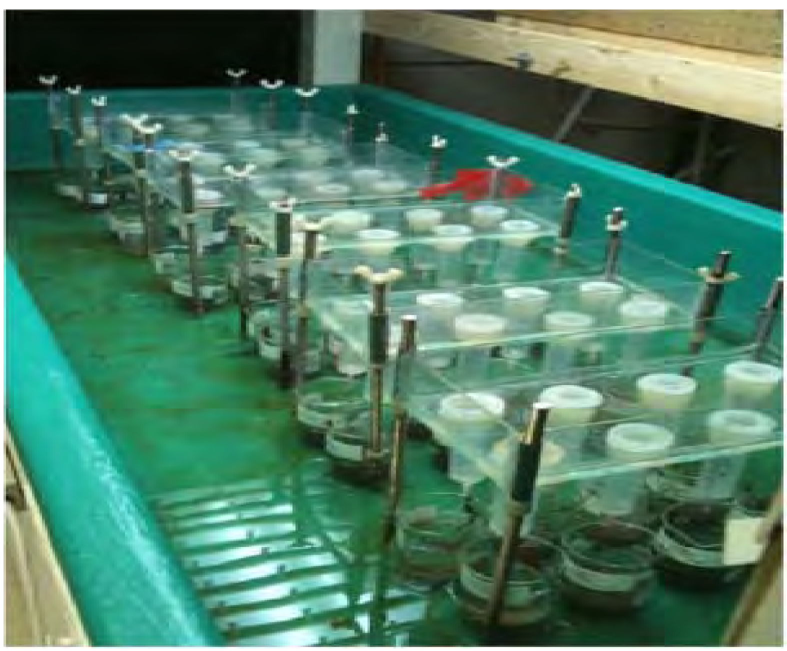


Figure 2-1 Sediment Toxicity Test Exposure System at ERDC Laboratory.

2.9 Chemical Analyses

The chemical analyses that were employed for the Sediment Quality Triad are summarized in Table 2-4 along with the rationale for each measurement.

Table 2-4 Chemical analyses for surface sediment samples and the rationale for each measurement used in support of the Sediment Quality Triad evaluation for Duck and Otter Creeks.

Type	Analysis	Method	Rationale
Surface Sediment	Metals	C200.7	Metals concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to apply toxicity test results to additional samples.
Surface Sediment	AVS/SEM	SW846-6010	This is the bioavailable fraction of divalent metals in sediments; data are needed to apply toxicity test results to additional samples.
Surface Sediment	SVOCs	SOM01.2	SVOC concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to apply toxicity test results to additional samples.
Surface Sediment	PAH_{34}	1734.2	PAH concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to apply toxicity test results to additional samples.
Surface Sediment	Aroclors	SOM01.2	PCB concentrations in sediments exceed conservative screening benchmarks; data are needed to apply toxicity test results to additional samples.
Surface Sediment	GRO/DRO/ORO	SW846-8015	More informative for source identification than "Oil and Grease" analyses conducted in previous investigations.
Surface Sediment	TOC	Lloyd Khan	TOC binds organic molecules in sediments; data are needed to apply toxicity test results to additional samples.
Surface Sediment	Particle size distribution	ASTM D421/D422	TOC binds organic molecules in sediments; data are needed to apply toxicity test results to additional samples.
Surface Sediment	Moisture	E160.3	Data are needed to compare these results with other studies.
Surface Sediment	Pyrethroid Pesticides	GC-MS/MS NCI SIM	Pyrethroid pesticides have been identified as a significant sediment toxicant in urban areas (Holmes et al. 2008).
Surface Sediment	10-day Bulk Sediment Toxicity Testing	Method 100.4 and 100.2 (U.S. EPA 200)	C. dilutus is a standard test organism that has been sensitive to some sediment samples from Duck and Otter Creeks in the SulTRAC 2007 study.
Pore Water	Metals	Method C200.7	Metals concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to interpret toxicity test results. Bulk sediment analyses are needed to apply Sediment Quality Triad results to sample locations where only bulk sediment chemistry has been measured.
Pore Water	34 PAHs	ASTM D 7363-07; Hawthorne et. al. 2005; SPME	PAH concentrations in sediments exceed conservative screening benchmarks; data, especially in pore water, are needed to interpret toxicity test results (USEPA 2003, Hawthorne et al. 2005). Bulk sediment analyses are needed to apply Sediment Quality Triad results to sample locations where only bulk sediment chemistry has been measured.
Pore Water	DOC	9060A/5310C	DOC binds metals and some organics in pore water; data are needed to interpret toxicity test results.
Pore Water	Hardness	2340C	Hardness competes with metals for uptake channels in gills; data are needed to interpret toxicity test results.
Pore Water	pH	150	pH controls metals solubility and precipitation and ammonia ionization; data are needed to interpret toxicity tests

Table 2-4 Chemical analyses for surface sediment samples and the rationale for each measurement used in support of the Sediment Quality Triad evaluation for Duck and Otter Creeks.

Type	Analysis	Method	Rationale
Pore Water	Ammonia	350.1	Ammonia can be a source of toxicity in sediments; data are needed to interpret toxicity test results.
Sediment	Arsenic bioavailability	OSU IVG 2007	Arsenic concentrations in soil/sediment were previously identified as a concern. Analyses conducted for a subset of stations.

In addition to the analyses conducted by the GLNPO contractors, the Duck and Otter Creek Industrial Partners received split samples of four fish tissues from the USFWS and contracted Columbia Analytical Services (CAS) to conduct the following chemical analyses: PCBs and PCB congeners by Method SW846-8082; PAHs by Method Sw846-8270SIM; metals by Method SW846-6020; lipids and moisture content.

2.10 Data Validation

All data generated in field and laboratory activities were reduced, reviewed and validated prior to reporting. No data were disseminated by the laboratory until they have been subjected to the procedures, which are summarized below.

Data Reduction and Review

Raw data from any field measurements and sample collection activities were appropriately recorded in the site logbook. If the data were used in the project reports, they were reduced and summarized, and the method of reduction were documented in the report. Laboratory data reduction procedures were in accordance with the requirements of the CLP SOM01.2 for SVOCs, sediment PAHs (extended list), and PCBs; and ILM05.4 for metals.

Laboratory data reduction procedures were in accordance with the requirements of the appropriate laboratory Standard Operating Procedures (SOPs) for PAHs (extended list and standard), PCBs, DRO/ORO/GRO, TOC, AVS/SEM, pyrethroid pesticides, ammonia, pH, hardness, DOC, lipids, toxicity, and grain size. For each of the laboratory methods, the Laboratory Project Manager completed a thorough inspection of all reports prior to release of the data. Following review and approval of the preliminary report by the Laboratory Project Manager, final reports were generated and signed by the Laboratory Project Manager.

Data Validation

Weston completed the data validation for all the analyses conducted by the Contract Laboratory Program (CLP) (sediment SVOCs, extended list PAHs, PCBs, and metals). Weston also completed data validation for all of the analysis conducted by the WESTON - procured subcontractor laboratories. Completeness was evaluated by auditing the data package for:

- Chain-of-Custody records.
- Technical holding times.

- Required analytical methods.
- Reporting limits.
- Reporting format.
- Laboratory and field Quality Control (QC) reporting forms (blanks, surrogates, laboratory control samples (LCSs), duplicates, matrix spikes (MSs), etc., as appropriate).
- Appropriate supporting data.
- Case narrative.
- Completeness of results.
- Data usability [compliance with project Data Quality Objectives (DQOs)].

Details of any missing, incomplete or incorrect parts of the data packages were stamped "Resubmitted on [date]", attached to the original data package, and returned to the analytical laboratory.

Validation and Verification Methods

Upon receipt of the CLP data, Weston conducted a compliance check to ensure that all quality control components (field quality control samples, etc) were properly evaluated and that the data met the project DQOs. Data were received in one of several acceptable electronic formats. In addition, a CLP-like data package (hardcopy or complete PDF) was received with each electronic data set (EDD). Data that were received from a subcontracted laboratory in a CLP-like data package (complete package with raw data, narrative, and quality control data), with the EDD were manually validated by Weston, independently of the Weston Project Manager. Weston completed the QA/QC checklist for each parameter, and prepared an overall data narrative summary that described any laboratory quality control, data usability , completeness, and any other issues pertaining to the project DQOs. Weston performed a manual data review of 5% of data packages for the CLP parameters.

Validation for data usability was accomplished by comparing the contents of the data packages and Quality Assurance/Quality Control (QA/QC) results to the requirements contained in the QAPP, the respective methods, and the laboratory SOPs.

General guidelines for data validation are presented in:

- National Functional Guidelines for Superfund Organics Method Data Review, U.S. EPA, June 2008
- National Functional Guidelines for Superfund Inorganics Method Data Review, U.S. EPA, January 2010
- National Functional Guidelines for Inorganic Data Review, U.S. EPA, October 2004

- Data that were not covered in the functional guidelines were compared against the applicable analytical methods, the laboratory SOPs, and the accuracy/precision limits described in the QAPP (WESTON 2010).

Weston performed a cursory review of the geotechnical parameters (grain size distribution). The data were compared against the applicable ASTM methods. Findings or QC concerns were included in the data narrative that Weston provided to GLNPO. Examples of USEPA data qualifier definitions are included in Appendix K.

The fish tissue data were validated by Laboratory Data Consultants, Inc. (LDC). LDC conducted a level IV validation of the four fish tissue samples. No issues were identified during data validation and no validation qualifiers were assigned by LDC. Data qualifiers assigned by CAS are included in Appendix L.

Chapter 3

Study Results

3.1 Field Observations and Physical Sediment Parameters

The sediment sampling crew recorded observations regarding the depth to which sediment cores were recovered, and visual and olfactory observations of the sediment and water during sampling. These observations are summarized in Table 3-1.

Sediment depths, as recorded by core recovery, varied from 6 to 62 inches throughout the DGI sampling locations. In general, sediment depths were shallow in the headwater areas: 6 inches in Amlosch Ditch; 8 inches in Grassy Creek; 10 inches in Duck Creek Segment D; however, in Otter Creek Segment E, (OC-23), the sediment depth was 27 inches. Most of the sediment samples collected from the middle reaches of Duck and Otter Creeks were collected with grab samplers for the DGI because sediment thickness was commonly about one foot during the 2007 SulTRAC investigation (Tetra Tech EMI 2008b). The recorded sediment depths for Duck Creek segment C and Otter Creek segments C and B ranged from 8 to 24 inches. Sediment thicknesses were greatest in the lacustuarine segments of Duck and Otter Creeks. Sediment thickness in segment A of Duck Creek ranged from 24 to 52 inches. Sediment thickness ranged from 12 to 62 inches in segment A of Otter Creek, with 9 of 12 DGI core samples in that reach exceeding a depth of 40 inches (Table 3-1).

Field observations described the majority of sediments as silt; clay, sand, gravel, and peat were also recorded somewhat frequently. Sediment colors included grey, brown and black; some sediments contained shells or fragments of shells, presumably from mussels. A few of the deeper sediments were described as “native”. The field observations in Table 3-1 are consistent with the particle size data from sieve and hydrometer tests that are included in Appendix E. Silt was present in all sediments, and was the dominant component of the in 18 of 32 (56.3%) sample locations. Sand was the dominant component in 12 of 32 (37.5%) locations, and gravel was the dominant component in sediments at two locations (OC-8-9 and OC-9-10). In general, silt and clay were the dominant particle sizes in the lacustuarine reaches (A segments) of Duck and Otter Creeks (Appendix E).

The sediment sampling team recorded the observance of sheen following disturbance of the sediments at several sampling locations in Otter Creek and one location in Duck Creek. No sheens were reported for Grassy Creek or Amlosch Ditch. Within Otter Creek, sheens were recorded in 7 of the 12 DGI locations in segment A, with the most frequent reports in the stretch between locations OC-3 and OC-5A, and again at OC6/7(2) near Millard Avenue. Sheens were also reported at single locations in segments C (OC-11/12), D (OC-22), and E (OC-24/25) of Otter Creek (Table 3-1).

Table 3-1. Summary of Field Observations During Sediment Sample Collection.

Segment	Otter Creek A												Otter Creek B		Urban Comparison Streams
Location	**OC-1A**	**OC-2**	**OC-2A**	**OC-3**	**OC-3A**	**OC-4**	**OC-4A**	**OC-5**	**OC-5A**	**OC-6**	**OC-6/7 (1)**	**OC-6/7(2)**	**OC-7/8**	**OC-8**	
Water Depth	3.9 feet	12 inches	6-12 inches	2.5 feet	2.5 feet	3 feet	3 feet	2.5 feet	2.5 feet	2.5 feet	2.5 feet	1 foot 5 inches	6 inches	12 inches	
Surface Grab	SILT, black wet, strong petroleum odor	As bio only:	SILT, with clay, black/grey, wet, some peat layering, moderate petroleum odor	SILT, sheen on water, mod-strong petroleum odor	SILT, sheen on water, moderate petroleum odor	SILT, sheen on water, strong petroleum odor	SILT and cobbles/gravel, sheen on water	NA	SANDY SILT, fn-med sand/grit, wet, sheen, petroleum odor	NA	SAND and GRAVEL, md-cr, wet, slight petroleum odor	SILT and iron pellets - harder substrate	Dark grey sediment, slight petroleum odor	NA	
Core Length Retreived	48 inches	39 inches	62 inches	30 inches	46 inches	42 inches	41 inches	47 inches	46 inches	41 inches	45.5 inches	12 inches	NA	24 inches	
0-24	SILT, black, wet, strong petroleum odor	SILT, with clay, trace fn sand, black/grey, wet, moderate-strong petroleum odor	SILT, with clay, black/grey, wet, some peat layering, moderate petroleum odor	SILT, with clay, trace fine sand, grey/brown, wet, mod-strong petroleum odor	SILT, with clay (muck), black/grey, wet, trace fn sand, moderate petroleum odor	SILT, trace fn sand, grey/black, sheen on water, moderate petroleum odor	SILT, with clay (muck), wet, black/grey, moderate petroleum odor (large cobble with md-cr gravel at surface)	SILT with clay, wet , black/grey, mod-strong petroleum odor, angular md-cr gravel at surface, trace fine sand - sheen on water when retrieving core	CLAYEY SILT, grey/black, wet, trace fn sand, moderate-strong petroleum odor	SILT, with clay, black/grey, some fine sand and md cobbles, wet, moderate petroleum odor	SILT, with clay, grey/black, with some fn sand and lg gravel, moderate petroleum odor	SILT, with fn sand and gravel, some iron pellets, sheen on water, mod-strong petroleum odor	NA	SILT, dark grey/black, slight odor	
24-48	SILT, with clay, some peat layering, trace fin sand/gravel, strong petroleum odor	SAA, some peat layering; 36-39 inches is fn-md gravel (rounded/subangular) and clay	SAA, layering of fine sand, layering of organic/roots/peat, strong petroleum odor	CLAY (silty), moist, some white shell fragments, no odor (26-30 inches is native)	SAA; 40-46 inches: CLAY, with silt, brown, moist, some white shell fragments, no odor (native)	SILT, with clay, brown organic layer/woody debris (clayey with trace white shell fragments), slight-moderate petroleum odor	SAA, brown woody debris layering, sl-mod petroleum odor	SAA, no gravel, increasing clay content	SAA, wet moist; (43-36 inches is native SILTY CLAY, brown, with fine sand and small white shell fragments)	SAA; (38-41 inches is CLAY, with lg cobbles, grey/brown, moist, no odor)	SAA; higher clay content, layering of brown moist clay with roots/organic near terminus	NA	NA	NA	
48-72	NA	NA	SILTY CLAY (native), brown, moist, organic/roots/peat, no odor, trace white shell fragments	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Segment	Otter Creek B				Otter Creek C						Otter Creek D		Otter Creek E		Grassy Creek
Location	**OC-8/9**	**OC-9**	**OC-9/10**	**OC-10/11**	**OC-11/12**	**OC-12/13**	**OC-15/16**	**OC-16**	**OC-16/17**	**OC-18**	**OC-18/19**	**OC-22**	**OC-23**	**OC-24/25**	**GC-1**
Water Depth	1.5 feet	6 inches	1 foot 5 inches	1 foot	~1 foot	1 foot 3 inches	~1.5 feet	1 foot	1 foot	1 foot	1 foot	1 foot	1 foot	1.5 feet	8 inches
Surface Grab	SILT, grey, slight odor	NA	SILT, grey/black, slight odor	CLAYEY SILT, light grey/grety, no odor	SILT, black, visible sheen, strong petroleum odor	SAND, cr, dark grey-dark brown, no odor/sheen, moderately solid creek bed	no sheen, no odor	SAND, cr, dark brown, no odor, moderate solid creek be with hard brown clay along shorelines	SAND/GRAVEL, no sheen, no odor	NA	No sheen, no odor	slight sheen, no odor	NA	Slight sheen, no odor	Dark grey sediment and sand, no odor
Core Length Retreived	NA	8 inches	NA	NA	NA	NA	NA	NA	NA	21 inches	NA	NA	27 inches	NA	NA
0-24	NA	0-3 inches: SAND, md-cr brown, with md subangular gravel, wet, no odor; 3-8 inches: CLAY, grey, dry-moist, sticky	NA	NA	NA	NA	NA	NA	NA	SILTY SAND, black, wet, moderate petroleum odor	NA	NA	SILT, some clay, grey wet, layering of gravel, md-cr, subangular-rounded, with cr sand	NA	NA
24-48	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	GRAVEL, with silt, md rounded-subangular gravel, wet	NA	NA
48-72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Segment	Duck Creek A						Duck Creek B			Duck Creek C		Duck Creek D			Amlosch Ditch
Location	**DC-1**	**DC-2**	**DC-3**	**DC-3/4**	**DC-4**	**DC-5**	**DC-5/6**	**DC-6/7**	**DC-7/8**	**DC-8**	**DC-9/10**	**DC-10/11**	**DC-11**	**DC-11/12**	**AD-1**
Water Depth	3 feet	8 inches	6 inches	6 inches	6 inches	1 foot	2 feet	2 feet	1 foot	1.5 feet	1 foot	1 foot	2 feet		6 inches
Surface Grab	NA	As bio only	SILT/CLAY, black	SILT/CLAY, black/grey	SILT/CLAY, black/grey	SILT, moderate-strong petroleum odor	SILT, black with vegetation		SILT/CLAY, dark grey, some vegetation	NA	SILT, dark grey, with vegetation, no odor	No sheen/odor	NA		Dark grey sediment, leaves, no odor
Core Length Retreived	36 inches	42.5 inches	24 inches	24 inches	24 inches	52 inches	NA		NA	20 inches	NA	NA	10 inches		NA
0-24	SILT/CLAY, black/grey, no odor	SILT/CLAY, black/grey, some roots, slight odor	SILT/CLAY, black/grey	SILT/CLAY, black/grey	SILT/CLAY, black/grey	SILT, some clay, grey/black, wet, moderate-strong petroleum odor	NA		NA	CLAYEY SILT, grey/black, wet, with fn sand, no odor; (17-20 inches is CLAY, grey/brown, trace cr rounded gravel, dry-moist, no odor	NA	NA	CLAYEY SILT, some fn sand, grey/black, wet, no odor, some whole white shells		NA
24-48	SILT/CLAY, black/grey, some grey sand, slight odor	SILT/CLAY, black/grey, slight odor	NA	NA	NA	SILTY CLAY, grey, with fn black sand layering, moist-wet, moderate-strong petroleum odor	NA		NA	NA	NA	NA	NA		NA
48-72	NA	NA	NA	NA	NA	SILTY CLAY, brown/grey, with md gravel (rounded), moist, no odor, sticky	NA		NA	NA	NA	NA	NA		NA

The sediment sampling team recorded that "odors" and "petroleum odors" were observed at several sampling locations in Otter and Duck Creeks. No odors were reported in Grassy Creek or Amlosch Ditch. Odors were recorded in only segment A of Duck Creek, and the odor was identified as "petroleum" in one location (DC/5), with "slight odors" at two of the other 6 locations in that segment. In Otter Creek, odors were recorded in segments C, B and A, but not D or E; in most cases the odor was identified as "petroleum." In segment C of Otter Creek, odors were reported in 2 of 6 DGI locations, described as "strong" or "moderate", and identified as "petroleum" in both cases. In segment B of Otter Creek, odors were recorded for 4 of 6 DGI locations, and all were described as "slight", and identified as "petroleum" in one location. In segment A of Otter Creek, "petroleum" odors were reported in all 12 DGI locations, and described as "moderate" or "strong" (Table 3-1).

3.2 Benthic Macroinvertebrate Community Structure

The structure of the benthic macroinvertebrate community is one component of the Sediment Quality Triad approach for assessing sediment quality. If sediment contaminants are present at concentrations that are sufficient to adversely affect biological life, the community of organisms that inhabit those sediments could be altered, or even completely absent. Aquatic communities can be affected by habitat modifications (physical stressors) or invasive species (biological stressors). Because the landscape of Lucas and Wood counties has been drained and developed during the last century, the benthic communities of two urban comparison streams were assessed along with Duck and Otter Creeks to obtain information about the general steam community conditions that are present in urban, non-industrial streams in the area. The complete benthic macroinvertebrate data set is included as Appendix B of this report; a summary is included as Table 3-2.

The benthic macroinvertebrate community summary is based on selected metrics, which included the following:

- Taxa Richness; the total number of taxa observed at the consistent effort described in Table 2.2., which can be viewed as a measure for biodiversity. Greater taxa richness indicates a more robust biological community;
- Abundance; the total number of individual organisms observed. Greater abundance can be indicative of a robust biological community unless the community is dominated by pollution-tolerant organisms;
- Abundance of Sensitive Taxa; four groups of benthic (bottom-dwelling) organisms are generally considered to be indicative of high-quality biological communities because they have been found to be relatively sensitive to habitat conditions such as nutrient enrichment, altered thermal regimens, and siltation. When these sensitive taxa are abundant (relative to other taxa) the water body is generally considered to have high quality. Conversely, the absence of sensitive taxa is generally considered to be evidence of an impaired water body. Images of sensitive taxa are shown in Figure 3-4. The sensitive taxa include:
  - Percent Ephemeroptera; this taxon includes the mayflies, which generally require high dissolved oxygen concentrations and are therefore sensitive to nutrient pollution. Some mayflies burrow into sediments and could be exposed to (and affected by) sediment-related contaminants. Lake Erie is famous for large "hatches" of the large mayfly

Hexagenia limbata, and the decreases in abundance of this species during the 1960s contributed to the environmental movement of that time;

- Percent Plecoptera; this taxon includes the stoneflies, which also generally require high dissolved oxygen conditions and are generally sensitive to nutrient pollution and warm water temperatures. The leaf-shredding stoneflies flourish in streams with forested riparian zones and are sensitive to changes in watershed land use as well. The predatory stoneflies prefer gravel and cobble substrates where prey items are abundant, and are sensitive to siltation. No stoneflies were observed in the data gap investigation, so they do not appear in Appendix B or Table 3-2;
- Percent Trichoptera; this taxon includes the caddisflies, which build cases from sand, plant material or other items. The caddisflies also prefer high dissolved oxygen temperatures, and cold, flowing waters; and
- Percent Amphipoda; this taxon includes the "scuds" or "sideswimmers", which are small crustaceans that have been observed to be sensitive to contaminants in laboratory toxicity tests. The amphipod *Hyalella azteca* is a standard sediment toxicity testing organism.

▪ Abundance of Tolerant Taxa; two groups of benthic organisms are considered to be generally tolerant of low oxygen concentrations, and will often flourish in nutrient-enriched water bodies. Water bodies are frequently considered to be impaired when tolerant species dominate the benthic macroinvertebrate community; images of tolerant taxa are shown in Figure 3-5.

- Percent Chironomidae; this taxon is a family of true flies (insects); the larvae are aquatic and are commonly called "bloodworms" that are red in color because their circulatory systems contain hemoglobin, which carries oxygen and allows them to survive in aquatic systems that have low dissolved oxygen concentrations. The adults are commonly known as "midges". Chironomids are naturally abundant in many aquatic ecosystems, and a few species are used as sediment toxicity testing organisms, including *Chironomus dilutus* that was used in this study;
- Percent Oligochaeta; this taxon includes the aquatic species of segmented worms. Some species of oligochetes thrive in silty, organic-rich sediments, and have been observed to be extremely abundant in water bodies that had received substantial inputs of untreated municipal wastewater, which earned the label "sludge worms" for these taxa. The oligochete *Lumbriculus sp*. is used in laboratory experiments to study the uptake of contaminants from sediments because they are large in size, burrow relatively deeply into sediments, and tolerate high densities so scientists have sufficient tissue mass for chemical analysis.

The study design for this data gap investigation used a system of five transects for benthic macroinvertebrate collection to ensure that all microhabitat features were sampled. Four transects were sampled across the width of the stream (transverse transects), and one (longitudinal) transect was sampled down the length of the stream channel. Arithmetic mean values for each macroinvertebrate community metric were calculated for these five transects (4 transverse, 1 longitudinal) for each of the selected locations Duck and Otter Creeks as well as the urban comparison streams, and those data are presented in Table 3-2.

Table 3-2 Summary of benthic macroinvertebrate data for Amlosch Ditch and Duck, Otter and Grassy Creeks.

Sample Location	Taxa Richness	Total Abundance	Abundance of Sensitive Taxa			Abundance of Tolerant Taxa	
			% Ephemeroptera	% Trichoptera	% Amphipoda	% Chironomidae	% Oligochaeta
Amlosch Ditch 1	8	419	0.00%	0.00%	46.78%	11.93%	13.60%
Amlosch Ditch 2	10	1140	0.00%	0.00%	41.87%	30.39%	16.10%
Amlosch Ditch 3	5	462	0.00%	0.00%	65.58%	0.65%	30.52%
Amlosch Ditch 4	6	265	0.00%	0.00%	89.43%	0.38%	4.15%
Amlosch Ditch Longitudinal	8	745	0.00%	0.00%	63.09%	9.40%	0.67%
Mean	7	606	0.00%	0.00%	61.35%	10.55%	13.01%
Standard Deviation	2	345	0.00%	0.00%	18.72%	12.23%	11.70%
DC3-1	5	110	0.00%	0.00%	34.55%	5.45%	29.09%
DC3-2	8	167	0.00%	0.00%	14.97%	18.56%	26.95%
DC3-3	12	734	0.27%	0.00%	4.36%	7.77%	65.67%
DC3-4	7	478	0.00%	0.00%	10.46%	5.44%	39.75%
DC3-Longitudinal	8	1204	0.00%	0.00%	25.58%	4.65%	13.62%
Mean	8	539	0.05%	0.00%	17.98%	8.37%	35.01%
Standard Deviation	3	449	0.12%	0.00%	12.08%	5.81%	19.49%
DC5-1	8	282	3.90%	0.35%	0.35%	84.75%	4.96%
DC5-2	9	586	14.85%	0.00%	0.00%	45.90%	37.37%
DC5-3	8	280	39.29%	0.36%	0.00%	28.57%	26.79%
DC5-4	6	50	0.00%	0.00%	2.00%	50.00%	32.00%
DC5-Longitudinal	7	540	20.74%	0.00%	1.48%	51.11%	8.15%
Mean	8	348	15.75%	0.14%	0.77%	52.07%	21.85%
Standard Deviation	1	219	15.56%	0.19%	0.92%	20.39%	14.50%

Table 3-2 Summary of benthic macroinvertebrate data for Amlosch Ditch and Duck, Otter and Grassy Creeks.

Sample Location	Taxa Richness	Total Abundance	Abundance of Sensitive Taxa			Abundance of Tolerant Taxa	
			% Ephemeroptera	% Trichoptera	% Amphipoda	% Chironomidae	% Oligochaeta
DC6/7-1	11	280	30.36%	1.43%	5.71%	45.36%	3.21%
DC6/7-2	6	215	13.02%	0.00%	0.00%	32.09%	50.70%
DC6/7-3	5	133	8.27%	0.00%	0.00%	37.59%	51.88%
DC6/7-4	6	49	32.65%	0.00%	0.00%	34.69%	14.29%
DC6/7-Longitudinal	7	344	1.16%	0.00%	0.00%	67.44%	15.12%
Mean	7	204	17.09%	0.29%	1.14%	43.44%	27.04%
Standard Deviation	2	117	13.84%	0.64%	2.56%	14.31%	22.63%
Grassy Creek 1	11	2662	0.00%	0.00%	0.00%	0.68%	92.82%
Grassy Creek 2	8	1355	0.00%	0.00%	0.00%	0.66%	89.23%
Grassy Creek 3	10	505	0.00%	0.00%	0.00%	0.59%	84.75%
Grassy Creek 4	6	307	0.00%	0.00%	0.00%	1.41%	70.42%
Grassy Creek Longitudinal	9	1520	0.00%	0.00%	0.00%	3.29%	62.17%
Mean	9	1270	0.00%	0.00%	0.00%	1.33%	79.88%
Standard Deviation	2	938	0.00%	0.00%	0.00%	1.15%	13.05%
OC4-1	4	155	0.00%	0.00%	0.00%	14.19%	66.45%
OC4-2	4	409	0.00%	0.00%	0.00%	9.05%	80.20%
OC4-3	4	280	0.00%	0.00%	0.00%	11.43%	83.93%
OC4-4	5	257	0.00%	0.00%	0.00%	21.01%	51.36%
OC4-Longitudinal	4	370	0.00%	0.00%	0.00%	20.27%	28.38%
Mean	4	294	0.00%	0.00%	0.00%	15.19%	62.06%

Table 3-2 Summary of benthic macroinvertebrate data for Amlosch Ditch and Duck, Otter and Grassy Creeks.

Sample Location	Taxa Richness	Total Abundance	Abundance of Sensitive Taxa			Abundance of Tolerant Taxa	
			% Ephemeroptera	% Trichoptera	% Amphipoda	% Chironomidae	% Oligochaeta
Standard Deviation	0	100	0.00%	0.00%	0.00%	5.31%	22.78%
OC5A-1	5	622	0.00%	0.00%	0.00%	12.38%	81.67%
OC5A-2	5	623	0.00%	0.00%	0.00%	6.26%	87.64%
OC5A-3	4	234	0.00%	0.00%	0.00%	5.13%	85.04%
OC5A-4	5	186	0.00%	0.00%	0.00%	5.38%	91.40%
OC5A-Longitudinal	4	120	0.00%	0.00%	0.00%	12.50%	66.67%
Mean	5	357	0.00%	0.00%	0.00%	8.33%	82.48%
Standard Deviation	1	246	0.00%	0.00%	0.00%	3.78%	9.53%
OC6/7(2)-1	1	3	0.00%	0.00%	0.00%	100.00%	0.00%
OC6/7(2)-2	2	10	0.00%	0.00%	0.00%	10.00%	90.00%
OC6/7(2)-3	2	61	0.00%	0.00%	0.00%	3.28%	96.72%
OC6/7(2)-4	3	36	0.00%	0.00%	0.00%	5.56%	91.67%
OC6/7(2)-Longitudinal	3	25	0.00%	0.00%	0.00%	40.00%	40.00%
Mean	2	27	0.00%	0.00%	0.00%	31.77%	63.68%
Standard Deviation	1	23	0.00%	0.00%	0.00%	40.91%	42.38%
OC9/10-1	3	19	0.00%	0.00%	0.00%	68.42%	26.32%
OC9/10-2	4	40	0.00%	0.00%	0.00%	25.00%	37.50%
OC9/10-3	6	19	0.00%	5.26%	0.00%	52.63%	15.79%
OC9/10-4	5	67	1.49%	0.00%	0.00%	5.97%	76.12%
OC9/10-Longitudinal	5	140	0.00%	0.00%	0.00%	31.43%	42.86%

Table 3-2 Summary of benthic macroinvertebrate data for Amlosch Ditch and Duck, Otter and Grassy Creeks.

Sample Location	Taxa Richness	Total Abundance	Abundance of Sensitive Taxa			Abundance of Tolerant Taxa	
			% Ephemeroptera	% Trichoptera	% Amphipoda	% Chironomidae	% Oligochaeta
Mean	5	57	0.30%	1.05%	0.00%	36.69%	39.72%
Standard Deviation	1	50	0.67%	2.35%	0.00%	24.34%	22.87%
OC12/13-1	4	21	0.00%	0.00%	0.00%	47.62%	23.81%
OC12/13-2	8	119	0.00%	0.00%	0.00%	11.76%	69.75%
OC12/13-3	4	51	0.00%	0.00%	0.00%	11.76%	82.35%
OC12/13-4	5	45	0.00%	0.00%	0.00%	2.22%	80.00%
OC12/13-Longitudinal	2	44	0.00%	0.00%	0.00%	27.27%	0.00%
Mean	5	56	0.00%	0.00%	0.00%	20.13%	51.18%
Standard Deviation	2	37	0.00%	0.00%	0.00%	17.80%	37.13%
OC16-1	3	28	0.00%	0.00%	0.00%	21.43%	60.71%
OC16-2	8	68	0.00%	1.47%	0.00%	67.65%	11.76%
OC16-3	5	43	0.00%	0.00%	0.00%	23.26%	69.77%
OC16-4	4	29	0.00%	0.00%	0.00%	27.59%	58.62%
OC16-Longitudinal	4	60	0.00%	0.00%	0.00%	20.00%	53.33%
Mean	5	46	0.00%	0.29%	0.00%	31.98%	50.84%
Standard Deviation	2	18	0.00%	0.66%	0.00%	20.14%	22.64%
OC22-1	4	76	0.00%	0.00%	0.00%	2.63%	88.16%
OC22-2	4	28	0.00%	0.00%	0.00%	17.86%	50.00%
OC22-3	8	187	3.21%	0.00%	0.00%	6.95%	74.87%
OC22-4	5	134	0.00%	0.00%	0.00%	5.22%	91.04%

Table 3-2 Summary of benthic macroinvertebrate data for Amlosch Ditch and Duck, Otter and Grassy Creeks.

Sample Location	Taxa Richness	Total Abundance	Abundance of Sensitive Taxa			Abundance of Tolerant Taxa	
			% Ephemeroptera	% Trichoptera	% Amphipoda	% Chironomidae	% Oligochaeta
OC22-Longitudinal	9	299	1.34%	0.00%	0.00%	8.03%	71.91%
Mean	6	145	0.91%	0.00%	0.00%	8.14%	75.20%
Standard Deviation	2	105	1.41%	0.00%	0.00%	5.80%	16.32%
OC24/25-1	15	421	5.94%	0.00%	0.00%	4.75%	8.08%
OC24/25-2	14	319	3.76%	0.00%	0.00%	10.34%	10.03%
OC24/25-3	10	497	0.00%	0.00%	0.00%	3.82%	16.90%
OC24/25-4	13	146	4.11%	0.00%	0.00%	3.42%	32.19%
OC24/25-Longitudinal	10	595	0.84%	0.00%	0.00%	2.52%	3.36%
Mean	12	396	2.93%	0.00%	0.00%	4.97%	14.11%
Standard Deviation	2	172	2.45%	0.00%	0.00%	3.11%	11.22%
Percentages do not necessarily sum to 100% because some benthic taxa are not designated as either sensitive or tolerant.							

Regarding taxa richness, Duck and Grassy Creeks along with Amlosch Ditch generally exhibited more taxa than Otter Creek (Figure 3-1). The most taxa observed at a single location, however, were recorded at OC-24/25.

Sensitive taxa were relatively abundant in Amlosch Ditch (Figure 3-2) location, which was dominated by Amphipoda. Stoneflies (Plecoptera) were absent in all locations, and mayflies (Ephemeroptera) were relatively abundant in Duck Creek. Caddisflies (Trichoptera) were rare to absent in all sample locations. Sensitive taxa were rare in Grassy and Otter Creeks.

Tolerant taxa, represented by Oligochaeta and Chironomidae, were relatively abundant in all streams with the least relative abundance of tolerant taxa in Amlosch Ditch (Figure 3-3). Specific locations with the lowest abundance of tolerant taxa were OC-24/25 and DC-3.

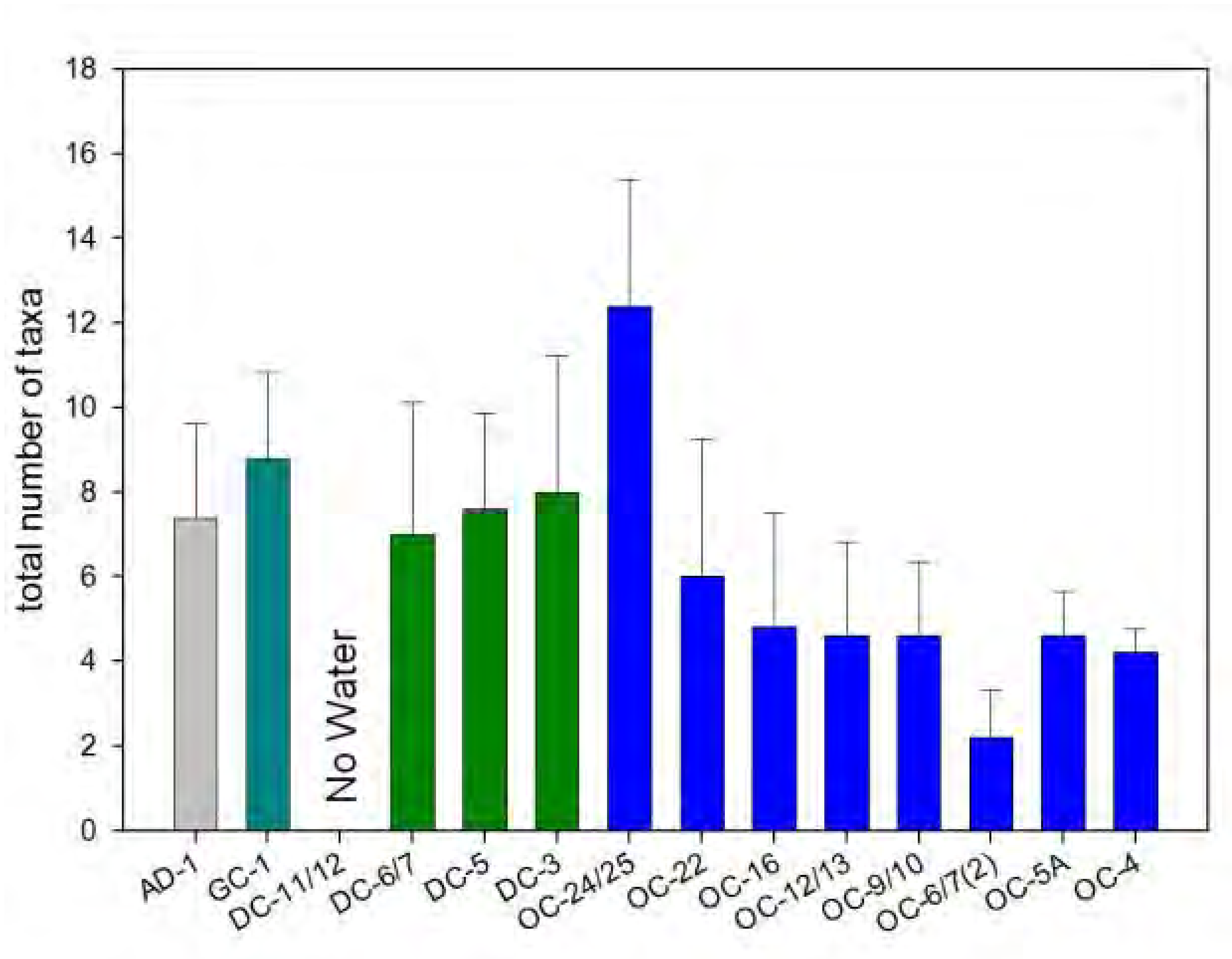


Figure 3-1 Summary of the total number of taxa in Duck, Otter and Grassy Creeks and Amlosch Ditch.

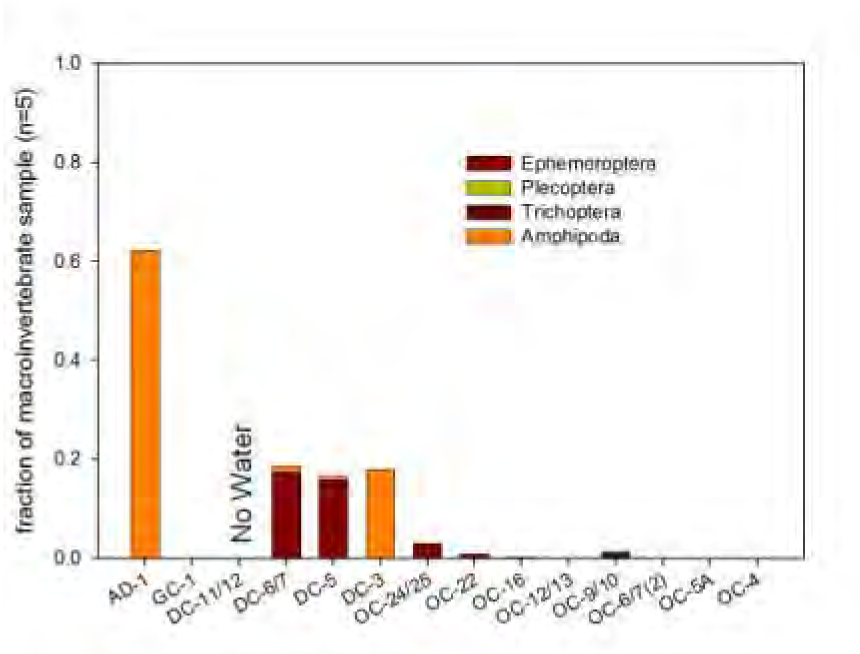


Figure 3-2 Summary of the relative abundance of sensitive benthic macroinvertebrate taxa in Duck, Otter and Grassy Creeks and Amlosch Ditch.

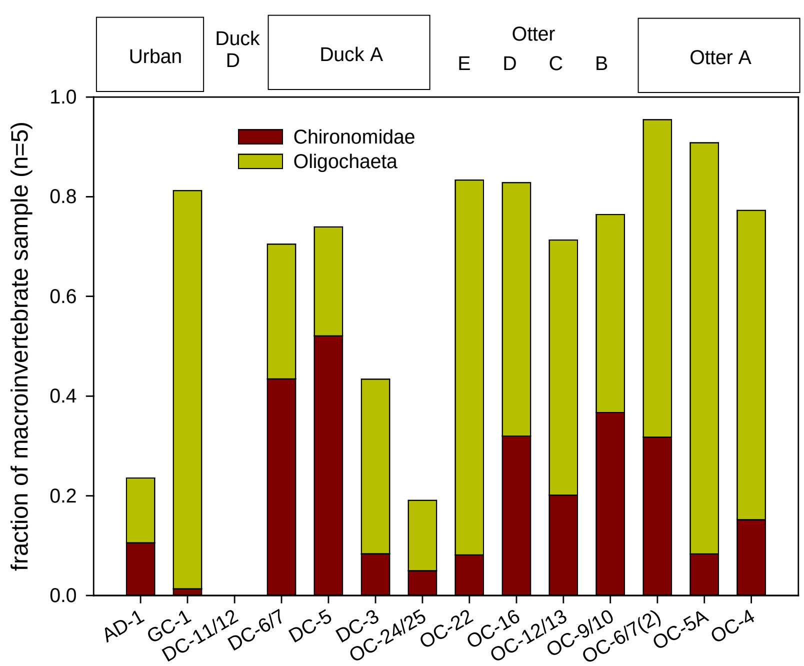
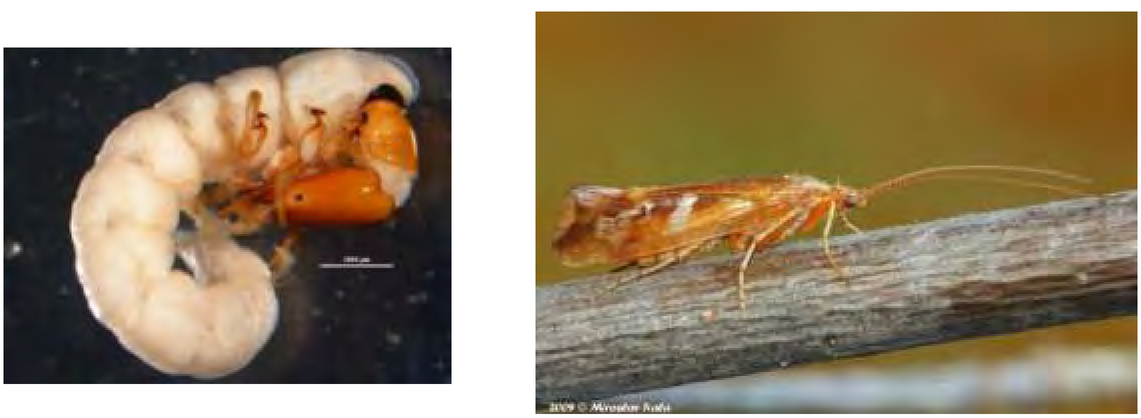


Figure 3-3 Summary of the relative abundance of tolerant benthic macroinvertebrate taxa in Duck, Otter and Grassy Creeks and Amlosch Ditch.

Gammarus **(amphipods)**

Ephemeroptera (mayfly larvae and adult), genus *Hexagenia*



Trichoptera (caddisfly adult), family *Limnephilidae*

Figure 3-4 Images of sensitive taxa of benthic macroinvertebrates.

Chironomidae (midge) larvae

Chironomidae (midge) adult

Oligochaeta (aquatic worm) and *Gammarus* (amphipod)

Figure 3-5 Images of tolerant taxa of benthic macroinvertebrates (except *Gammarus* which is sensitive).

3.3 Habitat Quality

Habitat quality was evaluated within the stream channels using the Ohio EPA Quantitative Habitat Evaluation Index and Use Assessment Field Sheets (QHEI), and outside of the stream channels using GIS-based approaches. The QHEI data sheets and a complete set of field photos are included in Appendix C. Maps of stormwater outfalls are included in Appendix D. Physical characteristics of sediment (particle size distribution, solids content and organic carbon content) are included in Appendix E. A detailed summary of riparian and watershed land use, as well as an accounting of the relative percent of impervious surface categories are included in Appendix F.

3.3.1 In-stream (channel) Habitat Quality

The QHEI assessment started on September 27, 2010 and was finished on September 30, 2010. Due to a rain event on September 28, 2010 some of the stream conditions such as water depth and current velocity may have varied slightly throughout the course of conducting the QHEI assessment, but it is unlikely that alterations in flow regimens were sufficient to change the OHEI scores.

In-stream channel habitat ranged from very poor to poor throughout the study area, including the two urban comparison streams. Low scores were observed for Amlosch Ditch on all metrics (Table 3-3), with the lowest scoring metrics including: Substrate, Instream Cover and Pool/Glide and Riffle/Run Quality. The Substrate contained heavy silt with extensive embeddedness and the Instream Cover was nearly absent. One of the positive habitat characteristic observed in Amlosch Ditch was the absence of bank erosion (Figure 3-6), which contributed to a rating of 6 for channel morphology at that location.

For Grassy Creek, the lowest metrics were Substrate and Pool/Glide and Riffle/Run Quality. The Substrate was composed of silt and detritus and was moderately embedded. There was no riffle in this sample station and the stream was shallow with slow moving water (Figure 3-7). Highlights of Grassy Creek included: moderate sinuosity, a recovering channel, and moderate channel stability. Little to no erosion was observed in Grassy Creek; the stream also exhibited a narrow but present forested riparian zone in a residential area. These features contributed to a score of 9 for QHEI Metric 4 (Bank Erosion and Riparian Zone).

Table 3-3 Summary of habitat quality for the local urban comparison streams.

Category	Max value	Amlosch Ditch*	Grassy Creek
River Mile	N/A	5.0	8.2
Substrate	20	2.5	4.5
Instream Cover	20	2	6
Channel Morphology	20	6	9
Bank Erosion and Riparian Zone	10	3.5	6
Pool/Glide and Riffle/Run Quality	20	3	3
Map Gradient	10	6	4
Total QHEI Score	100	23	32.5
Narrative Description		Very Poor	Poor

* Due to roads and culverts the sample station for Amlosch Ditch was limited to 195 meters.

Figure 3-6 Sample station in Amlosch Ditch (AD-1), depicting little to no bank erosion, high channel stability and little to no instream cover.

Figure 3-7 Sample station in Grassy Creek (GC-1), depicting good quality floodplain, no riffle and shallow slow moving water.

The QHEI scores for the three sample stations in Duck Creek ranged from 23.5 to 40 (Table 3-4); which correspond to OEPA narrative ratings of "Very Poor" to "Poor" stream habitat. All 3 sample stations on Duck Creek demonstrated low scores in the Substrate category, which indicates the substrate is poor habitat for colonization of "sensitive" macroinvertebrate taxa. Lower Duck Creek (segment A) scored poorly in the Pool/Glide and Riffle/Run Quality category, which is reflective of low channel variation and slow water velocities (Figure 3-8).

Station 6/7 in Duck Creek (segment B) scored relatively well in the category of Pool/Glide and Riffle/Run with 8 out of a possible score of 20. Duck Creek stations DC-5 and DC-6/7 scored 13 out of 20 for instream cover, which reflects the presence of logs and other woody debris (Figure 3-9) which provide habitat for invertebrate and fish populations.

The QHEI scores for Otter Creek ranged from 31 to 42 (Table 3-5), which correspond to narrative ratings of "poor". All 7 sample stations on Otter Creek demonstrated low scores in the Substrate category, which was representative of a silt substrate that was extensively embedded (see Figure 3-10). Scores Channel Morphology and Pool/Glide and Riffle/Run Quality metrics in Otter Creek were varied. Lower scores were observed in the channelized upper (segment E) and lower (segment A) reaches (see Figure 3-11), but higher in the meandering middle reaches (segments D-B) (see also Figure 3-12).

The riffle (fast-flowing water) pool (deep slow water) sequence at OC-9-10 was a major contribution to the relatively high overall QHEI score at that location. Even though the riffle-pool sequence constituted only 15% of the observed stream segment, it was sufficient to increase the habitat diversity of the location.

Table 3-4 Summary of habitat quality for the Duck Creek stations.

		Segment B	Segment A	
Category	**Max value**	**DC6-7**	**DC-5**	**DC-3**
River Mile	N/A	2	1.5	1
Substrate	20	4	2.5	2.5
Instream Cover	20	13	13	5
Channel Morphology	20	6	9	6
Bank Erosion and Riparian Zone	10	6	6	5
Pool/Glide and Riffle/Run Quality	20	8	4	2
Map Gradient	10	3	3	3
Total QHEI Score	100	40	37.5	23.5
Narrative Description		Poor	Poor	Very Poor

Figure 3-8 **Sample station DC-3, depicting stable stream bank conditions and straightened stream channel.**

Figure 3-9 **Sample station DC-5, representing moderate riparian width and relatively good instream cover.**

Table 3-5 Summary of habitat quality for the Otter Creek stations.

Stream segments		E	D	C		B	A	
Category	**Max value**	**OC24-25**	**OC22***	**OC16**	**OC12-13**	**OC9-10**	**OC6-7(2)**	**OC4**
River Mile	N/A	7.3	6	4.25	3.4	2.6	1.8	0.7
Substrate	20	3	2.5	2.5	2.5	2.5	4.5	2.5
Instream Cover	20	13	7	6	5	7	12	10
Channel Morphology	20	6	6	8	6	10	6	6
Bank Erosion and Riparian Zone	10	4	6	6.5	7.5	5.5	4	3.5
Pool/Glide and Riffle/Run Quality	20	3	6	4	6	11	4	6
Map Gradient	10	6	6	6	6	6	3	3
Total QHEI Score	100	35	33.5	33	33	42	33.5	31
Narrative Description		Poor	Poor	Poor	Poor	Poor	Poor	Poor

* Due to lack of access to private property the sample station for OC22 was limited to 125 meters.

Figure 3-10 Sample station OC9-10, depicting a silt substrate that is extensively embedded.

Figure 3-11 **Sample station OC-4, representing stream channelization and low to no sinuosity.**

Figure 3-12 **Sample station OC9-10, representing riffle, pool and glide characteristics.**

The QHEI scores for the stream stations that were evaluated for the GLLA data gap investigation were relatively low, and ranged from 23 at the Amlosch Ditch urban comparison stream location to 40 in the middle reach of Otter Creek (sample station OC9-10). The narrative QHEI descriptions for stream habitat quality scores range from “very poor” to “poor”. The results of the in-stream habitat assessments indicate that the urban comparison streams, which flow through non-industrial watersheds, exhibit physical habitat conditions that are similar to Duck and Otter Creeks study streams (Table 3-6).

Table 3-6 Summary of habitat quality for the Duck and Otter Creek stations and the urban comparison stream stations.

Category	Max possible value	Amlosch Ditch*	Grassy Creek	Range for Duck & Otter Creeks
Substrate	20	2.5	4.5	2.5 to 4.5
Instream Cover	20	2	6	5 to 13
Channel Morphology	20	6	9	6 to 10
Bank Erosion and Riparian Zone	10	3.5	6	3.5 to 7.5
Pool/Glide and Riffle/Run Quality	20	3	3	2 to 11
Map Gradient	10	6	4	3 to 6
Total QHEI Score	100	23	32.5	23.5 to 42
Narrative Description		Very Poor	Poor	Very Poor to Poor

*Due to roads and culverts the sample station for Amlosch Ditch was limited to 195 meters.

The generally low QHEI scores for all stream locations suggest that habitat quality may be contributing to the impaired biological communities of these northwest Ohio streams. Restoration of beneficial uses within Duck and Otter Creeks would benefit from, and possibly require, enhancement of the stream habitats even in cases where other stream restoration measures are warranted. The individual metrics of the QHEI scores provide additional information regarding which habitat enhancements may be considered for implementation in the channelized streams in this urbanized watershed, as discussed below:

- Metric 1: Substrate scores for the stream stations evaluated for the GLLA data gap investigation were uniformly low. The values ranged from 2.5 to 4.5 out of a maximum value of 20. The reason for the consistently low substrate scores across all of the streams is the prevalence of silty sediments that were likely deposited after the last ice age when the study area was covered by the Great Black Swamp. Gravel substrates are present, but are embedded in silt so the pore spaces are not available for aquatic life. Given the historic swamp sediments and the mobility of silt during periods of high flow, it is likely that placement of larger-sized substrates to create riffles may be only partly successful in terms of stream habitat enhancement because those riffles could become embedded by the transport of silt from upstream areas, or during seiches;
- Metric 2: Instream Cover scores for the stream stations in this study ranged from 2 to 13 out of a maximum value of 20: The instream cover values for the local urban comparison streams

were low, with 2 for Amlosch Ditch and 6 for Grassy Creek. The low instream cover scores for many of the stream stations evaluated for the GLLA data gap investigation indicate that habitat quality in some stream reaches in the area could be improved or enhanced by the addition of woody debris that would add cover and habitat for aquatic species;

- Metric 3: Channel Morphology scores for the stream stations in this study ranged from 6 to 9 out of a maximum value of 20. The generally low scores for channel morphology are likely the result of historic channelization. However, scores of 10 are on the high end of the range for scores typically observed at ditches and streams located within urbanized watersheds. Given the prevalence of private property and the highly-developed nature of the watersheds, some limitations or challenges may exist in these watersheds for adding meanders to improve stream habitat; however, some projects have been and could potentially be developed to incorporate meanders into some reaches of Duck and Otter Creeks;
- Metric 4: Bank Erosion and Riparian Zone scores for the stream stations in the study area ranged from 3.5 to 7.5 out of a maximum value of 10. The stream banks for Amlosch Ditch, Duck, Otter and Grassy Creeks and Amlosch are generally stable, and erosion is not an obvious problem within the study area. To ensure continued stability of stream banks, it would be helpful to protect the current riparian zones and potentially expand riparian width in areas with low scores for this QHEI metric. There may be opportunities for enhancement of the riparian buffer zone; however, most of the land appears to be privately owned, so management of riparian vegetation would need to be acceptable to the landowners. Given the prevalence of invasive vegetation such as *Phragmites* and honeysuckle along the stream banks in the “A” segments of both streams, portions of the floodplain and/or riparian corridor quality may be improved by increasing the floral diversity with native plants, which would enhance wildlife use and aesthetics of the stream corridors;
- Metric 5: Pool/Glide and Riffle/Run Quality scores for the stream stations in the study area ranged from 2 to 11 out of a maximum value of 20. Both urban comparison streams exhibited metric 5 scores of 3. Most stream stations had scores for this metric in the range of 3 to 6. The greatest pool/glide riffle/run score (11) in this study was observed for station OC9-10 on Otter Creek. The presence of at least one station with a much greater riffle/run and pool/glide score than most sample stations suggests there could be opportunities to enhance the stream microhabitats through in-channel projects; and
- Metric 6: Map Gradient scores in the stations evaluated for the GLLA data gap investigation ranged from 3 to 6 out of a maximum value of 10. The map gradients for all Duck Creek locations had scores of 3; Otter Creek gradients had scores of 6 in the upstream areas and scores of 3 in the lower reach (Table 3-4). The Amlosch Ditch station exhibited a gradient score of 6, while the Grassy Creek station had a gradient score of 4. Map gradients are determined by the topography of the landscape, so there are few, if any, opportunities to enhance stream gradients through in-stream projects.

The habitat quality information was incorporated into the DGI to supplement the sediment quality triad approach for these streams because they have a history of substantial modifications to the stream channels and watersheds. The QHEI metrics and scores were evaluated at a similar scale of effort, namely 12 independent observations across a variety of stream conditions, as was invested in the benthic community structure data (13 independent observations across the same stream conditions). The land use evaluation described in Section 3.3.3. was conducted at the watershed scale of aggregation (not on the basis of individual locations or stream segments), which does not provide equal precision for the following statistical evaluations. Consequently, land use data are not included in Tables 3-7or 3-8, or the corresponding discussion.

Table 3-7 Summary of selected benthic community metrics and stream channel habitat quality (QHEI metrics and scores from the DGI data set.

Sample location	Median taxa richness[1]	Median sensitive taxa abundance	Median tolerant taxa abundance	Total QHEI Score[1]	Substrate	Instream Cover[1]	Channel Morphology	Bank Erosion and Riparian Zone[1]	Pool/Glide and Riffle/Run Quality	Map Gradient
Amlosch Ditch	8	63.1%	25.5%	23	2.5	2	6	3.5	3	6
Grassy Creek	9	0%	85.3%	32.5	4.5	6	9	6	3	4
DC-11/12	-	-	-	-	-	-	-	-	-	-
DC-6/7	6	13.0%	82.6%	40	4	13	6	6	8	3
DC-5	8	14.8%	82.0%	37.5	2.5	13	9	6	4	3
DC-3	8	15.0%	45.2%	23.5	2.5	5	6	5	2	3
OC-24/25	13	3.76%	20.4%	35	3	13	6	4	3	6
OC-22	5	0%	81.8%	33.5	2.5	7	6	6	6	6
OC-16	4	0%	82.1%	33	2.5	6	8	6.5	4	6
OC-12/13	4	0%	81.5%	33	2.5	5	6	7.5	6	6
OC-9-10	5	0%	74.3%	42	2.5	7	10	5.5	11	6
OC-6/7(2)	2	0%	100%	33.5	4.5	12	6	4	4	3
OC-5A-01	5	0%	93.9%	-	-	-	-	-	-	-
OC-4	4	0%	80.6%	31	2.5	10	6	3.5	6	3

[1]The data for these valuables are normally-distributed; but others were not so the nonparametric Spearman Rank Order test was used for correlation analysis. Median (middle) values were used instead of mean (average) values to represent the (statistical) central tendency because most data sets were not normally distributed.

The QHEI and benthic community data provide an opportunity to assess how biological communities within an urbanized landscape are responding to stream metrics. Conversely, these data allow decision makers to investigate which stream channel features appear to have the greatest influence on the biological communities in the urban streams sampled in this investigation. The combined summary of QHEI and benthic community data for correlation analysis is presented in Table 3- 7. Statistical analyses are presented in full in Appendix N, and the significant correlations are summarized in Table 3-8. Five trends are suggested by the correlations among the habitat quality and benthic community quality variables:

- The correlation analysis revealed that the total QHEI scores for the DGI were influenced the most by *Instream Cover,* and *Pool/Glide and Riffle/Run Quality* metrics. These two metrics exhibited greater variation than the others, and these results suggest there is a presently a range of conditions regarding instream cover and riffle-pool sequences within the urbanized streams sampled in this investigation;

- The presence of sensitive taxa contributes to the overall taxa richness; or, stated another way, more diverse benthic communities tend to have more sensitive taxa than the less diverse benthic communities;

- The abundance of Senstive and Tolerant taxa were negatively correlated, which suggests these organisms are somewhat exclusive in their habitat preferences and/or distribution;

- Tolerant taxa were more abundant in locations that have higher substrate scores. This relationship is unusual, but appears to be the result of three unusual factors in this DGI data set. First, the substrate scores are generally low among all the stations; second, the tolerant taxa were generally abundant throughout the study; and third, the two stations with slightly higher substrate scores also had the greatest abundance of tolerant taxa; and

- In the DGI data set, *Taxa Richness* was negatively correlated with *Pool/Glide and Riffle/Run Quality*. This relationship is also unusual, but may also have resulted from three other unusual features of the DGI. First, the headwater sections of Otter & Grassy Creeks, and Amlosch Ditch had relatively diverse benthic communities, but lacked riffle-pool sequences; second the lacustuarine reach of Duck Creek contained diverse taxa, including mayflies that inhabit nearshore environments that are typically not assessed using the QHEI method; and third, location OC-9-10 had the only true riffle-pool sequence in the DGI data set, but had a moderate taxa richness.

The first three observed correlations are consistent with stream quality assessment principles, but the last two are not. The inconsistent correlations may have resulted from unusual circumstances in this specific data set, and/or there could be additional factors in the field to which the biological communities are responding in the streams sampled in this investigation that are not measured by these habitat metrics.

Table 3-8 Summary of significant Spearman Rank Order Correlation Coefficients between stream channel habitat quality (QHEI metrics and scores) and benthic community quality from the DGI data set..

Significant Correlations[1]	5% level of significance	10% level of significance
Total QHEI Score and **Instream Cover**	0.737	0.737
Total QHEI Score and **Pool/Glide and Riffle/Run Quality**	0.602	0.602
Taxa Richness and **Abundance of Sensitive Taxa**	0.637	0.637
Abundance of Sensitive Taxa and **Abundance of Tolerant Taxa**	-	-0.479
Abundance of Tolerant Taxa and **Substrate**	-	0.538
Taxa Richness and **Pool Glide and Riffle/Run Quality**	-	-0.563

[1]All correlations are reported in Appendix N

Correlations that are significant at the 5% level are also significant at the 10% level and have been repeated in this table.

3.3.2 Sediment Characteristics

The physical characteristics of the sediment samples that were collected during the GLLA Data gap investigation are consistent with the QHEI observations and those documented by the sediment sampling crew (Table 3-1). Silt was present at all locations, and typically was the most abundant particle size (Appendix E). Sand was present in many locations, and gravel was abundant at locations: DC-11/12; DC-5/6; OC-9/10 and OC-8/9. The organic carbon content of surface sediment samples ranged from 1.62% to 22.9%. Duck Creek sediments were generally in the range of 5% to 8% TOC, while most of the Otter Creek sediments contained from 3% to 4% TOC. Because TOC contains ligands that are important for binding many classes of sediment contaminants, the relatively large values in the DGI locations indicate that these streams have the ability to adsorb sediment contaminants and protect the resident aquatic life from harm. The least value was observed at OC-12-13, and the greatest TOC value was observed at DC-11/12. Sediment characteristics at DC-11/12, having 22.9% TOC, 12.2% solids, and 20% gravel, were atypical of sediments in this investigation, and may reflect this location being a heavily vegetated wetland area where a defined stream channel is difficult to identify and the sediment has extensive vegetation debris.

3.3.3 Watershed Quality

Land use is quite variable through the watersheds and riparian zones of Duck and Otter Creeks. In some areas, by example a portion of segment A of Duck Creek, the stream channels have meander through forested areas with gently-sloping banks (Figure 3-19). In contrast, Segment A of Otter Creek has industrial land use very near to the stream banks (Figure 3-14).

Figure 3-13 Riparian zone in Segment A of Duck Creek.

Figure 3-14 Riparian zone in Segment A of Otter Creek.

Even in watershed areas dominated by industrial land uses there are relicts of the wetlands that were historically abundant. By example, the mixed emergent and forested wetland shown in Figure 3-15 lies adjacent to the industrial area shown in Figure 3-14.

Figure 3-15 Wetland near Segment A of Otter Creek.

The headwaters of Otter and Grassy Creeks, and Amlosch Ditch are ditches with little to no riparian forest; Figure 3-16 is typical for the watershed conditions of these streams. The current headwaters of Duck Creek is Hecklinger Pond; however, the surface topography and watershed boundary (Figure 3-17) along with ah historic topographic map (see Appendix A) indicate that Duck Creek historically originated to the west of Highway I-280. Photographs of the Sediment Quality Triad sample locations (see Table 2-1) are included in Appendix B.

The field photographs represent only portions of the diverse riparian zones and watershed of Duck and Otter Creeks. A more comprehensive summary of land use was gleaned from the National Land Cover Dataset (USGS 2006). Detailed information regarding the land use within the riparian buffer zones of each stream segment is included in Appendix F; a summary is presented in the text of this report.

Eleven categories of land use are present in the Duck and Otter Creeks watershed (Table 3-9). Much of the watershed is developed, as shown in Figure 3-17. The most prevalent land use in the watershed is the “developed” (urban) category, and the combination of low, medium and high intensity development represents about 70% of land use for the entire watershed. There is a trend of less intense land use in the riparian zones, where open space, wetlands, and forest comprise between 43% and 53% of the land surface. These less intense land uses represent only 20% of the watershed land surface. Agricultural land uses are relatively minor, representing 10% or less of the land surface in the watershed.

Figure 3-16 Headwaters of Amlosch Ditch.

Table 3-9 Land cover and watershed of Duck and Otter Creeks.

Land Use Category	5 m Riparian buffer	100 m Riparian buffer	Watershed
Open water	0.11%	0.67%	0.20%
Developed, Open Space	24.76%	25.07%	15.65%
Developed, Low Intensity	25.59%	28.73%	35.28%
Developed, Med Intensity	9.34%	12.21%	23.34%
Developed, High Intensity	8.42%	11.46%	10.90%
Barren Land	0.00%	0.15%	0.33%
Deciduous Forest	5.04%	3.96%	2.01%
Grassland/Herbaceous	0.00%	0.28%	0.58%
Pasture Hay	0.00%	0.00%	0.48%
Cultivated Crops	3.43%	3.30%	9.26%
Emergent Herbaceous Wetlands	23.32%	14.17%	1.96%

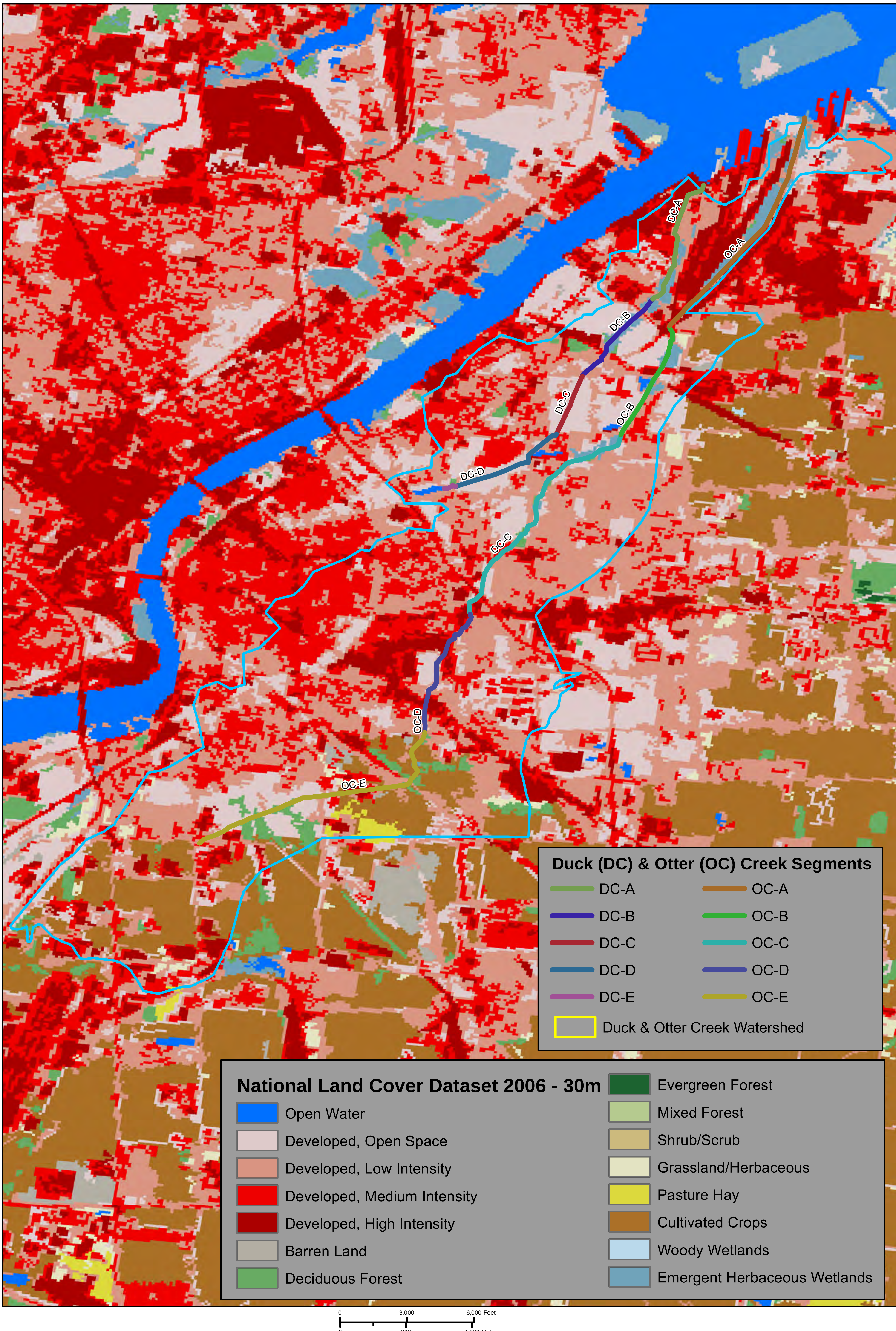


Figure 3-17 - NLCD 2006 Land Cover

Duck and Otter Creek
Lucas County, Ohio

N

Cardno ENTRIX
4295 Okemos Road Ste 101
Okemos MI 48864
ph. 517.381.1434
fx. 517.381.1435
www.entrix.com

Coordinate System:
Albers Conical Equal Area
NAD 1983

Date: 07/18/2011 Rev. Date: XX/XX/XXXX PM: SR GIS Analyst: AJB Map Document: LC_IMP_sampling_overview_20110726_ajb.mxd Project Number: 72606001.00 2000 PDF Document: LC_IMP_sampling_overview_20110726_ajb.mxdf Plot Size: 11 x 17

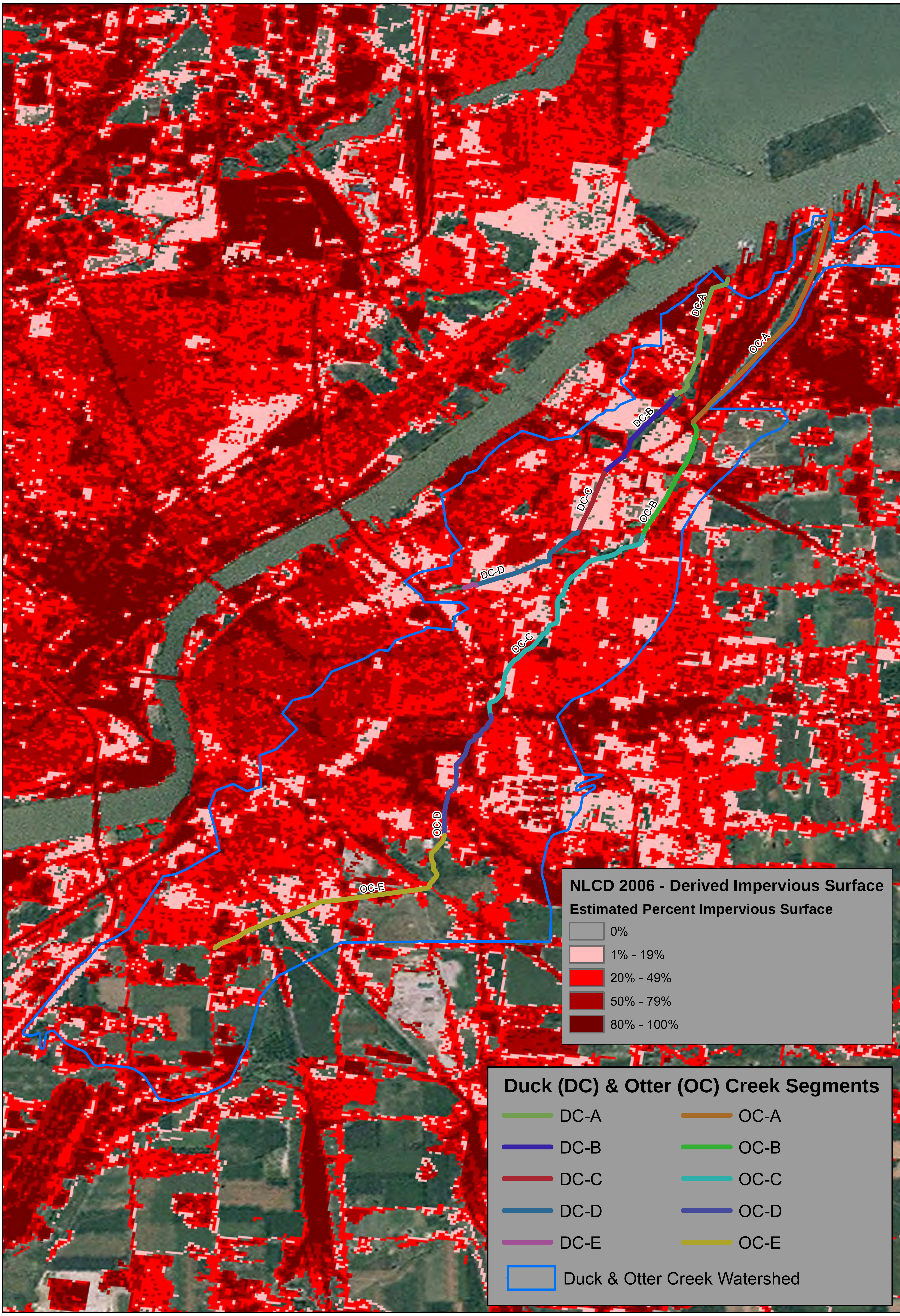


Figure 3-18 - NLCD 2006 Impervious Surfaces

Duck and Otter Creek
Lucas County, Ohio

Cardno ENTRIX
4295 Okemos Road Ste 101
Okemos MI 48864
ph. 517.381.1434
fx. 517.381.1435
www.entrix.com

Coordinate System:
Albers Conical Equal Area
NAD 1983

Date: 07/18/2011 Rev. Date: XX/XX/XXXX PM: SR GIS Analyst: AJB Map Document: IMP_LC_sampling_overview_20110726_ajb.mxd Project Number: 72606001.00 2000 PDF Document: IMP_LC_sampling_overview_20110726_ajb.mxdf Plot Size: 11 x 17

The relative percentages of impervious surface follow trends that are consistent with the land use categories (Figure 3-18). The least impervious categories is greatest in the narrow (5 m) riparian zone, where wetlands, forest and developed open space are most common (Table 3-10). At the watershed scale, about 70% of the land surface has more than 19% percent impervious surface, which increases surface runoff and diminishes groundwater recharge that is available for base flow during dry periods. Overall, the watershed land use suggests that flow regimens for Duck and Otter Creek are more variable in the present developed condition than they were historically.

Table 3-10 Impervious surface data for riparian zones and watersheds of Duck and Otter Creeks.

Impervious Surface Category	5 m Riparian buffer	100 m Riparian buffer	Watershed
0% to 19%	57%	47%	30%
20% to 49%	26%	30%	35%
50% to 79%	9%	13%	24%
80% to 100%	8%	10%	11%

The relatively level topography of the Duck and Otter Creek watershed, in combination with a relatively large proportion of impervious surface suggests that area could be susceptible to flooding if heavy precipitation is not managed effectively. Several large stormwater conveyances were observed during field sampling activities, as shown in Figures 3-19 and 3-20. These large stormwater management systems almost certainly transport large volumes of water to Duck and Otter Creek during precipitation events, so the biological communities are periodically exposed to high flow and velocity conditions. The hydraulic regimens of Duck and Otter Creek appear to be variable, with periods of shallow water and low velocities interspersed with periods of deep water that flow at greater velocity.

A review of utility maps for the City of Oregon, Ohio revealed that numerous stormwater sewers enter Otter Creek, with more than 50 outfalls in segments D and C (Table 3-11). The locations of the known stormwater outfalls for each stream segment are included in Appendix D. The presence of so many stormwater sewers in portions of Otter Creek suggests that the influence of stormwater will be more pronounced in some areas than in others. Of particular interest to a GLLA project is the potential for storm sewers to transport contaminants from sources located some distance from the riparian zone to the streams.

Table 3-11 Number of stormwater outfalls and approximate length of each stream segment of Duck and Otter Creeks.

Stream Segment	Duck Creek	Otter Creek
A	2 in 5,631 feet	0 in 10,722 feet
B	3 in 4,385 feet	5 in 4,693 feet
C	2 in 2,804 feet	29 in 10,648 feet
D	1 in 4,710 feet	22 in 6,188 feet
E	0 in 1,000 feet	0 in 10,255 feet

Figure 3-19 **Three large culverts are located immediately upstream of the Amlosch Ditch sampling location (AD-1). The center culvert transmits upstream flow beneath Dustin Road.**

Figure 3-20 **A large stormwater outfall enters Otter Creek from the east bank near OC-22 in Segment D.**

3.3.4 Previously-Identified Habitat Restoration Projects in Relation to GLLA Sampling

A previous investigation on behalf of the Duck and Otter Creeks Partnership, Inc., one of the stakeholders for these streams, has identified potential wetlands restoration projects within the Duck and Otter Creek watershed (Mannik & Smith et al 2003). Summary information of candidate wetlands restoration sites that are in proximity to GLLA sample locations is included here to provide context for other stakeholder activities in the watershed. At most candidate sites, the Ohio Rapid Assessment Method (ORAM) has been used to characterize and categorize the quality of the wetland. The ORAM in a method used develop scores for wetlands, in a manner similar to the QHEI. The overall ORAM score is used to categorize a wetland as low, medium, or high quality (categories 1, 2, and 3, respectively).

Duck Creek 1 - Hecklinger Pond & Lutheran Home Wetland

Duck Creek Site 1 consists of two sites: Hecklinger Pond and a large emergent wetland located adjacent for the Lutheran Home of Toledo. Because a defined stream channel is not present in either site, a Qualitative Habitat Evaluation Index (QHEI) was not conducted at this combined enhancement area. This site is near Ravine Park, where the GLLA data gap investigation collected samples at location DC-11/12 in segment D of Duck Creek.

An Ohio Rapid Assessment Method (ORAM) was completed on the Lutheran Home wetland, producing a score of 42.5. This score placed the wetland in the intermediate or ‘gray’ zone between Category 1 (poor quality) and 2 (medium quality). The wetland’s size, moderate buffer zones, consistent hydrology, and moderate habitat development contribute to the ORAM score. The wetland’s relative lack of heterogeneity and strong persistence of invasive species decreased the ORAM score. Duck Creek 1 has changed following restoration efforts in the pond in 2007 and the information from 2003 may no longer be accurate.

Duck Creek 2 - Collins Park Golf Course

The QHEI score for the segment of Duck Creek through the golf course between York and Consaul Streets was 32 (poor). The lack of diversity in substrate material, the heavy silt loading, the channelization of the stream, and a very low gradient contributed to the low score. Currently no wetlands exist on the site; thus, no ORAM was needed. This site corresponds with a portion of Duck Creek Segment C, and DGI sample DC-9/10 was located in this vicinity.

Duck Creek 3 - North of York Street

A QHEI score of 24 (very poor) was obtained for this section of Duck Creek. The low score was a result of a lack of riffle/run/pool development, heavy siltation, lack of floodplain on the west bank and limited in-stream habitat.

An ORAM scoring form was completed. The wetland scored 18, which places the wetland in Category 1 (poor quality) of Ohio’s Wetland Water Quality Standards (OAC 3745-1-54). The low score is due primarily to the small size of the wetland, the predominance of invasive plant species and presence of only one vegetation class (emergent community dominated by *Phragmites australis*). The GLLA data gap investigation location DC-7/8 was located between sites 2 and 3 on Duck Creek.

Duck Creek 4 – Chevron [now Port of Toledo] Property

The wetland area achieved an ORAM score of 36.5, which corresponds to a Modified Category 2 (moderate quality) wetland. Because of the site's elevation (below 575'), its hydrologic connection to Duck Creek and its proximity to Lake Erie, the site may automatically be classified by Ohio EPA as a Category 3 (high quality) wetland under ORAM. However, Mannik and Smith et al (2006) suggested that the predominance of invasive species merits reconsideration and possible lowering of this classification. Other factors that contributed to the score were channelization of the creek, lack of protective buffer and low diversity in the plant community. The QHEI score for Duck Creek adjacent to the wetlands was 35.5 (poor). The lack of diverse in-stream substrate, heavy silt loading, channelization, and low gradient contributed to a low score. Cardno ENTRIX assessed GLLA location DC 6-7 via the QHEI and assigned the location a score of 40 (Poor). Duck Creek 4 has been modified for development since 2003 and the information provided above might no longer be accurate.

Otter Creek 2 - Oakdale and Mahala Streets

A QHEI score of 28 (poor) was obtained for this section of Otter Creek. The low score was the result of a lack of riffle/run/pool development, moderate siltation, lack of floodplain on the west bank and limited in-stream habitat. Cardno ENTRIX assessed GLLA location OC-22 in this vicinity via the QHEI and assigned the location a score of 33.5 (Poor).

The emergent wetland attained an ORAM score of 24, which places the wetland in Category 1 of Ohio's Wetland Water Quality Standards (OAC3745-1-54). The low score was achieved due to the small size of the wetland, presence of only one vegetation community, and a predominance of the invasive reed canary grass (*Phalaris arundinacea*).

Otter Creek 4 - Starr Ave. to Earlwood St.

The section of Otter Creek within the project area was scored using the Qualitative Habitat Evaluation Index (QHEI) on July 16, 2003. A score of 40.5 (poor) was obtained for this section of Otter Creek, which indicates that the sample zone is lacking some of the characteristics needed for warm water habitat. The low score resulted from a lack of riffle/run/pool development, moderate siltation, lack of floodplain on the left bank, marginal habitat value on either floodplain, and a limited amount of in-stream habitat. Cardno ENTRIX assessed a nearby DGI site OC-16/17using the QHEI and assigned the location a score of 33 (Poor).

Because no wetlands were present, neither the Ohio Rapid Assessment Method nor the WET assessment were conducted.

Otter Creek 5 - Toledo Water Treatment Plant

The south wetland attained an ORAM score of 32.5, which falls within the gray zone between Categories 1 and 2. Factors that contributed to this score included the high intensity of surrounding land use, the lack of water and protective buffers, very low diversity and the high degree of past disturbance. The north wetland attained an ORAM score of 29, which equates to a Category 1 wetland. Factors that influenced this low score were the same as for the south wetland, as well as significantly greater coverage by invasive species.

The QHEI score for Otter Creek adjacent to the wetland was 45.75. The lack of diversity in substrate, the channelization of the creek, and the lack of gradient contributed to a lower score. Cardno ENTRIX assessed OC 9-10 for the DGI near the upstream end of this area via the QHEI and assigned the location a score of 42 (Poor). The GLLA sample location OC-8/9 was located near the downstream end of this site.

3.4 Sediment Toxicity Test

Sediment toxicity was assessed using the 10-day whole-sediment bioassay method with the midge *Chironomus dilutus.* The sediment toxicity tests were conducted by the US Army Corps of Engineers Engineering Research and Development Laboratory (ERDC). The full report is presented in Appendix G, and a summary is presented below. Control survival was acceptable for all tests; however, indigenous organisms (the flatworm *Planaria*) in the sediment samples adversely affected the survival of test organisms in several exposures. Data from test chambers that were affected by *Planaria* have not been included in the statistical analyses presented in Appendix G, or the summary included below.

Survival of the midge *C. dilutus* was significantly less than the test controls in one sample location, OC-4, which is located in segment A of Otter Creek (Figure 3-21). The presence of *Planaria* or other indigenous organisms was not mentioned in the 2007 study.

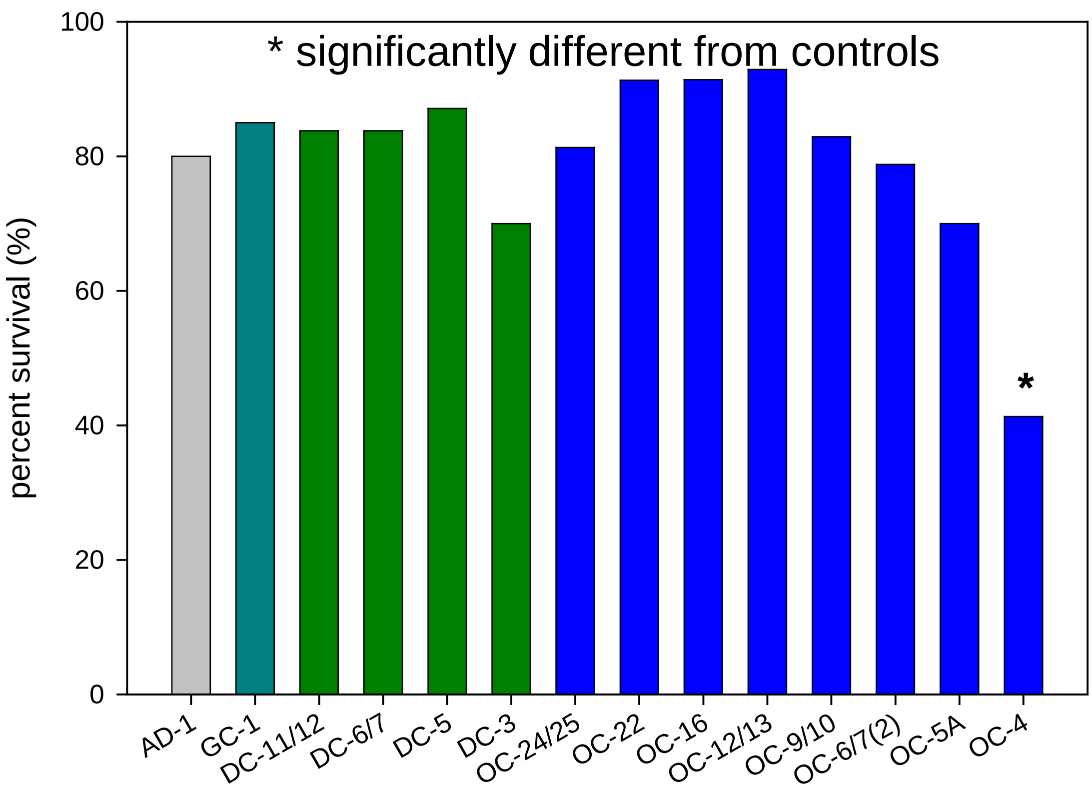


Figure 3-21 Survival of the Midge *C. dilutus* in sediments from Duck, Otter and Grassy Creeks and Amlosch Ditch.

Growth of the midge *C. dilutus*, expressed as ash-free biomass per initial organism was significantly less in sediments from three locations in Otter Creek than growth in laboratory control sediments (Figure 3-22). Ash-free biomass was used as the measure of growth to remove the potential influence of gut contents (ash) that could influence test interpretation. Biomass per initial organism was used (Table 3-12) instead of average weight to remove the potential influence of compensatory growth, which means that if food were limiting, individual larvae might grow larger in beakers where fewer individuals survived. Biomass is also relevant because in incorporated survival and weight gain. Because larger egg-laying animals tend to product more eggs and larger eggs that are more viable, size and survival of adults can affect reproductive success.

Table 3-12 Growth of midge larvae, as ash-free biomass per initial organism for toxicity tests with sediments from Duck, Otter and Grassy Creeks and Amlosch Ditch.

	A	B	C	D	E	F	G	H
Test 1 - mean control biomass per initial organism = 1.348 mg								
OC-4*	0.159	0.091	0.040	0.130	P	0.123	0.100	0.162
OC-5A-01*	0.315	0.112	0.563	0.290	0.060	0.303	0.311	0.162
OC-6/7	1.192	P	1.294	1.219	0.855	1.253	1.532	0.927
OC-9-10	0.620	0.803	0.709	0.762	0.804	P	0.617	0.326
DC-3	1.368	1.584	1.463	0.766	0.539	1.205	P	1.537
Test 2 - mean control biomass per initial organism = 1.412 mg								
AD-1	P	1.540	0.956	P	0.747	P	P	P
GC-1	0.271	1.139	P	P	0.710	P	0.847	P
OC-12/13	1.447	1.270	1.211	P	1.374	1.178	1.131	1.221
OC-16	1.195	0.866	1.174	1.072	1.008	1.339	1.660	P
DC-5	1.078	0.952	0.997	0.903	1.144	1.345	P	1.347
Test 3 - mean ash-free control biomass per initial organism = 2.840 mg								
OC-22	1.870	3.174	3.266	1.352	2.343	2.320	2.405	2.699
OC-24/25	2.144	2.891	3.519	2.998	0.567	1.813	1.976	2.436
DC-6/7	1.952	1.974	1.532	2.168	1.960	1.513	2.997	1.578
DC-11/12	0.897	2.044	1.417	2.093	1.259	1.446	1.405	1.754
Test 4 - mean as-free control biomass per initial organism = 1.130 mg								
AD-1	1.314	1.410	P	0.997	P	P	P	1.751
GC-1	P	1.170	P	1.098	0.952	1.379	0.794	1.444

Letters in header row indicate individual test replicates
P means indigenous organisms affected test outcome;
* mean significantly less than control biomass ($p < 0.05$) as reported by ERDC (see Appendix G)

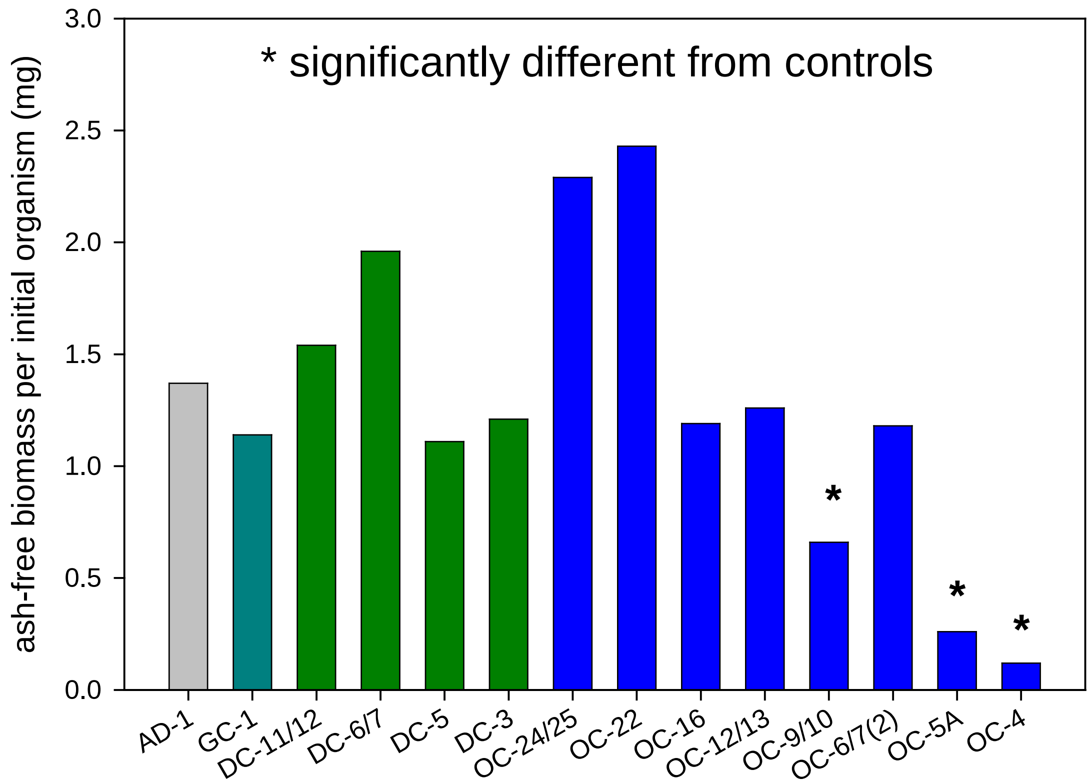


Figure 3-22 **Growth (biomass) of the midge *C. dilutus* was significantly less in sediments three locations in Otter Creek than in laboratory control sediments.**

Midge growth (biomass) was also tested for significance among all locations within the GLLA Data Gap Investigation study area. Midge growth, expressed as ash-free biomass, was scaled to the biomass of the control organisms (Table 3-13) to remove the influence of the test organisms in Test 3 being much larger than in the other tests. Control-scaled biomass was significantly different (less) at two locations, OC-5A and OC-4 (Figure 3-23).

Table 3-13 Growth (ash-free biomass) of midge larvae, scaled to control biomass to allow inter-test comparisons, for toxicity tests with sediments from Duck, Otter and Grassy Creeks and Amlosch Ditch.

	A	B	C	D	E	F	G	H
Test 1								
OC-4*	0.118	0.068	0.029	0.097	P	0.091	0.074	0.120
OC-5A-01*	0.233	0.083	0.418	0.215	0.044	0.225	0.231	0.120
OC-6/7	0.884	P	0.960	0.905	0.635	0.930	1.137	0.688
OC-9-10	0.460	0.596	0.526	0.566	0.597	P	0.458	0.242
DC-3	1.015	1.176	1.085	0.568	0.400	0.894	P	1.140
Test 2								
AD-1	P	1.090	0.677	P	0.529	P	P	P
GC-1	0.192	0.807	P	P	0.503	P	0.600	P
OC-12/13	1.025	0.899	0.857	P	0.973	0.834	0.801	0.865
OC-16	0.846	0.613	0.831	0.759	0.714	0.948	1.175	P
DC-5	0.763	0.674	0.706	0.639	0.810	0.952	P	0.954
Test 3								
OC-22	0.658	1.117	1.150	0.476	0.825	0.817	0.847	0.950
OC-24/25	0.755	1.018	1.239	1.055	0.200	0.638	0.696	0.858
DC-6/7	0.687	0.695	0.539	0.763	0.690	0.533	1.055	0.556
DC-11/12	0.316	0.719	0.499	0.737	0.443	0.509	0.495	0.617
Test 4								
AD-1	1.162	1.247	P	0.882	P	P	P	1.549
GC-1	P	1.035	P	0.971	0.842	1.220	0.703	1.278

Letters in header row indicate individual test replicates

P means indigenous organisms affected test outcome;

* mean significantly less than control biomass ($p < 0.05$) as determined by Analysis of Variance on Ranks and Dunns Pairwise Comparisons Test (Appendix N)

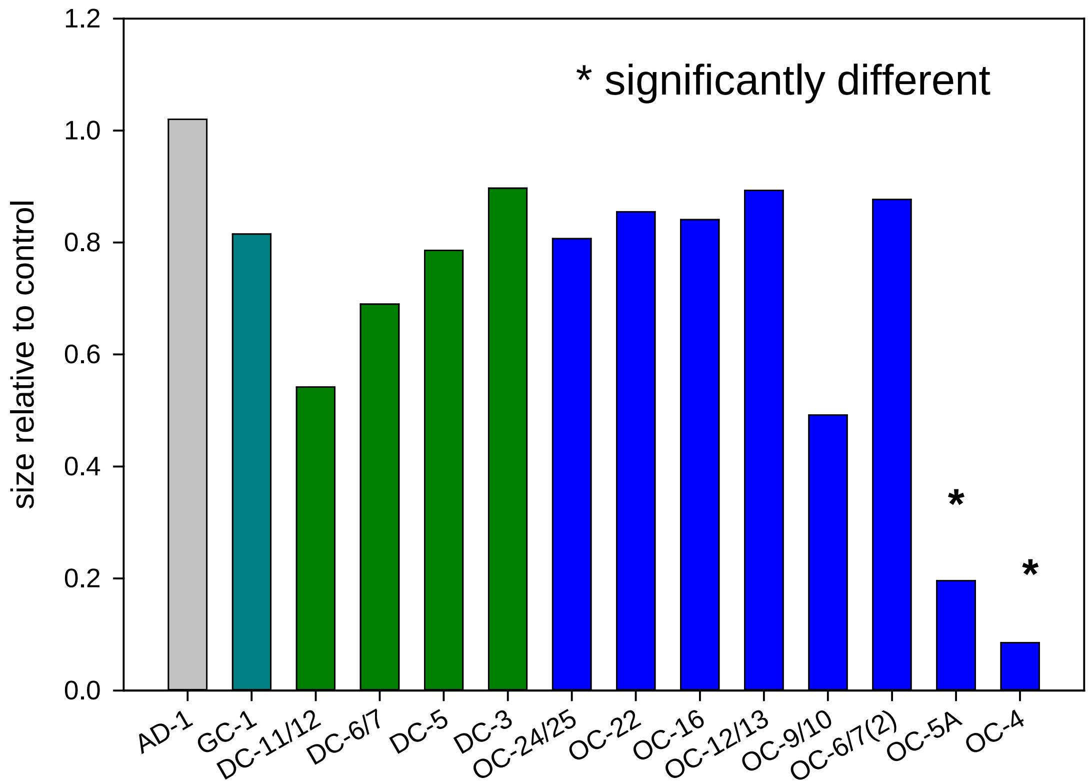


Figure 3-23 **Growth (mean biomass) of the midge *C. dilutus* was significantly different among two locations within the GLLA Data Gap Investigation study area.**

The sediment toxicity test results are a component of the Sediment Quality Triad approach for assessing sediment. In the Triad approach, benthic community structure, sediment toxicity and sediment chemistry are evaluated together to evaluate cause-effect relationships among these endpoints (see Table 3-14). The two biological metrics of sediment quality were generally in agreement: more growth in the laboratory corresponded with greater abundance of sensitive taxa in the field; less growth in the laboratory corresponded with a greater abundance of tolerant taxa in the field. However, a comparison of total taxa, abundance of sensitive taxa, and abundance of tolerant taxa, did not yield significant correlations with midge growth or midge survival (Appendix N), which suggests that sediment toxicity is not the sole factor affecting the benthic communities of Duck and Otter Creeks.

Table 3-14 Summary of aggregated benthic community structure and sediment toxicity test results for correlation analysis in support of sediment quality triad evaluations.

Sample location	Median taxa richness	Median sensitive taxa abundance	Median tolerant taxa abundance	Mean midge survival	Mean scaled biomass
Amlosch Ditch	8	63.1%	25.5%	75.7%	1.02
Grassy Creek	9	0%	85.3%	66.0%	0.815
DC-11/12	-	-	-	83.8%	0.542
DC-6/7	6	13.0%	82.6%	83.8%	0.690
DC-5	8	14.8%	82.0%	87.1%	0.786
DC-3	8	15.0%	45.2%	70.0%	0.897
OC-24/25	13	3.76%	20.4%	81.3%	0.807
OC-22	5	0%	81.8%	91.3%	0.855
OC-16	4	0%	82.1%	91.4%	0.841
OC-12/13	4	0%	81.5%	92.9%	0.893
OC-9-10	5	0%	74.3%	82.9%	0.492
OC-6/7(2)	2	0%	100%	78.8%	0.877
OC-5A-01	5	0%	93.9%	70.0%	0.196
OC-4	4	0%	80.6%	41.3%	0.085

Aggregated benthic community data were normally-distributed, so medians were used for statistical testing of these variables
Aggregated sediment toxicity test data were normally-distributed so mean values were used for statistical testing

3.5 GLLA Chemistry Data

The third component of the Sediment Quality Triad is an evaluation of sediment chemistry. The GLLA Data Gap Investigation employed several measurements of sediment chemistry, with a focused effort on evaluation of the biologically-available dose to aquatic organisms. These chemical measurements are evaluated by chemical classes that act through similar modes of action and have comparable measurements of the biologically-available dose. The following data evaluations are organized in a tiered approach.

- In the first tier, chemical concentrations in bulk sediment are compared against benchmarks to determine if additional evaluation is warranted, prior to evaluating site-specific bioavailability.

- In the second tier, the bioavailable fraction of each chemical class was assessed using calculations that are based on the processes by which chemicals can become available for uptake by aquatic organisms. Specifically, the organic carbon in sediments can bind organic compounds and some metals, and decrease the dissolution in water and uptake by biological organisms. Some metals form very insoluble salts with sulfide that also decrease uptake by biological organisms. The DGI analyses included measures of total organic carbon and acid-volatile sulfides so the partitioning of contaminants in sediments could be estimated. In addition, the "bioaccessible" fraction of arsenic that can be dissolved in simulated stomach fluids was measured at selected locations. For organic compounds equilibrium partitioning (EqP) calculations were used to calculate sediment pore water concentrations that were potentially available to aquatic organisms;

- The third tier of DGI chemistry assessment was to measure the concentrations of selected classes of contaminants in sediment pore water because pore water is generally accepted as the primary route of exposure for sediment-dwelling organisms; and

- The fourth tier of the chemistry assessment involved the measurement of tissue concentrations of aquatic organisms that were collected from Duck and Otter Creeks and the urban comparison streams.

This multi-tiered approach to chemistry interpretation involves multiple lines of evidence regarding the potential for sediment-associated chemicals to adversely affect aquatic life.

The chemistry data tables are somewhat complex and large, and are included in Appendix H to enhance the readability of the report. Summary charts of the chemical constituents that were identified as potentially important in previous investigations are included in the body of the report, and summary tables are presented as supplements to the figures and Appendix tables.

3.5.1 Metals and Ammonia

Metals were measured in sediments collected from Duck, Otter and Grassy Creeks and Amlosch Ditch. Total metals concentrations in sediment on a dry weight basis are presented in Tables H-1 and H-2 of Appendix H, along with the Probable Effects Concentrations (PECs), which are chemical-specific bulk sediment benchmarks that have been developed using databases of chemistry and biological endpoints for freshwater systems, including data from the Great Lakes region (MacDonald et al., 2000). The PECs are estimates of sediment concentrations above which adverse effects on exposed organisms often occurred in the MacDonald et al. (2000) database. PECs are used here as a first-tier evaluation of bulk sediment chemistry data.

Tier 1 - The PEC for lead was exceeded in one sediment sample from Duck Creek (Figure 3-24). Bulk sediment concentrations exceeded the PEC for arsenic in several samples from Duck Creek (Table H-1 and figure 3-26). In Otter Creek, the PECs for arsenic (Figure 3-27), chromium, copper, lead (figure 3-25) and mercury were exceeded in at least one sample location (Table H-2).

Of the metals, lead, arsenic and chromium most frequently exceeded its respective bulk sediment benchmark. Lead concentrations exceeded the bulk sediment benchmark in at least one surface sample in segment A of Duck Creek, and segments C, and B of Otter Creek. For subsurface sediments, lead concentration exceeded the benchmark in one sample from segment A in Otter Creek. Arsenic concentrations exceeded the bulk sediment benchmark in at least one surface sample in segments D, and A of Duck Creek, and segment E of Otter Creek. For subsurface sediments, the arsenic concentration exceeded the benchmark in one sample from segment E of Otter Creek. Chromium exceeded the sediment benchmark in at least one surface sediment sample in segments C, B and A of Otter Creek, and in at least one subsurface sediment sample in segment A of Otter Creek. The evaluation of metals in Duck and Otter Creeks proceeded to the second tier.

Figure 3-24 Summary of lead concentrations in sediments of Duck, Grassy Creeks and Amlosch Ditch.

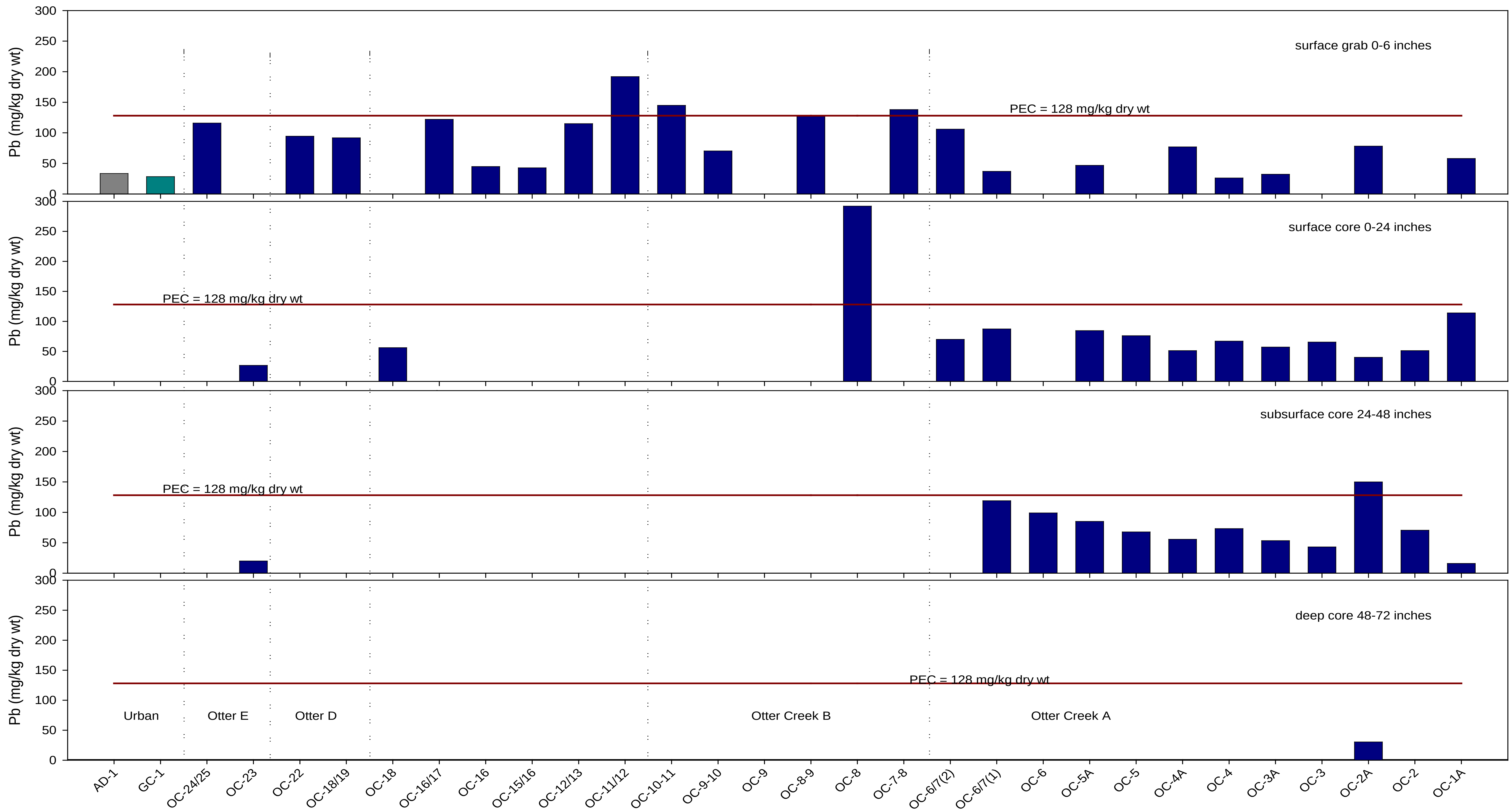


Figure 3-25 **Summary of lead concentrations in sediments from Otter, Grassy Creeks and Amlosch Ditch.**

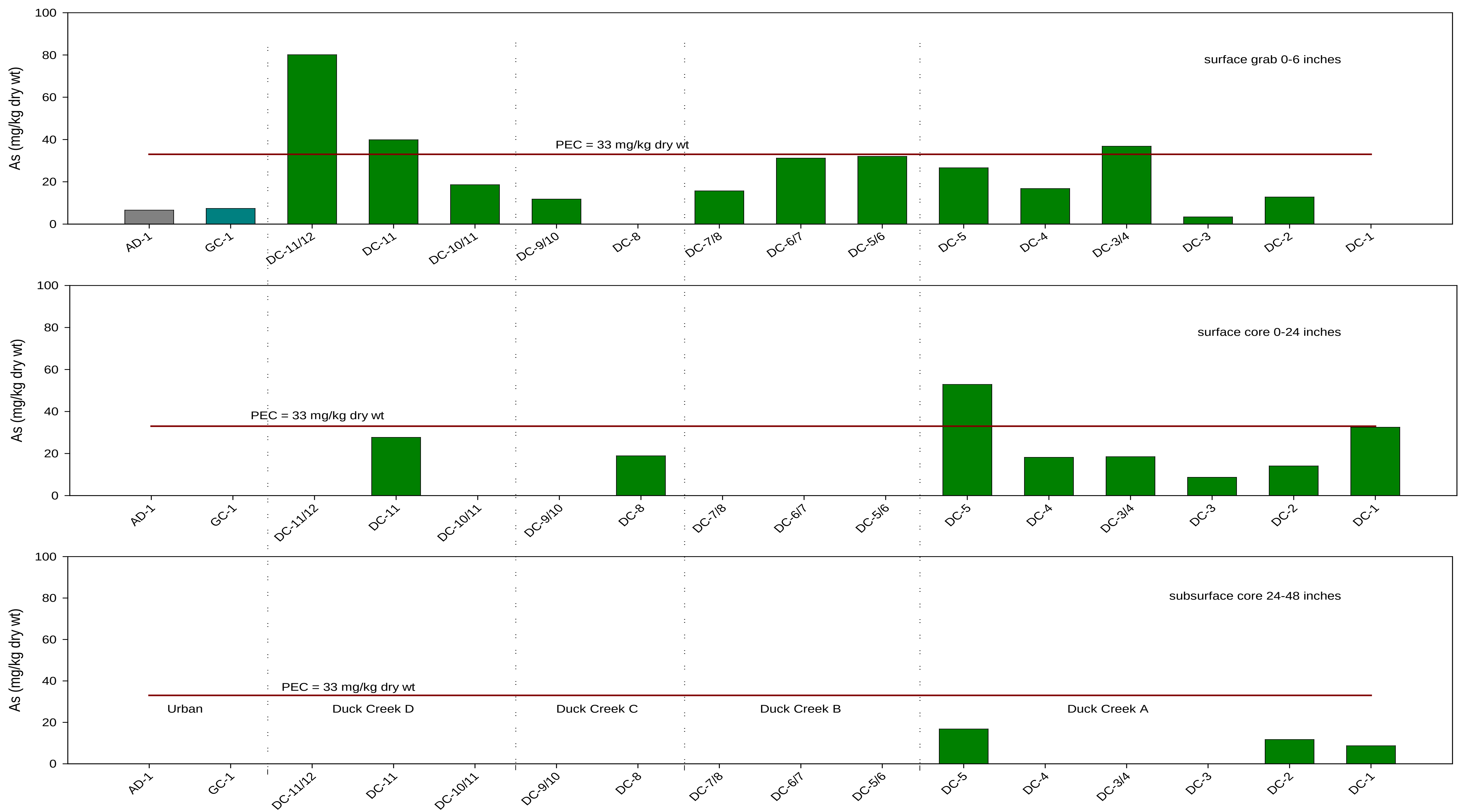


Figure 3-26 **Summary of arsenic concentrations in sediments of Duck and Grassy Creeks and Amlosch Ditch.**

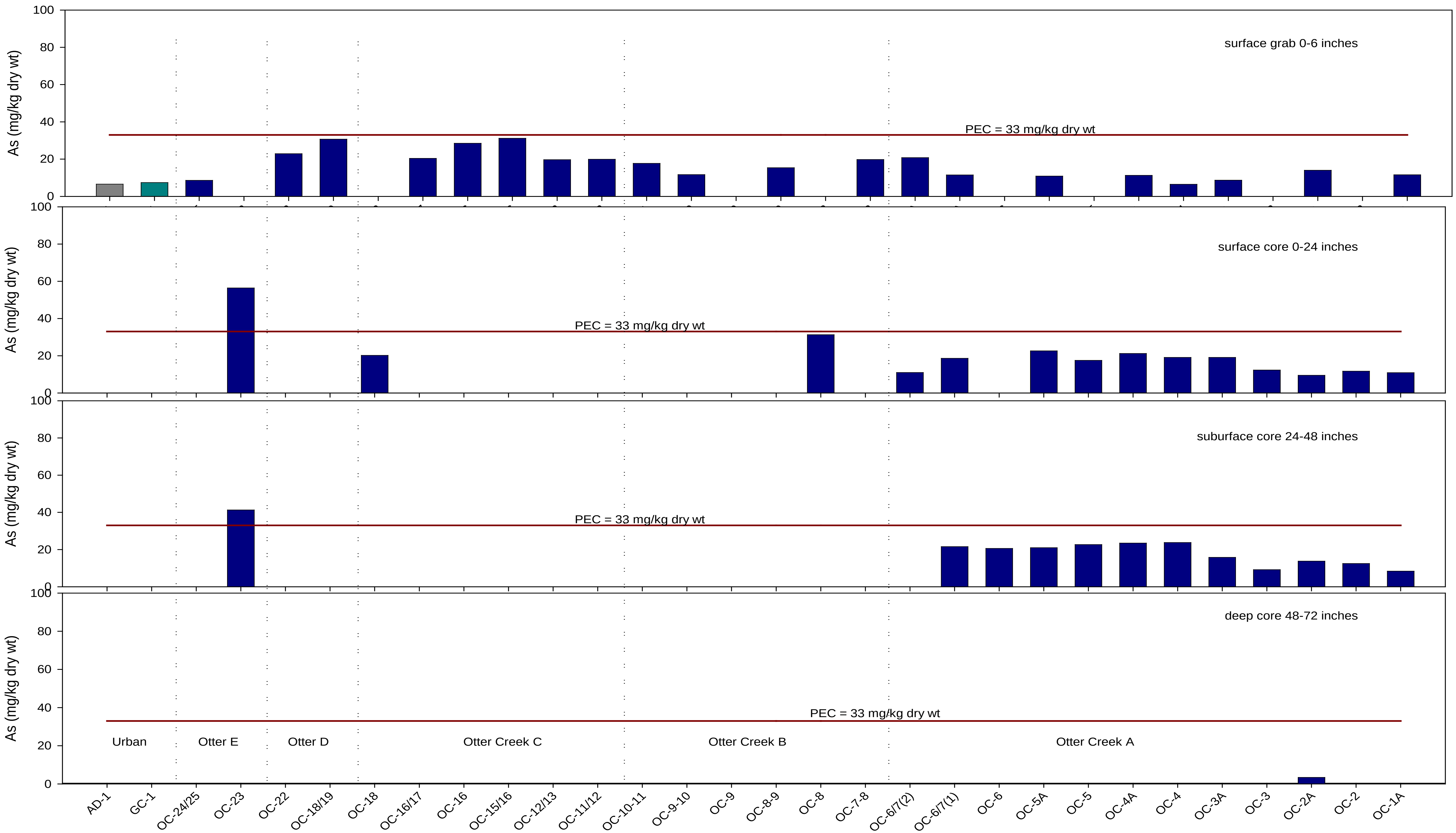


Figure 3-27 **Summary of arsenic concentrations in sediments from Otter and Grassy Creeks and Amlosch Ditch.**

Tier 2 - The second tier of the evaluation of metals in Duck and Otter Creek sediments was based on the chemical interaction of metals with sulfides. Under reducing conditions (about -100 mV), sulfate is microbially reduced to sulfide, which forms extremely insoluble salts with divalent metal ions. Environmental conditions that are favorable for metal-sulfide reactions are common in aquatic sediments, especially in water bodies with silty sediments and fertile watersheds or other nutrient sources. The ratio of acid volatile sulfide (AVS) , that fraction that can be extracted by cold HCl with the molar concentrations of cadmium, copper, lead, nickel, silver and zinc that are extracted simultaneously (SEM) can be used to determine if there is sufficient excess metal present to bind with the organic carbon content of sediments. If the ratio of excess SEM (e.g. SEM-AVS on a molar basis) to the fraction of organic carbon in the sediment (SEM-AVS/foc) is greater than 130 µmole/gOC, then divalent metals are potentially available for to aquatic organisms (USEPA 2005, OEPA 2010b). The SEM-AVS/foc analysis indicated that sediments from Duck and Otter Creek contained sufficient sulfide and organic carbon to bind the simultaneously extracted metals in all DGI locations (Tables H-3 and H-4 in Appendix H). In fact, for most sediment samples the AVS content was much greater than the SEM, and the SEM-AVS/foc values were negative numbers (Tables 3-15 and 3-16). These data indicate that the metals cadmium, copper, lead nickel silver and zinc are not bioavailable in the sediments of Duck, Otter and Grassy Creeks or Amlosch Ditch.

Table 3-15 Summary of SEM-AVS/foc data from the urban comparison streams and Duck Creek..

Sample location	ΣSEM (µmole/g dry weight)	AVS (µmole/g dry weight)	foc (g OC/g dry weight)	(ΣSEM-AVS)/foc (µmole/gOC)
Amlosch Ditch	1.1446	38.1	0.0507	-729
Grassy Creek	0.7664	20.7	0.0212	-940
DC-11/12	0.4510	8.06	0.229	-33
DC-10/11	1.3609	49.6	0.0679	-710
DC-9/10	1.1611	25.6	0.0537	-455
DC-7/8	0.8459	37.1	0.0629	-576
DC-6/7	5.0811	111	0.0755	-1403
DC-5/6	7.9690	209	0.0836	-2405
DC-5	3.7763	97	0.0499	-1868
DC-4	1.6133	13.7	0.0618	-196
DC-3/4	0.9755	29.8	0.0476	-606
DC-3	0.5382	13.8	0.0797	-166
Benchmark concentration for (ΣSEM-AVS/foc) is 130 µmole/gOC (USEPA 2005, OEPA 2010b) Includes: cadmium, copper, lead, nickel, silver and zinc				

Table 3-16 Summary of SEM-AVS/foc data from Otter Creek.

Sample location	ΣSEM (µmole/g dry weight)	AVS (µmole/g dry weight)	foc (g OC/g dry weight)	(ΣSEM-AVS)/foc (µmole/gOC)
OC-24/25	0.4260	14	0.0174	-780
OC-22	1.2840	41.6	0.0379	-1064
OC-18/19	1.4482	1.03	0.0326	13
OC-16/17	0.8916	1.19	0.0302	-10
OC-16	0.5944	2.02	0.0356	-40
OC-15/16	0.6841	0.74	0.0326	-2
OC-12/13	1.2670	13	0.0162	-724
OC-11/12	4.6856	77	0.0891	-812
OC-10-11	1.6264	0.408	0.0371	33
OC-9-10	2.6128	30.5	0.0468	-596
OC-8-9	2.5326	6.11	0.0305	-117
OC-7-8	1.6576	5.5	0.0334	-115
OC-6/7(2)-01	2.3870	12.8	0.0392	-266
OC-6/7(1)-01	0.6805	0.45	0.0196	12
OC-5A-01	1.8593	2.7	0.0317	-27
OC-4A-01	1.6223	1.32	0.0339	9
OC-4-01	1.5929	21.3	0.0495	-398
OC-3A-01	1.5456	5.4	0.0221	-174
OC-2A-	1.0139	19	0.0397	-453
OC-1A	1.4072	7.2	0.0381	-152

Benchmark concentration for (ΣSEM-AVS/foc) is 130 µmole/gOC (USEPA 2005, OEPA 2010b)
Includes: cadmium, copper, lead, nickel, silver and zinc

Tier 3 - The third tier evaluation was based on a comparison of the measured concentrations of metals (and ammonia) in sediment pore water with concentrations of metals that are known to be protective of aquatic life, namely, the State of Ohio's chronic ambient water quality criteria (AWQC) under Ohio Administrative Code (OAC) Rule 3745-1-07. The average values for outside the mixing zone (OMZA) were used for the calculations in Tables H-5 and H-6 of Appendix H. Several of the chronic OMZA criteria are based on the hardness of the water, with a maximum allowable value of 400 mg/L hardness (as mg $CaCO_3$/L). The specific equations for total recoverable (TR) metals in Rule 3745-1-07 are:

- Beryllium TR OMZA (µg/L) = $e^{(1.609\,[\ln \text{Hardness}] - 5.017}$;
- Cadmium TR OMZA (µg/L) = $e^{(0.7852\,[\ln \text{Hardness}] - 2.715}$;

- Chromium TR OMZA (µg/L) = $e^{(0.819 [\ln \text{Hardness}] + 0.6848}$;
- Copper TR OMZA (µg/L) = $e^{(0.8545 [\ln \text{Hardness}] - 1.702}$;
- Lead TR OMZA (µg/L) = $e^{(1.273 [\ln \text{Hardness}] - 4.003}$;
- Nickel TR OMZA (µg/L) = $e^{(0.846 [\ln \text{Hardness}] + 0.584}$;
- Zinc TR OMZA (µg/L) = $e^{(0.8473 [\ln \text{Hardness}] + 0.884}$;

Trace concentrations of several metals were measured in sediment pore water samples; however no pore water concentrations exceeded its applicable Tier 1 chronic AWQC. In one sample (DC-11/12) the barium concentration in pore water exceeded the Tier II standard (Table 3-17). The maximum pore water concentrations of lead and arsenic, which were identified as potentially important metals in previous investigations, were much less than the respective AWQCs lead and arsenic (see Figures 29 and 30). Except for barium, the maximum pore water concentration observed in the DGI was much less than the respective AWQCs (Table 3-17). The State of Michigan has a hardness-based standard for barium[2], which yields a sample-specific chronic standard for DC-11/12 of 1911µg/L, which is much greater than the measured pore water concentration. Neither midge survival nor growth were significantly decreased at sample location DC-11/12, which indicates that barium did not adversely affect sediment-dwelling organisms at the maximum concentration observed in the DGI. Aquatic organisms that could potentially be exposed to water above the sediments would be protected further by diffusion and dilution of pore water that might be released from sediments into the water column.

[2] Michigan Rule 57 standard for barium final chronic value (µg/L) = $e^{1.0629 [\ln \text{Hardness}] + 1.1869}$. At the maximum hardness used by the OEPA, the barium standard for DC-11/12 is 1911 µg/L.

Table 3-17 Summary of the maximum measured concentration for each metal and the Ohio surface water standards.

Constituent	Tier I Aquatic Life Standard (µg/L)	Tier II Aquatic Life Standard (µg/L)	Maximum detected pore water concentration (µg/L)	Sample location for maximum concentration
Antimony	Not available	190	1.81	OC-9-10
Arsenic	150	Not applicable	48.7	OC-22
Barium	Not available	220	329	DC-11/12
Beryllium[H]	Not available	28 to 102	0.025	DC-11/12
Cadmium[H]	3.9 to 7.3	Not applicable	0.054	OC-22
Chromium[H]	187 to 268	Not applicable	8.56	OC-4
Cobalt	Not available	24	2.51	DC-11/12
Copper[H]	21 to 30	Not applicable	1.56	OC-24/25
Lead[H]	21 to 37	Not applicable	1.12	OC-9-10
Mercury	0.91	Not applicable	<0.2	Not detected
Nickel[H]	85 to 169	Not applicable	9.31	OC-4
Selenium	5.0	Not applicable	3.7	DC-11/12
Silver	1.3	Not applicable	0.008	Grassy Creek
Thallium	Not available	17	0.076	Grassy Creek
Vanadium	Not available	44	5.02	OC-4
Zinc[H]	267 to 388	Not applicable	13.4	DC-5
H = water quality standard is based on the hardness of the water (up to a maximum value of 400 mg/L as $CaCO_3$) and the range of sample-specific values from the DGI is presented here.).				

Ammonia concentrations were greater than the AWQC in the sediment pore waters from several sediment samples, including the Amlosch Ditch urban comparison stream (see B-1 in Appendix G and Tables H-5 and H-6 in Appendix H). The AWQC is a protective value, so exposures at greater concentrations do not necessarily translate to adverse effects. Moreover, ammonia did not reach problematic concentrations in the overlying water during the sediment toxicity test (see tables B-2 through B-4 in Appendix G). The available site-specific data suggest that sediment-associated ammonia is not affecting the benthic community structure or contributing to sediment toxicity in the laboratory.

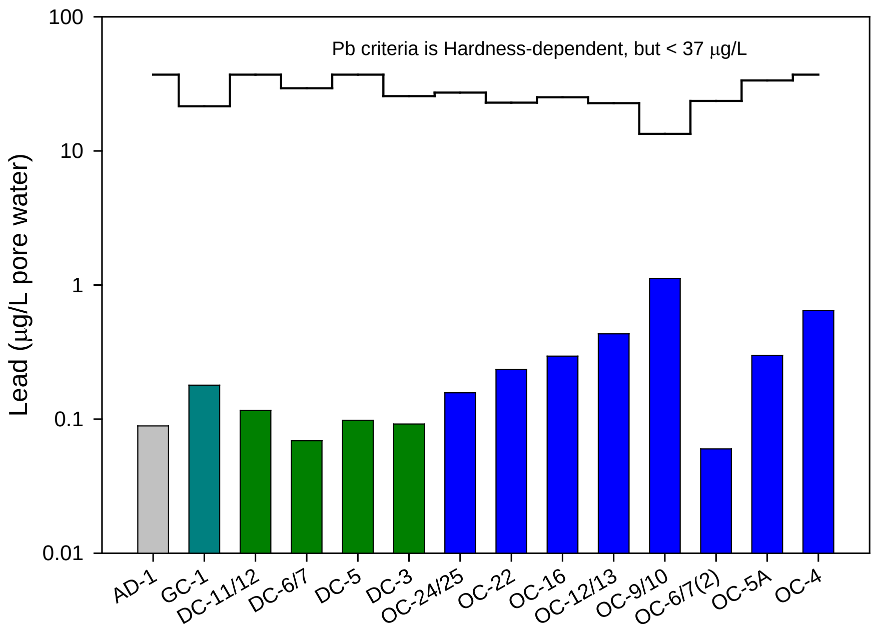


Figure 3-28 Summary of lead concentrations in sediment pore waters from Amlosch Ditch and Grassy, Duck and Otter Creeks. Note the logarithmic scale on the Y axis.

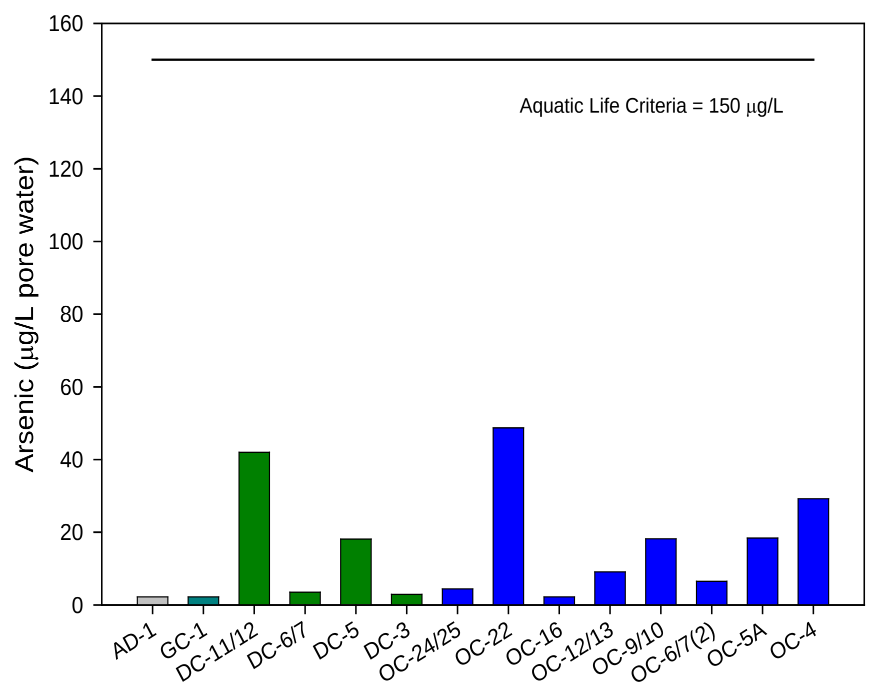


Figure 3-29 Summary of arsenic concentrations in sediment pore waters from Amlosch Ditch and Grassy, Duck and Otter Creeks.

Tier 4 - The third tier of assessment for metals, the evaluation of tissue data is difficult because there are no well-defined tissue residue-based benchmarks for adverse effects. A comprehensive study of tissue residues was undertaken by Jarvinen and Ankley at the USEPA Research Lab in Duluth, Minnesota in 1999; however they noted that the uptake rate of metals appeared to be more important than body residues for assessing toxicity. Many metals are essential micronutrients that are carefully regulated by metabolic processes. Some have specific modes of action, and whole-body residues are seldom reliable surrogates of the dose that is received in the target organs or site of toxicological action (Meador et al, 2010). The exception is selenium, for which the USEPA has drafted a whole-body tissue concentration of 7.91 mg/kg dry weight for protection of fish reproduction (USEPA 2004). The metals concentrations measured in invertebrate tissues are reported in Table H-7; the detected selenium concentrations ranged from 0.56 to 1.1 mg/kg dry weight. The fish tissue metals data are reported in Table H-8; selenium concentrations in fish from Duck and Otter Creeks ranged from 1.79 to 3.2 mg/kg dry weight.

The tissue data also provided information for evaluating site-specific bioaccumulation of metals, for example, lead (Table 3-18) and arsenic (Table 3-19). The site-specific DGI data show that neither lead nor arsenic are bioaccumulating in the aquatic food webs of Duck, Otter and Grassy Creeks, or Amlosch Ditch. The concentrations of both metals are greatest in sediments, relative to benthic macroinvertebrate tissues and fish. In general, lead and arsenic concentrations decrease about one order of magnitude between sediments and benthic invertebrate tissues, on a dry weight basis (Tables 3-19 and 3-20). The relationships between invertebrate and fish tissue concentrations vary among stream reach. In some cases the concentrations of these two metals decreases from invertebrates (prey) to fish (predator); in some cases the concentrations are about equal. Neither lead nor arsenic exhibited an increased concentration between invertebrates and fish. The tissue data are consistent with the SEM/AVS and sediment pore water evaluations in that all Tier 2, 3 and 4 evaluations in this DGI demonstrate that metals in the sediments of Duck, Otter and Grassy Creeks and Amlosch Ditch are bound to ligands, have very low bioavailability, and are not bioacccumulating.

Table 3-18 **Summary of lead concentrations in sediments, benthic macroinvertebrates and fish from the DGI data set.**

Stream Segment	Sample Location	Sediment Lead (mg/kg dry wt)	Invertebrate Tissue Lead (mg/kg dry wt)	Fish Tissue Lead (mg/kg dry wt)
Urban Comparison	Amlosch Ditch	33.5	3.6	No sample
	Grassy Creek	28.4	1.2	No sample
Duck Creek D	DC-11/12	66.1	0.48	0.194
Duck Creek A	DC-5	67.3	1.8	0.278
Otter Creek C	OC-16	44.8	4.7	0.627
	OC-12/13	115	3.6	
Otter Creek A	OC-5A	46.8	0.78	0.394
	OC-4	26.1	1.4	
Fish were collected within stream reaches and are generally more mobile than invertebrates so they are reported on a reach basis here				

Table 3-19 Summary of arsenic concentrations in sediments, benthic macroinvertebrates and fish from the DGI data set..

Stream Segment	Sample Location	Sediment Arsenic (mg/kg dry wt)	Invertebrate Arsenic (mg/kg dry wt)	Fish Tissue Arsenic (mg/kg dry wt)
Urban Comparison	Amlosch Ditch	6.6	1.3	No sample
	Grassy Creek	7.4	0.62	No sample
Duck Creek D	DC-11/12	80.1	2.6	0.42
Duck Creek A	DC-5	26.6	1.1	0.93
Otter Creek C	OC-16	28.5	2.1	0.69
	OC-12/13	19.7	1.8	
Otter Creek A	OC-5A	10.9	0.66	0.80
	OC-4	6.5	1.1	
Fish were collected within stream reaches and are generally more mobile than invertebrates so they are reported on a reach basis here				

Supplemental assessment – Protection of human health protection is a component of any environmental decision, including those based primarily on protection of aquatic communities. The lack of site-specific bioavailability of arsenic in sediments of streams that have residential riparian land use was a data gap that was identified and addressed in this DGI. The arsenic bioaccessibility may be useful to decision makers in a subsequent process, and has been included in this report. Arsenic bioaccessibility was measured using the in-vitro gastrointestinal (IVG) method. The full report from that study is included as Appendix I. Bioaccessible arsenic that was extracted by simulated digestive liquids represented from 29.8% to 57.6% of the total arsenic present in sediments from Duck and Otter Creek (Appendix I). A summary comparison of bioaccessible arsenic with total arsenic is presented in Figure 3-30.

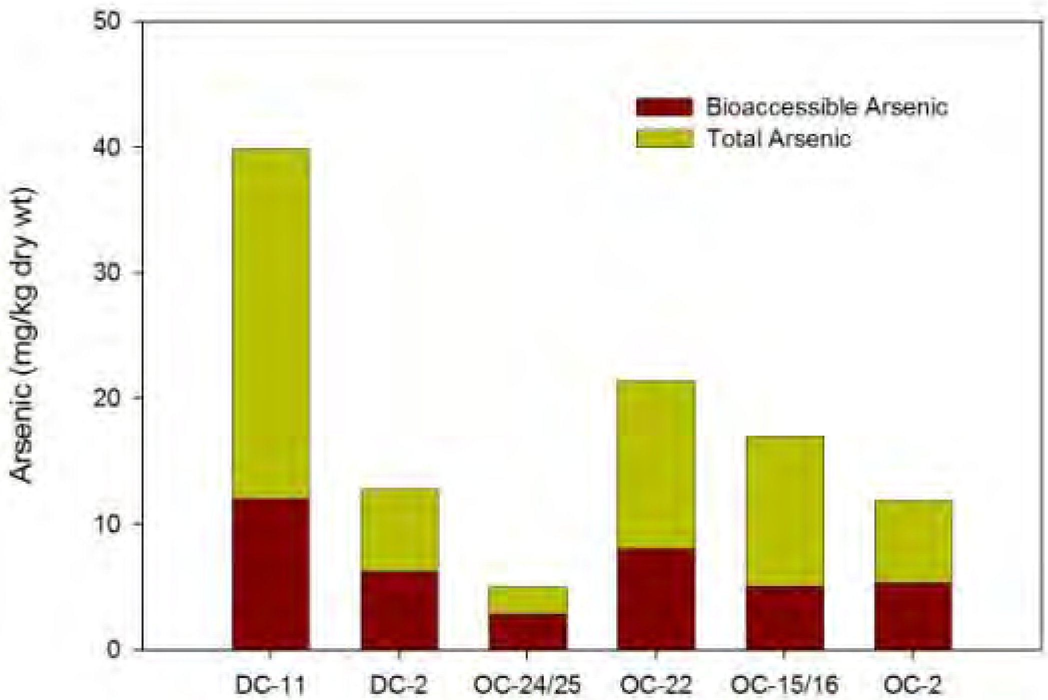


Figure 3-30 **Summary of in-vitro arsenic bioaccessibility in surface (0-6 inch) sediments from Duck and Otter Creeks.**

3.5.2 Pyrethroid Pesticides

Tier 1 – Only three of 12 pyrethroid pesticides, Bifenthrin, L-Cyhalothrin and Permethrin, were detected in DGI sediment samples (Tables H-9 and H-10).

- Bifenthrin was detected in 9 of 14 DGI locations: Amlosch Ditch; Grassy Creek; one location in Duck Creek (DC-6/7); and in six of the eight locations in Otter Creek;
- L-Cyhalothrin was detected only once in the DGI, at location OC-9-10 in Otter Creek;
- Permethrin was detected in two DGI locations, Amlosch Ditch and OC-22 in Otter Creek.

No bulk sediment benchmark concentrations are available for these compounds, so the assessment proceeded directly to Tier 2.

Tier 2 – None of the detected pyrethroid pesticides that were detected in DGI sediments exceeded the associated benchmark concentrations. The available benchmarks for pyrethroid pesticides (Maund et al. 2002, Amweg et al. 2005, Starner et al. 2006), are based on equilibrium partitioning calculations between the sediment organic carbon and sediment pore water. The EqP equation is:

Sediment benchmark = surface water benchmark *Koc * foc* 1kg/1000g

Where:

The surface water benchmark is concentration associated with an endpoint, for pyethroid pesticides, the water benchmarks are median lethal concentrations (µg/L) from 10-day toxicity tests with the amphipod *Hyalella azteca*;

Koc is the water-organic carbon partitioning coefficient (L/kg OC);

foc is the organic carbon fraction of the sediments (kg OC/kg sediment);

1kg/1000g is a conversion factor; and

The sediment benchmark units are µg/g OC.

In summary, the Tier 2 DGI pyrethroid pesticide evaluation includes:

- Detected Bifenthrin concentrations ranged from 0.0137 to 0.205 µg/g OC, which were all less than the benchmark concentration of 0.52 µg/g OC.
- The detected concentration of L-Cyhalothrin was 0.0571 µg/g OC, which was less than the benchmark of 0.45 µg/g OC.
- The detected concentrations of Permethrin ranged from 0.300 to 0.522 µg/g OC, which was less than the benchmark concentration of 10.83 µg/g OC.

No Tier 3 or 4 assessments were conducted for pyrethroid pesticides.

The greatest concentrations of the pyrethroids Bifenthrin and Permethrin were measured in the Amlosch Ditch sample; however, the concentrations were much less than the EqP-based benchmarks, and no sediment toxicity was observed at that location. It is interesting to note that the pyrethroid benchmarks are based on LC50 values from toxicity tests with amphipods, and amphipods were abundant in Amlosch Ditch. The results from the DGI indicate that pyrethroid pesticide concentrations were not present at quantities that would cause lethality to a sensitive species of amphipod in the fall of 2010. The DGI data do not indicate that pyrethroid pesticides were adversely affecting the biological communities of Duck, Otter, and Grassy Creeks, or Amlosch Ditch.

3.5.3 Polychlorinated Biphenyls (Aroclors)

Tier 1 - Trace concentrations of PCBs were detected in some sediment samples from Duck, Otter and Grassy Creeks, and Amlosch Ditch (Figures 3-31 and 3-32). Only two of nine Aroclor mixtures, 1248 and 1254, were detected in the DGI sediment samples. The greatest PCB concentrations (290 µg/kg dry weight Aroclor 1248 and 300 µg/kg dry weight Aroclor 1254) were measured in sediment from Grassy Creek. (Tables H-11 and H-12). All PCB concentrations, including the sum of both Aroclors in Grassy Creek (590 µg/kg dry weight) were less than the PEC of 676 µg/kg dry weight.

Tier 2 – The maximum PCB concentrations observed in the DGI samples were compared with EqP-based benchmarks using the method of Fuchsman et al 2006, and is summarized in Appendix A.

- The maximum Aroclor 1248 concentration (Grassy Creek) was 13.7 µg/g OC, which was much less than the EqP benchmark of 490 µg/g OC.

- The maximum Aroclor 1254 concentration (Grassy Creek) was 14.2 µg/g OC, which was much less than the EqP benchmark of 1500 µg/g OC.

The Tier 2 results indicate that concentrations of PCBs in the urban comparison stream do not exceed the binding capacity of those sediments and are not likely to harm aquatic life.

No Tier 3 evaluations were conducted for PCBs in the DGI.

Tier 4 - Some PCBs were also detected in invertebrate (Table H-13) and fish (table H-14) tissue samples. All of the detected Aroclors, as well as the sum of detected PCB congeners or Aroclors were much less than tissue benchmark concentration for larval fish from Monosson (2000). Specifically:

- The maximum Aroclor 1254 concentration observed in fish was 260 µg/kg wet weight in the log perch sample from Otter Creek segment A. The larval fish benchmark for Aroclor 1254 is 5000 µg/kg wet weight (Monosson 2000).

- The maximum Aroclor 1254 concentration observed for invertebrate tissues was 81 µg/kg wet weight at location OC-4, which is also much less than the available benchmark for fish tissue.

- The fish larvae benchmark for PCB 77 is 1300 µg/kg wet weight (Monosson 2000). PCB 77 was not detected in any of the fish tissue samples from the DGI, and the detection limits for PCB congeners were approximately 2 orders of magnitude less than the benchmark.

A comparison of Aroclor 1254, which was the most frequently-detected PCB mixture, data in sediments, benthic macroinvertebrates and fish demonstrated evidence of biomagnification from invertebrates to fish (Table 3-20). There was no clear evidence of biomagnification from sediments because benthic invertebrate tissue concentrations were generally less than sediment concentrations. The fish tissue concentration was nearly equal to the sediment concentration in Otter Creek Segment A, but was less than the sediment concentration in Duck Creek Segment A. The DGI data suggest that PCBs are not present at concentrations that are sufficient to adversely affect the biological communities of Duck, Otter and Grassy Creeks, or Amlosch Ditch.

Table 3-20 Summary of PCB (Aroclor 1254) concentrations in sediments, benthic macroinvertebrates and fish from the DGI data set.

Stream Segment	Sample Location	Sediment Aroclor 1254 (µg/kg dry wt)	Invertebrate Aroclor 1254 (µg/kg wet wt)	Fish Tissue Aroclor 1254 (µg/kg wet wt)
Urban Comparison	Amlosch Ditch	Not detected	Not detected	No sample
	Grassy Creek	300	16	No sample
Duck Creek D	DC-11/12	Not detected	5.8	Not detected
Duck Creek A	DC-5	170	24	99
Otter Creek C	OC-16	Not detected	21	150
	OC-12/13	Not detected	25	
Otter Creek A	OC-5A	Not detected	36	260
	OC-4	240	81	
Fish were collected within stream reaches and are generally more mobile than invertebrates so they are reported on a reach basis here				

3.5.4 Semivolatile Organic Compounds (SVOCs)

Tier 1 – Most of the SVOCs were not detected in any DGI sediment samples. The most frequently-detected SVOCS were the PAHs, which are evaluated in the following section. The non-PAH SVOC data are included in Tables H-17 through H-23 of Appendix H. PEC values are not available for the non-PAH SVOCs, so bulk sediment benchmark concentrations that are based on equilibrium partitioning (see equation in section 3.5.2) and the assumption that sediments contain 1% total organic carbon are presented in Table 3-21.

Tier 2 – None of the non-PAH SVOCs that were detected in sediments from the urban comparison streams exceeded the equilibrium partitioning-based benchmark concentrations that assume a sediment organic content of 1%. Sediments from the urban comparison streams contained between 1.62% and 22.9% TOC (Appendix E), so the sediments have more binding capacity than is assumed for the benchmark values.

The maximum measured values of three SVOCs (carbazole, diethyl phthalate, and phenol) were greater than the EqP-based benchmarks that assumed 1% TOC (Table 3-21). Sample-specific evaluations using the measured TOC were conducted to determine if the greater sediment organic carbon that is typical of these streams provided a different interpretation.

- For 4-methyl phenol, the sediment sample that contained the maximum concentration (DC-08-02), which is a subsurface sample, had an organic carbon content of 5.417%, which is 54.1 g OC/kg dry sediment. The 4-methyl phenol concentration in the sediment sample from DC-08-02 (420 µg/kg) converts to 7.76 µg/ g OC. The 4-methyl phenol benchmark at 1% TOC (10 g OC/kg sediment) converts to 26.6 µg/g OC. The carbon-based sample concentration was less than the carbon-based benchmark (e. g. 7.76 µg/g OC < 26.6 µg/g OC). A sample-specific evaluation of 4-methyl phenol indicated the maximum observed concentration of this SVOC was unlikely to adversely affect sediment-dwelling organisms.

- For carbazole, the sediment sample that contained the maximum concentration (Amlosch Ditch) had an organic carbon content of 5.07%, which is 50.7 g OC/kg dry sediment. The carbazole concentration in the sediment sample from Amlosch Ditch (1900 µg/kg) converts to 37.5 µg/ g OC. The carbazole benchmark at 1% TOC (10 g OC/kg sediment) converts to 18.6 µg/g OC. The carbon-based sample concentrations remained greater than the carbon-based benchmark (e. g. 37.5 µg/g OC > 18.6 µg/g OC); however, the sediment at this location did not affect midge survival. Midge lavae exhibited the maximum growth (in terms of biomass scaled to control organisms) at this location, and benthic community was dominated by sensitive taxa. The DGI data indicate that the maximum concentration of carbazole detected in sediments did not adversely affect aquatic life.

- For diethyl phthalate, the sediment sample that contained the maximum concentration (DC-11/12) had an organic carbon content of 22.9%, which is 229 g OC/kg dry sediment. The diethyl phthalate concentration in that sediment sample (410 µg/kg) converted to 1.79 µg/ g OC. The diethyl phthalate benchmark at 1% TOC (10 g OC/kg sediment) converted to 15.2 µg/g OC. The carbon-based sample concentration in DC-11/12 was much less than the carbon-based benchmark (e. g. 1.79 µg/g OC 15.2 µg/g OC), so a sample-specific evaluation of diethyl phthalate indicated the maximum observed concentration of this SVOC was unlikely to adversely affect sediment-dwelling organisms. The TOC content at DC-11/12 was unusually high compared with other DGI samples, and may have been caused by the presence of detritus from the abundant emergent plant community at that location. The remaining sample data were scanned to assess the overall situation with diethyl phthalate. This compound was detected in one additional sample (DC-6/7) at a concentration of 260 µg/kg. The organic carbon content of that sample was 7.55% (75.5 µg/g OC). The carbon –based concentration of diethyl phthalate in DC-6/7 was 3.44 µg/g OC, which is also less than the 15.2 µg/g OC screening benchmark. Sample-specific evaluations of diethyl phthalate indicate that this SVOC was unlikely to adversely affect sediment-dwelling organisms.

- For n-nitrosodiphenylamine, the sediment sample that contained the maximum concentration (OC-18-02, which is a subsurface sample) had an organic carbon content of 5.41%, which is 54.1 g OC/kg dry sediment. The n-nitrosodiphenylamine concentration in that sediment sample (570 µg/kg) converted to 7.09 µg/ g OC. The phenol benchmark at 1% TOC (10 g OC/kg sediment) converted to 24.0 µg/g OC, which was greater than the sample concentration. A sample-specific evaluation of n-nitrosodiphenylamine l indicated the maximum observed concentration of this SVOC was unlikely to adversely affect sediment-dwelling organisms.

No Tier 3 or 4 assessments were conducted for non-PAH SVOCs.

In summary, most of the non-PAH SVOCs were rarely detected in the DGI sediment samples. When detected, the SVOC concentrations were almost always less than EqP-based benchmarks; the exception was carbazole at the Amlosch Ditch sample location, which produced the largest midge larvae relative to controls, and had a benthic community that was dominated by sensitive taxa. In general, non-PAH SVOCs are unlikely to harm aquatic life in the DGI streams.

Table 3-21 Sediment benchmark concentrations for SVOCs (µg/kg dry weight) that were detected in DGI sediment samples. Benchmarks are based on 1% TOC.

Name of detected SVOC	Water benchmark (µg/L)	Benchmark Source	log Koc	Sediment Benchmark Concentration (µg/kg dry weight)	Maximum concentration detected in a DGI sample (µg/kg dry weight)
4-methylphenol	53	Ohio OMZAstandard [a]	2.70	266	420 (DC-8-02)
Acetophenone	ID	Van Leeuwen et al 1992	N/A	977[b]	270 (DC-8-02)
Benzaldehyde	14000	Illinois chronic standard [c]	1.514	4572	270 (OC-5A-02)
Bis(2-ethylhexyl)phthalate	8.4	Ohio OMZA standard [a]	4.94	7316	1500 (OC-4A-02)
Benzyl butyl phthalate	23	Ohio OMZA standard [a]	3.72	1207	570 (OC-11/12)
Carbazole	7.4	Illinois chronic standard [c]	3.40	186	1900 (Amlosch Ditch)
Diethyl phthalate	220	Ohio OMZA standard [a]	1.84	152	410 (DC-11/12)
N-Nitrosodiphenylamine	58.5	USEPA Region IV[d]	2,613	240	570 (OC-18-02)
Phenol	400	Ohio OMZA standard [a]	1.90	318	180 (DC-8-02)

a equilibrium partitioning-based concentration, assumes 1% TOC and uses Ohio chronic (outside mixing zone average) water quality criterion from Chapter 3745-1 of Ohio Administrative Code for Lake Erie tributaries

b equilibrium partitioning-based No Effect Level from Van Leeuwen et al 1992

c equilibrium partitioning-based concentration, assumes 1% TOC and uses Illinois general use water quality criterion

d equilibrium partitioning-based benchmark from USEPA IV freshwater screening value, assumes 1% TOC

log Koc data from EpiSuite (experimental data when available, log Kow-derived values used when experimental data were not available

ID = Ohio has determined there are insufficient data to develop a water quality standard

Figure 3-31 **Summary of PCB concentrations in sediments from Duck and Grassy Creeks and Amlosch Ditch.**

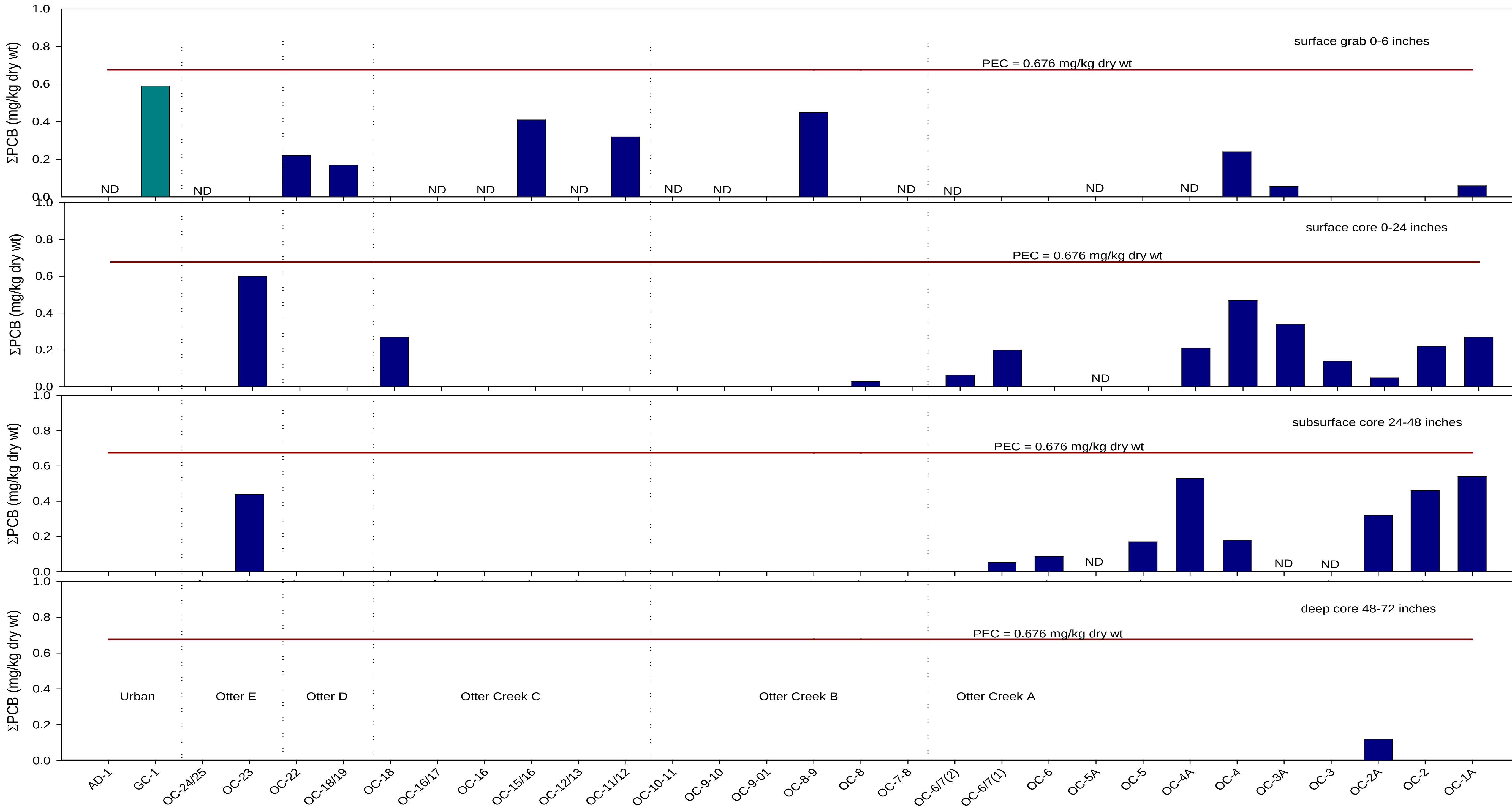


Figure 3-32 **Summary of PCB concentrations in sediments from Otter and Grassy Creeks and Amlosch Ditch.**

3.5.5 Total Petroleum Hydrocarbons

Tier 1 - Total petroleum hydrocarbons (TPH) concentrations were measured in the gasoline (C_8-C_{12}), diesel (C_{10}-C_{28}) and residual (C_{25} to C_{36}) ranges. Gasoline-range hydrocarbons were absent from most samples (Tables H-15 and H-16); the greatest concentrations were measured in surface core samples collected near the mouth of Otter Creek (Figures 3-33 and 3-34). Diesel- and residual-range hydrocarbons were generally comparable; however, the concentrations in Otter Creek (Figure 3-34) tended to be greater than those measured in Duck Creek (Figure 3-33). The presence of elevated TPH concentrations in several locations indicated that additional tiers of evaluation were warranted.

Tier 2 – The available benchmarks for TPH ranges (Battelle 2007) are based on equilibrium partitioning; however, the values are based on carbon ranges of alkanes and aromatic compounds, and appropriate application of the values requires that the analytical data be available in the same fractions as the benchmarks,

- Aliphatic Hydrocarbons which are saturated structures that contain 2 hydrogen atoms per carbon, in four different size fractions: C_5 to C_8; C_9 to C_{12}; C_{13} to C_{18} and C_{19} to C_{36}.

- Aromatic Hydrocarbons which are unsaturated ring structures that contain double bonds, also in four different size fractions: C_6 to C_8; C_9 to C_{12}; C_{13} to C_{15} and C_{16} to C_{24}.

The TPH analyses conducted for the DGI did not separate alkane and aromatic compounds; moreover, it is not possible to estimate the 8 TPH fractions from the 3 ranges of mixed alkanes and aromatics that were reported in this study, so the DGI TPH data cannot be readily interpreted using the available benchmarks.

No Tier 2, 3 or 4 evaluations were conducted for TPH. The evaluation of petroleum hydrocarbon proceeded to assessment of PAHs, which are generally accepted as the main cause for petroleum hydrocarbon toxicity, and this group of compounds is quantitatively addressed in the next subsection. Other petroleum components may also contribute to petroleum toxicity, but quantitative methods have not been developed to assess them.

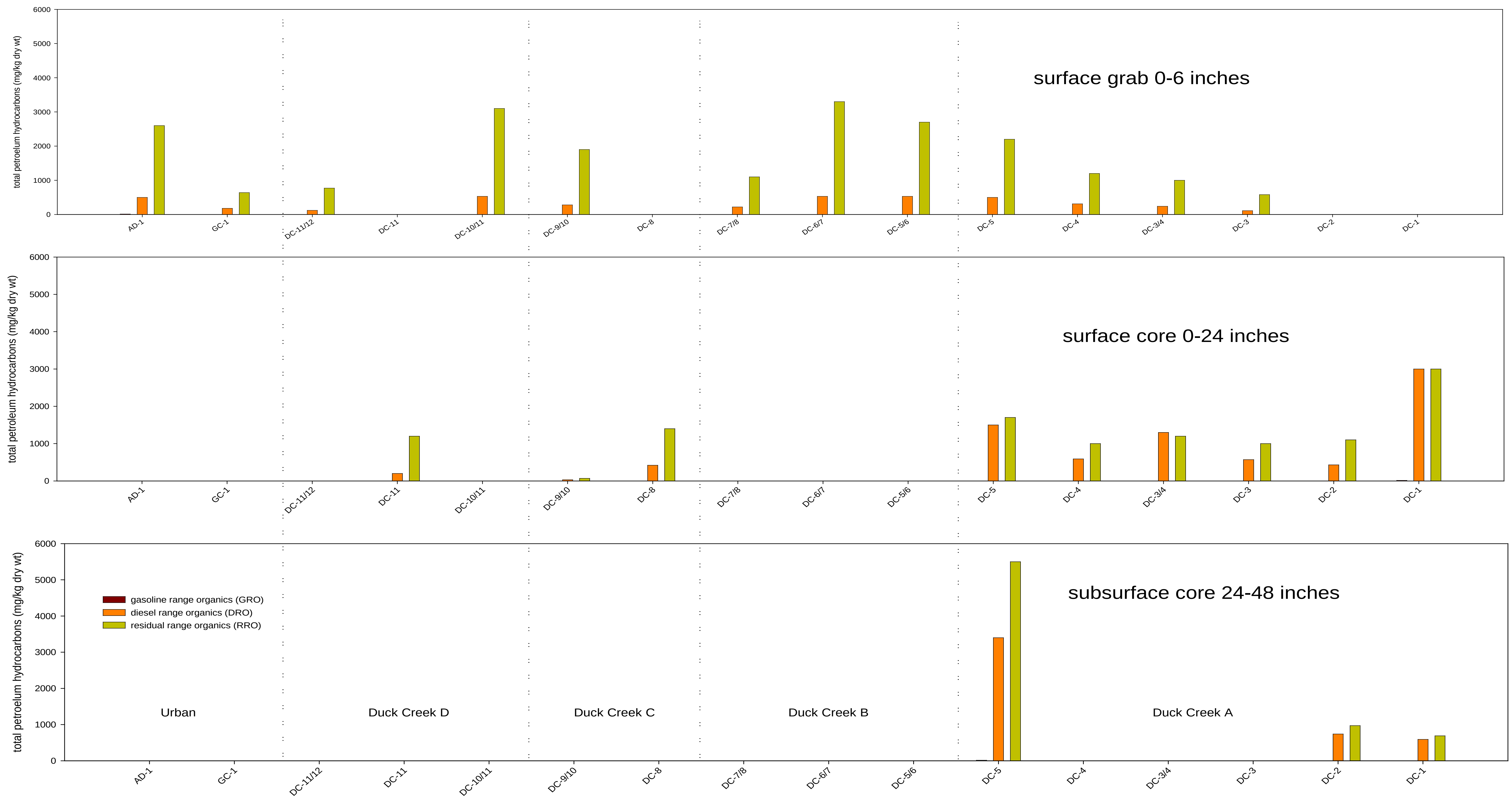


Figure 3-33 Summary of TPH concentrations with sediment depth in Duck Creek.

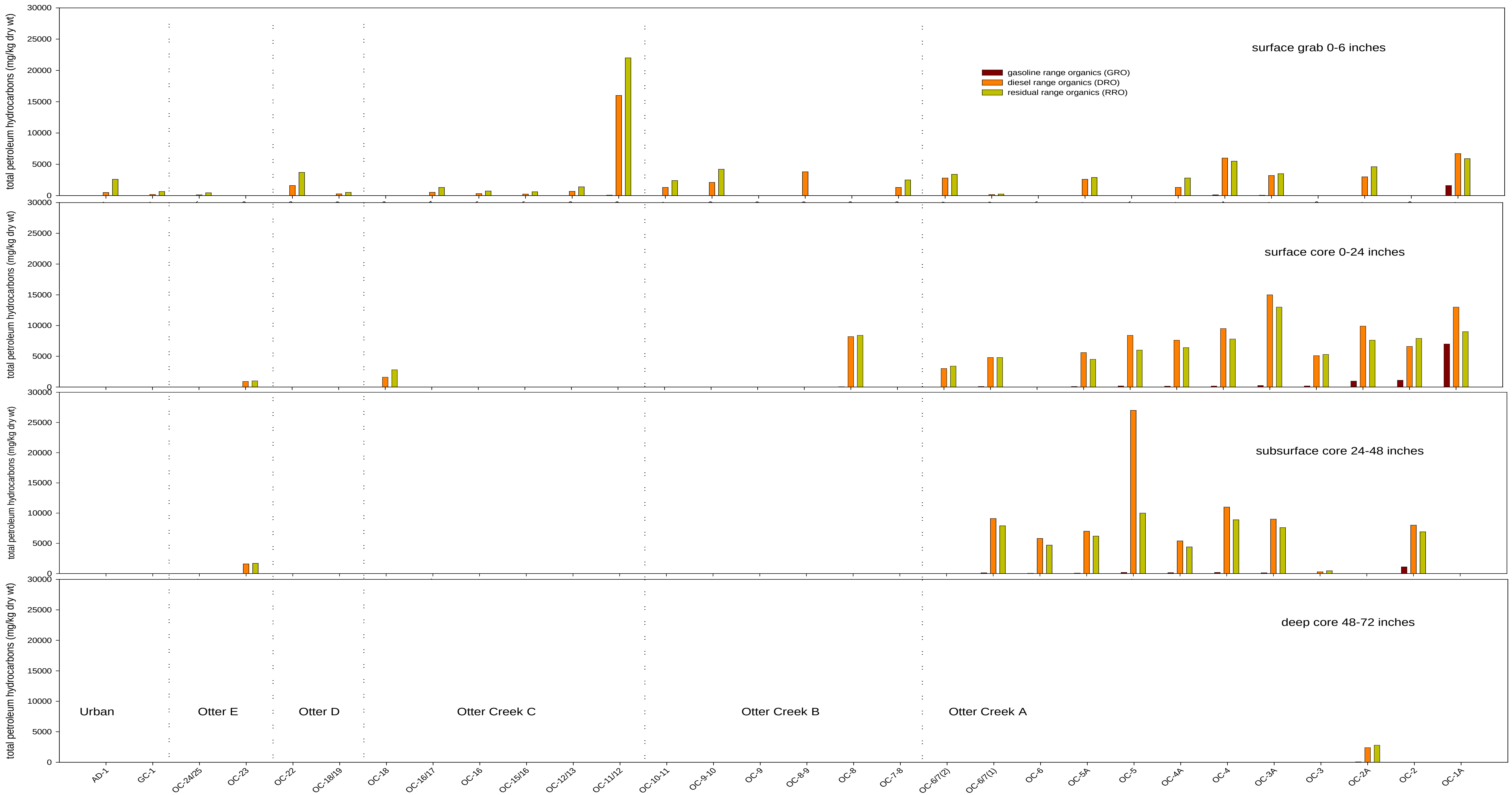


Figure 3-34 Summary of TPH concentrations with sediment depth in Otter Creek.

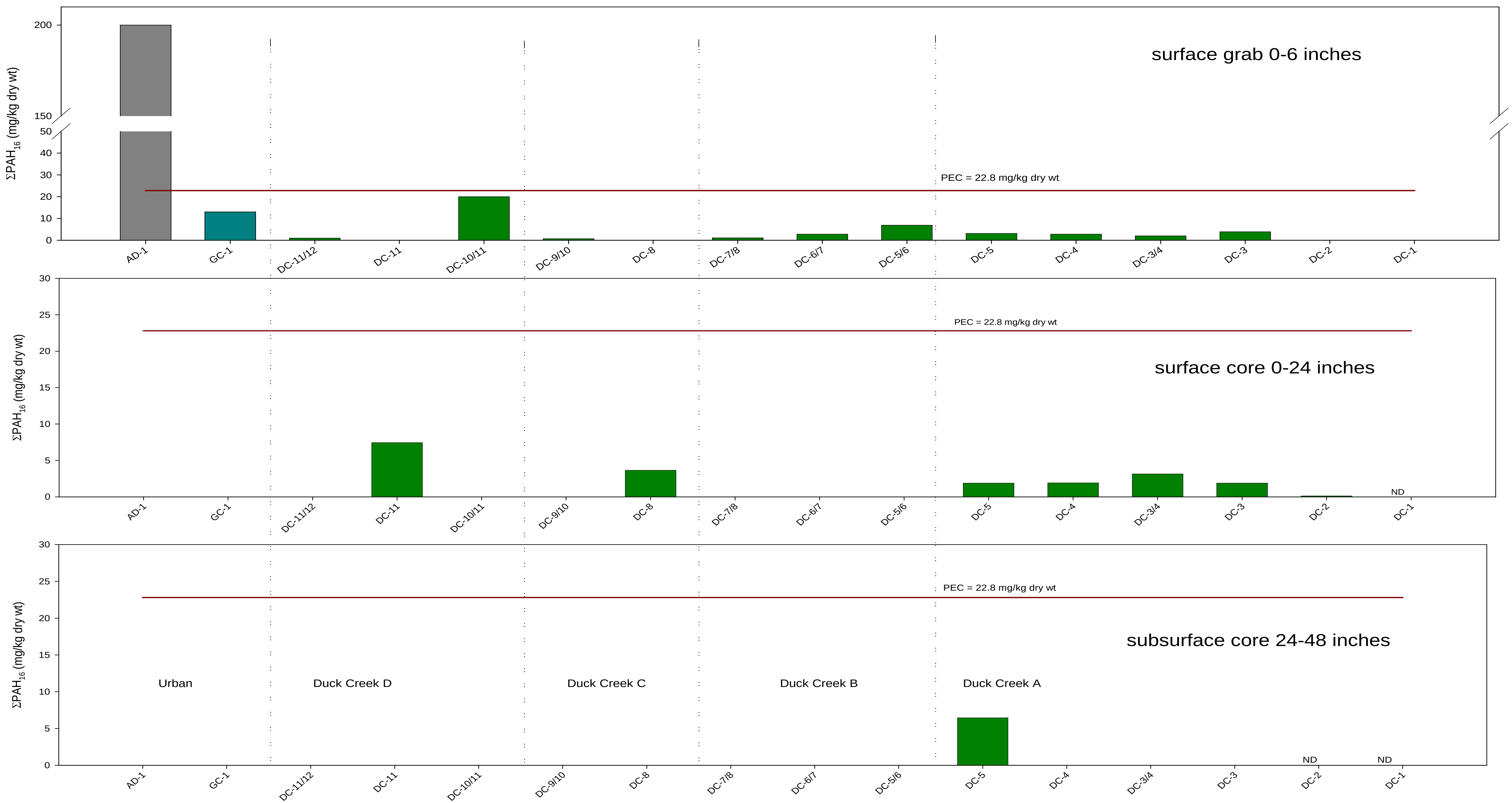


Figure 3-35 Summary of PAH16 Concentrations with depth for Duck Creek sediments.

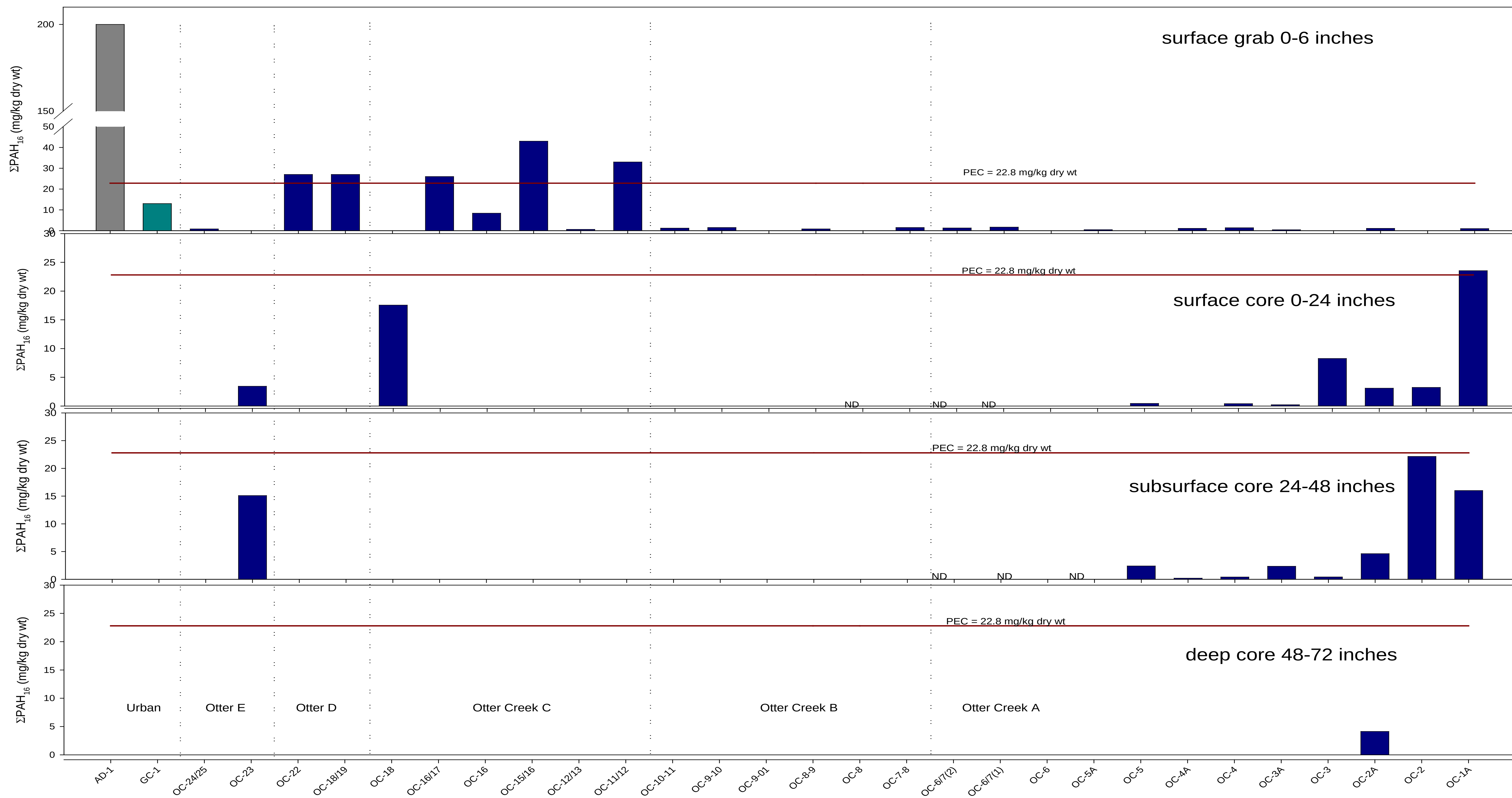


Figure 3-36 **Summary of PAH16 Concentrations at sediment depths in Otter Creek**

3.5.6 Polycyclic Aromatic Petroleum Hydrocarbons

The toxicity of petroleum mixtures can be readily interpreted with existing mechanistic interpretive tools that utilize polycyclic aromatic hydrocarbon (PAH) data. The PAHs are generally more bioavailable than alkanes, and the USEPA (2003) has developed an Ecological Screening Benchmark (ESB) method based on the interpretation of PAHs to assess petroleum toxicity in aquatic environments, and the OEPA (2010) has adopted them.

Tier 1 - The summed concentration of the 16 priority pollutant PAHs (PAH_{16}) in sediment samples were greater than the bulk sediment PEC_{16} for PAH_{16} in several samples in Duck and Otter Creek (Tables H-24 and H-25), with the greatest concentration in Amlosch Ditch (Figures 3-35 and 3-36). The PEC_{16} benchmarks that are based on dry weight were used for the first tier assessment of PAHs in this DGI. PEC_{16} values that account for binding to sediment organic carbon are available, and the TOC-rich silty sediments in these streams would decrease the number and magnitude of exceedences in the DGI data set.

Tier 2 **–** Because pore water concentrations of priority pollutant PAHs and their alkylated homologues (i. e. PAH_{34}) were measured directly, the DGI interpretation proceeded directly to a Tier 3 evaluation. Some studies have observed that the standard partitioning coefficients that are included in the ESB document do not accurately predict sediment pore water concentrations in all sediments types, or with sediments that have organic carbon from different origins (Hawthorne et al, 2006). The investment in measured pore water PAH_{34} concentrations allowed this DGI to conduct a site-specific evaluation of PAHs.

Tier 3 - Concentrations of PAH_{34} in pore water samples were elevated, relative to the final chronic value (FCV) benchmarks proposed by USEPA (2003) guidance (Tables H-26 and H-27). The ratios of pore water concentrations to FCV benchmarks were summed to calculate a summed toxic unit approach for interpretation of the PAH_{34} pore water data. In terms of toxic unit contributions (e.g. PAH_i concentration in pore water/$FCV_i = TU_i$), the alkylated naphthalenes contributed the greatest proportion of the total toxic units in segment A of Otter Creek. The alkylated anthrancenes, phenanthrenes and fluorenes were also prominent, relative to the other PAHs in pore water (Table 3-22). There was a negative relationship between the summed toxic units of PAHs in sediment pore water ($PAH_{34}\ \Sigma TU_{FCV}$) and growth (scaled biomass) of the midge *C. dilutus* (see Figure 3-37). The relationship was not linear, and the correlation was not statistically significant (see also Appendix N); however, the two samples that contained 6.7 or more summed toxic units of PAHs in sediment pore water ($PAH_{34}\ \Sigma TU_{FCV} \geq 6.7$) co-occurred with significant inhibition of midge growth, and the sample in which $PAH_{34}\ \Sigma TU_{FCV} = 18.2$ co-occurred with significant mortality in midge larvae (Figure 3-37).

Table 3-22 Summary of PAH_{34} ΣTU_{FCV} in sediment pore water samples from segment A of Otter Creek.

Individual PAH (PAH_i)	OC-6/7-01 Pore Water PAH Toxic Units (TU_i)	OC-5A-01 Pore Water PAH Toxic Units (TU_i)	OC-4-01 Pore Water PAH Toxic Units (TU_i)
Naphthalene	0.00052	0.00393	0.00450
1-Methylnaphthalene	0.00066	0.00876	0.03980
2-Methylnaphthalene	0.00069	0.00180	0.01192
C2- Naphthalenes	0.00496	0.11111	0.42626
C3- Naphthalenes	0.06667	0.71982	2.93964
C4 Naphthalenes	0.57312	1.23271	6.35375
Acenaphthylene	0.00065	0.00065	0.00072
Acenaphthene	0.00179	0.00179	0.00645
Fluorene	0.00102	0.00153	0.00560
C1- Fluorenes	0.00786	0.01930	0.08363
C2- Fluorenes	0.07917	0.10556	0.36192
C3- Fluorenes	0.49061	0.53758	1.26305
Phenanthrene	0.00523	0.00523	0.01202
Anthracene	0.00241	0.00241	0.00338
C1-Phenanthrenes/Anthracenes	0.00807	0.05648	0.15196
C2- Phenanthrenes/Anthracenes	0.17818	0.45639	0.93467
C3- Phenanthrenes/Anthracenes	0.81210	1.08280	1.97452
C4- Phenanthrenes/Anthracenes	1.64462	2.05577	3.25349
Flouranthene	0.00703	0.00141	0.00141
Pyrene	0.00890	0.00791	0.01187
C1-Fluoranthenes/Pyrenes	0.02865	0.03274	0.06139
Chrysene	0.00988	0.00494	0.00988
C1 Chrysenes	0.01169	0.01169	0.02337
C2 Chrysenes	0.02072	0.02072	0.02072
C3 Chrysenes	0.05970	0.05970	0.05970
C4 Chrysenes	0.14160	0.14160	0.14160
Perylene	0.00444	0.00444	0.00444
Benzo[A]Anthracene	0.00449	0.00000	0.00000
Benzo[B+K]Fluoranthene	0.00779	0.00779	0.00779
Benzo[A]Pyrene	0.00836	0.00836	0.00836
Benzo[E]Pyrene	0.00555	0.00555	0.00555
Dibenzo[A,H]Anthracene	0.00708	0.00708	0.00708

Table 3-22 Summary of PAH_{34} ΣTU_{FCV} in sediment pore water samples from segment A of Otter Creek.

Individual PAH (PAH_i)	OC-6/7-01 Pore Water PAH Toxic Units (TU_i)	OC-5A-01 Pore Water PAH Toxic Units (TU_i)	OC-4-01 Pore Water PAH Toxic Units (TU_i)
Indeno[1,2,3-CD]Pyrene	0.00364	0.00364	0.00364
Benzo[G,H,I]Perylene	0.00228	0.00228	0.00228
PAH_{34} ΣTU_{FCV}	4.21013	6.72347	18.19634
Pore water PAH_{34} ΣTU_{FCV} calculated by dividing the measured pore water concentration by the final chronic value water criterion and summing the quotients (ISEPA 2003).			

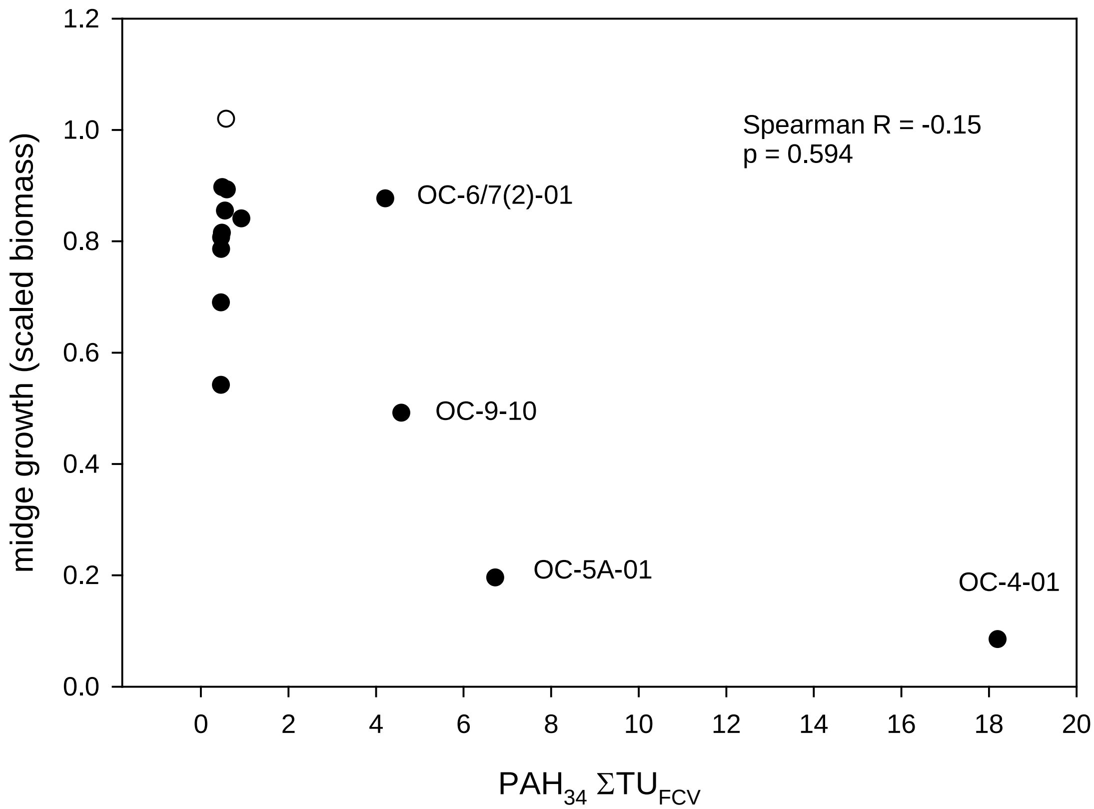


Figure 3-37 The relationship between the summed final chronic value toxic units for PAH_{34} in sediment pore water (PAH_{34} ΣTU_{FCV}) and growth of the midge *C. dilutus* is not linear.

Tier 4 – The PAH_{34} concentrations in tissues of benthic invertebrates and fish that were collected from Duck, Otter and Grassy Creeks did not exceed the lipid-normalized tissue residue benchmark (2.24 µmole/g lipid) upon which the ESB method is based (Tables H-28 and H-29). In summary, benthic invertebrate tissue concentrations ranged from 0.025 to 0.763 µmoles/g lipid in Duck and Otter Creeks, and 1.09 µmoles/g lipid in Grassy Creek. In contrast, the PAH_{34} tissue concentration in the benthic macroinvertebrate sample from Amlosch Ditch (17.3 µmoles/g lipid) did exceed the tissue benchmark concentration. The invertebrate tissue data from Amlosch Ditch appear to contradict the sediment pore water data from that stream; however, the two PAHs (fluoranthene and pyrene) that were reported at elevated concentrations in the invertebrate sample are also prominent in the sediment sample. This correlation suggests that sediment may have been present in the Amlosch Ditch invertebrate tissue sample, either within the digestive tracts of the animals, or possibly, adhered to the cuticle. The PAH_{34} concentrations in tissues of fish that were collected from Duck and Otter Creeks ranged from 0.00243 to 0.157 µmoles/g lipid which were one to three orders of magnitude less than the lipid-normalized tissue residue benchmark of 2.24 µmole/g lipid.

Data to support an evaluation of PAH_{34} bioaccumulation in the DGI streams is summarized in Table 3-23. There is no consistent relationship among the stream segments, or between compartments of the aquatic food web. The DGI data reveal that simplistic, empirical approaches will likely be inadequate for addressing PAH_{34} bioaccumulation or lack thereof. The chemical and physical properties of individual PAHs vary, which affects the binding coefficients, bioavailability, bioaccumulation and metabolism of the individual components. The tissue data from the DGI indicate that PAHs are not bioaccumulating in aquatic organisms in Duck and Otter Creeks.

Table 3-23 Summary of PAH_{34} concentrations in sediments, pore water, benthic macroinvertebrates and fish from the DGI data set.

Stream Segment	Sample Location	Sediment PAH_{34} (µg/kg dry wt)	Pore Water PAH_{34} (µg/L)	Invertebrate PAH_{25} (µg/kg wet wt)	Fish Tissue PAH_{34} (µg/kg wet wt)
Urban Comparison	Amlosch Ditch	260000	2.321	22594	No sample
	Grassy Creek	17000	1.546	1632	No sample
Duck Creek D	DC-11/12	1700	1.393	35.59	45.93
Duck Creek A	DC-5	9700	1.413	191.6	624.4
Otter Creek C	OC-16	12000	2.721	2606	216.0
	OC-12/13	980	2.081	690.9	
Otter Creek A	OC-5A	3200	24.976	127.1	1729
	OC-4	3100	91.526	163.5	

Only 25 PAHs were reported for benthic macroinvertebrate tissue samples, and several of those were not detected; non-detect concentrations were treated as 0 in these calculations.

Fish were collected within stream reaches and are generally more mobile than invertebrates so they are reported on a reach basis here

Chapter 4

Discussion

The discussion of this report is structured around the five specific objectives of the Statement of Work for the Duck and Otter Creeks Data Gap Investigation.

4.1 Determining the extent of contamination in both surface and subsurface sediments

The extent of contamination can be evaluated at two tiers; the first tier involves the bulk sediment chemistry, which provides information about the presence and locations of contaminants. Bulk sediment chemistry data provide information about the locations and magnitude of contaminant concentrations, but does not provide information about the availability of those contaminants to aquatic life. The second tier of the evaluation of sediment chemistry contaminants addresses the bioavailable fraction of the contaminants and provides information about which contaminants could potentially be adversely affecting aquatic organisms. Bulk sediment chemistry data help to identify “what” and “where” aspects of contaminant presence, but pore water data give the most useful information regarding the potential for contaminants to cause adverse effects. The pore water data provide the important link to biology that informs decisions regarding where the management of sediment contaminants has the greatest potential to produce positive improvements in the biological communities, which is an important connection for restoring beneficial use impairments that could be associated with sediment contamination.

The two categories of sediment contaminants that exceeded bulk sediment benchmarks were metals, and petroleum hydrocarbons. The pyrethroid pesticides and PCBs did not exceed sediment benchmarks in any sample. Of the metals, lead, arsenic and chromium most frequently exceeded the respective bulk sediment benchmarks. Surface samples had elevated concentrations (relative to benchmarks) of metals in segments D and A of Duck Creek, and segments E, C, B and A of Otter Creek. Subsurface sediments had elevated concentrations of metals in at least one sample from segments E and A of Otter Creek. Gasoline-range organic carbons (C_8-C_{12}) were infrequently detected, except at the mouth of Otter Creek, while hydrocarbons in diesel (C_{10}-C_{25}) and residual (C_{25}-C_{36}) ranges were present at measureable concentrations in nearly all surface sediment samples, including both urban comparison streams. Hydrocarbon concentrations were elevated in surface sediments of Otter Creek, relative to Duck and Grassy Creeks and Amlosch Ditch. PAH_{16} concentrations were greatest in Amlosch Ditch, and also exceeded sediment benchmarks in segments D, C and a single sample in segment A of Otter Creek. PAH_{16} concentrations were detected in most subsurface sediment samples, but did not exceed sediment benchmarks in either Duck or Otter Creek.

Regarding the extent of the bioavailable sediment contaminants, only two classes of sediment contaminants were present in pore water at concentrations that were sufficient to potentially affect sediment-dwelling organisms: ammonia and PAH_{34} (see Table 4-1). Ammonia concentrations were not elevated in the overlying water of the sediment toxicity test chambers, and ammonia was not correlated with midge survival, midge growth, or any of the benthic community metrics. Thus, the available site-specific data suggest that sediment-associated ammonia is not affecting the benthic community structure or contributing to sediment toxicity in the laboratory.

Sediment toxicity, as expressed by reduced biomass (growth) was observed in two surface sediments of Otter Creek Segment A, and PAHs were elevated in the sediment pore water at both of those locations. Moreover, PAH_{34} concentrations in sediment pore water were significantly correlated with growth of the midge in the sediment toxicity test (Figure 3-38). Sediment cores (0-4 feet) also contained measureable concentrations of PAHs (Figure 3-36), in the downstream portion of Otter Creek segment A. Elevated concentrations of TPH DRO and RRO were also observed in sediment to a depth of approximately four feet in segment A of Otter Creek (Figure 3-34).

Pore water PAH concentrations and reduced midge growth were also elevated in OC-9/10; however the sediment thickness in this area was only 6 inches, and the sample contained much more gravel than most others (Table E-2), which could also have affected midge growth. The presence of the only riffle-pool sequence that was observed during the habitat evaluation at sample location OC-9/10 indicates that spot is not representative of segment B, or Otter Creek in general, but is unique.

Table 4-1 Summary Table of the Chemical Analyses of Sediment Samples.

Analysis	Bulk sediment	Pore water	Summary of Results
Metals	√	√	Metals concentrations in sediments exceed conservative screening benchmarks; however, SEM- AVS/foc data indicated that metals were not bioavailable, and in only one sample did a metal concentration in pore water exceed a chronic surface water quality criterion. That pore water concentration did not exceed a hardness-based chronic water quality criterion from an adjacent state. Metals (selenium) concentrations in benthic invertebrate and fish tissues did not exceed available benchmarks, and no evidence of biomagnification was observed.
SVOCs	√	-	Most of the SVOCs, with the exception of the PAHs, were seldom detected. The maximum detected non-PAH SVOC concentrations exceeded the associated benchmark concentrations in only one (urban comparison stream) sample, but no toxicity occurred in that sample
PAH_{16} and PAH_{34}	√	√	PAH_{16} concentrations in some sediments exceed conservative screening benchmarks; PAH_{34} concentrations were elevated in sediment pore waters at the locations were growth of midge larvae was reduced. PAH_{34} concentrations in biological tissues did not exceed benchmark concentrations with the exception of one benthic macroinvertebrate sample from Amlosch Ditch that may have contained sediment.
Aroclors	√	-	PCB concentrations were rarely detected in sediments and biological tissues, and did not exceed screening benchmarks in either sediments or tissues.
GRO/DRO/RRO	√	-	TPH DRO and RRO concentrations in sediments were elevated in Otter Creek relative to other streams. TPH DRO and RRO concentrations were elevated in sediment cores relative to surface sediment grabs in segment A of Otter Creek. TPH GRO concentrations were elevated in some sediment core samples in segment A of Otter Creek
Ammonia	-	√	Ammonia concentrations in pore water exceeded surface water criteria in several sample locations; however ammonia was not elevated in the overlying water in sediment toxicity test

Table 4-1 Summary Table of the Chemical Analyses of Sediment Samples.

			chambers. Ammonia concentrations are not correlated with midge survival or growth, or the benthic community metrics.
Pyrethroid pesticides	√	-	Some of the pyrethroid pesticides were detected in some sediment samples, but did not exceed screening benchmarks.

4.2 Verifying sediment toxicity and identify cause(s), to the extent practicable within the constraints of this data gap investigation

The Sediment Quality Triad, as supplemented by a habitat evaluation, reveals that Duck and Otter Creeks are complex streams that have generally poor habitat quality because of modification of both the stream channels and watersheds. Given the physical conditions of these streams, the resident benthic communities are expected to be comprised of species that are tolerant of silty sediments, low base flows and very high discharges during precipitation events.

Sediment toxicity has been verified for three locations within Otter Creek by this study. In the DGI sediment toxicity tests, a careful examination of the exposure chambers at the end of the test revealed that indigenous sediment predators severely affected the survival of test organisms in the majority (9 of 14) sample locations in this study. These predatory flatworms (*Planaria*) were not mentioned in the 2007 study report. The statistical tests for this DGI were conducted in way that the presence of indigenous organisms did not affect the data interpretation (i.e., affected replicate test chambers were excluded from the analysis).

The presence of multiple physical (poor habitat), biological (predator) and chemical stressors in this small data set make data interpretation a challenge, but a summary of the Sediment Quality Triad, with the supplemental habitat quality information is presented in Table 4-2. As discussed above, the strongest relationship between sediment contamination and the biological endpoints has been observed for PAH_{34} in the sediment pore waters of segment A in Otter Creek. Metals, PCBs, Pyrethroid pesticides, and non-PAH SVOCs can be ruled out as sources of toxicity in the DGI data set because these classes of contaminants are not generally elevated in sediments, or are not bioavailable. Ammonia concentrations in pore water were elevated in several sediment samples; however there was no relationship with biological endpoints.

Table 4-2 Interpretations of the Sediment Quality Triad plus Habitat Quality for the Duck and Otter Creek Data Gap Investigation

Sample Location	Invertebrate Community Structure	Habitat Quality	Sediment Toxicity	Chemistry	Interpretation
Amlosch Ditch (AD-1)	7 taxa 61% sensitive 24% tolerant	QHEI 23 (very poor) Stormwater	No *Planaria*[a]	PAH_{34} in invertebrate sample	Sensitive biological community co-occurs with very poor habitat quality ; PAH_{34} suspected to be sediment in gut or adhered to cuticle.
Grassy Creek (GC-1)	9 taxa 1% sensitive 80% tolerant	QHEI 32.5 (poor)	No *Planaria*	No bioavailability	Tolerant biological community co-occurs with poor habitat.
DC-11/12	No water	No water	No	No bioavailability	Extremely low base flow is limited the biological community during the DGI.
DC-6/7	7 taxa 1% sensitive 70% tolerant	QHEI 40 (poor)	No *Planaria*	No bioavailability	Tolerant biological community co-occurs with poor habitat.
DC-5	8 taxa 17% sensitive 73% tolerant	QHEI 37.5 (poor)	No *Planaria*	No bioavailability	Tolerant biological community co-occurs with poor habitat.
DC-3	8 taxa 18% sensitive 43% tolerant	QHEI 23.5 (very poor)	No *Planaria*	No bioavailability	Biological community with relatively fewer tolerant taxa co-occurs with very poor habitat.
OC-24/25	12 taxa 3% sensitive 19% tolerant	QHEI 35 (poor)	No	No bioavailability	Diverse biological community co-occurs with poor habitat.
OC-22	6 taxa 1% sensitive 83% tolerant	QHEI 33.5 (poor) Stormwater	No	No bioavailability	Tolerant biological community co-occurs with poor habitat.
OC-16	5 taxa 0.3% sensitive 83% tolerant	QHEI 33 (poor) Stormwater	No	No bioavailability	Tolerant biological community co-occurs with poor habitat.
OC-12/13	5 taxa 0% sensitive 72% tolerant	QHEI 33 (poor) Stormwater	No *Planaria*	No bioavailability	Tolerant biological community co-occurs with poor habitat.
OC-9/10	5 taxa 1% sensitive 77% tolerant	QHEI 42 (poor)	Growth *Planaria*	Pore water PAH_{34}	Tolerant biological community co-occurs with poor habitat, sediment contamination and toxicity.
OC-6/7(2)	2 taxa 0% sensitive	QHEI 33.5 (poor)	No *Planaria*	Pore water PAH_{34}	Tolerant biological community co-occurs with poor habitat: sediment contamination present

Table 4-2 Interpretations of the Sediment Quality Triad plus Habitat Quality for the Duck and Otter Creek Data Gap Investigation

Sample Location	Invertebrate Community Structure	Habitat Quality	Sediment Toxicity	Chemistry	Interpretation
	96% tolerant				without toxicity
OC-5A	5 taxa 0% sensitive 100% tolerant	No safe bank access	Growth	Pore water PAH_{34}	Tolerant biological community co-occurs with sediment contamination and toxicity.
OC-4	4 taxa 0% sensitive 77% tolerant	QHEI 31 (poor)	Survival Growth *Planaria*	Pore water PAH_{34}	Tolerant biological community co-occurs with poor habitat, sediment contamination and toxicity.

a the flatworm Planaria was present in some test chambers and adversely affected the midge larvae; to remove the influence of predation by indigenous sediment organisms, test replicates that included flatworms were not included in statistical analyses.

4.3 Evaluating whether sediment contaminants are bioaccumulating in benthic invertebrates and fish at levels likely to contribute significantly to the degradation of benthos and fish populations

The available benthic invertebrate and forage fish tissue data do not indicate that bioaccumulation of sediment contaminants is significant in Duck or Otter Creeks. PCB concentrations did not exceed benchmark concentrations for tissues in fish or benthic macroinvertebrates collected for the DGI. PAH_{34} concentrations did not exceed tissue benchmarks for aquatic species in fish or invertebrate samples from Duck, Otter or Grassy Creeks; however the PAH_{34} benchmark was exceeded in the benthic macroinvertebrate tissue sample from Amlosch ditch. Many metals are essential micronutrients, and are carefully modulated by living organisms. Whole body tissue concentrations for metals are not typically the best predictors of adverse effects (Meador et al 2010, Jarvenin and Ankley 1999) so only a benchmark for selenium is available (USEPA 2004)), which was not exceeded in any sample. A cursory review of the metals data for tissues does not suggest that metals are accumulating in aquatic life, which is consistent with the very low sediment pore water concentrations that have been observed in this study.

4.4 Evaluating habitat resources

More than a century of urbanization and industrial land use has modified the stream channels and watersheds in the streams sampled in this investigation. Instream aquatic habitat is generally poor, because of silty sediments, lack of in-stream structures, removal of meanders and riparian vegetation, and shallow water depths. About 70% of the watershed surface has more than 19% impervious surface, which inhibits infiltration and lessens base flow. During precipitation events, water moves rapidly into the stream via many subsurface storm sewers, and greatly increases flow volume and velocity. This combination of habitat conditions limits the biological communities to those species that can tolerate these hydraulic disturbances, and are adapted to silty sediments.

4.5 Collecting data to support development of a feasibility study (evaluation of remedial and restoration options to protect human health and the environment), if one is found to be necessary, and to advance progress toward delisting of beneficial use impairments.

Data collected through the QHEI and the Sediment Quality Triad (chemistry, toxicity, community structure) were key to understanding how a potential Feasibility Study for the Creeks may be focused toward key factors adversely affecting the Creeks within each segment. For example, as evidenced by the overall poor scores observed during the QHEI, the habitat quality information has applications for advancing progress toward delisting the beneficial use impairments regarding impaired benthic communities. The poor quality of the stream channels, combined with the transient nature of large volumes of stormwater influent, has implications for restoring the aquatic communities. In addition, the information obtained through the comparison between study streams and urban comparison streams regarding the structure of biological communities, chemical concentrations in sediment and pore water, and habitat quality were used to assess distinctive aspects of Duck and Otter Creek that may suggest particular, or combinations of, remediation approaches. Although, the physical constraints of Duck, Otter and the urban comparison streams are sufficient to preclude the establishment of more sensitive aquatic species, in-stream enhancements such as adding woody structures would likely be productive for restoring beneficial use impairments. Stormwater retention might also be advised, in cases where such modifications are acceptable to the landowners on the watershed.

Other remediation approaches may be considered at discrete locations within the Creeks, where data suggests that addressing sediments in areas where there is an apparent correlation between sediment toxicity and chemical concentrations in sediment and/or pore water, which may improve aquatic communities. In this case, data delineating the spatial extent of chemicals of concern is available to assist in supporting the evaluation of potential action.

4.6 Conclusions

The elevated PAH_{34} concentrations in sediment pore waters occurred at the same locations where the growth of the midge *C. dilutus* was inhibited in the sediment toxicity test (Figure 3-37). The data from this study suggest that PAHs in sediment pore water could be contributing to the observed sediment toxicity in lower Otter Creek. The poor benthic community structure in lower Otter Creek is generally consistent with the results of the sediment toxicity test.

PCBs, metals, pyrethroid pesticides, and non-PAH SVOCs can be ruled out as sources of toxicity in the 2010 Data Gap Investigation data set because these classes of contaminants generally are not elevated in sediments (Section 3.5.2 and 3.5.3), or are not bioavailable (Sections 3.5.1 and 3.5.4). Ammonia concentrations were at levels of concern in the pore water of several sediment samples; however, sediments at many of those locations were not toxic to midge larvae so the role of ammonia as a toxic agent, if any, is not known.

The in-stream habitat quality ranged from very poor to poor (Section 3.3.1.), which implies the biological communities in these creeks are likely to include species that are tolerant of poor habitat quality. Tolerant species dominated the biological communities at the majority of the

2010 sample locations (Figure 3-3), which is consistent with the poor habitat quality that was observed.

The section “Segment A” of Otter Creek that is downstream (North) of Millard Avenue differed from the other stream reaches of Otter Creek, the Duck Creek segments, and the urban comparison streams Grassy Creek and Amlosch Ditch. The observed differences in the lowest reach of Otter Creek include: reductions in the survival and growth of midge larvae in the sediment toxicity test (Section 3.4); the presence of elevated PAH concentrations in sediment pore waters (Table 3-20); the frequent observation of sheen and petroleum odor during field sampling (Table 3-1); and the presence of elevated hydrocarbon concentrations in sediment core samples (0-48 inches) relative to surface (0-6 inches) grab samples (Figures 3-34 and 3-36).

The 2010 data do not indicate there are sediment contamination or toxicity issues within Duck Creek or the upper segments of Otter Creek..

4.7 Recommendations

Further evaluate potential remedies for Segment A of Otter Creek in a subsequent phase of the project.

Further evaluate the combined 2007 and 2010 data sets for the remaining stream sections in a subsequent phase of the project.

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Chapter 5

Acknowledgments

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Chapter 6

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