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ENVIRONMENTAL PROTECTION AGENCY**

"...TO PROTECT HUMAN HEALTH AND SAFEGUARD THE NATURAL ENVIRONMENT..."

HUMAN HEALTH RISK ASSESSMENT NEAL'S LANDFILL BLOOMINGTON, MONROE COUNTY, INDIANA

**Work Assignment: 943-RSBD-0539
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Prepared for
**U.S. Environmental Protection Agency
Region 5
Chicago, IL**
through
**U.S. Environmental Protection Agency
Region 6
Dallas, TX**

Prepared by:



TETRA TECH EM INC.



**RESPONSE ACTION CONTRACT FOR
REMEDIAL, ENFORCEMENT OVERSIGHT, AND
NON-TIME-CRITICAL REMOVAL ACTIVITIES
IN REGION 6**

**HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL SITE
BLOOMINGTON, MONROE COUNTY, INDIANA**

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**U.S. Environmental Protection Agency
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ACRONYMS AND ABBREVIATIONS

95 UCL	95 Percent upper confidence limit of the mean
µg/L	Microgram per liter
ADD	Average daily dose
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient water quality criteria
bgs	Below ground surface
bss	Below sediment surface
CalEPA	California Environmental Protection Agency
CBS	CBS Corporation
COPC	Chemical of potential concern
CSM	Conceptual site model
cfs	Cubic feet per second
EDMS	Environmental Database and Management System
ELCR	Excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
g/day	Gram per day
GI	Gastrointestinal
HEAST	Health Effects Assessment Summary Tables
HHRA	Human health risk assessment
HQ	Hazard quotient
IRIS	Integrated Risk Information System
kg	Kilogram
L/day	Liter per day
LADD	Lifetime average daily dose
LOAEL	Lowest observed adverse effect level
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
mg/kg-day	Milligram per kilogram per day
mg/day	Milligram per day
MRL	Minimal risk level
NAS	National Academy of Sciences
NCP	National Oil and Hazardous Substances Contingency Plan
NOAEL	No observed adverse effect level
Normandeau	Normandeau Associates, Inc.
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated biphenyl
ppb	Part per billion
ppm	Part per million
PPRTV	Provisional peer-reviewed toxicity value
ppt	Part per trillion
PSARA	PSARA Technologies, Inc.
RA	Remedial action
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act

ACRONYMS AND ABBREVIATIONS (Continued)

REC	Real Estate Center
RfD	Reference dose
RME	Reasonable maximum exposure
SF	Slope factor
StationID	Station identification
STF	Spring treatment facility
STSC	Superfund Technical Support Center
TCDD	Tetrachloro-p-dioxin
TEF	Toxicity equivalency factor
TEQ	Toxicity equivalent
Tetra Tech	Tetra Tech EM Inc.
TSCA	Toxic Substances Control Act
Viacom	Viacom, Inc.
Westinghouse	Westinghouse Electric Corporation
WHO	World Health Organization

1.0 INTRODUCTION

Tetra Tech EM Inc. (Tetra Tech) prepared this human health risk assessment (HHRA) report for the U.S. Environmental Protection Agency (EPA) in partial fulfillment of the statement of work for Response Action Contract No. 68-W6-0037 for Region 6, Work Assignment No. 941-RSBD-0529. The primary objectives of the HHRA are (1) to assess the potential for and magnitude of human exposures to contaminants from the Neal's Landfill site in and along Conard's Branch and Richland Creek and (2) to characterize the risks and hazards associated with these potential exposures. The Neal's Landfill site is situated in karst terrain in Bloomington, Monroe County, Indiana. Polychlorinated biphenyl (PCB) contamination originating from electrical capacitors filled with oil containing PCBs and other PCB-contaminated materials deposited in the landfill is migrating from the site through a series of springs and discharging to Conard's Branch (a tributary to Richland Creek) (see Figures 1 and 2). This HHRA was conducted consistent with the approach applied to other Superfund sites in the Bloomington, Indiana, area (EPA 2004d, e, and f; Tetra Tech 2005 and 2006b).

The rest of this section summarizes the site history (Section 1.1), presents the HHRA scope and technical approach (Section 1.2), and discusses the HHRA report organization (Section 1.3).

1.1 SITE HISTORY

Neal's Landfill occupies nearly 18 acres surrounded by farms and woodlands about 4.5 miles west of Bloomington, Monroe County, Indiana (see Figure 1). The landfill accepted industrial and municipal wastes from 1950 to 1972. In particular, in 1966 and 1967, numerous electrical capacitors filled with PCB-containing oil and other PCB-contaminated materials (including rags, sawdust, and filter clay) generated by Westinghouse Electric Corporation (Westinghouse) were disposed of at the landfill (EPA 1998). (Note: Westinghouse was subsequently acquired by CBS Corporation [CBS]; Viacom, Inc. [Viacom], then acquired CBS. Presently, the entity responsible for Neal's Landfill is referred to once again as CBS. For the purposes of the HHRA, the entity responsible for Neal's Landfill will be referred to by the name applicable at the time of the action described or for the document referenced.) The landfill is situated over karst terrain. Several springs at the foot of the landfill drain to Conard's Branch, a tributary to Richland Creek, and several other springs in the landfill area drain directly to Richland Creek.

Based on elevated PCB concentrations measured in samples of surface soil, spring water, sediment, and fish in and along Conard's Branch and Richland Creek, the Neal's Landfill site was placed on the National Priorities List in 1981. In 1985, EPA, the State of Indiana, Monroe County, the City of Bloomington, and CBS signed a consent decree. Under the terms of the decree, CBS is to remediate six sites in the Bloomington area containing PCBs. Neal's Landfill is one of the six sites covered by the consent decree (EPA 1998).

In 1987, a number of interim measures were completed at the site, including removal of capacitors from the ground surface; removal of a total of 4,500 linear feet of contaminated sediment from Conard's Branch (4,267 linear feet) and Richland Creek (233 linear feet); and installation of a soil cap over primary landfill areas. The interim measures also included construction of a spring treatment facility (STF) that began operation in 1990. The purpose of the STF is to collect and treat spring flow of up to 1 cubic foot per second (cfs). This flow is collected in a lined basin and travels by gravity to the STF, which consists of a clarifier, filters, and an activated carbon water treatment system that remove PCBs. The STF is designed to achieve an effluent PCB concentration of 1 part per billion (ppb). Spring flow exceeding 1 cfs (for example during storm events) overflows the lined basin and discharges directly to Conard's Branch (Tetra Tech 2003a).

Under the consent decree, CBS was scheduled to excavate soil overlying the site for incineration in a municipal waste facility that CBS was to build (EPA 1998); however, remedial actions (RA) other than soil incineration had to be considered when the Indiana State legislature passed a law in 1993 intended to block implementation of the incineration remedy.

In March and April 1998, EPA and CBS conducted field investigations at the site. The objectives of these investigations were to characterize the landfill waste and identify PCB hot spots for removal. A total of 104 borings were drilled through landfill materials. Data from the investigations revealed the presence of PCB hot spots throughout the landfill at concentrations exceeding 500 parts per million (ppm), and the data were used by CBS and government parties to evaluate RA alternatives. The selected alternative included excavation of materials containing PCBs at concentrations exceeding 500 ppm and disposal of the materials in an off-site, Toxic Substances Control Act (TSCA)-permitted landfill. Materials containing PCBs at concentrations less than 500 ppm were to be consolidated on site and covered with a Resource Conservation and Recovery Act (RCRA) Subtitle C cap (Tetra Tech 2003a).

Beginning in April 1999, Viacom and its RA contractor began implementing the selected source removal RA under the oversight of government parties. By November 1999, Viacom had completed the RA, which included (1) the excavation of nearly 42,000 tons of PCB-contaminated materials for disposal in an off-site, TSCA-permitted landfill, and over 4,000 capacitors for off-site incineration; (2) consolidation of approximately 90,000 cubic yards of PCB-contaminated materials on site (thereby reducing the size of the landfill from 18 to 10 acres); and (3) construction of a RCRA Subtitle C cap over the consolidated material (EPA 2005d).

1.2 HHRA SCOPE AND TECHNICAL APPROACH

The scope of the HHRA is limited to evaluating potential human exposures to contaminants present in fish tissue, surface water, sediment, and soil (bank and floodplain) in or adjacent to Conard's Branch and Richland Creek and two springs (South and North Springs) that discharge to Conard's Branch. Figure 4 and Table 1 summarize the exposure scenarios (human receptors, exposure routes, and exposure point combinations) considered in the HHRA. The HHRA also characterizes the risks and hazards associated with these potential exposures.

The technical approach used to prepare this HHRA report is consistent with the technical approach applied at other Bloomington-area Superfund sites (EPA 2004d, e, and f; Tetra Tech 2005 and 2006b). In summary, the technical approach includes three elements: (1) a conventional Superfund risk assessment performed consistent with EPA guidance documents (such as EPA 1989), (2) comparison of fish tissue sample concentrations to an ambient water quality criteria (AWQC)-derived fish tissue concentration, and (3) comparison of fish tissue sample concentrations to a fish advisory action level.

1.3 HHRA REPORT ORGANIZATION

As described in EPA guidance, an HHRA is typically conducted in four basic steps: (1) data evaluation and identification of chemicals of potential concern (COPC), (2) exposure assessment, (3) toxicity assessment, and (4) risk and hazard characterization (EPA 1989). These four steps and a risk assessment summary step are summarized below and are discussed in detail in Sections 2.0 through 6.0.

- **Section 2.0, Data Evaluation and Identification of COPCs**, summarizes data collection and evaluation activities and identifies COPCs.
- **Section 3.0, Exposure Assessment**, identifies potential human exposure pathways,

estimates environmental concentrations of COPCs at potential exposure points (exposure point concentrations [EPC]), and estimates potential human intakes or doses.

- **Section 4.0, Toxicity Assessment**, identifies and summarizes the basis for COPC-specific toxicity criteria used in the HHRA.
- **Section 5.0, Risk and Hazard Characterization**, presents estimates of carcinogenic risks and noncarcinogenic hazards, general conclusions regarding potential risks and hazards associated with exposure to COPCs, and major uncertainties associated with the risk and hazard estimates.
- **Section 6.0, Summary and Conclusions**, summarizes the HHRA process, major assumptions, significant conclusions, and uncertainties related to the HHRA.

References cited in this report are listed after Section 6.0. Tables and figures for this report are provided after the list of references. Shorter tables are embedded in text. In addition, the report also includes Appendix A, which presents an assessment of the fish tissue ingestion rates that are considered to be sustainable in Richland Creek. (Note: The HHRA does not evaluate potential ingestion of fish from Conard's Branch [see Section 2.1.1].) Appendix B documents the calculation of medium-specific EPCs used in the HHRA. Appendix C presents receptor-specific exposure, risk, and hazard calculations.

2.0 DATA EVALUATION AND IDENTIFICATION OF COPCs

The primary purpose of this section is to identify and discuss analytical results considered in the HHRA and to discuss the basis for identifying site-specific COPCs. COPCs are chemicals carried through the entire HHRA process for which carcinogenic risks and noncarcinogenic hazards are estimated. Section 2.1 discusses data collection and evaluation, and Section 2.2 summarizes the COPC identification process.

2.1 DATA COLLECTION AND EVALUATION

As discussed in Section 1.2, the HHRA focuses on potential exposure to contaminants in fish tissue, surface water, sediment, and soil (bank and floodplain) based on analytical data sets for samples collected in and adjacent to Conard's Branch and Richland Creek.

2.1.1 Fish Tissue

Historically, fish tissue samples have been collected from Conard's Branch and Richland Creek at eight

locations (see Figures 2 and 3). The table below summarizes the dates on which fish tissue samples were collected from each location.

FISH TISSUE SAMPLING LOCATIONS AND DATES

Sampling Location	Distance Downstream from Neal's Landfill (miles)	Identifiers in Other Reports and Databases	Sampling Date(s)
Conard's Branch	0.5	CBB, NL-1, and Fish Site 1	May 1998; August 2001; November 2002; May 2003; November 2003; June 2004; September 2004; and November 2005
Richland Creek (upstream ^a)	Not applicable	RCUS25	November 2002
Richland Creek (1-Mile Site)	1.0	RCD, NL-2, and Fish Site 2	May 1998; August 2001; November 2002; May 2003; November 2003; and November 2005
Richland Creek (3-Mile Site)	3.0	RCF	August 2001 and June 2004
Richland Creek (5.5-Mile Site)	5.5	RCG, NL-3, and Fish Station 3	May 1998 and May 2003
Richland Creek (12.7-Mile Site)	12.7	RCI	August 2001
Richland Creek (21.8-Mile Site)	21.8	RCJ	August 2001
Richland Creek (34.5-Mile Site)	34.5	RCK	August 2001

Note:

^a The Richland Creek upstream sampling station is located about 0.25 mile upstream of the confluence with Conard's Branch.

Conard's Branch passes through the Conard family farm. The stream is characterized by lower-order, erosional habitat. Much of the reach is scoured to bedrock and does not provide the diverse habitat necessary to support a diverse community of fish, including species likely to be eaten by recreational anglers. Fish and aquatic life observed in Conard's Branch include creek chub, stone rollers, and crayfish; these species are preyed on by herons and other wildlife (Tetra Tech 2002, 2003b, 2003c,

2004a, and 2006a). Because human receptors are not expected to catch and consume the small stream fish present at the Conard's Branch sampling location, the HHRA does not consider potential exposure to fish tissue from this location.

Richland Creek upstream of the point where Conard's Branch enters the creek is characterized by predominantly depositional habitat with long pools, gentle meanders, and sluggish flow. The surrounding land use is primarily rural residential and agricultural. Richland Creek at this location provides appropriate habitat for most small fish and adequate habitat for bottom feeders (benthic fish) such as central stonerollers and white suckers. The shallow, unshaded pools in this reach provide minimal habitat for pelagic feeders such as sunfish and bass. Some of the fish observed and sampled from the upstream reach of Richland Creek may be fish from downstream portions of the creek (and, therefore, may have been impacted by site releases) that have simply swum upstream; however, it is also possible that the fish observed and sampled in this upstream reach migrate to downstream portions of the creek only a small portion of the time or not at all. In this case, these fish may be only minimally impacted by site releases or not impacted at all; therefore, because of the uncertainty associated with determining the extent to which fish from the upstream reach of Richland Creek are impacted by site releases, the HHRA does not quantitatively consider potential exposure to fish tissue from this location.

Based on analytical fish tissue data included in the most recent version of the Environmental Database and Management System (EDMS) prepared for the site (CBS 2006a), PCBs were not detected in a total of eight fillet and whole-body samples of longear sunfish, spotted bass, black redhorse, and carp collected from the downstream-most sampling location (the 34.5-mile site); therefore, the HHRA does not consider potential exposure to fish tissue from this location (see Table B-9 in Appendix B). Similarly, PCBs were detected in only 1 out of a total of 12 whole-body and fillet samples of pelagic species (longear sunfish, rock bass, and spotted bass) collected from the 21.8-mile site. PCBs were detected in three of five whole-body samples of benthic species (black redhorse and carp) collected from this same location; however, the concentrations measured in these samples were lower than those measured at the next upstream location (the 12.7-mile site); therefore, the HHRA does not consider potential exposure to fish tissue from the 21.8-mile site; the risk assessment results for the 12.7-mile site are considered to be conservative enough to represent an upper-bound on the results for the 21.8-mile site (see Tables B-7 and B-8 in Appendix B).

As discussed in Section 1.1, Viacom had completed the selected RA by November 1999 (Tetra Tech 2003a). The first sampling event at the 1- and 5.5-mile sites was conducted in May 1998 before Viacom

started the source removal RA. This sampling event is defined as a “pre-remedial” event; therefore, the HHRA does not consider analytical results for samples collected in May 1998.

Fish tissue samples were collected from the remaining four sampling locations (the 1-, 3-, 5.5-, and 12.7-mile sites) on one (12.7-mile site), two (3- and 5.5-mile sites), and five (1-mile site) occasions after Viacom completed the source removal RA. All post-remedial sampling results (after 1999) were used as the basis for the HHRA fish tissue calculations in order to create a robust data set that (1) reflects the fact that fish sampled historically may still be present in Richland Creek and could therefore be caught and consumed by anglers and (2) provides coverage of sampling locations well downstream of the site. Analytical results for fish tissue samples collected between August 2001 and June 2004 were obtained from the EDMS (CBS 2006a). Results for fish tissue samples collected in November 2005 were obtained from hard-copy reports (Tetra Tech 2006c; CBS 2006b).

A multiple-pass depletion population estimate like those conducted along Stout’s Creek (near Bennett’s Dump) was conducted at the 1-mile site on Richland Creek (Normandeau 2004 and 2006). To assess the sustainable fish ingestion rates (see note e in Table 3), the results of this population estimate were used as well as information regarding a qualitative habitat assessment (including the presence of eddies, riffle areas, pools, and run/glides); the stream width and depth; and the number, species, and size of fish observed or expected in Richland Creek (see Table 2). Appendix A documents the sustainable fish ingestion rate calculations used in the HHRA; these ingestion rates are discussed in Section 3.2.3.

2.1.2 Surface Water

Historical post-RA surface water analytical results (November 1999 through February 2005) are presented in Viacom (2005c) (for South, North, Branham, and Taylor Springs) and CBS (2006a) (for Conard’s Branch and Richland Creek) and are used as the basis for the HHRA’s surface water calculations. Analytical results for surface water samples collected from springs draining the site, Conard’s Branch, and Richland Creek are discussed further below.

South, North, Branham, and Taylor Springs

South and North Springs both drain the northern portion of the site and discharge into Conard’s Branch, and Branham and Taylor Springs both drain the southern portion of the site and discharge directly into an

unnamed branch of Richland Creek. The table below summarizes total PCB concentrations for all four springs from November 1999 through February 2005. Figure 2 shows each spring location.

**SURFACE WATER TOTAL PCB CONCENTRATIONS MEASURED AT
SOUTH, NORTH, BRANHAM, AND TAYLOR SPRINGS
(NOVEMBER 1999 THROUGH FEBRUARY 2005)^a (µg/L)**

Date	South Spring		North Spring		Branham Spring		Taylor Spring	
	Max	Avg	Max	Avg	Max	Avg	Max	Avg
1999	2.4	1.7	2.1	1.7	<0.1	<0.1	<0.1	<0.1
2000	2.35	1.5	1.6	0.79	<0.1	<0.1	0.11	0.1
2001	1.8	1.3	1.1	0.71	0.15	0.07	0.2	0.1
2002	2.5	1.3	1.6	0.72	<0.1	<0.1	0.2	0.08
2003	1.6	1.2	1.2	0.60	<0.1	<0.1	<0.1	<0.1
2004	1.85	1.1	1.4	0.55	<0.1	<0.1	<0.1	<0.1
2005 ^b	0.89	0.82	0.32	0.24	—	—	—	—

Notes:

µg/L Microgram per liter

Avg Average concentration (calculated as arithmetic mean)

Max Maximum detected concentration

— No samples collected at this location

^a Analytical results for South, North, Branham, and Taylor Springs are presented in Viacom (2005c).

^b Only two samples were collected from South and North Springs during 2005; therefore, the 2005 results presented for these springs are not representative of the variability of PCB concentrations measured throughout the year.

As the table above shows, the maximum and average total PCB concentrations measured in surface water at all four locations has remained fairly constant (except for the 2005 results for South and North Springs as described above in note b); however, this observation should be considered preliminary and carefully interpreted because potential co-factors such as stream flow and suspended solids loading in samples were not considered.

In order to reflect (1) current potential exposure conditions (to the extent possible) and (2) the variability of total PCB concentrations measured in surface water to which human receptors may be exposed, surface water analytical results for 2004 and 2005 were used as the basis for the HHRA surface water calculations for the South and North Springs. Potential exposure to PCBs in surface water from Branham

and Taylor Springs was not evaluated in the HHRA because PCBs have not been detected at either spring since 2001 and 2002, respectively.

Conard's Branch

Surface water samples have been collected from various points in and draining to Conard's Branch under a variety of circumstances. Analytical results for these samples are presented in the EDMS (CBS 2006a) but are not summarized in a table in this report because of the large amount of data (in particular, the large volume of storm event sampling data). In order to (1) reflect current potential exposure conditions (to the extent possible), (2) reflect the variability of total PCB concentrations measured in surface water to which human receptors may be exposed, and (3) be consistent with the data set used to evaluate potential exposure to surface water at South and North Springs, surface water analytical results for 2004 and 2005 were used as the basis for the HHRA surface water calculations for Conard's Branch.

Richland Creek

Surface water samples have been collected from various points in Richland Creek. Analytical results for these samples are presented in the EDMS (CBS 2006a) and are summarized in Table 4. These analytical results indicate that PCB concentrations in surface water samples collected at the locations RCVP (located near the fish sampling location referred to as the "1-mile site") and RC43 (located near the fish sampling location referred to as the "3-mile site") have not varied significantly (based on a "big picture" review) from May 2003 through January 2005; therefore, in order to (1) reflect current potential exposure conditions (to the extent possible), (2) reflect the variability of total PCB concentrations measured in surface water to which human receptors may be exposed, and (3) be consistent with the data set used to evaluate potential exposure to surface water at South and North Springs and Segments Pre-A and A in Conard's Branch, surface water analytical data for 2004 and 2005 were used as the basis for the HHRA surface water calculations for RCVP and RC43.

In contrast, surface water samples have not been collected since May 2003 from RCF and since August 2001 from the more downstream locations (RCI, RCJ, and RCK); therefore, analytical data for 2003 and 2001 were used as the basis for the HHRA surface water calculations for RCF and for RCI, RCJ, and RCK, respectively.

2.1.3 Sediment

Sediment and bank soil samples were collected in and along Conard's Branch and sediment samples were collected in Richland Creek at various times from about 1980 through April 2004. Analytical results associated with these samples were summarized and used as the basis for designing a comprehensive sampling program under which sediment, bank soil, and floodplain soil samples in and along Conard's Branch and Richland Creek were collected in October 2004 and January and October 2005 (Viacom 2005a and b). No floodplain soil samples were collected from either Conard's Branch or Richland Creek prior to October 2004 (CBS 2006a). Sediment, bank soil, and floodplain samples were collected from Conard's Branch and Richland Creek in October 2004 and January 2005; analytical results are available for these samples (Tetra Tech 2004a, and b; Viacom 2005a and b; CBS 2006a). Additional floodplain samples were collected along Conard's Branch and Richland Creek (upstream of the confluence with Conard's Branch) in October 2005 (CBS 2006c). As discussed above for fish tissue and surface water analytical results, only post-RA sediment, bank soil, and floodplain soil sample analytical results (later than 1999) were considered in the HHRA.

Comparison of results for sediment samples collected between 2001 and February 2004 from Conard's Branch and Richland Creek with results for sediment samples collected from these same areas in October 2004 and January 2005 shows that PCB concentrations are not dissimilar; therefore, in order to (1) reflect current potential exposure conditions (to the extent possible), (2) reflect the variability of total PCB concentrations measured in sediment to which human receptors may be exposed, and (3) be consistent with the data sets used to evaluate surface water, sediment analytical results for October 2004 and January 2005 were used as the basis for the HHRA sediment calculations (Tetra Tech 2004b; Viacom 2005a and b; CBS 2006a).

2.1.4 Soil

Soil samples have been collected from both the bank and floodplain at various points along Conard's Branch and Richland Creek. As discussed in Section 2.1.3, sediment and bank soil samples were collected in and along Conard's Branch and sediment samples were collected in Richland Creek at various times from about 1980 through April 2004 and used as the basis for designing a comprehensive sampling program under which sediment, bank soil, and floodplain soil samples in and along Conard's Branch and Richland Creek were collected in October 2004 and January and October 2005 (Viacom 2005a and b). No floodplain soil samples were collected from either Conard's Branch or Richland Creek

prior to October 2004 (CBS 2006a). Bank and floodplain soil samples were collected from Conard's Branch and Richland Creek in October 2004 and January 2005; analytical results are available for these samples (Tetra Tech 2004a and b; Viacom 2005a and b; CBS 2006a). Additional floodplain samples were collected along Conard's Branch and Richland Creek (upstream of the confluence with Conard's Branch) in October 2005 (CBS 2006c). As discussed above for fish tissue, surface water, and sediment (see Sections 2.1.1 through 2.1.3), only post-RA bank and floodplain soil sample analytical results (later than 1999) were considered in the HHRA. The bank and floodplain soil data sets considered in the HHRA are discussed in more detail below.

Bank Soil

Prior to October 2004, bank soil samples were collected along Conard's Branch at 15 locations in April 2004 (CBS 2006a). Comparison of the analytical results for these samples to analytical results for sediment samples collected from Conard's Branch in October 2004 results in two key observations. First, the detected PCB concentrations (5 of 15 samples) measured in April 2004 are similar to the upper end of the detected PCB concentrations measured in October 2004. Second, the nondetect PCB results (10 of 15 samples) measured in April 2004 have reported detection limits about one order of magnitude higher than the detection limits associated with nondetect PCB results from October 2004; therefore, in order to (1) reflect current potential exposure conditions to the extent possible, (2) reflect the variability of total PCB concentrations measured in bank soil to which human receptors may be exposed, (3) avoid artificially inflating the bank soil total PCB EPCs for Conard's branch by including results associated with elevated detection limits, and (4) be consistent with the data sets used to evaluate surface water and sediment, bank soil analytical results from October 2004 and January 2005 were used as the basis for the HHRA bank soil calculations (Tetra Tech 2004b; Viacom 2005a and b; CBS 2006a).

Floodplain Soil

Floodplain soil samples were collected along Conard's Branch in October 2004 and October 2005 (Tetra Tech 2004b; Viacom 2005a; CBS 2006a). All floodplain analytical results associated with these samples were used as the basis for the HHRA floodplain soil calculations.

2.2 COPC IDENTIFICATION

PCBs are the primary focus of the Neal's Landfill investigations. Fish tissue samples from Conard's Branch and Richland Creek have been analyzed for PCBs as both Aroclors and congeners (CBS 2006a and b; Tetra Tech 2006c), but surface water, sediment, and soil (bank and floodplain) samples have been analyzed for PCBs as Aroclors only (Tetra Tech 2004b; Viacom 2005a, b, and c; CBS 2006a).

Consistent with the approach taken at other Bloomington sites, most medium-specific PCB analytical results are summarized as total PCBs (either the sum of Aroclor- or congener-specific results). When available, results for fish tissue samples analyzed for PCB congeners are also summarized as World Health Organization (WHO) toxicity equivalents (TEQ) for all dioxin-like congeners; therefore, medium-specific COPCs considered in the HHRA are based on the following:

- S **Fish Tissue:** total PCBs and WHO TEQs
- S **Surface Water, Sediment, and Soil:** total PCBs

3.0 EXPOSURE ASSESSMENT

This section discusses methods used to estimate the types and magnitude of potential human exposure to COPCs in fish tissue, surface water, sediment, and soil samples collected from in and along Conard's Branch and Richland Creek. Exposure is defined as human contact with a chemical or physical agent (EPA 1989). The exposure assessment consists of three fundamental steps: (1) exposure setting characterization, (2) exposure pathway identification through a conceptual site model (CSM), and (3) exposure quantification. These steps are discussed below in Sections 3.1, 3.2, and 3.3, respectively.

3.1 EXPOSURE SETTING CHARACTERIZATION

The exposure setting consists of the physical setting and the populations living near the site area. Neal's Landfill occupies about 18 acres and is situated on karst terrain and surrounded by farms and woodlands about 4.5 miles west of Bloomington, Monroe County, Indiana (see Figure 1). The landfill drains through a series of springs. Two of these springs, Branham and Taylor Springs, drain the southern portion of the landfill and discharge directly into an unnamed branch of Richland Creek. Two other springs, South and North Springs, drain the northern portion of the landfill and discharge into Conard's Branch (a tributary to Richland Creek). Figure 2 shows the locations of the landfill, Conard's Branch, a portion of Richland

Creek, and the four springs identified above.

The City of Bloomington, Indiana, has a population of about 123,000 (REC 2005). Currently, the closest residences to the landfill are located along Vernal Pike east and northeast of the confluence of Conard's Branch and Richland Creek about 0.5 mile north-northwest of the landfill. Other residents live off of Conard's Branch west of the confluence. Land use near the site and downstream along Richland Creek is primarily agricultural and rural residential. The City of Whitehall (approximate population 50) is located on State Route 43 about 0.3 mile northwest of the intersection of State Routes 43 and 48 (Tetra Tech 2006d). The City of Hendricksville (population 3,744 [RelocationNow 2005]) is located along Richland Creek about 12.7 miles downstream from the site. Table 2 presents a qualitative exposure setting and habitat assessment for various points along Conard's Branch and Richland Creek downstream of the landfill. This assessment identifies points where human receptors have been observed in and along both surface water bodies or may have immediate access to the streams.

3.2 CONCEPTUAL SITE MODEL

Figure 4 presents the CSM illustrating potential exposure pathways for PCBs for human receptors in and along Conard's Branch and Richland Creek. Because capacitors and PCBs in site soil were addressed during the RA through soil excavation and off-site disposal or placement beneath a RCRA cap constructed over the site, potential human exposure to PCBs in site soil was not considered to represent a significant source of exposure; therefore, the HHRA does not consider potential direct exposures to contaminants in site soil. The CSM links potential or actual contaminant releases to potential human exposures. Specifically, the CSM identifies (1) potential contaminant sources and mechanisms of release, (2) potential receptors and exposure pathways, and (3) exposure scenarios. These three elements are discussed below.

3.2.1 Potential Contaminant Sources and Mechanisms of Release

The primary mechanism of release of PCBs from the site was the historical leaching of PCBs from waste material (including capacitors) disposed of at the site into subsurface soil and subsequently into groundwater. As discussed in Section 3.1, the landfill drains through a series of springs. Branham and Taylor Springs drain the southern portion of the site and discharge directly into an unnamed branch of Richland Creek, and South and North Springs drain the northern portion of the site and discharge into Conard's Branch, a tributary to Richland Creek. Additional mechanisms of release, such as surface water runoff, erosion, and the generation of fugitive dusts, are considered to be absent at the landfill because of

RA activities completed to date.

Figure 4 shows the transfer of PCBs from surface water to sediment and from sediment back to surface water as well as the transfer of PCBs from surface water and sediment to soil (bank and floodplain) as a result of stream flooding. Figure 4 also depicts the direct transfer of PCBs from sediment to aquatic animals (fish). Direct absorption of a chemical from water is called “bioconcentration,” exposure through food ingestion is known as “trophic transfer” or “biomagnification,” and integrated exposure through all routes is referred to as “bioaccumulation” (in this example, the combined effects of bioconcentration, trophic transfer, and sediment ingestion). Fish are shown as receiving an integrated exposure. As discussed in Section 3.2.2, human receptors are assumed to ingest fish caught in Richland Creek.

Finally, volatilization of PCBs from surface water, sediment, and soil to the atmosphere does play a role in influencing global distribution of PCBs; however, inhalation of PCBs in air above or adjacent to Conard’s Branch and Richland Creek is expected to be a minor contributor to total potential exposure and is therefore not evaluated in this HHRA.

3.2.2 Potential Receptors and Exposure Pathways

Identification and evaluation of potential current and future receptors and exposure pathways in and along Conard’s Branch and Richland Creek are based primarily on the following factors:

- C Physical setting
- C Field observations
- C Demographics

Potential receptors and exposure pathways identified based on these factors are discussed below.

Potential Receptors

Human exposures in and along Conard’s Branch and Richland Creek are expected to occur almost exclusively as a result of recreational activities, including fishing, wading, hiking, and hunting along the streams. This assumption is consistent with field observations made at other Bloomington area sites and along Conard’s Branch and Richland Creek as summarized in Table 2. Typically, children 6 years of age or less are expected to have less direct exposure to contaminants in and along a body of water (such as the

creek or springs) compared to older children or youths (7 to 18 years of age) and adults primarily because of safety concerns; however, because of the immediate proximity of residential areas to both surface water bodies, it was conservatively assumed that children may be exposed as often as youths and adults. This exposure could occur if children are accompanied or supervised during their visits to the creek by youths or adults. Potential human receptors evaluated in the HHRA include child (1 to 6 years of age), youth (7 to 18 years of age), and adult recreationalists.

Exposure Pathways

Receptors are expected to be exposed to contaminants in and along Conard's Branch and Richland Creek through a variety of exposure pathways as shown in the CSM (see Figure 4). The potentially complete exposure pathways evaluated in the HHRA include the following:

- C Ingestion of aquatic life (assumed to be entirely fish)
- C Direct contact with surface water, sediment, and soil (bank and floodplain)
- C Incidental ingestion of surface water, sediment, and soil (bank and floodplain)

Medium-specific analytical results form the basis for all chemical concentrations used in the quantitative exposure assessment (see Section 3.3). Fate and transport modeling was not performed as part of the HHRA.

3.2.3 Exposure Scenarios

Exposure pathways and scenarios are considered complete when a point of contact exists between an affected medium and a receptor. For Conard's Branch and Richland Creek, potentially complete exposure scenarios are identified in the CSM (see Figure 4) and are associated with the following receptors:

- C Child recreationalists (1 to 6 years of age)
- C Youth recreationalists (7 to 18 years of age)
- C Adult recreationalists

Exposure scenarios for these receptors are discussed below.

Child Recreationalists

Children have been observed playing in Richland Creek at the 1-mile site. Small clusters of homes or individual residences are located near the landfill site and further downstream along Richland Creek, and children living in or visiting these residences may also play in or along Conard's Branch and Richland Creek.

Child recreationalists are expected to be exposed to contaminants in and along Conard's Branch and Richland Creek through direct contact and incidental ingestion of surface water, sediment, and soil (bank and floodplain). These receptors are also assumed to be exposed through ingestion of fish caught from Richland Creek; however, consistent with the approach taken at other Bloomington area sites, exposure through ingestion of fish is evaluated only for adult receptors.

Youth Recreationalists

Youths 7 to 18 years of age have been observed in and along streams in the Bloomington area participating in a variety of recreational activities, including fishing, wading, and hiking. Children observed playing in Richland Creek at the 1-mile site may include children older than 6 years of age. Youths living in or visiting residences along Richland Creek at more downstream locations may play in or along Richland Creek.

Youth recreationalists are expected to be exposed to contaminants in and along Conard's Branch and Richland Creek through direct contact with and incidental ingestion of surface water, sediment, and soil (bank and floodplain). These receptors are also assumed to be exposed through ingestion of fish caught from Richland Creek; however, consistent with the approach taken at other Bloomington area sites, exposure through ingestion of fish is evaluated only for adult receptors.

Adult Recreationalists

Adults have been observed in and along streams in the Bloomington area participating in a variety of recreational activities, including fishing, wading, and hiking. As described for child and youth recreationalists, adults living in or visiting residences along Richland Creek downstream of the landfill site may recreate in or along the creek. Specifically, the Monroe County Health Department reports that area residents have historically fished in Richland Creek (upstream of the confluence of Conard's Branch and Richland Creek and near the 1-mile site) for white suckers during spring spawning runs. Also, a

Viacom consultant mentioned that he had observed people (age not specified) fishing in Richland Creek off the bridge at the 3-mile site. Adult recreationalists are expected to be exposed to contaminants in and along Conard's Branch and Richland Creek through ingestion of fish caught from the creek and through direct contact with and incidental ingestion of surface water, sediment, and soil (bank and floodplain).

In order to evaluate the full range of potential exposure through ingestion of fish tissue, the HHRA initially considered two types of fishers: low-income (subsistence) and recreational fishers. A reasonable maximum exposure (RME) scenario and average fish tissue ingestion rate were considered for both fisher types. As a result, the HHRA initially considered four different fisher receptor populations: (1) RME low income, (2) RME recreational, (3) average low income, and (4) average recreational. This approach is consistent with similar calculations performed for various Bloomington area sites (EPA 2004d, e, f, and g; Tetra Tech 2005c, 2006b).

Appendix A presents an evaluation of the sustainability of the four fish tissue ingestion rates discussed above. These fish ingestion rates range from 110 (RME low income) to 15 grams per day (g/day) (average recreational). As discussed in Appendix A, only the lowest of these ingestion rates was judged to be sustainable in Richland Creek (and then only at the downstream-most location evaluated in the HHRA - the 12.7-mile site). Appendix A discusses location-specific fish tissue ingestion rates for pelagic and benthic fish that are considered to be sustainable. These ingestion rates range from 6 to 18.3 g/day (pelagic fish) and 4 to 12.2 g/day (benthic fish). These fish tissue ingestion rates are judged to be sustainable in particular reaches of Richland Creek and increase from the 1-mile site (lowest values) to the 12.7-mile site (highest values). For the purposes of the HHRA, these fish tissue ingestion rates are applied only to adult receptors for the purpose of calculating quantitative exposures. For all other exposure pathways, the HHRA considers adult, youth (7 to 18 years of age), and child (1 to 6 years of age) receptors.

3.3 EXPOSURE QUANTIFICATION

Exposure is defined as the contact of an organism with a chemical or physical agent. Potential chemical exposure depends on the amount of a chemical available at human exchange boundaries (skin, lungs, and gut) during a specified time. The magnitude of exposure was quantitatively assessed for the human receptors discussed in Section 3.2.3.

Exposure dose equations that consider contact rate, receptor body weight, and frequency and duration of exposure were used to estimate the intake or dose of each COPC for each receptor. Exposure doses were calculated for the RME case, which represents the highest exposure reasonably expected to occur.

An exposure can occur over a period of time. The total exposure can be divided by the time period to calculate an average exposure per unit of time. An average exposure can be expressed in terms of body weight. All exposures quantified in the HHRA were normalized for time and body weight, are presented in units of milligrams of chemical per kilogram of body weight per day (mg/kg-day), and are termed “intakes.” Equation 1 below is a generic equation for calculating chemical intake (EPA 1989).

$$D = (C \times CR \times EF \times ED) / (BW \times AT) \quad (1)$$

where

D	=	Dose: the amount of chemical at the exchange boundary (mg/kg-day); to evaluate exposure to noncarcinogenic chemicals, the intake is referred to as the average daily dose (ADD); to evaluate exposure to carcinogenic chemicals, the intake is referred to as the lifetime average daily dose (LADD)
C	=	Chemical concentration: the average concentration (referred to as the EPC) contacted over the exposure period (for example, milligrams per kilogram [mg/kg] for fish tissue and sediment and milligrams per liter [mg/L] for surface water)
CR	=	Contact rate: the amount of contaminated medium contacted per unit of time or event (for example, milligram per day [mg/day] for sediment or liter per day [L/day] for surface water)
EF	=	Exposure frequency: how often the exposure occurs (days/year)
ED	=	Exposure duration: how long the exposure occurs (years)
BW	=	Body weight: the average body weight of the receptor over the exposure period (kilograms [kg])
AT	=	Averaging time: the period over which exposure is averaged (days); for carcinogens, the averaging time is 25,550 days based on a lifetime exposure of 70 years; for noncarcinogens, the averaging time is calculated as ED (years) x 365 days/year

Variations of Equation 1 were used to calculate pathway-specific exposure to COPCs. The equations and parameter values used for each exposure pathway are presented in Figure 5 and Table 3, respectively. The EPC calculations and pathway-specific intake equations and exposure parameters are discussed below in Section 3.3.1. Pathway-specific intake equations and exposure parameters used in the HHRA are discussed in Section 3.3.2. Finally, as discussed in Section 3.2, receptors are assumed to be exposed to PCBs through various medium-specific exposure pathways (see Figure 4). The combination of an exposure pathway for a particular receptor (for example, an adult recreationalist) at a particular exposure point (for example, Section C of Richland Creek) is referred to as an exposure scenario. Because fish ingestion exposures were evaluated only for adult receptors (see Section 3.2.3), total exposures were calculated only for adult recreationalists. (Note: Medium- and exposure pathway-specific exposures were calculated for youth [age 7 to 18 years] and child [age 1 to 6 years] recreationalists.) Section 3.3.3 summarizes the medium-specific exposure scenarios that were summed in order to calculate total exposures for adult recreationalists at each exposure point.

3.3.1 EPC Calculations

The EPC is defined as the concentration of a COPC that a human receptor is exposed to at an exposure point. This section summarizes how EPCs were derived for fish tissue, surface water, sediment, and soil (bank and floodplain). Medium-specific EPCs are discussed below.

Fish Tissue EPCs

As discussed in Section 2.1.1, in order to create a robust data set that (1) reflects the fact that fish sampled historically may still be present in Richland Creek and could, therefore, be caught and consumed by anglers and (2) provides coverage of sampling locations well downstream of the site, all post-remedial sampling results (after 1999) were considered in the HHRA. Analytical results for fish tissue samples collected between August 2001 and June 2004 were obtained from the EDMS (CBS 2006a). Results for fish tissue samples collected in November 2005 were obtained from hard-copy reports (Tetra Tech 2006c; CBS 2006b).

Consistent with the Bennett's Dump and Lemon Lane HHRA and risk assessment calculations previously prepared for the Neal's Landfill site, fish EPCs were based on average tissue concentrations (Tetra Tech 2005 and 2006b; EPA 2004d, e, and f). Also, all HHRA calculations were based on actual or estimated fillet concentrations. The following whole-fish-to-fillet concentration conversion factors were

originally developed for the initial risk assessment calculations prepared for the Lemon Lane site (EPA 2005a) and were used in this HHRA:

- Sunfish – 25 percent (that is, fillet concentrations are 25 percent of whole fish concentrations)
- Suckers – 50 percent (that is, fillet concentrations are 50 percent of whole fish concentrations)

For the purposes of this HHRA, it was assumed that the sunfish conversion factor is applicable to all pelagic fish sampled in Richland Creek (green and longear sunfish, rock bass, and largemouth bass) and the sucker conversion factor is applicable to all benthic fish sampled in Richland Creek (white sucker, northern hogsucker, redhorse, and carp).

Finally, the HHRA evaluated exposures and characterized risks and hazards based on potential consumption of fillets from pelagic and benthic fish separately. Specifically, COPC-specific EPCs were calculated as average concentrations based on actual and estimated fillet concentrations from fish species sampled at each location. Separate exposure and risk calculations were prepared for total PCBs and WHO TEQs for dioxin-like PCBs. As for Bennett's Dump and the Lemon Lane Landfill, total PCB results were calculated as the sum of detected Aroclors (Tetra Tech 2005 and 2006b). On the other hand, TEQs were calculated based on both detected and undetected congener results; a value equal to one-half of the detection limit was used for all nondetected congener results.

Habitat niche-specific (pelagic and benthic) EPCs calculated for each exposure point are presented in Tables B-1 through B-9 in Appendix B and are summarized in Table 5.

Surface Water EPCs

As discussed in Section 2.1.2, in order to reflect (1) current potential exposure conditions (to the extent possible) and (2) the variability of total PCB concentrations measured in surface water to which human receptors may be exposed, surface water EPCs for total PCBs were calculated based on analytical results for 2004 and 2005 except for downstream locations in Richland Creek. Specifically, locations 5.5 or more miles downstream from the site were not sampled in 2004 and 2005; therefore, surface water EPCs for these locations are based on the latest available data: (1) the EPC for location RCF is based on

analytical data from 2003, and (2) the EPCs for locations RCI, RCJ, and RCK are based on analytical data from 2001.

With regard to the analytical data available for Conard's Branch and Richland Creek, two issues regarding use of these data in the HHRA require some explanation. First, much of the available surface water analytical data for Conard's Branch and Richland Creek is associated with surface water samples collected during storm events. During these storm events, surface water samples are collected at a rate of about 1 sample per hour for approximately 24 hours (including the duration of the storm event). Including each hourly sample result as an individual sample would overly weight the storm event-specific analytical results; therefore, for the purposes of the HHRA, all surface water analytical results for a specific storm event were averaged and the average concentration used as a single result for the purpose of calculating EPCs for Conard's Branch. Also, some of the results are from samples collected from barrels of Conard's Branch water after allowing various amounts of time for the settling out of suspended sediments. Because these "settled" water samples do not represent normal stream conditions, analytical results for these samples were not considered in the HHRA.

Also, in February, April, and May 2005, water from Conard's Branch was diverted to allow for observation and sampling of seeps and other features. Once again, because these samples are not representative of Conard's Branch under naturally occurring conditions, surface water samples collected in February, April, and May 2005 were not considered in the HHRA.

In addition, some surface water samples included in the EDMS currently identify "Sample Type" as "FB1" and "EB1" (CBS 2006a). These sample results are actually for field and equipment blanks, respectively. At some point in the future, the EDMS will be revised to assign these samples the station identification (StationID) "FIELDQC" (PSARA 2006). For the purposes of the HHRA, these sample results were not considered in calculating surface water EPCs.

For investigative purposes, Conard's Branch has often been divided into two sections – Pre-A and A. Section Pre-A begins in the drainage feature immediately downstream of the treatment plant and extends about 1,400 feet downstream; Section A begins at the downstream end of Section Pre-A and extends to the point where Conard's Branch enters Richland Creek (see Figure 2). The EDMS presents sample results for surface water associated with a series of different StationIDs (CBS 2006a). These StationIDs are listed and explained below (PSARA 2006).

- **CONRDBRNCH** – Although it is known that most of these samples were collected from immediately downstream of the treatment plant just upstream of the road culvert, the precise sampling locations for the remaining samples assigned this StationID are not known. Because downstream locations are assigned more specific StationIDs, it is assumed for the purposes of the HHRA that samples with the StationID “CONRDBRNCH” were collected from Section Pre-A.
- **CONRDBRNCH Station 1** – This station is located close to Vernal Pike just upstream of the culvert.
- **CONRDBRNCH Station 2** – This station is located close to the Conard family farm property line and the woods.
- **CONRDBRNCH Station 3** – This station is located just downstream of North Spring.
- **CBB and CBB2** – These stations are located at Conard’s Branch fish location “B,” which is assumed to be Fish Site 1.
- **CBVP** – This station is located at the point where Conard’s Branch passes under Vernal Pike.
- **CBPoolVP** – This station is located in the fish sampling pool upstream of Vernal Pike.

For the purposes of the HHRA, the following StationIDs were assigned to Sections Pre-A and A of Conard’s Branch (see Figure 2).

- **Section Pre-A** – CONRDBRNCH and CONRDBRNCH Station 3
- **Section A** – CONRDBRNCH Stations 1 and 2, CBB, CBB2, CBVP, and CBPoolVP

As discussed in Section 2.1.2, surface water samples have been collected from Richland Creek at various locations downstream of the landfill. These locations include RCVP (approximately equivalent to the 1-mile site), RC43 (equivalent to the 3-mile site), RCF (approximately equivalent to the 5.5-mile site), RCI (equivalent to the 12.7-mile site), RCJ (equivalent to the 21.8-mile site), and RCK (equivalent to the 34.5-mile site).

For investigative purposes, Richland Creek has often been divided into six sections: (1) Section B from the confluence of Conard’s Branch and Richland Creek to the point where Vernal Pike crosses the creek, (2) Section C from the Vernal Pike bridge to State Route 48, (3) Section D from State Route 48 to the State Route 43 bridge, (4) Section E – from the State Route 43 bridge to a point about 4,600 feet (0.86 mile) downstream, (5) Section F – from the downstream end of Section E to a point about 4,600 feet (0.86

mile) downstream, and (6) Section G – from the downstream end of Section F to a point about 4,600 feet (0.86 mile) downstream (near Hendricksville).

For the purposes of the HHRA, the following StationIDs were assigned as representative of the following Richland Creek sections (see Figures 2 and 3).

- **Sections B and C – RCV**
- **Sections D and E – RC43**

Consistent with EPA guidance and unless otherwise noted, location-specific surface water EPCs for total PCBs were calculated as the lower of the 95 percent upper confidence limit of the mean concentration (95 UCL) and the maximum detected concentration as summarized below unless otherwise specified in the HHRA (EPA 2002c).

- **South and North Springs** – Based on surface water concentrations measured in 2004 and 2005 (Viacom 2005c)
- **Conard's Branch Section Pre-A** – Based on surface water concentrations measured at StationIDs CONRDBRNCH AND CONRDBRNCH Station 3 in 2004 and 2005 with the exceptions discussed in the text above (CBS 2006a)
- **Conard's Branch Section A** – Based on surface water concentrations measured at StationIDs CONRDBRNCH Station 1, CONRDBRNCH Station 2, CBB, CBB2, CBVP, and CBPoolVP in 2004 and 2005 with the exceptions discussed in the text above (CBS 2006a)
- **Richland Creek StationIDs RCV and RC43** – Based on surface water concentrations measured in 2004 and 2005 (CBS 2006a)
- **Richland Creek StationsIDs RCF, RCI, RCJ, and RCK** – Analytical results show that PCBs have not been detected in samples collected from these stations (located 5.5, 12.7, 21.8, and 34.5 miles downstream of the site, respectively) (CBS 2006a); a surface water sample collected from StationID RCF did not contain PCBs at a detection limit of 0.02 microgram per liter (µg/L); PCB concentrations in surface water are assumed to be as low or lower at more downstream locations; therefore, the HHRA did not consider potential surface water exposure in Richland Creek downstream of Section E

Documentation of the calculated location-specific surface water EPCs are presented in Tables B-10 and B-11 (North and South Springs) and Table B-12 (all other locations) in Appendix B. All location-specific surface water EPCs are summarized in Table 5.

Sediment EPCs

As discussed in Section 2.1.3, sediment samples have been collected from various points along Conard's Branch and Richland Creek. Two types of sediment samples were collected: surface sediment samples and deep sediment cores. Surface sediment samples were collected from 0 to 3 inches below sediment surface (bss) in Sections A, B, C, and D. Three samples were collected from each deep sediment core: the top 3 inches (0 to 3 inches bss), the bottom 6 inches of the core, and the mid-section; deep core sediment samples were collected from Sections E, F, and G. Analytical results from surface sediment and deep core sediment samples (0 to 3 inches bss and the mid-section) collected were used as the basis for the HHRA's sediment calculations for Conard's Branch and Richland Creek.

For the purposes of collecting sediment samples and evaluating potential exposure to sediment, Conard's Branch has been divided into two sections: Sections Pre-A and A, and Richland Creek has been divided into Sections B through G (see descriptions above under "Surface Water EPCs"). For the purposes of the HHRA, separate exposure area (section)-specific EPCs were therefore calculated as the lesser of the 95 UCL and the maximum detected value of the analytical results for the following samples (EPA 2002c):

- **Conard's Branch** – Surface sediment (0 to 3 inches bss) and deep core sediment (0 to 3 inches bss and mid-section [3 to approximately 8 to 10 inches bss]); Note: A sediment EPC was calculated only for Section A (no sediment samples were collected from Section Pre-A) (Tetra Tech 2004a and b; Viacom 2005a and b; CBS 2006a)
- **Richland Creek** – Surface sediment (0 to 3 inches bss) and deep core sediment (0 to 3 inches bss and mid-section [3 to approximately 8 to 10 inches bss]); Note: Separate sediment EPCs were calculated for Sections B through G (Tetra Tech 2004a and b; Viacom 2005a and b; CBS 2006a)

Table B-12 in Appendix B documents the location-specific sediment EPCs. All location-specific sediment EPCs are summarized in Table 5.

Soil EPCs

As discussed in Section 2.1.4, soil samples (bank and floodplain) have been collected at various points along Conard's Branch and Richland Creek. Bank soil samples were collected from the approximate mid-point of the water level at the time of sample collection and the apparent high water mark at depths of 0 to 3 inches and 3 to 6 inches below ground surface (bgs) from the east and west banks of Conard's Branch and Richland Creek at each location in Sections Pre-A, A, C, D, E, and F. Analytical results for

samples collected from both depth intervals are used as the basis for the HHRA's bank soil calculations along Conard's Branch and Richland Creek. Similarly, floodplain samples were collected from 0 to 3, 3 to 6, 0 to 6, and 6 to 12 inches bgs in Sections Pre-A, A, and B. Floodplain soil samples collected from 0 to 3 and 0 to 6 inches bgs are used as the basis for the HHRA's floodplain soil calculations along Conard's Branch and Richland Creek.

For the purposes of collecting soil samples and evaluating potential exposure to soil (both bank and floodplain), Conard's Branch and Richland Creek have been divided into two (Pre-A and A) and six (B through G) sections, respectively (see descriptions above under "Surface Water EPCs"). For the purposes of the HHRA, separate exposure area (section)-specific bank and floodplain soil EPCs were calculated as the lesser of the 95 UCL and the maximum detected value (unless otherwise noted) of the analytical results for the following samples (EPA 2002c):

- **Bank Soil** – Samples collected from 0 to 3 and 3 to 6 inches bgs on the east and west sides of the creek; Note: Separate bank soil EPCs will be calculated for Sections Pre-A, A, C, D, and E in Conard's Branch and Richland Creek (Tetra Tech 2004a and b; Viacom 2005a and b; CBS 2006a)
- **Floodplain Soil** – Samples collected from 0 to 3, 0 to 6, and 3 to 6 inches bgs; Note: Separate floodplain soil EPCs will be calculated for Sections Pre-A, A, B, and others in Conard's Branch and Richland Creek (Tetra Tech 2004a and b; Viacom 2005a and b; CBS 2006a and c)

Table B-12 in Appendix B documents the calculated soil type- and location-specific soil EPCs. All soil type- and location-specific soil EPCs are summarized in Table 5.

3.3.2 Pathway-Specific Intake Equations and Exposure Parameters

Figure 5 and Table 3, respectively, present the pathway-specific intake equations and exposure parameter values used to estimate receptor-specific exposure under RME conditions for each exposure pathway. Chemical-specific parameters referred to in Table 3 regarding the calculation of the term " DA_{event} " are presented in Table 6. The intake equations and exposure parameter values used in the HHRA were taken or adapted from EPA guidance documents, including Risk Assessment Guidance for Superfund (RAGS) (EPA 1989); "Exposure Factors Handbook" (EPA 1997b); "RAGS, Volume I: Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors" (EPA 1991a); and RAGS Part E (EPA 2004a). These documents provide guidance for selection of exposure

parameters and were used along with site-specific information and information from peer-reviewed literature to identify appropriate RME exposure parameter values.

Exposure was calculated for three receptor groups: child recreationalists (1 to 6 years of age), youth recreationalists (7 to 18 years of age), and adult recreationalists. Table 3 summarizes the basis for each exposure parameter value for the potential exposure routes evaluated. Receptor-specific doses under RME conditions are presented in Appendix C, Tables C-1 (fish tissue ingestion), Table C-2 (direct contact with and incidental ingestion of surface water), and Table C-3 (direct contact with and incidental ingestion of sediment and soil [bank and floodplain]).

3.3.3 Calculation of Total Exposures

As discussed in Section 3.3, human receptors are expected to be exposed to PCBs through various medium-specific exposure pathways. Exposures were evaluated for a series of 11 exposure points. These exposure points are patterned after the stream reaches routinely considered as part of Neal's Landfill investigations and can be grouped as follows:

- **Conard's Branch** – North Spring, South Spring, Section Pre-A, and Section A
- **Richland Creek** – Sections B through G and Section I

Human receptors are assumed to be to fish tissue, surface water, sediment, bank soil, and floodplain soil; however, all media are not present at each exposure point. Also, although present at a particular exposure point, one or more media may not have been sampled. For the purposes of the HHRA, it was therefore assumed that human receptors were exposed to all medium present and that all media were sampled at each exposure point. If a medium was not present or not sampled at a particular exposure point, it was assumed that the receptor was exposed to that medium at the next closest exposure point. For example, only surface water samples were collected from South Spring; therefore, it was assumed that receptors were exposed to sediment from Section Pre-A (the stretch of Conard's Branch into which South Spring drains). The medium-specific exposure pathways that were summed to calculate exposure point-specific total exposures for adult receptors are summarized below.

Conard's Branch

- **South Spring** – Fish ingestion from the 1-mile site; surface water incidental ingestion and dermal contact from South Spring; bank soil and floodplain soil incidental ingestion and dermal contact from Section Pre-A; and sediment incidental ingestion and dermal contact from Section A
- **North Spring** – Fish ingestion from the 1-mile site; surface water incidental ingestion and dermal contact from North Spring; bank soil and floodplain soil incidental ingestion and dermal contact from Section Pre-A; and sediment incidental ingestion and dermal contact from Section A
- **Section Pre-A** – Fish ingestion from the 1-mile site; surface water, bank soil and floodplain soil incidental ingestion and dermal contact from Section Pre-A; and sediment incidental ingestion and dermal contact from Section A
- **Section A** – Fish ingestion from the 1-mile site; surface water, bank soil, floodplain soil, and sediment incidental ingestion and dermal contact from Section A

Richland Creek

- **Section B** – Fish ingestion and surface water incidental ingestion and dermal contact from the 1-mile site (Section C), sediment and floodplain incidental ingestion and dermal contact from Section B, and bank soil from Section C
- **Section C** – Fish ingestion and surface water incidental ingestion and dermal contact from the 1-mile site (Section C), and sediment and floodplain soil incidental ingestion and dermal contact from Section B
- **Section D** – Fish ingestion and surface water incidental ingestion and dermal contact from the 3-mile site (Section E), sediment incidental ingestion and dermal contact from Section D, and bank soil incidental ingestion and dermal contact from Section E; floodplain soil incidental ingestion and dermal contact not evaluated for Section D.
- **Section E** – Fish ingestion and surface water, sediment, and bank soil incidental ingestion and dermal contact from the 3-mile site (Section E); floodplain soil incidental ingestion and dermal contact not evaluated for Section E
- **Section F** – Fish ingestion from the 5.5-mile site (Section F) and sediment incidental ingestion and dermal contact from Section F; bank soil and floodplain soil incidental ingestion and dermal contact not evaluated for Section F
- **Section I** – Fish ingestion from the 12.7-mile site (Section I); surface water, sediment, bank soil, and floodplain soil incidental ingestion and dermal contact not evaluated for Section I

4.0 TOXICITY ASSESSMENT

This section identifies the toxicity values used to quantify potential adverse effects on human health associated with potential exposures to COPCs in and along Conard's Branch and Richland Creek. These toxicity factors include slope factors (SF) for carcinogenic COPCs and reference doses (RfD) for noncarcinogenic COPCs. Section 4.1 summarizes PCB toxicity. Sections 4.2 and 4.3 discuss the toxicity factors used to assess the carcinogenic and noncarcinogenic effects of PCBs, respectively. Section 4.4 discusses the estimation of toxicity values for dermal exposure.

4.1 PCB TOXICITY

Animal studies reveal considerable variation in the susceptibility of different species to equivalent doses of the same PCB. In addition, the toxicity and potency of the PCB formulations differ. In general, the more highly chlorinated mixtures are more toxic than the less chlorinated ones, with this trend holding predominantly for studies defining the acute lethal dose or carcinogenicity.

In humans, the primary acute toxic effect of PCBs is chloracne. Toxic effects in experimental animals chronically exposed to PCBs include severe weight loss, liver damage, immune system effects, adverse reproductive effects, and malformed offspring. In humans, chronic ingestion of PCBs causes "Yusho Disease," named after the town of Yusho, Japan, where an epidemic occurred when residents ate PCB-contaminated food for several months. Chloracne developed after a latent period, along with pigmentation of skin areas, visual disturbances, gastrointestinal distress, jaundice, and lethargy. Infants from exposed mothers had low birth weight and pigment blotches. Some of these effects, however, have been ascribed to the chemically related polychlorinated dibenzofurans, which are by-products found in most complex mixtures of PCBs. Industrial exposure, which is generally limited to dermal contact, produces chloracne and, in severe cases, hepatotoxicity; effects on the gastrointestinal tract and neuromuscular system have also been observed.

PCBs are classified by EPA as B2 carcinogens (probable human carcinogens; see Section 4.2.1) based on the induction of liver tumors in experimental animals. Several studies were conducted with mice and rats. In one study, 70 female and 70 male rats were administered a diet containing Aroclor 1260 in corn oil at 100 mg/kg for 16 months, followed by a 50-mg/kg diet for an additional 8 months, then a basal diet for 5 months. This diet resulted in a 91 percent incidence of liver tumors in females that lived

for at least 18 months, and an additional 4 percent had neoplastic nodules. Males exhibited a 4 percent incidence of tumors and an 11 percent incidence of neoplastic nodules. Many studies conducted concerning the carcinogenic effects of PCBs on humans have been ruled inadequate because of confounding exposures or lack of exposure quantification. In the Integrated Risk Information System (IRIS), EPA states that it is currently reassessing the cancer potency factor for PCBs and will revise the IRIS summary to reflect the reassessment results (EPA 2005b).

PCBs are well absorbed from the gastrointestinal system, skin, and lungs. More than 90 percent of most PCB congeners is absorbed after oral exposure. PCBs initially concentrate in the liver, blood, and muscle, but soon are sequestered in fat tissue, where they have a long half-life. PCBs are metabolized to biphenyls, biphenyldiols, and dihydrodihydroxybiphenyls. Excretion occurs through urine and feces. Although there are species variations, the more highly chlorinated compounds are primarily excreted in the feces and are less readily metabolized than the less chlorinated congeners (EPA 1996 and 2005b).

4.2 TOXICITY FACTORS FOR CARCINOGENIC COPCs

This section discusses the development and use of SFs for quantifying the potential adverse effects on human health resulting from exposure to carcinogenic COPCs. Section 4.2.1 discusses the general development of SFs. Section 4.2.2 discusses the development and use of PCB-specific SFs.

4.2.1 Slope Factor Development

The potential for exposure to a given chemical to result in carcinogenic effects is evaluated differently than for noncarcinogenic effects. The upper-bound excess lifetime cancer risk (ELCR) associated with a given dose is calculated by multiplying the dose from a given route of exposure (LADD) by an SF. An SF is an upper-bound estimate of the probability of a carcinogenic response per unit dose of a chemical over a lifetime. SFs are derived through use of mathematical models based on a high-to-low dose extrapolation and under the assumption that no threshold exists for initiation of cancer. Because of the use of the nonthreshold assumption and the 95 UCL of the slope of the dose-response curve, SFs provide a conservative, upper-bound estimate of potential cancer risks. The actual response to a given dose of a chemicals is therefore probably less than the predicted response (EPA 1989).

EPA assigns weight-of-evidence designations to indicate the likelihood that a chemical agent is a carcinogen in humans. These designations are defined below (EPA 1989).

- “A” indicates that a chemical is considered a proven human carcinogen.
- “B” indicates that a chemical is considered a probable human carcinogen. “B1” indicates that a suggestive but inconclusive evidence of human carcinogenicity is associated with the chemical, and “B2” indicates that conclusive evidence of a chemical’s human carcinogenicity is documented in repeated animal studies but that evidence of carcinogenicity in humans is inconclusive.
- “C” indicates that a chemical is a possible human carcinogen either because a single high-quality animal study demonstrates carcinogenicity or because several low-quality animal studies indicate carcinogenicity.
- “D” indicates that evidence of a chemical’s carcinogenicity in animals or humans is inconclusive.
- “E” indicates that no evidence of a chemical’s carcinogenicity is available from adequate human or animal studies.

SFs are specific to a chemical and a route of exposure and are generally available for both the oral (ingestion or gavage) and inhalation routes. Chemical-specific SFs are selected in accordance with EPA’s revised recommended toxicity value hierarchy (EPA 2003b), which is summarized below.

- **Tier 1** - EPA’s IRIS (EPA 2005b)
- **Tier 2** - EPA’s provisional peer-reviewed toxicity values (PPRTV; EPA 2005c)
- **Tier 3** - Other EPA and non-EPA sources of toxicity information, including, but not limited to, (1) the California Environmental Protection Agency (CalEPA) toxicity values (CalEPA 2003), (2) the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRL) (ATSDR 2005), and (3) EPA’s Health Effects Assessment Summary Tables (HEAST) (EPA 1997a)

The SFs used to characterize risks associated with potential exposure to PCB-contaminated media are discussed in Section 4.2.2.

4.2.2 Slope Factors for PCBs

As described in Section 2.2, two types of PCB analytical data are considered in the HHRA. Most of the fish and all of the surface water, sediment, and soil samples were analyzed for a series of congener mixtures trade-named “Aroclors.” Based on EPA guidance (EPA 1996) and a review of the major congener composition of commercial PCB mixtures, Aroclors were organized into the following three groups:

- Group 1: Aroclors 1248, 1254, and 1260
- Group 2: Aroclors 1232 and 1242
- Group 3: Aroclors 1016 and 1221

Studies of one or more Aroclors within each group are the primary bases for the SFs developed by EPA for high risk and persistence, low risk and persistence, and lowest risk and persistence conditions.

Based on EPA guidance, SFs were assigned as summarized below (EPA 1996).

PCB EXPOSURE PATHWAYS AND SLOPE FACTORS

PCB Group	Exposure Pathway	SF (mg/kg-day) ⁻¹
1 and 2	Fish ingestion, surface water and sediment ingestion, and dermal contact with surface water and sediment	2
3	All complete exposure pathways	0.07

Notes:

mg/kg-day = Milligram per kilogram per day
 PCB = Polychlorinated biphenyl

Based on the analytical data, most Aroclors detected in fish tissue, surface water, sediment, and soil samples from and along Clear Creek and the Quarry Springs area are from PCB Groups 1 and 2; therefore, for the purposes of the HHRA, a slope factor of 2 (mg/kg-day)⁻¹ was used to characterize risks associated with potential exposure to total PCBs (calculated as the sum of sample-specific Aroclor or congener results).

As discussed in Section 2.2, some fish tissue samples were also analyzed for specific congeners, not Aroclors; therefore, an alternative procedure was used to estimate carcinogenic risk for these specific PCB congeners. Research of the health effects of specific congeners (referred to as “dioxin-like PCBs”) has revealed “a spectrum of biochemical and toxic responses similar to chlorinated dibenzo-p-dioxins and dibenzofurans” (EPA 1996). Based on structure-activity studies, WHO has derived toxicity equivalency factors (TEF) for 13 PCB congeners (see the table below). The congener-specific TEFs represent the fractional toxicity for each congener relative to 2,3,7,8-tetrachloro-p-dioxin (TCDD). The concentration of each congener was multiplied by its congener-specific TEF to generate a congener-specific 2,3,7,8-TCDD TEQ. The congener-specific TEQs were summed to generate a composite 2,3,7,8-TCDD TEQ for each sample. For the purposes of the HHRA, dioxin-like PCBs (2,3,7,8-TCDD)

were treated as a separate COPC. The “dioxin-like PCB” congeners and their WHO TEFs are summarized below (Van den Berg and others 1998).

PCB CONGENERS AND WHO TEFs

Congener	Congener Number	WHO TEF
3,3',4,4'-Tetrachlorobiphenyl	77	0.0001
2,3,3',4,4'-Pentachlorobiphenyl	105	0.0001
2,3,4,4',5-Pentachlorobiphenyl	114	0.0005
2,3',4,4',5-Pentachlorobiphenyl	118	0.0001
2',3,4,4',5-Pentachlorobiphenyl	123	0.0001
3,3',4,4',5-Pentachlorobiphenyl	126	0.1
2,3,3',4,4',5-Hexachlorobiphenyl	156	0.0005
2,3,3',4,4',5'-Hexachlorobiphenyl	157	0.0005
2,3',4,4',5,5'-Hexachlorobiphenyl	167	0.00001
3,3',4,4',5,5'-Hexachlorobiphenyl	169	0.01
2,2',3,3',4,4',5-Heptachlorobiphenyl	170	0.0001
2,2',3,4,4',5,5'-Heptachlorobiphenyl	180	0.00001
2,3,3',4,4',5,5'-Heptachlorobiphenyl	189	0.0001

Notes:

TEF = Toxicity equivalency factor
 WHO = World Health Organization

The SF for 2,3,7,8-TCDD is $1.5\text{E}+05$ (mg/kg-day)⁻¹ (EPA 1997a). As part of its draft exposure reassessment for 2,3,7,8-TCDD, EPA proposes an alternate SF for 2,3,7,8-TCDD of $1\text{E}+06$ (mg/kg-day)⁻¹ (EPA 2003a). Dioxin TEQs and total risks for “dioxin-like” PCBs were therefore calculated based on both dioxin SFs. Risks calculated using the proposed dioxin SF are presented for comparison purposes only. The proposed SF is currently under review and may be modified as a result of this review by the National Academy of Sciences. PCB exposure and toxicity factors used in the HHRA are presented in Table 6.

4.3 TOXICITY FACTORS FOR NONCARCINOGENIC COPCs

This section discusses the development and use of RfDs for quantifying the potential adverse effects on human health resulting from exposure to noncarcinogenic COPCs. Section 4.3.1 discusses the general development of RfDs. Section 4.3.2 discusses the development and use of PCB-specific RfDs.

4.3.1 Reference Dose Development

Standard risk assessment models are based on the assumption that noncarcinogenic effects, unlike carcinogenic effects, exhibit a threshold (that is, a level of exposure exists below which no adverse effects are observed). The potential for noncarcinogenic health effects resulting from exposure to a COPC was assessed by comparing an exposure estimate for intake (ADD) to an RfD. The RfD represents an estimated daily intake rate for a noncarcinogenic COPC that is believed to pose no appreciable risk of adverse effects on human health, including the health of sensitive populations, during a lifetime. RfDs also apply to the noncarcinogenic effects of potential carcinogens.

An RfD is specific to a chemical and a route of exposure, such as ingestion or inhalation. This HHRA does not consider the inhalation route of exposure (see Section 3.2.1). Chronic and subchronic RfDs are developed for different periods of exposure. Chronic RfDs are used to evaluate exposures occurring over periods of more than 7 years, and subchronic RfDs are used to evaluate exposures occurring over periods of less than 7 years. The HHRA only considers potential noncarcinogenic health effects over a 30-year period of exposure; therefore, for the purposes of the HHRA, chronic oral RfDs were used. These RfDs were identified in accordance with EPA's recommended hierarchy (see Section 4.2.1).

To derive an RfD, EPA workgroups review all human and animal studies relevant to a chemical and select the study or studies pertinent to the derivation of the RfD. RfDs are often derived from a measured no observed adverse effect level (NOAEL). The NOAEL corresponds to the dose (in mg/kg-day) administered during the toxicity study without inducing observable adverse effects. If a NOAEL cannot be determined, the lowest observed adverse effect level (LOAEL) is used. The LOAEL corresponds to the lowest daily dose administered in the toxicity study that induces an observable adverse effect. The toxic effect characterized by the LOAEL is referred to as the "critical effect."

To derive an RfD, the NOAEL or LOAEL is divided by uncertainty factors to ensure that the RfD will be protective of human health. Uncertainty factors usually occur in multiples of 10, and each factor represents a specific area of uncertainty inherent in extrapolation from available data. Uncertainty factors account for (1) variations in the general population to protect sensitive human populations such as child and elderly receptors, (2) extrapolation of data from animals to humans (interspecies extrapolation), (3) derivation of a chronic RfD based on a subchronic rather than a chronic study, and (4) derivation of an RfD based on a LOAEL instead of a NOAEL. Modifying factors may be applied to data in order to reflect additional uncertainties associated with the data. Modifying factors range from 0 to 10.

The RfDs used to characterize hazards associated with potential exposure to PCB-contaminated media are discussed in Section 4.3.2.

4.3.2 Reference Doses for PCBs

EPA's IRIS database lists an oral RfD of 2E-05 mg/kg-day for Aroclor 1254 (EPA 2005b). Consistent with the Aroclor groupings described in Section 4.1 and the fact that most Aroclors detected in samples from in and along Conard's Branch and Richland Creek are from Groups 1 and 2, the oral RfD for Aroclor 1254 was used to represent the RfD total PCBs.

The RfD for 2,3,7,8-TCDD is 1 picogram per kilogram per day (or 1E-09 mg/kg-day) (EPA 2003a). It should be noted that EPA is currently evaluating procedures to assess noncarcinogenic hazards, and these procedures may deviate from conventional RfD approaches. PCB RfDs used in the HHRA are presented in Table 6.

4.4 ESTIMATION OF TOXICITY VALUES FOR DERMAL EXPOSURE

RfDs are not available for the dermal exposure pathway; however, in many cases, noncarcinogenic hazards and carcinogenic risks associated with the dermal exposure pathway can be evaluated using oral SFs and RfDs. Most oral SFs and RfDs are expressed as the amount of substance administered per unit time and unit body weight, or the administered dose; however, exposure estimates developed for dermal exposure to COPCs in soil or water are expressed as the amount of substance absorbed, or the absorbed dose. Adjustments are sometimes required to ensure that the exposure estimate and the toxicity value are both expressed as absorbed doses or are both expressed as administered doses (EPA 1989).

To ensure that the exposure estimate and toxicity value are comparable, the toxicity value (SF or RfD), which is generally based on an administered dose, is adjusted to reflect an absorbed dose. Specifically, the oral RfD or SF for a COPC is adjusted using the gastrointestinal (GI) absorption efficiency for that COPC. For a carcinogen, the absorbed dose SF is the quotient of the oral administered dose SF and the GI absorption efficiency. For a noncarcinogen, the absorbed dose RfD is the product of the oral administered dose RfD and the GI absorption efficiency (EPA 1989).

PCBs have a GI absorption efficiency of 80 percent or more (EPA 2004a). As recommended by EPA Region 5, oral administered toxicity values for chemicals with a GI absorption efficiency greater than about 70 percent are generally not adjusted for use in characterizing risks and hazards associated with dermal exposures (Tetra Tech 1998); therefore, the oral administered SFs and RfDs for PCBs were used directly and were not adjusted to characterize risks and hazards associated with dermal exposures.

5.0 RISK AND HAZARD CHARACTERIZATION

This section characterizes the carcinogenic risks and noncarcinogenic hazards associated with the exposure pathways identified in Section 3.0. Risks and hazards are characterized for individual COPCs (total PCBs and TCDD TEQs) and for exposures attributable to multiple exposure pathways, as appropriate. Carcinogenic risk estimates were derived based on LADDs, and noncarcinogenic hazard estimates were derived based on ADDs.

Section 5.1 discusses the methodologies used to characterize carcinogenic risks and hazards. Section 5.2 discusses the receptor-specific risks and hazards estimated following the conventional RAGS risk and hazard estimation methodology. Sections 5.3 and 5.4 discuss the comparison of PCB concentrations in fish tissue to the State of Indiana AWQC-derived and fish advisory action levels, respectively. Section 5.5 presents the uncertainty analysis for the HHRA.

5.1 RISK AND HAZARD CHARACTERIZATION METHODOLOGIES

The methodologies used to quantify carcinogenic risks and noncarcinogenic hazards are discussed in Sections 5.1.1 and 5.1.2, respectively.

5.1.1 Carcinogenic Risks

For carcinogenic COPCs, risk estimates represent the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to the COPC (EPA 1989). These ELCRs are calculated as shown in Equation 2 below:

$$\text{Upper-Bound ELCR (Risk)} = \text{LADD} \times \text{SF} \quad (2)$$

where

LADD = Lifetime average daily dose (mg/kg-day)

SF = Slope factor (mg/kg-day)⁻¹

Risk is expressed as a probability. For example, a risk of 1E-06 indicates one additional case of cancer in an exposed population of 1 million. The SF in almost all cases represents a 95 UCL of the probability of a carcinogenic response based on experimental data used in a multistage model. The resulting risk estimate therefore represents an upper-bound estimate of the carcinogenic risk. The actual risk probably does not exceed the estimate and is likely to be less.

In the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP), EPA has established an “acceptable” range for carcinogenic risk associated with exposure at Superfund sites of 1E-06 to 1E-04 (1 additional case of cancer in an exposed population of 10,000) (EPA 1990). In general, a potential upper-bound risk of 1E-06 is used by EPA as a point of departure for determining remediation goals. The EPA assistant administrator has clarified EPA’s interpretation of the risk range by stating that remedial action is generally not warranted when risk is below 1E-04 unless there is a high probability of ecological effects (EPA 1991b).

Within a given exposure pathway, receptors may be exposed to more than one chemical. For the purposes of this HHRA, PCBs are considered the only COPC. The risk associated with PCBs is characterized in terms of total PCBs using an Aroclor-based SF and total dioxin TEQs using an SF for “dioxin-like” PCB congeners. These two sets of risk results will be compared but will not be summed.

At particular exposure points, receptors may be exposed through a number of exposure pathways (see the CSM in Figure 4). At each exposure point, the total exposure for a receptor equals the sum of the exposures through the various exposure pathways to which the receptor is exposed. Under each

exposure scenario, exposure pathway combinations were developed for each receptor. The total risk posed to a receptor through a combination of pathways was calculated as shown below in Equation 3.

$$\text{Total Risk} = \text{Risk (EP}_1\text{)} + \text{Risk (EP}_2\text{)} + \dots + \text{Risk (EP}_i\text{)} \quad (3)$$

where

$$\text{Total Risk} = \text{Risk resulting from multiple exposure pathways}$$

$$\text{Risk (EP}_i\text{)} = \text{Risk resulting from the } i\text{th exposure pathway}$$

The approach described above is consistent with the widely held belief that the total carcinogenic risk associated with exposure to multiple carcinogenic COPCs can be estimated as the sum of the carcinogenic risks posed by individual COPCs (EPA 1986).

5.1.2 Noncarcinogenic Hazards

The potential for receptors to develop noncarcinogenic health effects is characterized by comparing an intake for a specific exposure period (the ADD) to an RfD developed for a similar exposure period. When performed for a single chemical, this comparison yields a ratio known as the hazard quotient (HQ), which is calculated as shown below in Equation 4.

$$\text{HQ} = \text{ADD/RfD} \quad (4)$$

where

$$\text{ADD} = \text{Average daily dose (mg/kg-day)}$$

$$\text{RfD} = \text{Reference dose (mg/kg-day)}$$

Generally, an HQ of less than or equal to 1 is considered to be health-protective. An HQ exceeding 1 indicates a potential for adverse noncarcinogenic health effects (EPA 1989). For the purposes of the HHRA, chronic RfDs were used to characterize noncarcinogenic hazards for all receptor-exposure pathway combinations.

As described in Section 4.3.2, hazards associated with PCBs are characterized using RfDs based on Aroclors and dioxin TEQs. These two sets of hazards will be compared but will not be summed. Total noncarcinogenic hazards posed for a particular hazard through a combination of exposure pathways were calculated as shown below in Equation 5.

$$\text{Total HI} = \text{HQ (EP}_1\text{)} + \text{HQ (EP}_2\text{)} + \dots + \text{HQ (EP}_i\text{)} \quad (5)$$

where

$$\begin{aligned} \text{Total HI} &= \text{HI resulting from multiple exposure pathways} \\ \text{HI (EP}_i\text{)} &= \text{HI resulting from the } i\text{th exposure pathway} \end{aligned}$$

5.2 RISKS AND HAZARDS - CONVENTIONAL METHODOLOGY

This section discusses risks and hazards estimated following the conventional EPA RAGS methodology (EPA 1989). Results are presented separately by exposure medium for fish tissue (Section 5.2.1), surface water (Section 5.2.2), sediment (Section 5.2.3), and soil (Section 5.2.4). Total risks and hazards across all four exposure media are discussed in Section 5.2.5.

5.2.1 Fish Tissue

This section discusses risks and hazards associated with ingestion of fish tissue from Richland Creek.

5.2.1.1 Risks

Receptor-specific risks from ingestion of fish tissue are detailed in Appendix C, Table C-1, and are summarized in Table 7. The observations below were noted based on review of Table 7.

- Risks do not vary significantly by location or fish type; that is, risks for the 1-, 3-, 5.5-, and 12.7-mile sites are similar. (Note: Risks at the 3-mile site appear to be slightly lower than at the other sites.) Likewise, risks for pelagic and benthic fish are similar at each location, with one possible exception: at the 1-mile site, benthic fish risks are about three times higher than risks associated with pelagic fish.
- Risks based on total PCBs range from 2.0E-05 (about 2 in a population of 100,000)

based on ingestion of benthic fish at the 1-mile site to $5.1\text{E-}06$ (about 5 in a population of 1,000,000) based on ingestion of pelagic fish at the 3-mile site.

- Risks calculated based on total PCBs match closely with those calculated based on TCDD TEQs using the existing SF ($1.5\text{E}+05$ [mg/kg-day]⁻¹). Risks based on EPA's proposed alternative TCDD SF ($1\text{E}+06$ [mg/kg-day]⁻¹) are about 5 to 10 times higher than those based on total PCBs and 6 to 7 times higher than those based on the TCDD TEQ using the current TCDD SF. (Note: Risks based on TCDD TEQs were calculated for pelagic fish only at the 1- and 3-mile sites and for benthic fish only at the 1-, 3-, and 5.5-mile sites).
- Risks based on total PCBs and assuming ingestion of pelagic fish are less than $1\text{E-}04$ (the upper end of EPA's acceptable risk range) at all locations and equaled $1\text{E-}05$ only at the 12.7-mile site.
- Risks based on total PCBs and assuming ingestion of benthic fish are less than $1\text{E-}04$ at all locations and equaled or exceeded $1\text{E-}05$ only at the 1- ($2.0\text{E-}05$) and 12.7-mile ($1.2\text{E-}05$) sites.
- Risks based on total PCBs and assuming ingestion of both pelagic and benthic fish are less than $1\text{E-}04$ at all locations and equaled or exceeded $1\text{E-}05$ at the 1- ($2.7\text{E-}05$), 3- ($1.1\text{E-}05$), and 12.7-mile ($2.2\text{E-}05$) sites.
- Risks based on TCDD TEQs and the existing SF ($1.5\text{E}+05$ [mg/kg-day]⁻¹) are less than $1\text{E-}04$ at all locations assuming ingestion of pelagic, benthic, and both types of fish. Similarly, risks based on EPA's proposed SF ($1.0\text{E}+06$ [mg/kg-day]⁻¹) are less than $1\text{E-}04$ assuming ingestion of pelagic, benthic, and both types of fish at the 3-, 5-, and 12.7-mile sites. At the 1-mile site, risks based on ingestion of benthic fish ($1\text{E-}04$) and ingestion of both pelagic and benthic fish ($2\text{E-}04$) equal and exceed $1\text{E-}04$, respectively.

5.2.1.2 Hazards

Receptor-specific fish tissue hazards are detailed in Appendix C, Table C-1, and are summarized in Table 8. The observations below were noted based on review of Table 8.

- Hazards do not vary significantly by location or fish type; that is, hazards for the 1-, 3-, 5.5-, and 12.7-mile sites are similar. (Note: As for risks, hazards at the 3-mile site appear to be slightly lower than at the other sites.) Likewise, hazards for pelagic and benthic fish are similar at each location, with one possible exception: at the 1-mile site, benthic fish hazards are about three times higher than hazards associated with pelagic fish.
- Hazards based on total PCBs range from 1.2 based on ingestion of benthic fish at the 1-mile site to 0.3 based on ingestion of pelagic fish at the 3-mile site.
- Hazards calculated based on total PCBs do not match as closely with those calculated based on TCDD TEQs as the risks (see Section 5.2.1.1). Hazards based on TCDD TEQs range from about 3 to 5 times lower than hazards based on total PCBs

- Hazards based on total PCBs and assuming ingestion of pelagic fish are less than 1 at all locations (maximum hazard of 0.6 at the 12.7-mile site).
- Hazards calculated based on total PCBs and assuming ingestion of benthic fish equaled or exceeded 1 only at the 1-mile site (hazard = 1.2).
- Hazards calculated based on total PCBs and assuming ingestion of both pelagic and benthic fish equaled or exceeded 1 only at the 1- (hazard = 1.6) and 12.7-mile (hazard = 1.3) sites.
- Hazards based on TCDD TEQs are less than 1 at all locations assuming ingestion of pelagic, benthic, and both types of fish.

5.2.2 Surface Water

This section discusses risks and hazards associated with incidental ingestion of and dermal contact with total PCBs in surface water from South and North Springs, Conard's Branch, and Richland Creek. Risks and hazards calculated for adult, youth, and child receptors are discussed in Sections 5.2.2.1 and 5.2.2.2, respectively.

5.2.2.1 Risks

Receptor-specific risks are detailed in Appendix C, Table C-2. The total risks for adult, youth, and child receptors equal or exceed $1\text{E-}06$ at all locations (South Spring, North Spring, Conard's Branch Section A, and Richland 1-mile site, and 3-Mile Site) with two exceptions: the total child risk at Section A and the 1-mile site are $8.3\text{E-}07$ and $7.6\text{E-}07$, respectively. The maximum total risk is for adult receptors at South Spring (total risk = $5\text{E-}06$). These risks are within EPA's acceptable risk range of $1\text{E-}06$ to $1\text{E-}04$ (EPA 1990) and are driven by potential dermal contact with total PCBs in surface water.

5.2.2.2 Hazards

Receptor-specific hazards are detailed in Appendix C, Table C-2. The total hazards for adult, youth, and child receptors equal or exceed 1 only for child receptors at one location: Conard's Branch Section Pre-A (hazard = 1.3). Total hazards for all other receptors are less than 1 at all other locations. As for risks, the total hazards are driven by potential dermal contact with total PCBs in surface water.

5.2.3 Sediment

This section discusses risks and hazards associated with incidental ingestion of and dermal contact with total PCBs in sediment from Conard's Branch and Richland Creek. Risks and hazards calculated for adult, youth, and child receptors are discussed in Sections 5.2.3.1 and 5.2.3.2, respectively.

5.2.3.1 Risks

Receptor-specific risks are detailed in Appendix C, Table C-3, and are summarized below.

- **Adult recreationalists:** Total risks are less than 1E-06 at all locations and are considered insignificant.
- **Youth recreationalists:** Total risks are less than 1E-06 at all locations and are considered insignificant.
- **Child recreationalists:** Total risks are less than 1E-06 at all locations and are considered insignificant.

5.2.3.2 Hazards

Receptor-specific hazards are detailed in Appendix C, Table C-3, and are summarized below.

- **Adult recreationalist:** Total hazards are less than 1 at all locations and are considered insignificant.
- **Youth recreationalist:** Total hazards are less than 1 at all locations and are considered insignificant.
- **Child recreationalist:** Total hazards are less than 1 at all locations and are considered insignificant.

5.2.4 Soil

This section discusses risks and hazards associated with incidental ingestion of and dermal contact with total PCBs in bank and floodplain soil adjacent to Conard's Branch and Richland Creek. Risks and hazards calculated for adult, youth, and child receptors are discussed in Sections 5.2.4.1 and 5.2.4.2, respectively.

5.2.4.1 Risks

Receptor-specific risks are detailed in Appendix C, Table C-3, and are summarized below.

- **Adult recreationalist:** Total risks for bank and floodplain soil equal or exceed $1\text{E-}06$ only at Conard's Branch Section Pre-A: bank soil ($2.5\text{E-}06$). This total risk is near the low end of EPA's risk range. All other total risks are less than $1\text{E-}06$ and are considered insignificant.
- **Youth recreationalist:** Total risks for bank and floodplain soil equal or exceed $1\text{E-}06$ only at Conard's Branch Sections Pre-A (bank soil [$4.5\text{E-}06$] and floodplain soil [$1.6\text{E-}06$]) and A (floodplain soil [$1\text{E-}06$]). These total risks are within EPA's acceptable risk range. All other total risks are less than $1\text{E-}06$ and are considered insignificant.
- **Child recreationalist:** Total risks for bank and floodplain soil equal or exceed $1\text{E-}06$ only at Conard's Branch Sections Pre-A (bank soil [$6.0\text{E-}06$] and floodplain soil [$2.1\text{E-}06$]) and A (floodplain soil [$1.3\text{E-}06$]). These total risks are within EPA's acceptable risk range. All other total risks are less than $1\text{E-}06$ and are considered insignificant.

5.2.4.2 Hazards

Receptor-specific hazards are detailed in Appendix C, Table C-3, and are summarized below.

- **Adult recreationalists:** Total hazards for bank soil and floodplain soil are less than 1 at all locations (maximum hazard = 0.15 for bank soil at Conard's Branch Section Pre-A).
- **Youth recreationalists:** Total hazards for bank soil and floodplain soil are less than 1 at all locations (maximum hazard = 0.67 for bank soil at Conard's Branch Section Pre-A).
- **Child recreationalists:** Total hazards for bank soil and floodplain soil are less than 1 at all locations, with one exception. The total hazard for bank soil at Conard's Branch Section Pre-A (1.7) exceeds 1 and is driven by potential exposure through incidental ingestion.

5.2.5 Total Risks and Hazards

Total risks and hazards for exposure points in and along Conard's Branch (South Spring, North Spring, Section Pre-A, and Section A) and in and along Richland Creek (Sections B through G and Section I [12.7-mile site]) were calculated for adult receptors as described in Section 3.3.3. It should be noted that risks and hazards calculated for child and youth receptors are similar to those calculated for adult

receptors, so the exclusion of child and youth receptor-specific surface water, sediment, and soil risks and hazards from the total risk and hazard estimates should have minimal impact on the HHRA. Tables 9 and 10 summarize total risks and hazards based on total PCBs as Aroclors and do not contain TCDD TEQ values. It should be noted that total risks were calculated at all locations assuming ingestion of (1) pelagic fish only, (2) benthic fish only, and (3) both pelagic and benthic fish.

Total risks at all locations are less than 1E-04 and within or below EPA's acceptable risk range at all locations (see Table 9) with and range from 4E-05 (at South Spring assuming ingestion of both pelagic and benthic fish) to 2E-07 (Section F). (Note: Ingestion of pelagic fish was not evaluated at Section F.) The range of total risks based on ingestion of pelagic fish only, benthic fish only, and both pelagic and benthic fish are summarized below.

- **Pelagic fish only** – Total risks range from 2E-05 (South Spring) to 2E-07 (Section F). These totals are driven by potential exposure through ingestion of fish (Sections A through G) and by potential exposure through ingestion of fish, dermal contact with surface water, and incidental ingestion and dermal contact with bank and floodplain (incidental ingestion only) soil. It should be noted that the total risk for Section F is unique because ingestion of pelagic fish was not evaluated at this location; therefore, the total risk for this location does not include fish ingestion.
- **Benthic fish only** – Total risks range from 3E-05 (South Spring, North Spring, and Section Pre-A) to 7E-06 (Section F). These totals are driven by potential exposure through ingestion of fish at all locations. It should be noted that potential exposure through dermal contact with surface water also contributes up to about 25 percent of the total risks.
- **Pelagic and benthic fish** – Total risks range from 4E-05 (South Spring) to 7E-06 (Section F). These totals are driven by potential exposure through ingestion of fish at all locations. It should be noted that potential exposure through dermal contact with surface water also contributes up to about 25 percent of the total risks.

Total hazards exceed 1 (but are less than 3) at all locations with assumed ingestion of fish from the 1-mile site (South Spring; North Spring; and Sections Pre-A, A, B, and C) and at the 12.7-mile site (assuming ingestion of both pelagic and benthic fish). Total hazards range from 2.0 (South Spring and Section Pre-A assuming ingestion of both pelagic and benthic fish) to 0.0093 (Section F). (Note: Ingestion of pelagic fish was not evaluated at Section F.) The range of total hazards based on ingestion of pelagic fish only, benthic fish only, and both pelagic and benthic fish are summarized below.

- **Pelagic fish only** – Total hazards range from 0.89 (South Spring) to 0.0093 (Section F). These totals are driven by potential exposure through ingestion of fish (Sections A

through G) and by potential exposure through ingestion of fish, dermal contact with surface water, and incidental ingestion and dermal contact with bank and floodplain (incidental ingestion only) soil. It should be noted that the total risk for Section F is unique because ingestion of pelagic fish was not evaluated at this location; therefore, the total hazard for this location does not include fish ingestion.

- **Benthic fish only** – Total hazards range from 1.7 (South Spring) to 0.43 (Section F). These totals are driven by potential exposure through ingestion of fish at all locations. It should be noted that potential exposure through dermal contact with surface water also contributes up to about 25 percent of the total hazards.
- **Pelagic and benthic fish** – Total hazards range from 2.0 (South Spring and Section Pre-A) to 0.43 (Section F). These totals are driven by potential exposure through ingestion of fish at all locations. It should be noted that potential exposure through dermal contact with surface water also contributes up to about 25 percent of the total hazards.

5.3 COMPARISON OF FISH TISSUE PCB CONCENTRATIONS TO AWQC-DERIVED CONCENTRATION

The State of Indiana has an AWQC of 0.79 nanograms per liter (or parts per trillion [ppt]) for PCBs based on the following assumptions: (1) 6.5 grams per day of fish tissue consumption (less than one meal per month of fish assuming a 0.5-pound meal), (2) a target cancer risk of $1\text{E-}05$, (3) an SF of 4.4 (mg/kg-day^{-1}), and (4) a bioaccumulation factor of 31,200 (this value is 10 to 100 times lower than biomagnification factors now applied in PCB risk assessments for aquatic systems). PCB levels in fish tissue would need to be 0.025 part per million (ppm) in order to comply with the state's AWQC; this fish tissue concentration is similar to the 0.05-ppm PCB concentration used to trigger fish tissue advisories (see Section 5.4). It should be noted that the AWQC is based on whole fish, but the fish consumption advisories are based on fillet concentrations only.

Table 11 compares whole-body fish tissue total PCB concentrations to the AWQC-derived fish tissue level. The average concentration of PCBs in whole body pelagic and benthic fish collected from Richland Creek (see Appendix B, Tables B-1, B-3, B-5, and B-7) range from 10.2 to 24.9 and from 13.2 to 69.8 times higher, respectively, than the AWQC-derived PCB fish tissue level of 0.025 ppm at the 1-, 3-, 5.5-, and 12.7-mile sites.

5.4 COMPARISON OF FISH TISSUE PCB CONCENTRATIONS TO FISH ADVISORY ACTION LEVEL

Great Lakes states such as Indiana use a PCB action level of 0.05 ppm for fish tissue (fillet) to trigger fish consumption advisories. Such an advisory is present on Richland Creek. The basis of the action level is to protect against noncarcinogenic hazards; this fish tissue action level is also associated with a target cancer risk of 1E-04 (about 1 in 10,000). Table 12 compares the fillet fish tissue total PCB concentrations to the state fish advisory level. The average concentration of PCBs in pelagic and benthic fish fillet samples (based on analytical results for actual fillet samples [see Appendix B, Tables B-1, B-3, B-5, and B-7]) collected from Richland Creek ranged from 2.3 to 5.8 and from 3.2 to 12.2 times higher, respectively, than the state fish advisory level of 0.05 ppm at the 1-, 3-, 5.5-, and 12.7-mile sites.

5.5 UNCERTAINTY ANALYSIS

The risk and hazard estimates presented in this report are subject to various degrees of uncertainty from a variety of sources associated with all major phases of the HHRA process, including COPC selection, the exposure assessment, the toxicity assessment, and the characterization of risks and hazards. The most significant site-specific uncertainties are related to (1) the calculation of medium-specific EPCs, (2) the sustainability of fishing in Richland Creek, (3) the potential for and extent of benthic fish ingestion, (4) the presence and activity patterns of human receptors along Conard's Branch and Richland Creek, and (5) the identification and use of PCB toxicity factors. The nature and relative magnitude of uncertainty associated with each potential source of uncertainty are discussed in Sections 5.5.1 through 5.5.5.

5.5.1 Medium-Specific EPCs

EPCs represent the concentrations of COPCs to which human receptors are assumed to be exposed. A variety of uncertainties is associated with the medium-specific EPCs calculated for and used in the HHRA. Uncertainties associated with fish tissue; surface water; sediment, bank soil, and floodplain soil EPCs are discussed below.

Fish Tissue EPCs

Three potential sources of uncertainty are of particular importance regarding the calculation of fish tissue EPCs: (1) the use of whole-body results, (2) small numbers of samples, and (3) the use of historical sample results. Each source is discussed below.

Use of Whole Body Results

Except for the 3-mile site, analytical data used to calculate fish tissue EPCs consisted of analytical data from whole-body as well as fillet samples. (Note: All fish tissue samples used to calculate EPCs for the 3-mile site were fillet samples.) The HHRA assumes that human receptors consume only fish fillets; therefore, COPC concentrations based on whole-body samples had to be converted to equivalent fillet concentrations using the following species-specific whole fish-to-fillet concentration conversion factors: 0.25 for sunfish and 0.50 for white suckers. These factors are the same as those used in other Bloomington area risk assessments (EPA 2004d, e, f, and g; Tetra Tech 2005 and 2006b); however, the use of these conversion factors rather than actual fillet concentrations for most fish tissue exposure, risk, and hazard calculations introduces uncertainty into the risk assessment.

The magnitude of the uncertainty introduced by using conversion factors to derive fillet concentrations was evaluated by comparing the EPCs calculated for fillets and whole-fish samples converted to fillet equivalents at each location for various species. As shown in Tables B-3, B-5, and B-7, the total PCB concentrations measured in fillet samples are generally similar to total PCB concentrations measured in whole-fish samples and converted to fillet equivalents. These results indicate that the uncertainty introduced by using the conversion factors is likely to be small.

Small Numbers of Samples

The table below shows the numbers of pelagic and benthic fish used to calculate fish tissue EPCs at each exposure point.

NUMBER OF FISH TISSUE SAMPLES USED TO CALCULATE EPCs

Exposure Point	Pelagic	Benthic
1-Mile Site	50	27
3-Mile Site	3	5
5.5-Mile Site	–	8
12.7-Mile Site	12	5

Notes:

-- = No post-remedial pelagic fish samples available from this location

EPC = Exposure point concentration

A large number of both pelagic and benthic fish samples were considered for the 1-mile site; therefore, the number of samples is not considered an issue at this location. But at the other exposure points (3-, 5.5-, and 12.7-mile sites), the number of fish tissue samples used to calculate EPCs ranged from 3 to 12 fish. These small numbers of samples (in particular, 3 to 5 fish samples considered at the 3- and 5.5-mile [benthic only] sites) mean that the calculated EPCs may not adequately represent pelagic and benthic fish potentially consumed by human receptors at these locations. More representative pelagic and benthic fish tissue EPCs for these locations may be higher or lower than the values used in the HHRA.

Use of Historical Sample Results

The HHRA considers all post-remedial fish tissue samples (samples collected in 2001 and later) to calculate the pelagic and benthic fish tissue EPCs used in the exposure and risk calculations. All post-remedial data were used in order to create a robust data set that (1) reflects the fact that fish sampled historically may still be present in Richland Creek and could therefore be caught and consumed by anglers and (2) provides coverage of sampling locations downstream of the Neal's Landfill site.

To the extent that fish sampled are no longer present in Richland Creek, the EPCs based on these historical results are uncertain. In fact, the further downstream from the site, the older the fish tissue data used to calculate fish tissue EPCs as shown in the table below.

YEARS OF FISH TISSUE DATA USED TO CALCULATE EPCs

Exposure Point	Years
1-Mile Site	2001 through 2005
3-Mile Site	2004
5.5-Mile Site	2003
12.7-Mile Site (and further downstream)	2001

This information suggests that the calculated fish tissue EPCs are increasingly uncertain the farther downstream from the Neal's Landfill site the exposure point is located.

Surface Water EPCs

Surface water samples collected from the South and North Springs, Conard's Branch, and Richland Creek were not filtered prior to analysis; therefore, the PCB concentrations measured in surface water samples represent both PCBs dissolved in water and adsorbed to fine particles suspended in the water. The distinction between dissolved and suspended PCBs is most critical in the assessment of potential exposure through dermal contact with surface water. To the extent that PCBs adsorbed to fine particles dominate the total PCBs measured in surface water samples, the estimates of exposure to PCBs through dermal contact with surface water will be overestimated.

In order to reflect (1) current potential exposure conditions (to the extent possible) and (2) the variability of total PCB concentrations measured in surface water to which humans may be exposed, surface water EPCs for total PCB concentrations were calculated separately for each potential exposure point (South Spring, North Spring, Section Pre-A, Section A, 1-mile site, and 3-mile site). (Note: PCBs were not detected at locations further downstream; therefore, surface water EPCs were not calculated for these locations.) The most recent available surface water sample results (2004 and 2005) were used to represent total PCB EPCs at these locations. The use of recent data helps ensure that the EPCs reflect current conditions. Also, 10 to 22 sample results were used to calculate EPCs in accordance with EPA guidance using procedures that incorporate intra-sample variability (see Appendix B). The use of recent data and recommended statistical techniques helps limit the uncertainty associated with the calculated surface water EPCs.

It should be noted, however, that only a small number of samples (3 and 4) were considered for the 3- and 1-mile sites, respectively. This means that potentially large uncertainty is associated with EPCs for these locations. In fact, the calculated EPCs may overestimate the actual concentrations of PCBs in surface water to which human receptors may be exposed at these locations. For example, at the 3-mile site, the maximum detected concentration was used as the EPC.

Finally, as discussed in Section 3.3.1, most of the available surface water analytical results are associated with storm events. During storm events, surface water samples were collected at a rate of about 1 sample per hour for approximately 24 hours (including the duration of the storm event). Including each 1-hour result as its own value would result in surface water EPCs weighted heavily toward storm events (a time when human receptors are least likely to be exposed in the streams); therefore, the decision was made to average storm event results into a single value reflecting a particular storm event. This averaged result was considered along with other discrete sample results. This approach introduces uncertainty because sample variability is reduced; however, because human receptors are least likely to be exposed during storm events, the reduced variability was assumed to be balanced by the increased weighting to non-storm events.

Sediment, Bank Soil, and Floodplain Soil EPCs

Sediment, bank soil, and floodplain soil EPCs are based on sample sets that ranged in size from 3 to 37 sample results. Calculations based on less than about 10 sample results are associated with uncertainty to the extent that the data are not representative of the exposure area. Data sets meeting this criteria are for sediment (Sections B [n = 4], C [n = 3], D [n = 7], and G [n = 9]); bank soil (Sections C [n = 4] and D [n = 8]); and floodplain soil (Section B [n = 6]).

It should be noted, however, that available analytical results were used following EPA-recommended statistical procedures that incorporate intra-sample variability to calculate well-founded and conservative estimates of the average total PCB concentrations to which human receptors may be exposed. Overall, the uncertainty associated with the calculated sediment, bank soil, and floodplain soil EPCs based on a large number (10 or more) of sample results is considered small and the uncertainty associated with EPCs based on a small number (less than 10) of sample results is considered moderate.

5.5.2 Sustainability of Fishing in Richland Creek

Richland Creek is one of the largest streams associated with any of the Bloomington-area PCB sites; nonetheless, uncertainty is associated with the assumption that a sufficient fish population exists (and will continue to exist) in the creek to support the receptor-specific fish tissue ingestion rates. This uncertainty was reduced by combining available species-specific analytical results into average total PCB concentrations for two habitat niches (pelagic and benthic fish) at each location. Also, as discussed in Section 2.1.1, multiple-pass depletion population estimates were conducted at the 1-mile site. The results of these population estimates (Normandeau 2006), along with a qualitative habitat assessment (including the presence of eddies, riffle areas, pools, and runs/glides; the stream width and depth; and the number, species, and size of fish observed or expected), and the primary factors known to affect the distribution, abundance, and community structure of fish in temperate streams (Moyle and Cech 2000; Vannote and others 1980) were used to establish ingestion rate for both pelagic and benthic fish judged to be sustainable in various stream reaches (see Appendix A). As discussed in Table 3 (see footnote e), it is assumed that at least one individual consuming fish at each of the considered fish tissue ingestion rates can be supported by the fish population at each location. Uncertainty remains regarding whether more than one individual can be supported by fish populations at each location. This uncertainty is expected to be moderate.

5.5.3 Ingestion of Benthic Fish

EPA recognizes that benthic species such as white sucker and creek chub are generally less desirable for consumption compared to game fish. As a result, these benthic fish species are generally expected to make up a small portion of a typical angler's diet; however, individual anglers may be more opportunistic than others. It is therefore not unreasonable to assume that an angler may ingest a larger percentage of white sucker and carp, for example, compared to more desirable species if that angler is able to catch harvestable white sucker and carp more readily than other more preferred fish species. (Note: EPA recognizes that creek chub are a small fish and may not be consumed by anglers; therefore, benthic fish tissue EPCs did not consider tissue concentrations measured in creek chub.)

Moderate uncertainty is associated with the assumption that an angler will consume white sucker, carp, and other less desirable benthic species at the proposed ingestion rates given the presence of more desirable fish in Richland Creek; however, the Monroe County Health Department reports that area

residents have historically fished for white suckers at the 1-mile site during spring spawning runs. The HHRA therefore assumes that at least one individual consumes benthic fish at all four exposure points.

5.5.4 Human Receptors and Activity Patterns

Human receptors have been observed in and along various streams in the Bloomington area engaged in a variety of recreational activities such as fishing, wading, and hiking. The specific number and ages of human receptors engaged in recreational activities in and along Conard's Branch and Richland Creek is not known. Likewise, locations and details of the activity patterns of these receptors is also not known; however, the HHRA evaluates a range of potential exposure points and considers a range of fish tissue ingestion rates. Uncertainties certainly exist with regard to the specific exposure parameter values and exposure points considered in the HHRA. The magnitude of these uncertainties is, however, expected to be low to moderate.

5.5.5 PCB Toxicity Factors

The HHRA identifies and applies toxicity factors in accordance with EPA's recommended hierarchy (EPA 2003b). As noted in EPA's response to Viacom's comments on "Human Health Evaluation for Fish Consumption at Neal's Landfill," EPA's derivation of cancer potency values and RfDs undergoes a rigorous scientific review process that includes an evaluation of key literature, weight-of-evidence considerations, and external peer review. Furthermore, EPA "continually reviews new chemical information, draws conclusions from that information, and modifies toxicity values as needed." EPA's policy is to use "previously derived toxicity values in risk assessments, until new ones are determined" (EPA 2004d).

EPA also notes that it has previously responded to literature regarding the toxicity of PCBs submitted by General Electric and other responsible parties (and reproduced in part in Viacom comments on Bloomington risk assessments). Specifically, EPA developed two white papers (White Paper No. 12 on PCB carcinogenicity and White Paper No. 13 on PCB non-cancer health effects) that were included in the records of decision for both the Hudson River and Fox River sites (EPA 2002a and b). These white papers "serve as a response to documents and analyses provided by Viacom" (EPA 2004d). Again, it is EPA policy not to consider alternative cancer potency or RfD approaches and values until new information has undergone thorough review.

EPA's dioxin reassessment has undergone and continues to undergo extensive external peer review. As part of this review, the proposed dioxin SF of $1\text{E}+06 \text{ (mg/kg-day)}^{-1}$ is being closely evaluated. The HHRA calculates risks based on both the current ($1.5\text{E}+05 \text{ [mg/kg-day]}^{-1}$) and proposed ($1\text{E}+06 \text{ [mg/kg-day]}^{-1}$) SFs. In light of EPA's policy as summarized above and the continued review of EPA's dioxin reassessment, the HHRA clearly indicates that (1) risks calculated using this value are presented for comparison purposes only and (2) the proposed SF is currently under review and may be modified as a result of this review by the National Academy of Sciences (NAS).

The HHRA also uses the TEQ process to evaluate risks from PCBs in terms of the toxicity of "dioxin-like" PCB congeners. EPA recognizes that the use of the TEQ methodology as an official policy is still under internal review and that the NAS is reviewing dioxin toxicity. Nonetheless, use of the TEQ methodology "has a sound science basis and is widely applied in peer reviewed published literature" (EPA 2004b). Much of the current debate centers around the compound-specific TEFs that should be applied and the uncertainty associated with these TEFs rather than an application of the TEQ methodology in general (EPA 2004c). EPA recognizes that a moderate to large amount of uncertainty is associated with use of the TEQ methodology. The presence of this uncertainty does not warrant dropping the TEQ methodology entirely (EPA 2004c).

In addition to the "big picture" sources of uncertainty discussed above, additional uncertainty exists with regard to the most appropriate manner with which to quantify PCB concentrations. For the purposes of the HHRA, PCB concentrations are evaluated as both total PCBs (the sum of detected Aroclors or congeners) and as TCDD TEQs. Consistent with EPA guidance, the SF selected to represent total PCBs is the value for PCB Groups 1 and 2 (the more heavily chlorinated PCBs). This selection is consistent with the Aroclors detected most frequently and at the highest concentrations in various media and with the exposure scenarios considered in the HHRA (EPA 1996). The largest source of uncertainty associated with the total PCB SF is the methodology used by EPA to derive SFs. This methodology is generally considered to be conservative (based on use of multiple uncertainty factors and extrapolation from animal study results to human receptors). It should be noted, however, that risks for fish ingestion based on total PCBs are similar to the risks based on TCDD TEQs (using the current EPA SF for TCDD TEQs); however, a greater amount of uncertainty is associated with EPA's alternate TCDD TEQ SF (about 6.7 times higher than the existing SF). EPA's alternate TCDD TEQ SF is the subject of a significant amount of debate.

The RfD used to characterize hazards associated with potential exposure to total PCBs is the RfD for Aroclor 1254. Aroclor 1254 is considered a Group 1 PCB; therefore, this selection is consistent with the approach used to select the SF for total PCBs. The hazards based on TCDD TEQs were characterized using the RfD for 2,3,7,8-TCDD. It should be noted that unlike the risk results for total PCBs and TCDD TEQs, which are similar, the hazards calculated for TCDD TEQs are about 2 to 7 times lower than the hazards calculated for total PCBs. These results confirm that, at least for hazards, a moderate amount of uncertainty is associated with the selection of RfDs.

6.0 SUMMARY AND CONCLUSIONS

Three methods were used to characterize risks and hazards associated with potential exposure to PCBs in various media in and along Conard's Branch and Richland Creek: the traditional RAGS approach, comparison to an AWQC-based fish tissue concentration, and comparison to a fish tissue advisory level. Results indicate that total risks (based on total PCBs) are within EPA's acceptable risk range of 1E-06 to 1E-04 at all exposure points (maximum total risk of 4E-05 at South Spring - assuming ingestion of both pelagic and benthic fish). Hazards exceed 1 in Conard's Branch and downstream in Richland Creek to the 1-mile site and again in Section G (maximum total hazard of 2.0 at South Spring and Section Pre-A). The total risks and hazards are driven by ingestion of fish tissue and, to a lesser extent, dermal contact with surface water.

The characterization of risks and hazards associated with potential ingestion of fish tissue from Richland Creek is considered to be fairly robust for five primary reasons. First, average rather than upper-bound fish tissue concentrations were used in the analysis. Second, total PCB EPCs were calculated for two habitat niches (pelagic and benthic fish) rather than for individual species. Third, risk associated with stream reach-specific fish tissue ingestion rates were determined to be sustainable. Fourth, risks and hazards were characterized based on both total PCBs and TCDD TEQs. Fifth, risks and hazards were characterized based on three different methodologies (the traditional RAGS approach, comparison to a AWQC-based fish tissue concentration, and comparison to a fish tissue advisory level).

As discussed in Section 5.5, five areas of uncertainty that directly impact the characterization of risks and hazards associated with potential ingestion of fish tissue are related to (1) the calculation of medium-specific EPCs, (2) the sustainability of fishing in Richland Creek, (3) the potential for and extent of benthic fish ingestion, (4) the presence and activity patterns of human receptors in and along Conard's Branch and Richland Creek, and (5) the identification and use of toxicity factors applied to

PCBs and “dioxin-like” PCB congeners. The two sources of uncertainty that are expected to have the biggest impact on the calculation and interpretation of risks and hazards are the sustainability of fishing in Richland Creek and the identification and use of toxicity factors applied to PCBs and “dioxin-like” PCB congeners.

With regard to the first issue, the HHRA used stream reach-specific pelagic and benthic fish tissue ingestion rates that were judged to be sustainable. This determination was based on population data collected from the 1-mile site (Normandeau 2006), the results of a qualitative habitat assessment, and consideration of the primary factors known to affect the distribution, abundance, and community structure of fish in temperate streams.

With regard to the second issue, toxicity factors were identified and applied consistent with EPA guidance and policy. EPA understands that alternative toxicity factors and methodologies have been identified by various parties. Many of these alternative toxicity values (particularly those proposed for PCBs) have already been the subject of EPA review and the subject of two EPA white papers. Dioxin toxicity factors and the TEQ methodology are well established but are also the subject of an intense review process.

Finally, it should be noted that compliance with the State of Indiana’s AWQC-based and fish advisory levels does not depend on whether or not a particular stream (Richland Creek) will be used for fishing. As discussed in Sections 5.3 and 5.4, fish tissue concentrations for both pelagic and benthic fish exceed the AWQC-based and fish advisory levels, respectively, at the 1-, 3, 5.5-, and 12.7-mile sites.

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TABLES

TABLE 1

**EXPOSURE SCENARIO SUMMARY
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Location	Exposure Point	Fish Ingestion	Surface Water		Sediment		Bank Soil		Floodplain Soil	
			Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact
Neal's Landfill	South Spring	--	A, Y, C	A, Y, C	--	--	--	--	--	--
	North Spring	--	A, Y, C	A, Y, C	--	--	--	--	--	--
Conard's Branch	Section Pre-A	--	A, Y, C	A, Y, C	--	--	A, Y, C	A, Y, C	A, Y, C	A, Y, C
	Section A	--	A, Y, C	A, Y, C	A, Y, C	A, Y, C	A, Y, C	A, Y, C	A, Y, C	A, Y, C
Richland Creek	Section B	--	--	--	A, Y, C	A, Y, C	--	--	A, Y, C	A, Y, C
	Section C	--	--	--	--	--	A, Y, C	A, Y, C	--	--
	Section D	--	--	--	A, Y, C	A, Y, C	--	--	--	--
	Section E	--	--	--	A, Y, C	A, Y, C	A, Y, C	A, Y, C	--	--
	Section F	--	--	--	A, Y, C	A, Y, C	--	--	--	--
	Section G	--	--	--	A, Y, C	A, Y, C	--	--	--	--
	1-Mile Site	A	A, Y, C	A, Y, C	--	--	--	--	--	--
	3-Mile Site	A	A, Y, C	A, Y, C	--	--	--	--	--	--
	5.5-Mile Site	A	--	--	--	--	--	--	--	--
	12.7-Mile Site	A	--	--	--	--	--	--	--	--

Notes:

-- = Not applicable

A = Adult

C = Child (age 1 to 6 years)

Y = Youth (age 7 to 18 years)

^a

Figures 2 and 3 show the locations of each exposure point.

TABLE 2 QUALITATIVE EXPOSURE SETTING AND HABITAT ASSESSMENT HUMAN HEALTH RISK ASSESSMENT NEAL'S LANDFILL BLOOMINGTON, MONROE COUNTY, INDIANA							
Location	Distance Downstream from Neal's Landfill (miles)	Human Exposure Setting	Fishing Observed (describe)	Other Signs of Human Activity	Qualitative Habitat Assessment (including presence of eddies, riffle areas, pools, and runs/glides)	Stream Width and Depth	Number, Type, and Size of Fish Observed or Expected
Conard's Branch	0.5	Conard's Branch passes through the Conard family farm. Most of the streamside woody vegetation has been removed to facilitate farming and other activities on the property.	None	Working farm (owned by Conard family) adjacent to Conard's Branch	Characterized by lower-order erosional habitat with sharp, distinct meanders and steeply incised banks 3 to 5 feet high. Much of the reach is scoured to bedrock and does not provide the diverse habitat necessary to support a diverse community of fish species.	Two large pools (about 40 to 60 feet apart) are present in the reach; the pools are about 2 feet deep. The remainder of the reach is about 3 to 5 feet wide and less than 12 inches deep.	The sparse, shallow habitat in Conard's Branch is capable of supporting small fish (for example, creek chub and stonerollers) and crayfish that are preyed on by herons and other wildlife. (Note: Dan Sparks of the U.S. Fish and Wildlife Service has observed a great blue heron feeding regularly in Conard's Branch). The habitat does not, however, support larger fish likely to be eaten by recreational anglers.
Richland Creek upstream of confluence with Conard's Branch	Not applicable	Land use is primarily rural residential and agricultural.	Monroe County Health Department reports that area residents historically fished for white suckers during spring spawning runs.	Unknown	Predominantly depositional habitat with long pools, gentle meanders, and sluggish flow. In November 2002, the middle and upper portions of the sampling reach contained large piles of debris and numerous snags. Removal of woody vegetation along the stream corridor in these portions of the reach contributed to severe erosion along the stream bank. The lower portion of the reach was predominantly erosional.	In November 2002, the middle and upper portions of the sampling reach were 10 to 20 feet wide and 1 to 3 feet deep; riffle areas were rare. Downstream of the bridge, the lower portion of the reach was more erosional and was about 10 feet wide and 1 to 2 feet deep in meandering runs.	The upstream reach provides appropriate habitat for most small fish species and adequate habitat for bottom feeders such as central stonerollers and white suckers. The shallow, unshaded pools provide minimal habitat for pelagic feeders such as sunfish and bass.
Richland Creek at the Vernal Pike bridge	1	Land use is primarily agricultural, with limited rural residential use.	Monroe County Health Department reports that area residents historically fished for white suckers during spring spawning runs.	Property owners living adjacent to the reach indicated that children play in the creek.	Characterized by erosional habitat with some depositional habitat, including numerous side, channel, and point gravel bars; broad riffle areas; long, shallow runs; and occasional deeper pools. Immediately downstream of the bridge at Vernal Pike, the reach is scoured to bedrock. Upstream of the Vernal Pike bridge, the reach consists of deeper runs and pools. The downstream portion of this reach is shallower, and the stream banks are heavily wooded.	Most of the reach is 10 to 30 feet wide and less than 2 feet deep. Upstream of and near the bridge at Vernal Pike, the reach is deeper, with pools up to 3 feet deep and runs up to 2 feet deep.	During electrofishing efforts, most of the creek chub and crayfish were collected from shallower habitat in the downstream portion of the reach. Deeper runs and pools upstream of the bridge at Vernal Pike provide more suitable habitat for white sucker and sunfish species; however, both species were found throughout the reach. Based on historical sampling events, about 20 species of fish have been observed in this reach, including creek chub, longear sunfish, green sunfish, blue gill, rock bass, stoneroller, and white sucker. Longear sunfish were generally observed in two size classes: about 15 and 30 grams. In November 2003, three specimens of rock bass were observed; all were large, mature specimens (greater than 100 grams). In May 2003, the three largest white suckers collected for sampling ranged from 20.5 to 22.5 centimeters long and weighed between 95 and 120 grams. Numerous larger fish have been observed during sampling efforts, but they were larger than the target weight range and were not recorded.
Richland Creek near the State Route (SR) 43 bridge (south of intersection of SRs 43 and 48)	3	Land use is primarily rural residential and agricultural.	A Viacom consultant observed people fishing off the bridge at this location.	Unknown; however, easy access including available parking	Richland Creek at this location consists of gently meandering erosional habitat with numerous pools, riffles, and gravel bars. The streambed primarily consists of gravel and cobbles. Downstream of the bridge, stream-side vegetation is dominated by grassy and herbaceous species. Upstream of the bridge, a mature tree canopy is dominated by sycamore and elm trees.	During June 2004 sampling, water levels were above bank-full conditions; side channels, riffle areas, debris dams, and shorelines were inundated. The water depth was up to 3 feet or more in deeper pools and runs and as shallow as 1 foot elsewhere. The creek is about 30 to 40 feet wide at this point.	Based on June 2004 sampling, about 15 species were observed in the reach, including redbreast, suckers, smallmouth bass, rock bass, sunfish, and creek chub. Specimens retained for sampling included stonerollers (21 to 38 grams), white suckers (99 to 163 grams), northern hogsuckers (196 to 219 grams), golden redbreast (391 grams), smallmouth bass (335 grams), rock bass (95 to 143 grams), longear sunfish (50 to 54 grams), and creek chub (71 to 103 grams).
Richland Creek midway between intersection of SRs 43 and 48 and Hendricksville	5.5	Land use is primarily rural residential and agricultural.	The owner of the property near this reach stated that people fished this reach.	Unknown	Richland Creek at this location consists of (1) an upper reach with deep, shaded pools with woody debris; (2) a middle reach with long, shallow riffle areas resulting from engineered alterations (including a ford) across the creek; and (3) a lower reach with deep, sluggish pools and engineered banks downstream of the bridge at SR 43. In some parts of the upper reach, the tree canopy covers the entire stream corridor, providing optimal deep pool habitat needed by larger fish. Where the tree canopy has been removed or is not complete, the stream channel is steeply eroded and incised, and the banks were 12 feet high in some places.	Most of the reach is about 10 to 20 feet wide. One long pool just upstream of the ford was 3 to 4 feet deep, nearly 90 feet long, and contained numerous snags, root balls, and woody debris. As a result, swimming is unlikely at this location. Additional pools farther upstream were not as long, but most were about 3 feet deep. Outside of the pools, the stream is about 18 to 24 inches deep in this reach.	In May 2003, a variety of benthic, pelagic, and omnivorous fish species were observed, including shorthead and black redbreast (specimens from 200 to 300 grams were collected), white suckers (many as large as the redbreast specimens), largemouth bass (8 to 12 inches long), and several species of sunfish (large, mature specimens, 5 to 6 inches long); catfish and bullheads are also likely to be present.

Note:

Historically, Richland Creek has also been sampled at three locations 12.7, 21.8, and 34.5 miles downstream from Neal's Landfill. Because these locations have not been observed directly in recent years and the 21.8 and 34.5 mile locations are not evaluated directly in the human health risk assessment (see Section 2.1.1), the table does not include the qualitative exposure setting and habitat assessment for these three locations; however, based on the River Continuum Concept, it is expected that these three locations are likely to be wider and deeper and are likely to support more abundant and diverse fish communities than the upstream locations described above.

TABLE 3

EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Exposure Parameter	Value			Source or Basis
	Adult	Youth (7 to 18 years)	Child (1 to 6 years)	
Exposure point concentrations (EPC) (various)	Medium-specific	Medium-specific	Medium-specific	See Table 5 and Section 3.3.1.
Exposure frequency - surface water and sediment (EF _{sw} and EF _{sed}) (days/year)	68 (34)	68 (51)	68 (51)	Professional judgment ^a
Exposure frequency - bank soil and floodplain soil (EF _{bks} and EF _{fs}) (years)	76 (38)	76 (57)	76 (57)	Professional judgment ^b
Exposure frequency - aquatic life (EF _{al}) (days/year)	365	365	365	See note c
Exposure duration (ED) (years)	30	12	6	EPA 1989
Body weight (BW) (kg)	70	47	15	EPA 1989 and 1997a ^d
Ingestion rate - aquatic life (IR _{al}) (kg/day)	Receptor-specific	NA	NA	See note e
Ingestion rate - sediment and soil (IR _{sed} and IR _{soil}) (mg/day)	100	200	200	EPA 1997a
Ingestion rate - surface water (IR _{sw}) (L/day)	3.82E-02	7.65E-02	7.65E-02	EPA 1989 ^f
Cooking reduction factor (CRF) (unitless)	0.5	0.5	0.5	See note g
Skin surface area - sediment (SA _{sed}) (cm ²)	2,129	1,640	809	EPA 2004b ^h
Skin surface area - soil (SA _{soil}) (cm ²)	5,700	4,373	2,378	EPA 2004b ⁱ
Skin surface area - surface water (SA _{sw}) (cm ²)	Location-specific	Location-specific	Location-specific	EPA 2004b ^j
Adherence factor - sediment (AF _{sed}) (mg/cm ²)	0.3	3.3	3.3	EPA 2004b ^k
Adherence factor - soil (AF _{soil}) (mg/cm ²)	0.07	0.2	0.2	EPA 2004b ^l
Dermal absorption (ABS) (unitless)	Chemical-specific	Chemical-specific	Chemical-specific	EPA 2004b ^m
Absorbed dose per event (DA _{event}) (mg/cm ² -event)	Chemical-specific	Chemical-specific	Chemical-specific	EPA 2004b ⁿ

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Exposure Parameter	Value			Source or Basis
	Adult	Youth (7 to 18 years)	Child (1 to 6 years)	
Exposure time (ET) (hr/day)	2	2	2	Professional judgment
Event frequency (EV) (event/day)	1	1	1	Professional judgment
Conversion factor 1 (CF1) (mg/ng)	1E-06	1E-06	1E-06	NA
Conversion factor 2 (CF2) (mg/μg)	1E-03	1E-03	1E-03	NA
Conversion factor 3 (CF3) (kg/mg)	1E-06	1E-06	1E-06	NA
Averaging time - carcinogens (AT _c) (days)	25,550	25,550	25,550	EPA 1989
Averaging time - noncarcinogens (AT _{nc}) (days)	10,950	4,380	2,190	EPA 1989 ^o
Gastrointestinal absorption (GI) (unitless)	Chemical-specific	Chemical-specific	Chemical-specific	EPA 1989 and 2004b ^p

Notes:

cm ²	=	Square centimeter
EPA	=	U.S. Environmental Protection Agency
hr/day	=	Hour per day
kg	=	Kilogram
kg/day	=	Kilogram per day
kg/mg	=	Kilogram per milligram
L/day	=	Liter per day
mg/cm ²	=	Milligram per square centimeter
mg/day	=	Milligram per day
mg/ng	=	Milligram per nanogram
mg/μg	=	Milligram per microgram
NA	=	Not applicable

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

- ^a The exposure frequencies for adult, youth (age 7 to 18 years), and child (age 1 to 6 years) receptors potentially exposed to surface water and sediment in Richland Creek downstream of Neal's Landfill was calculated based on the assumption of exposure for 4 days per week for 13 weeks (June through August) and 4 days per month for 4 months (April, May, September, and October). Conard's Branch is assumed to be less attractive, particularly for adult receptors, because the fish in Conard's Branch are limited primarily to small creek chubs. Also, Conard's Branch is assumed to be less accessible than Richland Creek because receptors must cross private land to reach Conard's Branch. The exposure frequency for adult receptors in Conard's Branch was therefore assumed to be one-half of that assumed for Richland Creek. Similarly, exposure frequencies for youth and child receptors were assumed to be 75 percent of those assumed for Richland Creek. (Note: No exposure to sediment is assumed for any receptors in Conard's Branch Section Pre-A for two primary reasons: (1) sediment in the upper half of the branch has been scoured away, leaving only bedrock, and (2) previously identified contaminated sediment in Conard's Branch has been removed (see Section 3.3.1).
- ^b The exposure frequencies for adult, youth (age 7 to 18 years), and child (age 1 to 6 years) receptors potentially exposed to soil along the banks and in the floodplain of Richland Creek was calculated based on the assumption of exposure 4 days per week for 13 weeks (June through August) and 4 days per month for 6 months (March through May and September through November). As discussed in footnote a, Conard's Branch is assumed to be both less attractive and less accessible than Richland Creek. The exposure frequency for adult receptors in Conard's Branch was therefore assumed to be one-half of that assumed for Richland Creek. Similarly, exposure frequencies for youth and child receptors in Conard's Branch were assumed to be 75 percent of those assumed for Richland Creek.
- ^c The aquatic life ingestion rates discussed in footnote e are annual averages; therefore, EF_{al} is set equal to 365 days/year.
- ^d The body weights for adult and child receptors are the standard default adult and child body weights (EPA 1989). The body weight for the youth receptor (age 7 to 18 years) was calculated as the average body weight for boys and girls age 7 to 18 years (EPA 1997b, Table 7-3).
- ^e Aquatic life (such as fish) ingestion rates consistent with those used for other Bloomington sites were considered for use in this risk assessment (EPA 2005 and 2006b). Specifically, the following receptor-specific fish ingestion rates were considered: (1) reasonable maximum exposure (RME) low-income (LI) receptors – 0.11 kg/day (about three 0.5-pound meals per week) (West and Others 1993); (2) RME recreational (Rec) receptor – 0.059 kg/day (about two 0.5-pound meals per week) (average of West and others RME values; West and others 1989 and 1993); (3) average LI receptors – 0.043 kg/day (one to two 0.5-pound meals per week) (West and others 1993); and (4) average Rec receptors – 0.015 kg/day (about two 0.5-pound meals per month) (mean of West and others average values; West and

TABLE 3 (continued)
EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

others 1989 and 1993). The West and others studies, which are considered among the best for sport fish consumption information, provide intake rates in the ranges of studies recommended under Superfund and other EPA guidance (EPA 1989 and 1997b).

As discussed in Section 2.1.1, Conard's Branch is dominated by small creek chub and other fish that anglers are unlikely to consume; therefore, it was assumed that fish from Conard's Branch are not ingested.

In order to evaluate whether sufficient fish are present in Richland Creek to support the considered fish ingestion rates, information regarding the number, size, and species of fish in Richland Creek at or near the 1-mile site as presented in a sampling effort conducted by Normandeau (2006) was reviewed. Appendix A of the HHRA report provides fish tissue calculations for the 1-mile site (near the point Vernal Pike crosses the creek). The sustainability of fish tissue rates for the 3-, 5.5-, and 12.7-mile sites was evaluated considering the results presented in Normandeau (2006) and the comparability of stream habitat at the 3-, 5.5-, and 12.7-mile sites as compared with the 1-mile site as sampled by Normandeau (2006). Appendix A also present calculations of the sustainable fish tissue ingestion rates for the 1-, 3-, 5.5-, and 12.7-mile sites.

As detailed in Appendix A, the following sustainable fish tissue ingestion rates were calculated for the 1-, 3-, 5.5-, and 12.7-mile sites.

- **1-mile site** – 6 g/day (pelagic fish) and 4 g/day (benthic fish)
- **3-mile site** – 7.3 g/day (pelagic fish) and 4.8 g/day (benthic fish)
- **5.5-mile site** – 9.2 g/day (pelagic fish) and 6.1 g/day (benthic fish)
- **12.7-mile site** – 18.3 g/day (pelagic fish) and 12.2 g/day (benthic fish)

^f Adult, youth (age 7 to 18 years), and child (age 1 to 6 years) receptors are assumed to ingest surface water at a rate equal to that assumed for swimming; however, receptors are assumed to swim only on a percentage of available days in Clear Creek. Nonetheless, child and youth receptors are assumed to ingest water during the summer months (a total of 52 days of potential exposure), and adult receptors are assumed to ingest water 50 percent of summer days (a total of 26 days of potential exposure). For all receptors, it is assumed that surface water is ingested at a rate of 0.05 liter per hour (L/hr) (EPA 1989); therefore, potential surface water ingestion for each available day was

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

calculated as $0.05 \text{ L/hr} \times 2 \text{ hr/day} = 0.1 \text{ L/day}$. Receptor-specific IR_{sw} values were obtained by prorating the daily ingestion rates by the fraction of days each receptor is assumed to ingest surface water as follows:

Child and Youth Receptors: $(0.1 \text{ L/day} \times 52/68) = 7.65\text{E-}02 \text{ L/day}$

Adult receptors: $(0.1 \text{ L/day} \times 26/68) = 3.82\text{E-}02 \text{ L/day}$

^g A cooking reduction factor of 0.5 was applied to account for a reduction in contaminant concentration associated with trimming and cooking of fish tissue. This value is the same used in other Bloomington area risk assessments (Tetra Tech 2005 and 2006b).

^h All surface areas were obtained for adult, youth (age 7 to 18 years), and child (age 1 to 6 years) receptors from EPA (2004a), Exhibit C-1. It was assumed that receptors are exposed only through their hands and feet.

ⁱ Adult and child surface areas were obtained from EPA (2004a), Exhibit 3-5, and represent RME values for residential receptors. The child value was adjusted from the EPA-recommended value of $2,800 \text{ cm}^2$ to assume that children wear shoes and therefore are not exposed through the feet. The surface area for the youth receptor was obtained from EPA (2004a), Exhibit C-1. The youth receptor was assumed to be exposed through the head, hands, forearms, and lower legs. These surface areas assume that receptors wear short-sleeved shirts, shorts, and shoes. During the spring (March through May) and fall (September through November), receptors may dress more warmly in clothing such as long-sleeved shirts, jackets, coats, and long pants; however, some studies suggest that exposure can occur under clothing; therefore, no adjustment was made to reflect receptors wearing more clothing during the spring and fall. No exposure was assumed to occur during the winter (December through February).

^j All surface areas were obtained from EPA (2004a), Exhibit C-1. Receptor-specific surface area values were estimated primarily based on the depth of water at each potential exposure location. Specifically, receptor-specific skin surface area values were determined for nine exposure points: **South and North Springs** (both springs drain into Conard's Branch) (less than 6 inches deep on average); two reaches of Conard's Branch – **Sampling Section Pre-A** (from the spring treatment facility [STF] discharge to the fish sampling location referred to as "Fish Site 1" or "CBB" near the south property boundary for the Conard family farm) (about 6 inches deep on average) and **Sampling Section A** (the remainder of Conard's Branch downstream to its confluence with Richland Creek) (about 9 inches deep on average); and six sections of Richland Creek – **Sampling Section B** (from the confluence of Conard's Branch and Richland Creek to the point where

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Vernal Pike crosses the creek) (about 12 inches deep on average), **Sampling Section C** (from the Vernal Pike bridge to the point where State Route 48 crosses the creek) (12 to 15 inches deep on average), **Sampling Section D** (from the downstream end of Sampling Section C to the point where State Route 43 crosses the creek) (15 to 18 inches deep on average), **Sampling Section E** (from the downstream end of Sampling Section D to a point about 4,600 feet (0.86 mile) downstream) (24 inches deep on average), and **Sampling Section F** (from the downstream end of Sampling Section E to a point about 4,600 feet (0.86 mile) downstream (near Hendricksville) (about 30 inches deep on average). See Figures 2 and 3 for the location of all exposure points.

Child, youth, and adult receptors are assumed to be exposed through wading at all locations; however, during the summer months (June through August), child receptors are assumed to be exposed through full-body exposure (through swimming or floating) for 50 percent of the available summer days in Section F. Receptor-specific exposure assumptions and skin surface area calculations are presented below.

- **Child receptors (age 1 to 6 years):** Assumed to be exposed through wading only at South and North Springs and Sections Pre-A through E; assumed to have full-body exposure 50 percent of summer days and wade (feet and legs) the remainder of available days at Section F. Wading assumed to result in exposure of feet only at North and South Springs; feet and one-half of the lower legs at Section Pre-A; feet and 75 percent of the lower legs at Section A; feet and lower legs at Section B; feet and one-half of the legs at Section C; feet and three-quarters of legs at Section D; feet and legs at Section E; and whole body exposure for 50 percent of summer days and feet and legs the remainder of available days at Section F. Body part-specific skin surface areas were obtained from Exhibit C-1 in EPA (2004a); therefore, SA_{SW} values for child receptors were calculated as follows:

South and North Springs – 451 cm^2

Section Pre-A – $451 \text{ cm}^2 + (650 \text{ cm}^2 \times 0.5) = 776 \text{ cm}^2$

Section A – $451 \text{ cm}^2 + (650 \text{ cm}^2 \times 0.75) = 939 \text{ cm}^2$

Section B – $451 \text{ cm}^2 + 650 \text{ cm}^2 = 1,101 \text{ cm}^2$

Section C – $451 \text{ cm}^2 + (1,624 \text{ cm}^2 \times 0.5) = 1,263 \text{ cm}^2$

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Section D – $451 \text{ cm}^2 + (1,624 \text{ cm}^2 \times 0.75) = 1,669 \text{ cm}^2$

Section E – $451 \text{ cm}^2 + 1,624 \text{ cm}^2 = 2,075 \text{ cm}^2$

Section F – $(6,560 \text{ cm}^2 \times 26 \text{ days}/68 \text{ days}) + (2,075 \text{ cm}^2 \times 42 \text{ days}/68 \text{ days}) = 3,790 \text{ cm}^2$

Youth receptors (age 7 to 18 years): Assumed to be exposed through wading only at all locations. Specifically, wading was assumed to result in exposure of feet only (South and North Springs); feet and one-quarter of lower legs (Section Pre-A); feet and one-half of lower legs (Section A); feet and three quarters of lower legs (Section B); feet and lower legs (Section C); feet and one-half of legs (Section D); feet and three quarters of legs (Section E); and feet and legs (Section F). Body part-specific skin surface areas were obtained from Exhibit C-1 in EPA (2004a); therefore, SA_{SW} values for youth receptors were calculated as follows:

South and North Springs – 949 cm^2

Section Pre-A – $949 \text{ cm}^2 + (1,610 \text{ cm}^2 \times 0.25) = 1,352 \text{ cm}^2$

Section A – $949 \text{ cm}^2 + (1,610 \text{ cm}^2 \times 0.5) = 1,754 \text{ cm}^2$

Section B – $949 \text{ cm}^2 + (1,610 \text{ cm}^2 \times 0.75) = 2,157 \text{ cm}^2$

Section C – $949 \text{ cm}^2 + 1,610 \text{ cm}^2 = 2,559 \text{ cm}^2$

Section D – $949 \text{ cm}^2 + (4,026 \text{ cm}^2 \times 0.5) = 2,962 \text{ cm}^2$

Section E – $949 \text{ cm}^2 + (4,026 \text{ cm}^2 \times 0.75) = 3,969 \text{ cm}^2$

Section F – $949 \text{ cm}^2 + 4,026 \text{ cm}^2 = 4,975 \text{ cm}^2$

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

- **Adult Receptors:** Assumed to be exposed through wading only at all locations. Specifically, wading was assumed to result in exposure of feet only (South and North Springs); feet and one-eighth of lower legs (Section Pre-A); feet and one-quarter of lower legs (Section A); feet and one-half of lower legs (Section B); feet and three quarters of lower legs (Section C); feet and lower legs (Section D); feet and one-half of legs (Section E); and feet and three quarters of legs (Section F). Body part-specific skin surface areas were obtained from Exhibit C-1 in EPA (2004a); therefore, SA_{sw} values for adult receptors were calculated as follows:

South and North Springs – $1,225 \text{ cm}^2$

Section Pre-A – $1,225 \text{ cm}^2 + (2,370 \text{ cm}^2 \times 0.125) = 1,521 \text{ cm}^2$

Section A – $1,225 \text{ cm}^2 + (2,370 \text{ cm}^2 \times 0.25) = 1,818 \text{ cm}^2$

Section B – $1,225 \text{ cm}^2 + (2,370 \text{ cm}^2 \times 0.5) = 2,410 \text{ cm}^2$

Section C – $1,225 \text{ cm}^2 + (2,370 \text{ cm}^2 \times 0.75) = 3,003 \text{ cm}^2$

Section D – $1,225 \text{ cm}^2 + 2,370 \text{ cm}^2 = 3,595 \text{ cm}^2$

Section E – $1,225 \text{ cm}^2 + (5,925 \text{ cm}^2 \times 0.5) = 4,188 \text{ cm}^2$

Section F – $1,225 \text{ cm}^2 + (5,925 \text{ cm}^2 \times 0.75) = 5,669 \text{ cm}^2$

TABLE 3 (continued)

EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

The table below summarizes the assumed receptor- and location-specific SA_{sw} values.

Receptor	Skin Surface Area - Surface Water (SA_{sw}) (cm²)							
	North and South Springs	Pre-A	A	B	C	D	E	F
Child (age 1 to 6 years)	451	776	939	1,101	1,263	1,669	2,075	3,790
Youth (age 7 to 18 years)	949	1,352	1,754	2,157	2,559	2,962	3,969	4,975
Adult	1,225	1,521	1,818	2,410	3,003	3,595	4,188	5,669

^k The sediment adherence value for adults is based on a gardener exposed to soil, and the values for child (age 1 to 6 years) and youth (age 7 to 18 years) receptors are based on “children playing in wet soil” from EPA (2004a), Exhibit C-3.

^l The soil adherence values represent RME values for adult and child residents (see Exhibit 3-5 in EPA 2004a). The child value was assumed to adequately represent the youth receptor.

^m Dermal absorption values were obtained from EPA (2004a), Exhibit 3-4. Values for the primary chemicals of concern are as follows: polychlorinated biphenyls (PCB) - 0.14, and tetrachloro-p-dioxin (TCDD) - 0.03 (0.001 if total organic carbon is greater than 10 percent).

ⁿ See Exhibit C, Table C-6, of EPA (2004a).

TABLE 3 (continued)

**EXPOSURE PARAMETER VALUES
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

^o Based on ED x 365 days/year.

^p GI absorption values were obtained from EPA (2004a), Exhibit 4-1. Values for the primary chemicals of concern are as follows: PCB at greater than 80 percent, so no adjustment of oral toxicity factors is necessary (EPA 1989); TCDD at about 60 percent; however, for consistency with PCB calculations to which TCDD results are compared, no adjustment of oral toxicity factors will be conducted (EPA 1989).

TABLE 4
SURFACE WATER TOTAL PCB CONCENTRATIONS MEASURED AT
VARIOUS LOCATIONS IN RICHLAND CREEK^a
(AUGUST 2001 THROUGH JANUARY 2005) (µg/L)

Date	RCVP		RC43		RCF		RCI		RCJ		RCK	
	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
August 2001	--	--	--	--	<0.1	NA	<0.1	NA	<0.1	NA	<0.1	NA
May 2003	0.013 J	NA	--	--	<0.02	NA	--	--	--	--	--	--
December 2003	<0.6	<0.5	<0.4	<0.4	--	--	--	--	--	--	--	--
March 2004	0.19	0.1	<0.2	<0.2	--	--	--	--	--	--	--	--
April 2004	<0.02	<0.02	--	--	--	--	--	--	--	--	--	--
June 2004	<0.2	NA	0.15 J	NA	--	--	--	--	--	--	--	--
January 2005	0.135	0.1 ^b	0.12	0.1 ^b	--	--	--	--	--	--	--	--

Notes:

-- No samples collected from this location

< Less than

µg/L Microgram per liter

Avg Average concentration (calculated as arithmetic mean)

J Result considered estimated for quality control reasons

Max Maximum detected concentration

NA Not applicable

RCVP Richland Creek where Vernal Pike crosses the creek (also referred to as RCC and NL-2)

RC43 Richland Creek downstream of State Route 43 (about 3 miles downstream from the landfill)

RCF Richland Creek in Section F (about 5.5 miles downstream from the landfill)

RCI Richland Creek in Section I (about 12.7 miles downstream from the landfill)

RCJ Richland Creek in Section J (about 21.8 miles downstream from the landfill)

RCK Richland Creek in Section K (about 34.5 miles downstream from the landfill)

^a All concentrations obtained from Viacom database (CBS 2006a)

^b Value based almost entirely on nondetect results represented by a numeric value equal to one-half of the reporting limit

TABLE 5

SUMMARY OF MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATIONS^a
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Exposure Point ^b	Fish Tissue				Surface Water (mg/L)	Sediment (mg/kg)	Bank Soil (mg/kg)	Floodplain Soil (mg/kg)
	Pelagic		Benthic					
	PCB (ug/kg)	TCDD TEQ (ng/kg)	PCB (µg/kg)	TCDD TEQ (ng/kg)				
South Spring	--	--	--	--	1.25E-03	--	--	--
North Spring	--	--	--	--	6.76E-04	--	--	--
Section Pre - A	--	--	--	--	9.28E-04	--	12.5	4.5
Section A	--	--	--	--	1.91E-04	1	1.8	2.7
Section B	--	--	--	--	--	3.20E-02	--	2.20E-01
Section C	--	--	--	--	--	--	1.40E-02	--
Section D	--	--	--	--	--	1.90E-02	--	--
Section E	--	--	--	--	--	2.70E-02	2.40E-01	--
Section F	--	--	--	--	--	3.60E-01	--	--
Section G	--	--	--	--	--	2.10E-01	--	--
1 - Mile Site	182	3.5	808	8	1.04E-04	--	--	--
3 - Mile Site	114.8	1.4	182.8	2.3	1.50E-04	--	--	--
5.5 - Mile Site	--	--	192	3.3	--	--	--	--
12.7 - Mile Site	92	--	165	--	--	--	--	--

Notes:

-- = Not applicable

µg/kg = Microgram per kilogram

mg/kg = Milligram per kilogram

mg/L = Milligram per liter

ng/L = Nanogram per kilogram

PCB = Polychlorinated biphenyl

TCDD = Tetrachloro-p-dioxin

TEQ = Toxicity equivalent

a Medium-specific exposure point concentrations are discussed in Section 3.3.1 and documented in Appendix B.

b Exposure points are shown in Figures 2 and 3.

TABLE 6

CHEMICAL-SPECIFIC EXPOSURE AND TOXICITY FACTORS

HUMAN HEALTH RISK ASSESSMENT

NEAL'S LANDFILL

BLOOMINGTON, MONROE COUNTY, INDIANA

Chemical	Exposure Factors ^a							Toxicity Factors ^b	
	ABS	FA	K _p	C _w	τ _{event}	t _{event}	GI	RfD	SF
PCB	0.14	0.5	4.30E-01	see note	11.29	2	0.8 to .96	2.00E-05	2
TEQ	--	--	--	--	--	--	0.5 to 0.83	1.00E-09	1.50E+05
TEQ _{EPA alternate}	--	--	--	--	--	--	--	--	1.00E+06

Notes:

-- = Not applicable

ABS = Dermal absorption factor (unitless)

C_w = Chemical concentration in water; this concentration is equivalent to the location -specific surface water exposure point concentration (EPC) (see Table 4) in units of milligrams per cubic centimeter (mg/cm³)

EPA = U.S. Environmental Protection Agency

FA = Fraction absorbed water (unitless)

GI = Gastrointestinal absorption (unitless)

K_p = Dermal permeability coefficient in water (centimeter per hour [cm/hr])

PCB = Polychlorinated biphenyl

RfD = Oral reference dose (milligram per kilogram - day [mg/kg-day])

SF = Oral slope factor (mg/kg-day)⁻¹

τ_{event} = Lag time per event (hour per event [hr/event])

t_{event} = Event duration (hr/event)

TEQ = Toxicity equivalent

^a PCB-specific exposure factors were obtained from EPA (2004a).

^b PCB-specific toxicity factors were identified as discussed in Sections 4.2.2 and 4.3.2.

TABLE 7

FISH TISSUE RISK SUMMARY
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Site Location	Fish	PCB Risk	TCDD TEQ	
			Risk	Risk _{EPA Alt}
Adult (18 or more years old)				
1 - Mile	Pelagic	6.7E-06	9.6E-06	6.4E-05
	Benthic	2.0E-05	1.5E-05	9.8E-05
3 - Mile	Pelagic	5.1E-06	4.7E-06	3.1E-05
	Benthic	5.4E-06	5.1E-06	3.4E-05
5.5 - Mile	Pelagic	--	--	--
	Benthic	7.2E-06	9.2E-06	6.2E-05
12.7 - Mile	Pelagic	1.0E-05	--	--
	Benthic	1.2E-05	--	--

Notes:

-- = Not calculated

LADD = Lifetime average daily dose (mg/kg-day)

PCB = Polychlorinated biphenyl

TCDD = Tetrachlorodibenzo-p-dioxin

TEQ = Toxicity equivalent

Risk_{EPA Alt} = U.S. Environmental Protection Agency's alternative TCDD slope factor of $1.5E+06 \text{ (mg/kg-day)}^{-1}$ for TCDD TEQ (see Section 4.2.2)

TABLE 8

FISH TISSUE HAZARD SUMMARY
HUMAN HEALTH HAZARD ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Site Location	Fish	PCB Hazard	TCDD TEQ Hazard
Adult (18 or more years old)			
1 - Mile	Pelagic	3.9E-01	1.5E-01
	Benthic	1.2E+00	2.3E-01
3 - Mile	Pelagic	3.0E-01	7.3E-02
	Benthic	3.1E-01	7.9E-02
5.5 - Mile	Pelagic	--	--
	Benthic	4.2E-01	1.4E-01
12.7 - Mile	Pelagic	6.0E-01	--
	Benthic	7.2E-01	--

Notes:

-- = Not calculated
 ADD = Average daily dose (mg/kg-day)
 PCB = Polychlorinated biphenyl
 TCDD = Tetrachlorodibenzo-p-dioxin
 TEQ = Toxicity equivalent

TABLE 9

RISK SUMMARY^a
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Exposure Pathway		Location ^b															
		Conard's Branch ^c								Richland Creek ^d							
		South Spring		North Spring		Section Pre-A		Section A		Section B		Section C		Section D		Section E	
Fish Ingestion ^e	Pelagic	6.7E-06		6.7E-06		6.7E-06		6.7E-06		6.7E-06		6.7E-06		5.1E-06		5.1E-06	
	Benthic	2.0E-05		2.0E-05		2.0E-05		2.0E-05		2.0E-05		2.0E-05		5.4E-06		5.4E-06	
Surface Water	Incidental Ingestion	5.4E-08		2.9E-08		4.0E-08		8.3E-09		9.1E-09		9.1E-09		1.3E-08		1.3E-08	
	Dermal Contact	4.9E-06		2.7E-06		4.5E-06		1.1E-06		1.8E-06		1.8E-06		3.8E-06		3.8E-06	
Sediment	Incidental Ingestion	1.1E-07		1.1E-07		1.1E-07		1.1E-07		7.3E-09		7.3E-09		4.3E-09		6.2E-09	
	Dermal Contact	1.0E-07		1.0E-07		1.0E-07		1.0E-07		6.5E-09		6.5E-09		3.9E-09		5.5E-09	
Bank Soil	Incidental Ingestion	1.6E-06		1.6E-06		1.6E-06		2.3E-07		3.6E-09		3.6E-09		6.1E-08		6.1E-08	
	Dermal Contact	8.9E-07		8.9E-07		8.9E-07		1.3E-07		2.0E-09		2.0E-09		3.4E-08		3.4E-08	
Floodplain Soil	Incidental Ingestion	5.7E-07		5.7E-07		5.7E-07		3.4E-07		5.6E-08		5.6E-08		--		--	
	Dermal Contact	3.2E-07		3.2E-07		3.2E-07		1.9E-07		3.1E-08		3.1E-08		--		--	
TOTALS - Pelagic Fish Only		2E-05	(44)	1E-05	(52)	1E-05	(45)	9E-06	(75)	9E-06	(78)	9E-06	(78)	9E-06	(57)	9E-06	(57)
TOTALS - Benthic Fish Only		3E-05	(70)	3E-05	(76)	3E-05	(71)	2E-05	(90)	2E-05	(91)	2E-05	(91)	9E-06	(58)	9E-06	(58)
TOTALS - All Fish		4E-05	(76)	3E-05	(81)	3E-05	(76)	3E-05	(92)	3E-05	(93)	3E-05	(93)	1E-05	(73)	1E-05	(73)

Notes:

-- = Not applicable

^a

See Appendix C for detailed receptor- and exposure pathway-specific calculations. All risk values presented are for adult receptors.

^b

See Figures 1, 2 and 3 for locations of Neal' Landfill (including South and North Springs), Conard's Branch (including Sections Pre-A and A), and Richland Creek (including Sections B through G).

^c

For exposure points in and along Conard's Branch (South and North Springs and Sections Pre-A and A), the totals were calculated as follows:

South Spring: Fish ingestion risks from the 1-mile site (Section C); surface water risks from South Spring; bank soil and floodplain soil risks from Section Pre-A; and sediment risks for Section A**North Spring:** Fish ingestion risks from the 1-mile site (Section C); surface water risks from North Spring; bank soil and floodplain soil risks from Section Pre-A; and sediment risks for Section A**Section Pre-A:** Fish ingestion risks from the 1-mile site (Section C); surface water, bank soil, and floodplain soil risks from Section Pre-A; and sediment risks from Section A**Section A:** Fish ingestion risks from the 1-mile site (Section C); surface water, sediment, bank soil, and floodplain soil risks from Section A^d

For exposure points in Richland Creek (Sections B through G), the totals were calculated as follows:

Section B: Fish ingestion and surface water risks from the 1-mile site (Section C); sediment and floodplain soil risks from Section B; and bank soil risks from Section C**Section C:** Fish ingestion and surface water risks from the 1-mile site (Section C); sediment and floodplain soil risks from Section B; and bank soil risks from Section C**Section D:** Fish ingestion and surface water risks from the 3-mile site (Section E); sediment risks from Section D; bank soil risks from Section E; floodplain soil risks not evaluated for Section D**Section E:** Fish ingestion and surface water risks from the 3-mile site (Section E); sediment and bank soil risks from Section E; floodplain soil risks not evaluated for Section E**Section F:** Fish ingestion risks for the 5.5-mile site and sediment risks for Section F; bank soil, surface water, and floodplain soil risks not evaluated for Section F**Section G:** Fish ingestion risks for the 12.7-mile site; sediment risk from Section G; surface water, bank soil, and floodplain soil risks not evaluated for Section G^e

Risks presented represent polychlorinated biphenyl (PCB) risks calculated based on total PCBs.

TABLE 10

**HAZARD SUMMARY
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Exposure Pathway		Location ^b																			
		Conard's Branch ^c				Richland Creek ^d															
		South Spring	North Spring	Section Pre-A	Section A	Section B	Section C	Section D	Section E	Section F	Section G										
Fish Ingestion ^e	Pelagic	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.0E-01	3.0E-01	--	6.0E-01										
	Benthic	1.2E+00	1.2E+00	1.2E+00	1.2E+00	1.2E+00	1.2E+00	3.1E-01	3.1E-01	4.2E-01	7.2E-01										
Surface Water	Incidental Ingestion	3.2E-03	1.7E-03	2.4E-03	4.9E-04	5.3E-04	5.3E-04	7.6E-04	7.6E-04	--	--										
	Dermal Contact	2.9E-01	1.6E-01	2.7E-01	6.5E-02	1.1E-01	1.1E-01	2.2E-01	2.2E-01	--	--										
Sediment	Incidental Ingestion	6.7E-03	6.7E-03	6.7E-03	6.7E-03	4.3E-04	4.3E-04	2.5E-04	3.6E-04	4.8E-03	--										
	Dermal Contact	5.9E-03	5.9E-03	5.9E-03	5.9E-03	3.8E-04	3.8E-04	2.3E-04	3.2E-04	4.3E-03	--										
Bank Soil	Incidental Ingestion	9.3E-02	9.3E-02	9.3E-02	1.3E-02	2.1E-04	2.1E-04	3.6E-03	3.6E-03	--	--										
	Dermal Contact	5.2E-02	5.2E-02	5.2E-02	7.5E-03	1.2E-04	1.2E-04	2.0E-03	2.0E-03	--	--										
Floodplain Soil	Incidental Ingestion	3.3E-02	3.3E-02	3.3E-02	2.0E-02	3.3E-03	3.3E-03	--	--	--	--										
	Dermal Contact	1.9E-02	1.9E-02	1.9E-02	1.1E-02	1.8E-03	1.8E-03	--	--	--	--										
TOTALS - Pelagic Fish Only		8.9E-01	(44)	7.6E-01	(52)	8.7E-01	(45)	5.2E-01	(75)	5.0E-01	(78)	5.0E-01	(78)	5.3E-01	(57)	5.3E-01	(57)	9.1E-03	(0)	6.0E-01	(100)
TOTALS - Benthic Fish Only		1.7E+00	(70)	1.5E+00	(76)	1.6E+00	(71)	1.3E+00	(90)	1.3E+00	(91)	1.3E+00	(91)	5.4E-01	(58)	5.4E-01	(58)	4.3E-01	(98)	7.2E-01	(100)
TOTALS - All Fish		2.0E+00	(76)	1.9E+00	(81)	2.0E+00	(76)	1.7E+00	(92)	1.7E+00	(93)	1.7E+00	(93)	8.4E-01	(73)	8.4E-01	(73)	4.3E-01	(98)	1.3E+00	(100)

Notes:

-- = Not calculated

^a See Appendix C for detailed receptor- and exposure pathway-specific calculations. All hazard values presented are for adult receptors.^b See Figures 1, 2 and 3 for locations of Neal' Landfill (including South and North Springs), Conard's Branch (including Sections Pre-A and A), and Richland Creek (including Sections B through G).^c For exposure points in and along Conard's Branch (South and North Springs and Sections Pre-A and A), the totals were calculated as follows:**South Spring:** Fish ingestion hazards from the 1-mile site (Section C); surface water hazards from South Spring; bank soil and floodplain soil hazards from Section Pre-A; and sediment hazards for Section A**North Spring:** Fish ingestion hazards from the 1-mile site (Section C); surface water hazards from North Spring; bank soil and floodplain soil hazards from Section Pre-A; and sediment hazards for Section A**Section Pre-A:** Fish ingestion hazards from the 1-mile site (Section C); surface water, bank soil, and floodplain soil hazards from Section Pre-A; and sediment hazards from Section A**Section A:** Fish ingestion hazards from the 1-mile site (Section C); and surface water, bank soil, and floodplain soil, and sediment hazards from Section A^d For exposure points in and along Richland Creek (Sections B through G), the totals were calculated as follows:**Section B:** Fish ingestion and surface water hazards from the 1-mile site (Section C); sediment and floodplain soil hazards from Section B; and bank soil hazards from Section C**Section C:** Fish ingestion and surface water hazards from the 1-mile site (Section C); sediment and floodplain soil hazards from Section B; and bank soil hazards from Section C**Section D:** Fish ingestion and surface water hazards from the 3-mile site (Section E); sediment hazards from Section D; bank soil hazards from Section E; floodplain soil hazards not evaluated for Section D**Section E:** Fish ingestion and surface water hazards from the 3-mile site (Section E); and sediment and bank soil hazards from Section E; floodplain soil hazards not evaluated for Section E**Section F:** Fish ingestion hazards for the 5.5-mile site and sediment hazards for Section F; bank soil, surface water, and floodplain soil hazards not evaluated for Section F**Section G:** Fish ingestion hazards for the 12.7-mile site; surface water, sediment, bank soil, and floodplain soil hazards not evaluated for Section G^e Hazards presented represent polychlorinated biphenyl (PCB) hazards calculated based on total PCBs.

TABLE 11

**COMPARISON OF WHOLE-BODY FISH TISSUE TOTAL PCB CONCENTRATIONS
TO AWQC - BASED TISSUE CONCENTRATION
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Habitat Niche	Exposure Point ^a	Average Whole-Body Total PCB Concentration (ppm) ^b	Ratio of Average Whole-Body Total PCB Concentration to AWQC - Based Tissue Concentration ^c
Pelagic	1-Mile Site	0.622	24.9
	3-Mile Site	–	NC
	5.5-Mile Site	–	NC
	12.7-Mile Site	0.254	10.2
Benthic	1-Mile Site	1.754	69.8
	3-Mile Site	–	NC
	5.5-Mile Site	0.448	17.9
	12.7-Mile Site	0.33	13.2

Notes:

– = Not available
 AWQC = Ambient water quality criterion (for the State of Indiana)
 NC = Not calculated
 PCB = Polychlorinated biphenyl
 ppm = Part per million

^a PCBs were not detected in fish tissue samples collected from the 21.8- and 34.5-mile sites; therefore, ratios were not calculated for these exposure points.

^b Calculated based on location - specific whole body results as presented in Appendix A, Tables A-1, A-3, A-5, and A-7

^c AWQC - based tissue concentration of 0.025 ppm calculated as described in Section 5.3

TABLE 12

**COMPARISON OF FILET FISH TISSUE TOTAL PCB CONCENTRATIONS
TO THE STATE FISH ADVISORY LEVEL
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Habitat Niche	Exposure Point^a	Average Fillet Total PCB Concentration (ppm)^b	Ratio of Average Fillet Total PCB Concentration to State Fish Advisory Level^c
Pelagic	1-Mile Site	0.29	5.8
	3-Mile Site	0.115	2.3
	5.5-Mile Site	–	NC
	12.7-Mile Site	ND	NC
Benthic	1-Mile Site	0.609	12.2
	3-Mile Site	0.183	3.7
	5.5-Mile Site	0.16	3.2
	12.7-Mile Site	–	NC

Notes:

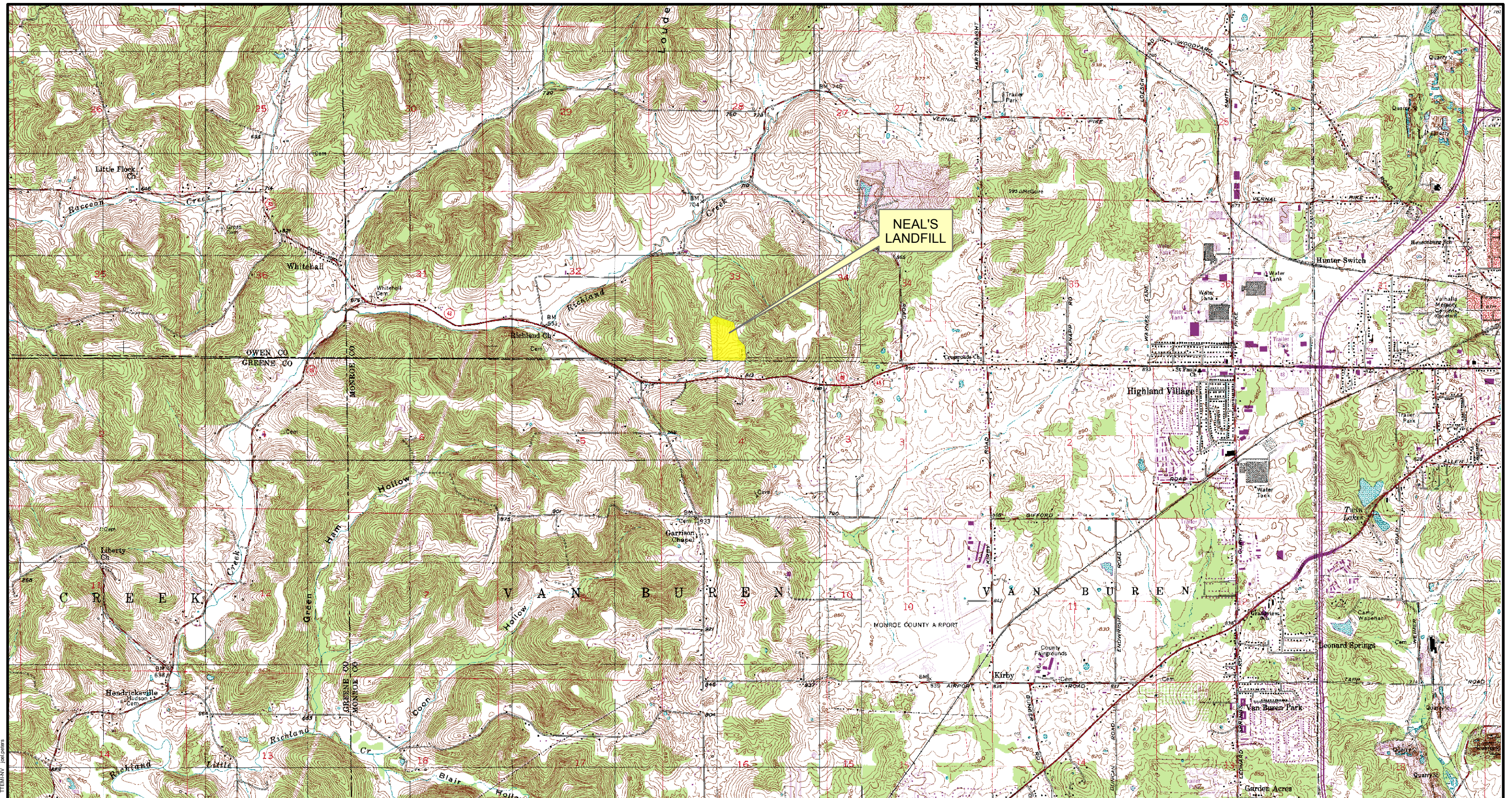
– = Not available
 NC = Not calculated
 ND = Not detected
 PCB = Polychlorinated biphenyl
 ppm = Part per million

^a PCBs were not detected in fish tissue samples collected from the 21.8- and 34.5-mile sites; therefore, ratios were not calculated for these exposure points

^b Calculated based on location-specific fillet results as presented in Appendix A, Tables A-1, A-3, A-5, and A-7

^c Section 5.4 discusses of the state fish advisory level of 0.05 ppm

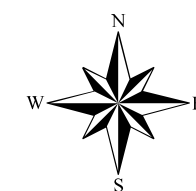
FIGURES



LEGEND

NEAL'S LANDFILL

SOURCE: MODIFIED FROM USGS, WHITEHALL, INDIANA, QUADRANGLE, 1980, AND BLOOMINGTON, INDIANA, QUADRANGLE, 1990.



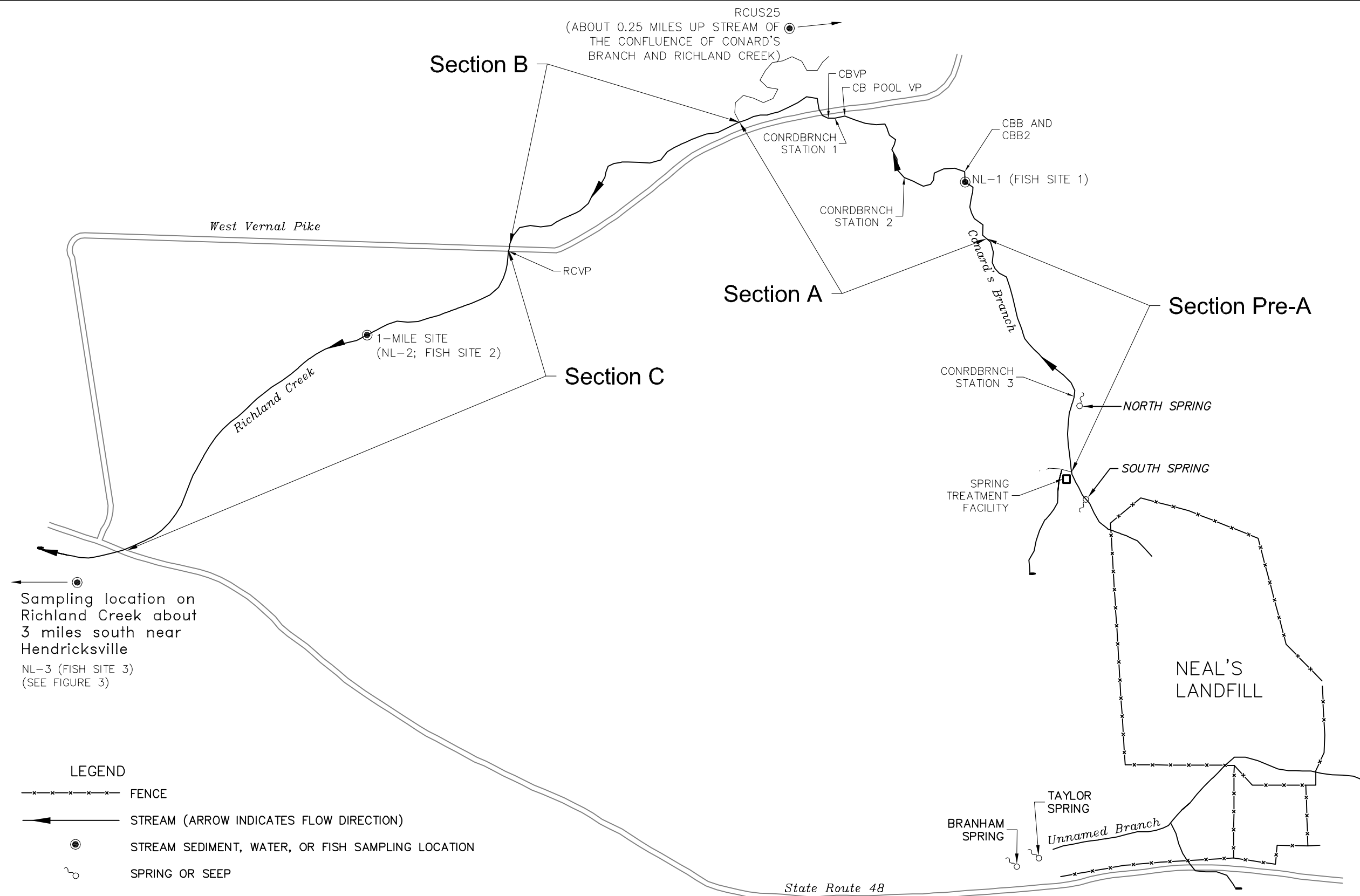
0 3,000 Feet

NEAL'S LANDFILL
BLOOMINGTON, INDIANA

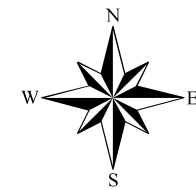
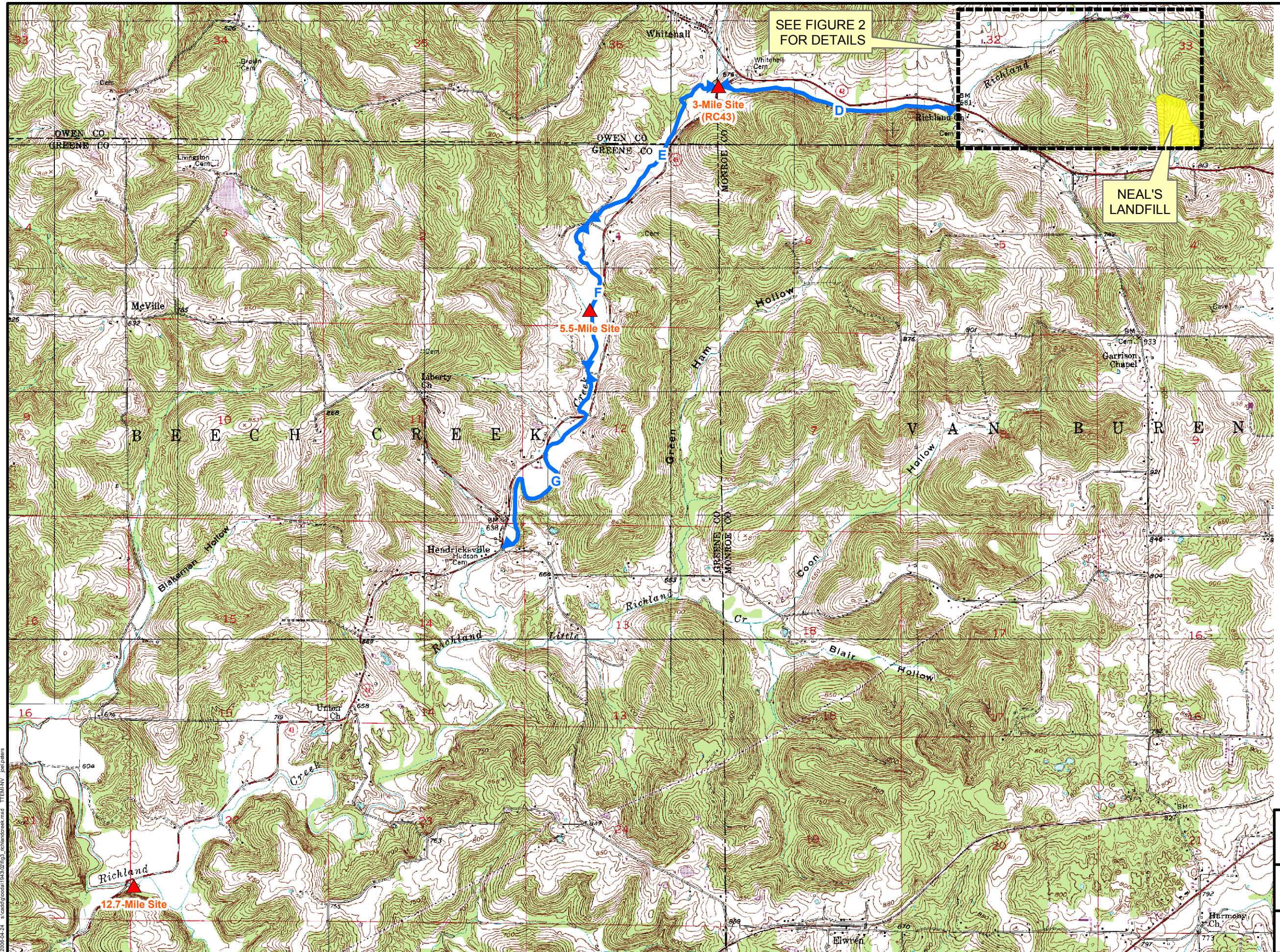
FIGURE 1
SITE LOCATION

 **TETRA TECH EM INC.**

G:\G\00DA\1943\0739\ SectionsSampling.dwg 04/24/2006 chris.caron CH



SOURCE: Modified from McLaren/Hart Chemrisk 1998



- LEGEND**
- NEAL'S LANDFILL
 - RICHLAND CREEK SECTION
 - FISH SAMPLING LOCATION



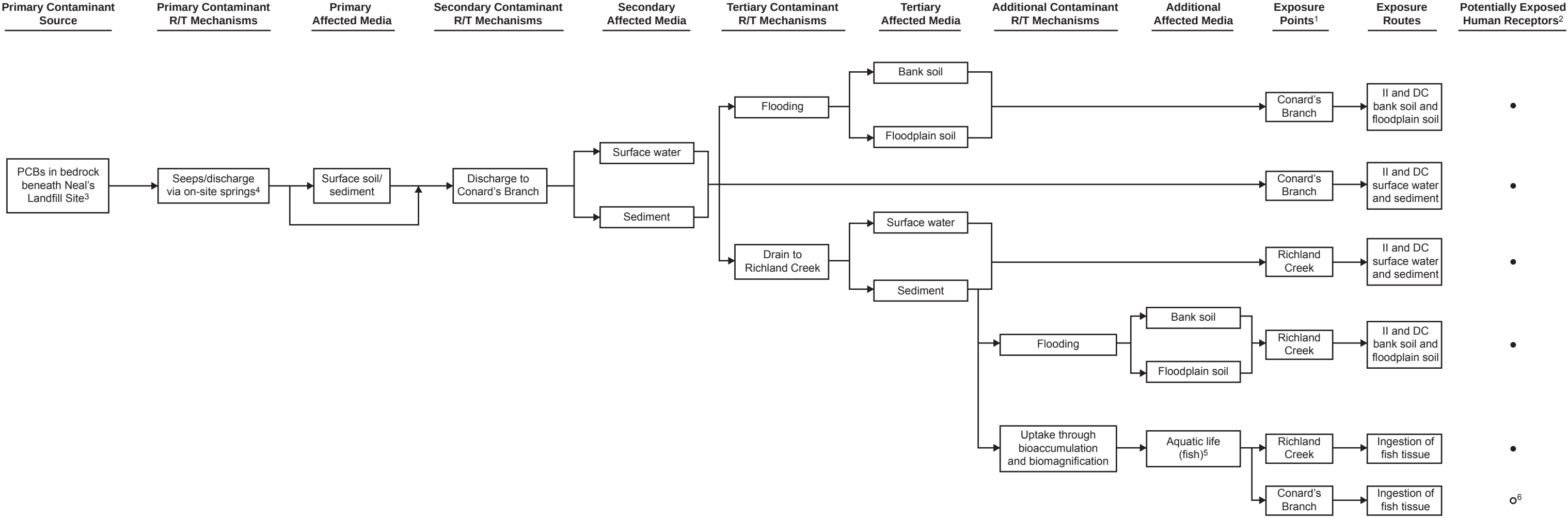
SOURCE: MODIFIED FROM USGS, WHITEHALL, INDIANA, QUADRANGLE, 1980, AND BLOOMINGTON, INDIANA, QUADRANGLE, 1990.

NEAL'S LANDFILL
BLOOMINGTON, INDIANA

FIGURE 3
RICHLAND CREEK SAMPLING
LOCATIONS AND EXPOSURE POINTS



2008-04-24 c:\adg\jocad\1043\02\fig3_rchlandcrk.mxd TETRA TECH EM INC.



- Notes:
- DC = Dermal contact
 - II = Incidental ingestion
 - R/T = Release/Transport
 - = Potentially complete, but insignificant exposure pathway -- will not be evaluated
 - = Potentially complete exposure pathway -- will be retained for quantitative analysis

- See Figures 2 and 3 for exposure point locations.
- Potentially exposed human receptors include adult, youth (age 7 to 18 years), and child (age 1 to 6 years) recreationalists.
- As discussed in Section 1.1, excavation of polychlorinated biphenyl (PCB) - contaminated source material including electrical capacitors and soil was completed in 1999. Remaining landfill material was consolidated and covered with a Resource and Recovery Act (RCRA) Subtitle C cap.
- See Figure 2 for location of on-site springs. Interim remedial measures implemented in 1987 included the installation of a collection and treatment system for spring water discharges.
- For the purposes of the human health risk assessment (HHRA) only ingestion of aquatic life (eg. fish) was evaluated. Potential exposure to chemicals of potential concern (COPC) through ingestion of other fauna and flora in Conard's Branch and Richland Creek is considered to be insignificant compared to potential exposure through ingestion of fish tissue.
- Conard's Branch is a first-order stream. The sparse, shallow habitat in this stream is only capable of supporting small, non-game fish (e.g., creek chub) and crayfish. These species are unlikely to be consumed with any regularity by anglers.

NEAL'S LANDFILL
BLOOMINGTON, INDIANA

FIGURE 4
HUMAN HEALTH
CONCEPTUAL SITE MODEL



FIGURE 5

EXPOSURE DOSE EQUATIONS
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Aquatic Life

Ingestion

$$ADD_{(mg/kg-day)} = \frac{EPC_{al} \times IR_{al} \times EF_{al} \times ED \times CF1 \text{ or } CF2 \times CRF}{BW \times AT_{nc}}$$
$$LADD_{(mg/kg-day)} = \frac{EPC_{al} \times IR_{al} \times EF_{al} \times ED \times CF1 \text{ or } CF2 \times CRF}{BW \times AT_c}$$

Surface Water

Ingestion

$$ADD_{(mg/kg-day)} = \frac{EPC_{sw} \times IR_{sw} \times EF_{sw} \times ED}{BW \times AT_{nc}}$$
$$LADD_{(mg/kg-day)} = \frac{EPC_{sw} \times IR_{sw} \times EF_{sw} \times ED}{BW \times AT_c}$$

Dermal Contact

$$ADD_{(mg/kg-day)} = \frac{DA_{event} \times SA_{sw} \times EV \times EF_{sw} \times ED}{BW \times AT_{nc}}$$
$$LADD_{(mg/kg-day)} = \frac{DA_{event} \times SA_{sw} \times EV \times EF_{sw} \times ED}{BW \times AT_c}$$
$$DA_{event} = 2 \times FA \times K_p \times C_w \sqrt{\frac{6\tau_{event} \times t_{event}}{\pi}}$$

FIGURE 5 (Continued)
EXPOSURE DOSE EQUATIONS
HUMAN HEALTH RISK ASSESSMENTS
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sediment

Ingestion

$$ADD_{(mg/kg-day)} = \frac{EPC_{sed} \times IR_{sed} \times EF_{sed} \times ED \times CF3}{BW \times AT_{nc}}$$

$$LADD_{(mg/kg-day)} = \frac{EPC_{sed} \times IR_{sed} \times EF_{sed} \times ED \times CF3}{BW \times AT_c}$$

Dermal Contact

$$ADD_{(mg/kg-day)} = \frac{EPC_{sed} \times SA_{sed} \times AF_{sed} \times ABS \times EF_{sed} \times ED \times CF3}{BW \times AT_{nc}}$$

$$LADD_{(mg/kg-day)} = \frac{EPC_{sed} \times SA_{sed} \times AF \times ABS \times EF \times ED \times CF3}{BW \times AT_c}$$

Soil

Ingestion

$$ADD_{(mg/kg-day)} = \frac{EPC_{soil} \times IR_{soil} \times EF_{soil} \times ED \times CF3}{BW \times AT_{nc}}$$

$$LADD_{(mg/kg-day)} = \frac{EPC_{soil} \times IR_{soil} \times EF_{soil} \times ED \times CF3}{BW \times AT_c}$$

FIGURE 5 (Continued)

EXPOSURE DOSE EQUATIONS HUMAN HEALTH RISK ASSESSMENTS NEAL'S LANDFILL BLOOMINGTON, MONROE COUNTY, INDIANA

Dermal Contact

$$ADD_{(mg/kg-day)} = \frac{EPC_{soil} \times SA_{soil} \times AF_{soil} \times ABS \times EF_{soil} \times ED \times CF3}{BW \times AT_{nc}}$$

$$LADD_{(mg/kg-day)} = \frac{EPC_{soil} \times SA_{soil} \times AF_{soil} \times ABS \times EF_{soil} \times ED \times CF3}{BW \times AT_c}$$

Notes: Receptor- and chemical-specific values for all of the parameters included in the equations above are presented or referenced in Tables 3, 5, and 6.

J_{event}	=	Lag time per event (hour [hr]/event)
t_{event}	=	Event duration (hr/event)
ABS	=	Dermal absorption factor (unitless)
ADD	=	Average daily dose (milligram per kilogram per day [mg/kg-day])
AF_{sed}	=	Adherence factor - sediment (milligram per square centimeter [mg/cm ²])
AF_{soil}	=	Adherence factor - soil (mg/cm ²)
AT_c	=	Averaging time - carcinogens (days)
AT_{nc}	=	Averaging time - noncarcinogens (days)
BW	=	Body weight (kilograms [kg])
CF1	=	Conversion factor 1 (milligram per nanogram [mg/ng])
CF2	=	Conversion factor 2 (milligram per microgram [mg: g])
CF3	=	Conversion factor 3 (kilogram per milligram [kg/mg])
CRF	=	Cooking reduction factor (unitless)
C_w	=	Chemical concentration in water (milligram per cubic centimeter [mg/cm ³])
DA_{event}	=	Absorbed dose per event (mg/cm ² - event)
ED	=	Exposure duration (years)
EF_{al}	=	Exposure frequency - aquatic life (days/year)
EF_{sed}	=	Exposure frequency - sediment (days/year)
EF_{soil}	=	Exposure frequency - soil (days/year)
EF_{sw}	=	Exposure frequency - surface water (days/year)
EPC_{al}	=	Exposure point concentration - aquatic life (microgram per kilogram [: g/kg] for total PCBs and nanograms per kilogram [ng/kg] for TCDD TEQs)
EPC_{sed}	=	Exposure point concentration - sediment (milligram per kilogram [mg/kg])
EPC_{soil}	=	Exposure point concentration - soil (mg/kg)
EPC_{sw}	=	Exposure point concentration - surface water (milligram per liter [mg/L])
EV	=	Event frequency (event/day)
FA	=	Fraction absorbed water (unitless)
IR_{al}	=	Ingestion rate - aquatic life (kilogram per day [kg/day])
IR_{sed}	=	Ingestion rate - sediment (milligram per day [mg/day])
IR_{soil}	=	Ingestion rate - soil (mg/day)
IR_{sw}	=	Ingestion rate - surface water (liter per day [L/day])
K_p	=	Dermal permeability coefficient of compound in water (centimeters per hour [cm/hr])
LADD	=	Lifetime average daily dose (mg/kg-day)
PCB	=	Polychlorinated biphenyl
SA_{sed}	=	Skin surface area - sediment (square centimeter [cm ²])

FIGURE 5 (Continued)

**EXPOSURE DOSE EQUATIONS
HUMAN HEALTH RISK ASSESSMENTS
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

SA_{soil}	=	Skin surface area - soil (cm ²)
SA_{sw}	=	Skin surface area - surface water (cm ²)
TCDD	=	Tetrachloro-p-dioxin
TEQ	=	Toxicity equivalent

APPENDIX A

**SUSTAINABLE FISH INGESTION RATE CALCULATIONS
FOR RICHLAND CREEK
MONROE COUNTY, INDIANA**

(16 Pages)

APPENDIX A
SUSTAINABLE FISH INGESTION RATE CALCULATIONS
FOR RICHLAND CREEK
MONROE COUNTY, INDIANA

1.0 INTRODUCTION

This appendix presents draft fish tissue ingestion rate calculations for Richland Creek in Monroe County, Indiana. Quantitative calculations presented for the 1-mile site are primarily based on fish population estimates and other field work conducted by Normandeau Associates, Inc. (Normandeau), in November 2005 (Normandeau 2006). Section 2.0 presents separate estimates of sustainable fish tissue ingestion rates for pelagic and benthic fish at the 1-mile site. The 1-mile site is located about 1 stream mile downstream from the Neal's Landfill site; various site-related documents have referred to the 1-mile site as RCD, NL-2, and Fish Site 2.

Section 3.0 presents estimates of sustainable fish tissue ingestion rates for other downstream sites considered in the human health risk assessment (HHRA) for the Neal's Landfill site. Sustainable fish tissue ingestion rates are presented for stream sections assumed to be represented by sampling sites located 3, 5.5, and 12.7 miles downstream from the Neal's Landfill site. Estimates for sustainable fish tissue ingestion rates at the downstream sites were developed after considering the primary factors known to affect the distribution, abundance, and community structure of fish in temperate streams (Moyle and Cech 2000; Vannote and others 1980). References cited in the text are listed at the end of this appendix.

2.0 SUSTAINABLE FISH TISSUE INGESTION RATES AT THE 1-MILE SITE

As noted above, sustainable fish tissue ingestion rates for the 1-mile site are primarily based on the population estimates presented in Normandeau (2006). Section 2.1 calculates the total number of pelagic and benthic fish assumed to be present in the portion of Richland Creek represented by the 1-mile sampling site. Sections 2.2 and 2.3 calculate the sustainable pelagic and benthic fish tissue ingestion rates, respectively, for the 1-mile site.

2.1 TOTAL NUMBER OF PELAGIC AND BENTHIC FISH AT 1-MILE SITE

Based on fish population estimates conducted in November 2005, Normandeau (2006) reports that about

24,225 fish per hectare (ha) are present at the 1-mile site. Normandeau conducted the population estimate for the 1-mile site at a 100-meter stream reach located upstream of the bridge at Vernal Pike.

Historically, fish tissue samples for the 1-mile site have been collected from a much longer stream reach than the 100-meter reach used for the population estimate. Depending on the specific sampling event (Tetra Tech 2002, 2003a, 2003b, 2004, and 2006), the downstream extent of the historical reach was between 1,000 and 1,500 feet downstream of the bridge at Vernal Pike, and fish samples were collected upstream of the bridge to about 600 feet downstream of the confluence with Conard's Branch.

For the purposes of the HHRA, population estimates for the 1-mile site are assumed to be representative of the portion of Richland Creek that begins about 300 feet downstream of its confluence with Conard's Branch. The downstream end of the reach is assumed to be a point about midway between the 1-mile site and the 3-mile site. The downstream end of the reach is about midway between the intersection of Vernal Pike and State Route 48 and the intersection of State Routes 43 and 48.

The total length of this reach is about 6,000 feet, and it includes Section B (1,000 feet), Section C (2,500 feet), and Section D (2,500 feet) of Richland Creek (see Figure 3 in the HHRA). The average width of Richland Creek in Sections B and C is about 20 feet, and in Section D it is about 35 feet (see qualitative exposure setting); therefore, the stream area included in the reach was calculated as follows:

$$\begin{aligned}\text{Area} &= (3,500 \text{ feet} \times 20 \text{ feet}) + (2,500 \text{ feet} \times 35 \text{ feet}) \\ &= 70,000 \text{ square feet (ft}^2\text{)} + 87,500 \text{ ft}^2 = 1.575\text{E}+05 \text{ ft}^2 \\ &= 1.575\text{E}+05 \text{ ft}^2 \times (1 \text{ ha}/1.076\text{E}+05 \text{ ft}^2) = 1.46 \text{ ha}\end{aligned}$$

The total number of fish in the reach was therefore calculated as $24,225 \text{ fish/ha} \times 1.46 \text{ ha} = 35,368 \text{ fish}$.

The HHRA report evaluates potential ingestion of pelagic and benthic fish. For the purposes of these calculations, pelagic fish are assumed to include rock bass, green sunfish, and longear sunfish. Benthic fish are assumed to include white sucker and yellow bullhead. As shown in Table 1 of Normandeau (2006), of the total number of fish present at the 1-mile site, an estimated 1.9, 3.0, and 0.7 percent are rock bass, green sunfish, and longear sunfish, respectively. The total numbers of rock bass, green sunfish, and longear sunfish present at the 1-mile site were therefore calculated as follows:

$$\text{Rock Bass} = 35,368 \times 0.019 = 672$$

$$\begin{aligned}\text{Green Sunfish} &= 35,368 \times 0.030 &= 1,061 \\ \text{Longear Sunfish} &= 35,368 \times 0.007 &= 248\end{aligned}$$

Similarly, of the total number of fish present at the 1-mile site, an estimated 1.4 and 0.4 percent are white sucker and yellow bullhead, respectively. The total numbers of white sucker and yellow bullhead were therefore calculated as follows:

$$\begin{aligned}\text{White Sucker} &= 35,368 \times 0.014 &= 495 \\ \text{Yellow Bullhead} &= 35,368 \times 0.004 &= 141\end{aligned}$$

2.2 SUSTAINABLE PELAGIC FISH TISSUE INGESTION RATE AT 1-MILE SITE

Based on Figure 2 from Normandeau (2006), approximately 11.4 percent (4 out of 35 fish) of the green sunfish at the 1-mile site are of harvestable size (greater than or equal to 100 millimeters [mm]). Similarly, based on Figure 3 of Normandeau (2006), approximately 72.7 (16 out of 22 fish) percent of the rock bass at the 1-mile site are of harvestable size. The percentage of harvestable longear sunfish is not reported in Normandeau (2006) and is assumed to be the same as for green sunfish (11.4 percent). The number of harvestable sunfish (sum of green and longear sunfish) was therefore calculated as follows:

$$(1,061 \text{ Green Sunfish} + 248 \text{ Longear Sunfish}) \times 0.114 = 149 \text{ Harvestable Sunfish}$$

Similarly, assuming that 72.7 percent of the rock bass at the 1-mile site are of harvestable size, the number of harvestable rock bass was calculated as follows:

$$672 \text{ Rock Bass} \times 0.727 = 489 \text{ Harvestable Rock Bass}$$

The average length of 121 mm for harvestable green sunfish was obtained from Figure 2 of Normandeau (2006). The length-weight regression equation from Figure 7b of Normandeau (2006) is presented below and was used to calculate the average mass of harvestable green sunfish:

$$\begin{aligned}\text{Natural log (ln) weight (grams [g])} &= 3.2696 \times \ln \text{ length (mm)} - 12.118 \\ \ln \text{ weight (g)} &= 3.2696 \times \ln (121) - 12.118\end{aligned}$$

$$\text{Ln weight} = 3.563$$

$$\text{Weight (g)} = 35.2$$

Assuming the fillet weight for green sunfish equals 50 percent of the total mass (based on the percent weight for the Stout's Creek population study [Normandeau 2004], the average fillet from a harvestable green sunfish weighs an estimated 17.6 g (35.2 g x 0.5). (Note: The average ratio of fillet to total body weight for the fish studied was calculated as 43 percent [39 to 46 percent]). In order to account for the ingestion of other muscle tissue besides the fillet (for example, the cheeks of pan-fried fish are often ingested) and to account for the uncertainty associated with the small number of samples used to calculate the fillet-to-total-body-weight ratio, it was assumed that the fillet represented about 50 percent of the total body weight. The four standard fish ingestion rates typically considered in Bloomington area HHRAs are 110 g/day for the reasonable maximum exposure (RME) low income (LI) scenario, 59 g/day for the RME recreational scenario, 43 g/day for the average (Avg) LI scenario, and 15 g/day for the Avg Recreational scenario. Based on these ingestion rates, the mass and number of green sunfish required were calculated as shown in the table below.

Receptor	Annual Mass Required (g)	Required No. of Fish at 1-Mile Site^a
RME LI	40,150	2,281
RME Recreational	21,535	1,224
Avg LI	15,695	892
Avg Recreational	5,475	311

^a Calculated as annual mass/fillet weight.

Clearly, the number of harvestable sunfish (149) is not sufficient to meet even the lowest default ingestion rate; therefore, a lower ingestion rate was investigated. An ingestion rate of 0.7 g/day requires an annual mass of 256 g (0.7 g/day x 365 days/year). The number of fish at the 1-mile site required to meet this annual mass was calculated as follows:

$$(256 \text{ g/year}) / (17.6 \text{ g/fish}) = 14.5 \text{ fish}$$

The ratio of the required number of fish to the number of harvestable sunfish was calculated as follows:

$$14.5 \text{ fish}/149 \text{ fish} = 9.7 \text{ percent}$$

This value is less than the 10 percent population reduction assumed to be sustainable. Specifically, it is understood that “localized, intensive angling pressure” can adversely impact fish population and size structure (FAO 2001). It was assumed that capture of up to 10 percent of the harvestable sunfish (or in general of “harvestable” pelagic and benthic fish) will not significantly impact the number of fish and the size structure in a given reach. It was therefore assumed that an ingestion rate of 0.7 g/day of green sunfish is sustainable at the 1-mile site.

Normandeau (2006) does not present a length-weight regression equation for rock bass as discussed above for sunfish; therefore, the average weight of rock bass at the 1-mile site was calculated in a different manner. Figure 2 from Normandeau (2006) shows that the biomass of 411 rock bass at the 1-mile site is 25.7 kg/ha (25,700 g); therefore, the average rock bass is assumed to weigh 62.5 grams (25,700 g/411 rock bass). If it is assumed (as for other sunfish) that the fillet represents about 50 percent of the total weight for rock bass, then the average rock bass fillet weighs about 31 grams (62.5 g x 0.5).

The number of rock bass required to meet the four standard fish ingestion rates typically considered in Bloomington area HHRAs (110 g/day RME LI, 59 g/day RME recreational, 43 g/day Avg LI, and 15 g/day Avg Recreational) was calculated as shown in the table below.

Receptor	Annual Mass Required (g)	Required No. of Fish at the 1-Mile Site^a
RME LI	40,150	1,295
RME Recreational	21,535	695
Avg LI	15,695	506
Avg Recreational	5,475	177

^a Calculated as annual mass/fillet weight.

The ratio of the required number of fish to the number of harvestable rock bass at the lowest default ingestion rate (15 g/day) is 0.26, which exceeds the sustainable ratio of 0.10 (10 percent); therefore, an alternate lower ingestion rate was investigated.

An ingestion rate of 5.25 g/day requires a total annual mass of 1,916 g (5.25 g/day x 365 d/year). The number of harvestable rock bass at the 1-mile site required to meet this annual mass is calculated as follows:

$$(1,916 \text{ g/year}) / (31 \text{ g/fish}) = 62 \text{ fish/year}$$

The ratio of the required number to the number of harvestable rock bass is calculated as follows:

$$62 \text{ fish} / 672 \text{ harvestable rock bass} = 0.092 \text{ (9.2 percent)}$$

It was therefore assumed that an ingestion rate of 5.25 g/day for rock bass is sustainable at the 1-mile site.

The total sustainable pelagic fish tissue ingestion rate at the 1-mile site is calculated as the sum of the sustainable ingestion rates for sunfish and rock bass as follows:

$$0.7 \text{ g/day (sunfish)} + 5.25 \text{ g/day (rock bass)} = 5.95 \text{ g/day}$$

This value will be rounded to 6 g/day for the purposes of the HHRA.

2.3 SUSTAINABLE BENTHIC FISH TISSUE INGESTION RATE AT 1-MILE SITE

Based on Figure 4 from Normandeau (2006), about 69 percent (11 out of 16) of the white suckers at the 1-mile site are of harvestable size (greater than or equal to 100 mm in length). The number of harvestable suckers was calculated as $495 \times 0.69 = 341$. Based on Figure 4 from Normandeau (2006), the average length of harvestable white suckers is 159 mm. (The average length of all white suckers at the 1-mile site is 137 mm.).

Normandeau (2006) does not present a length-weight regression equation for white suckers; therefore, the average weight of white suckers at the 1-mile site was investigated in several ways. First, Table 2 in

Normandeau (2006) shows that the biomass of white suckers at the 1-mile site equals 9.7 kilogram (kg) or 9,700 g; this total is based on 299 fish. The average white sucker at the 1-mile site therefore weighs 32.4 g (9,700 g/299 fish). This average weight underestimates the weight of harvestable white suckers because it includes all white suckers at the 1-mile site; however, this average mass (32.4 g) compares favorably to the mass estimated using the average length of 137 mm and the length-weight regression equation for white sucker from Stout's Creek (Normandeau 2004) calculated as follows:

$$\ln \text{ mass (g)} = 2.9835 \times \ln \text{ length (mm)} - 11.322$$

$$\ln \text{ mass (g)} = (2.9835 \times 4.92) - 11.322$$

$$\ln \text{ mass (g)} = 3.357$$

$$\text{Mass (g)} = 28.7$$

This same regression equation was therefore used with the average length of harvestable white suckers at the 1-mile site (159 mm). The resulting mass of harvestable white suckers at the 1-mile site was calculated as 45 g. Assuming that a white sucker fillet represents 40 percent of the total body mass, the fillet from a harvestable white sucker was assumed to weigh 18 g (45 g x 0.4).

The number of rock bass required to meet the four standard fish ingestion rates typically considered in Bloomington area HHRAs (110 g/day RME LI, 59 g/day RME recreational, 43 g/day Avg LI, and 15 g/day Avg Recreational) was calculated as shown in the table below.

Receptor	Annual Mass Required (g)	Required No. of Fish at the 1-Mile Site^a
RME LI	40,150	2,231
RME Recreational	21,535	1,196
Avg LI	15,695	872
Avg Recreational	5,475	304

^a Calculated as annual mass/fillet weight.

The ratio of the number of fish required to meet the lowest default ingestion rate (15 g/day) to the number of harvestable white suckers was calculated as 0.89 (304/341), which exceeds the sustainable ratio of 0.10 (10 percent); therefore, a lower ingestion rate was investigated.

An ingestion rate of 2.5 g/day requires a total annual mass of 913 g/year (2.5 g/day x 365 days/year). The required number of harvestable white suckers needed to meet this annual mass is calculated as follows:

$$(913 \text{ g/year}) / (18 \text{ g/fish}) = 51 \text{ fish/year}$$

The ratio of the required number of fish (51) to the number of harvestable white suckers (495) equals 0.103 (10.3 percent); therefore, a white sucker ingestion rate of 2.5 g/day is considered sustainable at the 1-mile site.

Normandeau (2006) does not present a length frequency histogram for yellow bullhead; therefore, it was assumed that the percentage of harvestable yellow bullhead is the same as for white sucker (69 percent). The number of harvestable yellow bullhead at the 1-mile site was calculated as follows:

$$141 \text{ Fish} \times 0.69 = 97 \text{ Harvestable Yellow Bullheads}$$

Normandeau (2006) reports the biomass of yellow bullheads at the 1-mile site as 11 kg or 11,000 g, based on a total of 93 fish; therefore, the average mass of a yellow bullhead at the 1-mile site is 118 g (11,000 g/93 fish). Assuming that the fillet to total body mass ratio for yellow bullhead is the same as for white sucker (40 percent), a fillet for a harvestable yellow bullhead was assumed to weigh 47.2 g (118 g x 0.4).

The number of yellow bullheads required to meet the four standard fish ingestion rates typically considered in Bloomington area HHRAs (110 g/day RME LI, 59 g/day RME Recreational, 43 g/day Avg LI, and 15 g/day Avg Recreational) was calculated as shown in the table below.

Receptor	Annual Mass Required (g)	Required No. of Fish at the 1-Mile Site ^a
RME LI	40,150	851
RME Recreational	21,535	456
Avg LI	15,695	333
Avg Recreational	5,475	116

^a Calculated as annual mass/fillet weight.

Clearly, the number of harvestable yellow bullheads (97) is not sufficient at the 1-mile site to sustain even the lowest default ingestion rate; therefore, an alternate lower ingestion rate was investigated. An ingestion rate of 1.25 g/day requires an annual mass of 456 g/year (1.25 g/day x 365 days/year). The number of harvestable yellow bullhead required to meet this annual mass was calculated as follows:

$$(456 \text{ g/year}) / (47.2 \text{ g/fish}) = 10 \text{ fish}$$

The ratio of the required number of harvestable yellow bullhead to the total number of harvestable yellow bullhead is 0.103 (10.3 percent); therefore, an ingestion rate of 1.25 g/day is considered sustainable for yellow bullhead at the 1-mile site.

The total sustainable benthic fish tissue ingestion rate at the 1-mile site is calculated as the sum of the sustainable ingestion rates for white sucker and yellow bullhead as follows:

$$2.5 \text{ g/day (white sucker)} + 1.25 \text{ g/day (yellow bullhead)} = 3.75 \text{ g/day}$$

This value will be rounded to 4 g/day for the purposes of the HHRA.

3.0 SUSTAINABLE FISH TISSUE INGESTION RATES AT DOWNSTREAM SITES

To summarize the results of Section 2.0, the estimated sustainable fish tissue ingestion rates for pelagic and benthic fish at the 1-mile site are 6 and 4 g/day, respectively. These fish tissue ingestion rates are based primarily on the population sampling results for the 1-mile site presented in Normandeau (2006). The HHRA considers three exposure points located downstream of the 1-mile site for which fish tissue analytical results are available. These locations include the 3-, 5.5-, and 12.7-mile sites. Because population studies similar to the one conducted by Normandeau (2006) have not been conducted at these downstream locations, estimates of sustainable fish tissue ingestion rates were developed after considering the primary factors known to affect the distribution, abundance, and community structure of fish in temperate streams (Moyle and Cech 2000; Vannote and others 1980).

Moyle and Cech (2000) discuss four general categories of factors that affect the distribution of fishes in a particular stream: physical, chemical, biological, and zoogeographic. Richland Creek has not been studied for the purposes of evaluating these four categories of factors; therefore, information on some of

these factors is sparse and qualitative. Most available information can be related to the evaluation of physical factors; therefore, this category is discussed last. The remaining three categories are briefly discussed below in Sections 3.1 through 3.3; physical factors are discussed in Section 3.4. Section 3.5 presents a summary of the recommended fish ingestion rates at downstream locations in Richland Creek.

3.1 CHEMICAL FACTORS

As summarized in Moyle and Cech (2000), the abundance and distribution of fish species in a stream reach can be related to water chemistry. Varying concentrations or levels of factors such as hardness, conductivity, dissolved oxygen, acidity, salinity, and chemical contamination have been observed to affect the size, number, and distribution of fish species at a variety of sites. No information is available to suggest that any of these factors other than chemical contamination varies significantly in Richland Creek between the 1- and 12.7-mile sites. Numerous previous sampling events in Richland Creek have indicated that the concentrations of polychlorinated biphenyls (PCB) in fish tissue, sediments, and surface water decrease with increasing distance downstream from Neal's Landfill. To the extent that concentrations of PCBs adversely impact the size, abundance, and distribution of fish species in Richland Creek, with increasing distance downstream of the 1-mile site, fish populations are expected to be less impacted by PCBs.

3.2 BIOLOGICAL FACTORS

Biological factors that may affect the distribution of stream fishes include (1) predator-prey interactions, (2) competitive interactions, (3) symbiotic interactions, and (4) intraspecific interactions (Moyle and Cech 2000). Sufficient information is not available regarding the presence, absence, or degree of these interactions in Richland Creek to allow evaluation of their impact on the distribution of fish species.

3.3 ZOOGEOGRAPHIC FACTORS

Zoogeographic factors relate to the presence of barriers, including physical barriers (such as waterfalls or dams) and chemical barriers (such as extreme differences in pH, salinity, and dissolved oxygen concentration) (Moyle and Cech 2000). Zoogeographic factors are not likely to affect the abundance or distribution of fish species in Richland Creek. The elevation gradient in Richland Creek between the 1-

mile site and Hendricksville (near the 12.7-mile site) is fairly consistent and gradual, with no dams, waterfalls, or other extreme elevation changes over short distances. Similarly, between the 1- and 12.7-mile sites, measurements of standard water quality parameters are not expected to vary beyond the tolerance limits of any native fish species.

3.4 PHYSICAL FACTORS

Four physical factors may be most useful in predicting patterns of fish distribution and abundance: temperature regime, elevation gradient, flow regime, and stream order (Moyle and Cech 2000). Each of these factors is briefly discussed below.

3.4.1 Temperature Regime

No information is available to suggest that temperature differences in Richland Creek would limit the distribution of native fish species between the 1- and 12.7-mile sites. On any given day, water temperatures are not expected to differ significantly in Richland Creek or among similar streams throughout Monroe County and much of central Indiana. Very slight temperature variations may occur among and between stream reaches as a result of differences in stream habitat features (such as the presence or absence of a tree canopy); however, minor variations in microhabitat temperature would not limit the distribution or dispersal of native fish species, which are adapted to tolerate a wide range of water temperatures. The temperature regime in Richland Creek is therefore not expected to be a factor in any differences in the distribution of fish species at various points downstream from Neal's Landfill.

3.4.2 Elevation Gradient

Based on a review of area topographic maps, the gradient in Richland Creek appears to change at a gradual and fairly consistent rate from the 1- to the 12.7-mile site (USGS 1957); therefore, it is not expected that any differences in the distribution of fish species in Richland Creek at various points downstream from Neal's Landfill are due to extreme gradient differences.

3.4.3 Flow Regime

Richland Creek flows year round, with higher water levels expected in the spring, and lower water levels expected in late summer and early fall. Over time, droughts and extreme floods are not expected to affect the distribution of fish species in Richland Creek because native stream fish are adapted to such events. Severe, prolonged drought may result in short-term or interannual variation in the distribution of some fish species; however, fish displaced by low water levels would be expected to disperse to appropriate habitat after normal base-flow water levels are restored. Although low water levels may alter the distribution of stream fish in the short term, many fish require springtime high flows to maintain their distribution over the length of a stream. Some native stream fish have evolved life history strategies that take advantage of flooding and high flow events. During springtime high flow events, native fish in the sucker family (including the white sucker, northern hogsucker, and redhorse species) migrate upstream to spawn in the exposed substrate of shallow, lower order streams. Fry that hatch successfully in upstream areas are then distributed downstream as they mature. In this manner, the variable high flow regime in Richland Creek promotes the distribution of these species. As a result of their life history strategies, sucker species in downstream areas of Richland Creek are expected to be larger and more abundant than at the 1-mile site.

The flow regime in Richland Creek depends on inputs from the watershed. The volume of flow in Richland Creek increases from headwater areas to downstream locations in proportion to the increase in watershed area that drains to the creek. As indicated in Table 2 of the HHRA, stream locations downstream of the 1-mile site are generally wider and deeper than upstream areas. As the flow regime changes from upstream areas to downstream locations, fish habitat is expected to become more diverse, with an increase in depositional areas, broader riffle areas, and deeper pools and runs. These changes in flow regime and the resulting increase in habitat diversity in downstream areas is expected to support more diverse and abundant fish communities. Well-accepted ecological theories (Vannote and others 1980; Karr 1981; Kuehne 1962) predict that fish species diversity, abundance, and biomass will increase with increasing flow volume - that is, more fish will be present in larger streams than in smaller streams. As a result, downstream fish communities are expected to support an increasingly higher fish tissue ingestion rate than the 1-mile site.

3.4.4 Stream Order

Vannote and others (1980) categorize first- through third-order streams as “headwaters.” The 1-mile site is located near the headwaters of Richland Creek and exhibits the characteristics of a lower-order stream (Vannote and others 1980). Several tributary and intermittent streams flow into Richland Creek between the 1- and 12.7-mile sites (USGS 1980). As these tributaries join Richland Creek, the stream order increases, and the stream becomes generally wider and deeper as it flows from the 1- to the 12.7-mile site (see Table 2 in the HHRA). Well-accepted ecological theories (Vannote and others 1980; Karr 1981; Kuehne 1962) predict that fish communities will become more complex with increasing stream order - that is, fish communities in larger streams will include more species, more individual fish, and greater overall biomass than in smaller streams. Based on evidence presented in the literature and field observations of the fish communities in Richland Creek (Tetra Tech 2002, 2003a, 2003b, 2004, and 2006), downstream fish communities are expected to support an increasingly higher fish tissue ingestion rate than the 1-mile site.

3.5 SUMMARY

About 20 species of fish have historically been observed at the 1-mile site in Richland Creek. During field work in November 2005, 15 fish species were observed in a 100-meter portion of the 1-mile sampling reach. As noted in Normandeau (2006), the 1-mile site has a “dense and moderately rich fish community,” with 11 species each representing more than 5 percent of the community in terms of abundance or biomass. (Note: The number of species achieving the indicated criteria appears to be in error. Table 1 in Normandeau [2006] indicates that only nine species meet the criteria.) For a lower order stream, the fish community at the 1-mile site would generate high index scores for both species diversity (based on the number of species present) and community evenness (based on the relative proportion of each species). The fish community at the 1-mile site would also generate a relatively high Index of Biotic Integrity (IBI) score (Karr 1981). Karr originally developed the IBI based on fish communities expected to be present in Indiana streams. Some of the key factors that increase the IBI score for a fish community include (1) relatively high numbers of total, sucker, darter, and sunfish species; (2) high relative abundance of top carnivores and insectivorous species; and (3) high overall fish abundance. The population estimate conducted at the 1-mile site revealed a high number of total species, including two sucker species, four darter species, and three sunfish species. According to Karr (1981),

expectations for species richness metrics increase with increasing stream order. As a result, IBI scores are scaled to reflect the fact that larger streams should support more complex, more diverse, and more abundant fish communities.

As predicted by Karr (1981), Vannote and others (1980), and Kuehne (1962), sites located downstream of the 1-mile site are expected to support more individual fish, more fish species, and greater biomass production. As summarized in Table 2 of the HHRA, observations of fish communities during sampling at the 3- and 5.5-mile sites provide additional support for these predicted trends. (Species diversity data is not available for the 12.7-mile site.) At the 3- and 5.5-mile sites, additional insectivorous and top predator species were observed, and larger individuals were encountered during electrofishing. For example, during sampling at the 5.5-mile site in 2003, white bass, largemouth bass, numerous large sunfish species, large white suckers, and two species of redhorse were observed. Thirteen of the fourteen redhorse originally taken from the 5.5-mile site weighed more than 200 grams, with the largest specimen weighing 368 grams. (These fish were larger than the target weight range for sampling and were returned to Richland Creek.) As predicted by these widely accepted ecological theories and as supported by field observations, fish species diversity, abundance, and biomass in Richland Creek is expected to increase with increasing stream order and distance from the Neal's Landfill site; therefore, compared to the 1-mile site, fish communities present at downstream locations are expected to support a higher sustained fish tissue ingestion rate.

Because quantitative data have not been collected for fish communities in the downstream reaches of Richland Creek, the relative rate of increase in harvestable fish biomass must be estimated based on data available for the 1-mile site. For the purposes of the HHRA, a conservative rate of increase of 10 percent per stream mile is assumed. This rate of increase is likely to underestimate the increase in the harvestable biomass at downstream locations based on field observations, sampling data, and professional judgment. Given this assumption, the rate of increase can be modeled as follows:

$$I = 1.10^{(M_f - M_i)}$$

where,

I	=	Rate of biomass increase between sampling reaches
M _f	=	Final stream mile location
M _i	=	Initial stream mile location

Using this model, the estimated rate of biomass increase between the 1-mile site and the 3-, 5.5, and 12.7-mile sites can be calculated as shown in the table below.

Sampling Reach	M_i	M_f	M_f - M_i	I
3-Mile Site	1	3	2	1.21
5.5-Mile Site	1	5.5	4.5	1.54
12.7-Mile Site	1	12.7	11.7	3.05

The estimated biomass of harvestable fish at the three downstream sampling reaches can then be calculated as follows:

$$B_n = (B_i)I_n$$

where

$$B_n = \text{Biomass of harvestable fish at downstream site } n$$

$$B_i = \text{Biomass of harvestable fish at the 1-mile site}$$

$$I_n = \text{Rate of biomass increase for site } n$$

Applying this equation, the location-specific sustainable pelagic and benthic fish tissue ingestion rates proposed for use in the HHRA are provided in the table below.

Feeding Guild	Location-Specific Fish Tissue Ingestion Rates (g/day)			
	1-Mile Site	3-Mile Site	5.5-Mile Site	12.7-Mile Site
Pelagic fish	6	7.3	9.2	18.3
Benthic fish	4	4.8	6.1	12.2
Total	10	12.1	15.3	30.5

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APPENDIX B

MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION CALCULATIONS

(19 Pages)

APPENDIX B

CALCULATION OF SUMMARY STATISTICS AND EXPOSURE POINT CONCENTRATIONS FOR SEDIMENT, SOIL, AND SURFACE WATER

Exposure point concentrations (EPC) for fish tissue sample results were calculated as average concentrations as described in Section 3.3.1 of the human health risk assessment (HHRA); Table B-1 through B-9 summarize fish tissue EPCs for total polychlorinated biphenyls (PCB) and 2,3,7,8-tetrachloro-p-dioxin (TCDD) toxicity equivalents (TEQ). Surface water EPCs for North and South Springs were calculated using U.S. Environmental Protection Agency's (EPA) ProUCL software (EPA 2004); Tables B-10 and B-11 summarize surface water EPCs for total PCBs for North and South Springs. The remainder of this appendix discusses the methods and procedures used to calculate summary statistics and EPCs for sediment, bank soil, floodplain soil, and surface water EPCs in and along Conard's Branch and Richland Creek.

Table B-12 presents summary statistics and estimates of EPCs for total PCBs in sediment, bank soil, floodplain soil, and surface water in and along Conard's Branch and Richland Creek near the Neal's Landfill site. Summary statistics include (1) the number of detected sample results, total number of samples, and detection frequency; (2) the minimum and maximum censored (nondetect) concentrations; (3) the minimum and maximum detected concentrations; and (4) the median and one-sided upper confidence limit (UCL) of the mean for detected and censored data combined. The methods used for calculating summary statistics and EPCs are summarized below and follow approaches described in Gilbert (1987), EPA (2002 and 2004), and Helsel (2005a and 2005b).

Median concentrations were estimated for the rank-ordered measurements (censored data entered at the detection limit) using the nonparametric approach described in Gilbert (1987). EPCs were estimated for all PCBs with at least four sample results and at least one detection using methods that depended on the relative number of samples and detection frequency (DF). The EPC was defined as the lesser of the maximum detected concentration and the UCL of the sample concentration mean. For calculating EPCs, PCB sample results for each sediment, bank soil, floodplain soil, and surface water location were assigned to one of four groups, as defined below:

- Group 1: DF greater than or equal to 85 percent
- Group 2: DF between 50 and 84 percent
- Group 3: DF less than or equal to 25 percent
- Group 4: Fewer than four measurements

For Group 1, EPCs were estimated using distribution-dependent methods and EPA's ProUCL Version 3.0 software package (EPA 2004). A value equal to one-half of the reporting limit was used for censored measurements in all calculations for Group 1. Distribution testing was performed using the Shapiro-Wilk W test for normal and lognormal distributions and the Anderson Darling test for gamma distributions. A Type I error rate of 0.05 (5 percent) was used for all goodness-of-fit tests. It should be noted that in accordance with EPA (2004), the value used for the UCL can be either a 95, 97.5, or 99 percent UCL.

For Group 2, EPCs were calculated using the flipped Kaplan-Meier method in accordance with recommendations in Helsel (2005a). The flipped Kaplan-Meier model employs a well-studied method that has been used for causal analysis for over 40 years (Kaplan and Meier 1958). The Kaplan-Meier model is still widely used today in medical research for calculating survivorship in clinical studies and is a principal tool for conducting failure analysis in many industrial fields (Meeker and Escobar 1998). Because the Kaplan-Meier model is a well-studied and proven technique for working with censored data, it is incorporated in most commercial statistical software packages that have platforms for calculating survival curves or conducting failure analysis. "Data flipping" is required to perform the analysis using software designed for right-censored data. The Kaplan-Meier estimator is an empirical, nonparametric procedure that can be applied to data with multiple censoring limits (reporting or detection limits in environmental applications). Confidence limits for the mean calculated using the Kaplan-Meier approach were estimated using a percentile bootstrap function.

For Group 3, EPCs were estimated using the "bounding" approach described in EPA (2002). When greater than 75 percent of the data are censored, it is unlikely that any model used to calculate a point estimate of the UCL will perform satisfactorily. In these cases, a "bounding" approach can be used to estimate a plausible upper limit for the UCL. This approach treats each censored datum as a random, uniform variable that can assume any value between zero and its respective reporting limit. Monte Carlo simulation is used to develop a distribution of the range of possible estimates for a UCL based on the selection of a particular mathematical form for the UCL. Random surrogate values between zero and the

reporting limit are used for individual censored measurements in each calculation (default is 2,000 calculations) of the UCL; therefore, the resulting distribution reflects the entire range of possible values that could be calculated for the UCL. Because substitution of random surrogate values is made for each censored measurement, this technique reflects the uncertainty contributed by varying levels of censored data and is appropriate for sample results with either single or multiple censoring limits. The nonparametric Chebyshev method (EPA 2002 and 2004) was the base model for calculating the UCL in the bounding simulations. If the range (difference between the minimum and maximum estimates) for the distribution of all potential values of the UCL is small, then theoretically, censored measurements probably contributed little to the uncertainty of the estimates. In practice, this situation is often not the case, and it is necessary to select a concentration to be used as a "plausible upper bound" for the UCL. The 95th percentile of the distribution was used as the upper-bound concentration. The maximum concentration is not appropriate because it represents the highest concentration that could theoretically be calculated from the sample data (or nearly so based on 2,000 calculations) and therefore represents a "worst-case" concentration rather than a plausible upper bound.

For Group 4, no calculations of the UCL were performed, and the EPC defaulted to the maximum detected concentration.

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**TABLE B-1
CALCULATION OF FISH TISSUE EPCs
1-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Fillet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Fillet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
8/1/2001	FINL0172	RCD	Longear sunfish	P	360	90.0	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0173	RCD	Longear sunfish	P	380	95.0	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0174	RCD	Longear sunfish	P	560	140.0	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0175	RCD	Longear sunfish	P	570	142.5	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0176	RCD	Longear sunfish	P	320	80.0	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0177	RCD	Longear sunfish	P	780	195.0	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0178	RCD	Longear sunfish	P	840	210.0	NA	NA	1.14	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0179	RCD	Longear sunfish	P	890	222.5	NA	NA	1.03	NA	NA	NA	Whole body	NA	NA	NA
11/13/2002	NL-0041	RCD	Longear sunfish	P	690	172.5	NA	NA	NA	95	16	1	Whole body	Aroclor	NA	NA
11/13/2002	NL-0042	RCD	Longear sunfish	P	46.5	11.6	NA	NA	NA	94	16	1	Whole body	Aroclor	NA	NA
11/13/2002	NL-0043	RCD	Longear sunfish	P	1,200 and 757	244.6	18.6	4.7	1.08	101	20	1	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0044	RCD	Longear sunfish	P	290 and 883	146.6	22.2	5.6	0.8	87	12	6	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0045	RCD	Longear sunfish	P	460 and 401	107.6	10.7	2.7	0.81	83	10	6	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0046	RCD	Longear sunfish	P	120 and 277	49.6	6.2	1.6	0.82	95	17	4	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0047	RCD	Longear sunfish	P	40.5	40.5	NA	NA	NA	110	28	4	Fillet	Aroclor	NA	NA
11/13/2002	NL-0048	RCD	Longear sunfish	P	46	46.0	NA	NA	NA	113	29	4	Fillet	Aroclor	NA	NA
11/13/2002	NL-0049	RCD	Longear sunfish	P	43	43.0	NA	NA	NA	109	24	4	Fillet	Aroclor	NA	NA
5/28/2003	NL-0025	RCD	Rock Bass	P	868	868.0	15.9	15.9	1.6	181	128	1	Fillet	Congener	M	NA
5/28/2003	NL-0035 (Dup of NL-0025)	RCD	Rock Bass	P	890	890.0	20	20.0	1.5	181	128	1	Fillet	Congener	M	NA
5/28/2003	NL-0036	RCD	Rock Bass	P	280	280.0	6.4	6.4	0.6	174	115	1	Fillet	Congener	M	NA
5/28/2003	NL-0037 (Dup of NL-0036)	RCD	Rock Bass	P	170	170.0	3	3.0	0.6	174	115	1	Fillet	Congener	M	NA
5/28/2003	NL-0038	RCD	Rock Bass	P	330	330.0	7.3	7.3	0.5	166	106	1	Fillet	Congener	M	NA
5/28/2003	NL-0039	RCD	Longear sunfish	P	350	350.0	5.3	5.3	0.6	128	50	1	Fillet	Congener	M	NA
5/28/2003	NL-0040	RCD	Longear sunfish	P	340	340.0	6.1	6.1	0.4	131	50	1	Fillet	Congener	M	NA
5/28/2003	NL-0041	RCD	Longear sunfish	P	360	360.0	8.5	8.5	0.4	121	37	1	Fillet	Congener	M	NA
5/28/2003	NL-0042	RCD	Longear sunfish	P	460	115.0	9.6	2.4	1	116	31	1	Whole body	Congener	M	NA
5/28/2003	NL-0043	RCD	Longear sunfish	P	1,100	275.0	21.7	5.4	1.7	123	35	1	Whole body	Congener	M	NA
5/28/2003	NL-0044	RCD	Longear sunfish	P	400	100.0	12.3	3.1	1	116	30	1	Whole body	Congener	M	NA
5/28/2003	NL-0045	RCD	Longear sunfish	P	150	37.5	3.2	0.8	0.5	108	20	1	Whole body	Congener	M	NA
5/28/2003	NL-0046	RCD	Longear sunfish	P	1,200	300.0	26.6	6.7	1.2	110	22	1	Whole body	Congener	M	NA
5/28/2003	NL-0047	RCD	Longear sunfish	P	1,900	475.0	35.3	8.8	4.4	118	33	2	Whole body	Congener	F/F	NA

**TABLE B-1
CALCULATION OF FISH TISSUE EPCs
1-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Filet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Filet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
5/28/2003	NL-0048 (Dup of NL-0047)	RCD	Longear sunfish	P	2,500	625.0	33.6	8.4	3.3	118	33	2	Whole body	Congener	F/F	NA
11/18/2003	NL-0007	RCD	Longear sunfish	P	1,345	336.3	31.3	7.8	1.52	110	24	1	Whole body	Congener	NA	NA
11/18/2003	NL-0008	RCD	Longear sunfish	P	1,122	280.5	31	7.8	2.08	105	20	1	Whole body	Congener	NA	NA
11/18/2003	NL-0009	RCD	Longear sunfish	P	270	67.5	5.5	1.4	1.42	96	17	1	Whole body	Congener	NA	NA
11/18/2003	NL-0010	RCD	Longear sunfish	P	278	69.5	9.3	2.3	0.99	103	20	1	Whole body	Congener	NA	NA
11/18/2003	NL-0011	RCD	Longear sunfish	P	775	193.8	20.2	5.1	0.87	103	20	1	Whole body	Congener	NA	NA
11/18/2003	NL-0012	RCD	Longear sunfish	P	543	135.8	15	3.8	2.09	100	21	1	Whole body	Congener	NA	NA
11/9/2005	NL-0001	RCD	Longear sunfish	P	878	219.5	26.6	6.7	2.20	125	39	1	Whole body	Congener	M	NA
11/9/2005	NL-0002	RCD	Longear sunfish	P	631	157.8	19.5	4.9	1.47	112	30	1	Whole body	Congener	M	NA
11/9/2005	NL-0003	RCD	Longear sunfish	P	250	62.5	9.1	2.3	1.70	137	47	1	Whole body	Congener	M	NA
11/9/2005	NL-0004	RCD	Longear sunfish	P	1,430	357.5	29.6	7.4	2.79	125	41	1	Whole body	Congener	M	NA
11/10/2005	NL-0016	RCD	Longear sunfish	P	621	155.3	21.2	5.3	1.05	111	30	1	Whole body	Congener	M	NA
11/10/2005	NL-0017	RCD	Longear sunfish	P	592	148.0	17	4.3	1.03	121	33	1	Whole body	Congener	M	NA
11/10/2005	NL-0018	RCD	Longear sunfish	P	210	52.5	7.1	1.8	1.03	118	31	1	Whole body	Congener	M	NA
11/10/2005	NL-0019	RCD	Longear sunfish	P	237	59.3	9.7	2.4	0.38	132	44	1	Whole body	Congener	M	NA
11/10/2005	NL-0020	RCD	Longear sunfish	P	92	23.0	2.2	0.6	0.34	114	30	1	Whole body	Congener	F	NA
11/10/2005	NL-0021	RCD	Longear sunfish	P	658	164.5	23	5.8	1.3	106	23	4	Whole body	Congener	3M / 1F	NA
11/10/2005	NL-0021 (Dup of NL-0021)	RCD	Longear sunfish	P	522	130.5	19	4.8	1.19	NA	NA	NA	NA	NA	NA	NA
11/10/2005	Ti-NL0021	RCVP (NL-2)	Longear sunfish	P	25.9	6.5	0.679	0.2			18 to 27	4	Whole body	Composite congener	1F/3M	NA
			Avg Pelagic			182.0		3.5								
8/1/2001	FINL0180	RCD	White Sucker	B	1,200	600.0	NA	NA	4.74	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0181	RCD	White Sucker	B	3,600	1,800	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0182	RCD	White Sucker	B	1,800	900.0	NA	NA	3.22	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0183	RCD	White Sucker	B	2700	1,350	NA	NA	NA	NA	NA	NA	Whole body	NA	NA	NA
8/1/2001	FINL0184	RCD	White Sucker	B	1,200	600.0	NA	NA	4.89	NA	NA	NA	Whole body	NA	NA	NA
11/13/2002	NL-0023	RCD	White Sucker	B	1,100 and 497	392.5	12.5	6.3	0.57	217	100	1	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0024	RCD	White Sucker	B	430 and 570	250.0	15.2	7.6	0.5	190	76	1	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0025	RCD	White Sucker	B	650	325.0	NA	NA	0.44	181	67	1	Whole body	Aroclor	NA	NA
11/13/2002	NL-0026	RCD	White Sucker	B	520	260.0	NA	NA	0.4	181	62	1	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0027	RCD	White Sucker	B	2,000 and 1747	936.8	39.9	20.0	1	196	79	1	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0028	RCD	White Sucker	B	2,500 and 2111	1,153	37	18.5	0.44	205	80	1	Whole body	Aroclor and Congener	NA	NA

TABLE B-1
CALCULATION OF FISH TISSUE EPCs
1-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Filet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Filet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
11/13/2002	NL-0029	RCD	White Sucker	B	1,100 and 1,150	562.5	26.7	13.4	0.64	197	76	1	Whole body	Aroclor and Congener	NA	NA
11/13/2002	NL-0030	RCD	White Sucker	B	630	630.0	NA	NA	0.41	224	134	1	Fillet	Aroclor	NA	NA
11/13/2002	NL-0031 (Dup of NL-0030)	RCD	White Sucker	B	490	490.0	NA	NA	0.29	224	134	1	Fillet	Arclor	NA	NA
11/13/2002	NL-0032	RCD	White Sucker	B	900	900.0	NA	NA	0.34	219	104	1	Fillet	Aroclor	NA	NA
11/13/2002	NL-0033	RCD	White Sucker	B	340	340.0	NA	NA	0.33	222	109	1	Fillet	Aroclor	NA	NA
5/28/2003	NL-0023	RCD	White Sucker	B	700	700.0	9.7	4.9	1.2	205	95	1	Fillet	Congener	F	NA
5/28/2003	NL-0024	RCD	White Sucker	B	730	700.0	15.9	8.0	1.8	210	120	1	Fillet	Congener	M	NA
5/28/2003	NL-0026	RCD	White Sucker	B	360	360.0	5	5.0	1.6	225	120	1	Fillet	Congener	M	NA
5/28/2003	NL-0027 (Dup of NL-0026)	RCD	White Sucker	B	490	490.0	7.3	7.3	2.3	225	120	1	Fillet	Congener	M	NA
5/28/2003	NL-0028	RCD	White Sucker	B	2,890	1,445	40	20.0	4	201	83	1	Whole body	Congener	M	NA
5/28/2003	NL-0029	RCD	White Sucker	B	1,600	800.0	41.4	20.7	3.2	195	72	1	Whole body	Congener	M	NA
5/28/2003	NL-0030	RCD	White Sucker	B	2,500	1,250	45.4	22.7	2.9	185	82	1	Whole body	Congener	F	NA
5/28/2003	NL-0031	RCD	White Sucker	B	1,200	600.0	16.6	8.3	8.5	160	50	1	Whole body	Congener	M	NA
5/28/2003	NL-0032	RCD	White Sucker	B	2,300	1,150	30.8	15.4	6.9	170	60	1	Whole body	Congener	F	NA
5/28/2003	NL-0033	RCD	White Sucker	B	2,700	1,350	36.9	18.5	7.2	167	45	1	Whole body	Congener	M	NA
5/28/2003	NL-0034	RCD	White Sucker	B	1,700	850.0	20.8	10.4	4.9	137	31	7	Whole body	Congener	5M/2F	NA
Avg. Benthic						808.0		8.0								

Notes:

µg/kg = Microgram per kilogram
 Avg = Average
 B = Benthic
 Dup = Duplicate
 EPC = Exposure point concentration
 F = Female
 ID = Identification
 M = Male
 NA = Not applicable or not available
 ng/kg = Nanogram per kilogram
 P = Pelagic
 PCB = Polychlorinated biphenyl
 RCD = Richland Creek Section D
 RCVP = Richland Creek at Vernal Pike
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-2
TCDD TEQ EPC CALCULATIONS (pg/kg)
1-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	77 TeCB	81 TeCB	105 PeCB	114 PeCB	118 PeCB	123 PeCB	126 PeCB	156/157 HxCB	167 HxCB	169 HxCB	189 HpCB	Mammalian WHO-TEQ
			Mammalian TEF:		0.0001	0.0001	0.0001	0.0005	0.0001	0.0001	0.1	0.0005	0.00001	0.01	0.0001	
11/13/2002	NL-0043	RCD	Longear sunfish	P	6,260	314	22,500	1,780	40,100	1,500	87.5	1,300	489	120.5	44.6	18.6
11/13/2002	NL-044	RCD	Longear sunfish	P	7,240	367	27,800	2,200	49,200	1,900	105	1,600	542	112	51.7	22.2
11/13/2002	NL-045	RCD	Longear sunfish	P	3,100	147	14,600	1,180	26,700	951	49.9	895	350	12.25	39.2	10.7
11/13/2002	NL-046	RCD	Longear sunfish	P	2,240	107	7,500	602	13,000	489	32.7	444	179	10.9	10.9	6.2
5/28/2003	NL-0025	RCD	Rock Bass	P	4,750	344	21,500	1,790	36,400	1,320	80	1,120	356	4	32.3	15.9
5/28/2003	NL-0035 (Dup of NL-0025)	RCD	Rock Bass	P	5,000	296	28,000	2,010	46,700	1,710	101	1,130	411	12.05	40.4	20.0
5/28/2003	NL-0036	RCD	Rock Bass	P	1,740	102	7,070	601	13,100	496	35.6	337	129	11.45	11.45	6.4
5/28/2003	NL-0037 (Dup of NL-0036)	RCD	Rock Bass	P	978	54.9	4,640	343	7,690	313	12.05	194	74.5	12.05	12.05	3.0
5/28/2003	NL-0038	RCD	Rock Bass	P	2,430	124	8,710	714	16,500	629	38	343	127	12.4	12.4	7.3
5/28/2003	NL-0039	RCD	Longear sunfish	P	2,060	90	11,100	902	19,100	886	12.05	493	176	12.05	12.05	5.3
5/28/2003	NL-0040	RCD	Longear sunfish	P	1,540	72.4	12,500	1,040	24,100	989	12	638	254	12	12	6.1
5/28/2003	NL-0041	RCD	Longear sunfish	P	2,680	131	12,900	1,060	22,700	987	36.1	566	214	12.35	12.35	8.5
5/28/2003	NL-0042	RCD	Longear sunfish	P	3,110	138	17,500	1,440	30,800	1,350	30	1,010	362	12.35	34.4	9.6
5/28/2003	NL-0043	RCD	Longear sunfish	P	7,480	317	33,100	2,620	59,000	2,540	92.1	1,590	623	11.4	62	21.7
5/28/2003	NL-0044	RCD	Longear sunfish	P	2,940	135	23,500	1,800	40,100	1,900	38.6	1,210	436	11.85	43.5	12.3
5/28/2003	NL-0045	RCD	Longear sunfish	P	1,290	54.5	4,780	408	8,550	376	12.2	212	70.2	12.2	12.2	3.2
5/28/2003	NL-0046	RCD	Longear sunfish	P	9,220	400	42,300	3,340	75,300	2,870	108	2,070	766	11.6	77.7	26.6
5/28/2003	NL-0047	RCD	Longear sunfish	P	16,200	685	46,900	3,320	79,000	3,160	180	1,900	730	10.55	73.8	35.3
5/28/2003	NL-0048 (Dup of NL-0047)	RCD	Longear sunfish	P	16,800	896	48,100	3,490	79,000	3,260	159	2,170	718	7.5	65	33.6
11/18/2003	NL-0007	RCD	Longear sunfish	P	11,300	3680	53,300	3,680	89,300	2,590	138	2,600	906	12.4	85.3	33.1
11/18/2003	NL-0008	RCD	Longear sunfish	P	7,960	411	42,600	3,030	74,000	2,260	155	2,240	767	12.35	73	31.0
11/18/2003	NL-0009	RCD	Longear sunfish	P	1,760	93.5	10,500	863	19,400	814	13.45	594	244	12.25	28.8	5.5
11/18/2003	NL-0010	RCD	Longear sunfish	P	3,320	124	10,700	909	19,800	718	48.9	687	252	12.1	39	9.3
11/18/2003	NL-0011	RCD	Longear sunfish	P	5,800	220	35,800	2,560	64,500	2,090	69.3	1,950	676	12.35	67.4	20.2
11/18/2003	NL-0012	RCD	Longear sunfish	P	4,750	230	19,600	1,630	38,800	1,520	70.8	1,050	399	12.45	43.8	15.0
11/9/2005	NL-0001	RCD	Longear sunfish	P	5,070	265	37,110	3,050	74,600	2,580	116	2,480	980	24.7	99.5	26.6
11/9/2005	NL-0002	RCD	Longear sunfish	P	3,990	252	29,700	2,380	52,400	2,030	84.4	1,950	675	4.8	66.6	19.5
11/9/2005	NL-0003	RCD	Longear sunfish	P	749	51.2	12,600	1,110	25,100	996	38.8	1,150	440	9.65	62.3	9.1
11/9/2005	NL-0004	RCD	Longear sunfish	P	9,570	438	45,200	3,430	78,500	2,380	127	2,220	769	49.65	77.2	29.6
11/10/2005	NL-0016	RCD	Longear sunfish	P	4,450	247	30,100	2,280	46,300	1,840	103	1,820	643	51.8	70.5	21.2
11/10/2005	NL-0017	RCD	Longear sunfish	P	3,210	110	31,900	2,770	46,000	2,800	54.9	2,240	797	58.6	91.9	17.0
11/10/2005	NL-0018	RCD	Longear sunfish	P	914	52.4	10,200	918	20,600	857	26.4	855	381	30.1	44.8	7.1

TABLE B-2
TCDD TEQ EPC CALCULATIONS (pg/kg)
1-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	77 TeCB	81 TeCB	105 PeCB	114 PeCB	118 PeCB	123 PeCB	126 PeCB	156/157 HxCB	167 HxCB	169 HxCB	189 HpCB	Mammalian WHO-TEQ
		Mammalian TEF:			0.0001	0.0001	0.0001	0.0005	0.0001	0.0001	0.1	0.0005	0.00001	0.01	0.0001	
11/10/2005	NL-0019	RCD	Longear sunfish	P	891	42.4	17,700	1,470	31,000	1,290	27.3	1,580	530	32.8	65	9.7
11/10/2005	NL-0020	RCD	Longear sunfish	P	826	35.9	03,290	255	5,460	218	10	227	93.4	0.4905	10.7	2.2
11/10/2005	NL-0021	RCD	Longear sunfish	P	5,660	344	29,700	2,590	49,400	2,110	119	2,010	676	5.1	69.7	23.0
11/10/2005	NL-0021 (Dup of NL-0021)	RCD	Longear sunfish	P	4,440	288	24,100	2,160	42,300	1,640	98.1	1,660	561	0.555	64.1	19.0
11/10/2005	Ti-NL-0021	RCVP (NL-2)	Longear sunfish	P	181	8.93	1,160	90.6	2,080	89.1	2.39	77.3	29.4	0.352	3.91	0.7
11/13/2002	NL-0023	RCD	White Sucker	B	3,520	293	14,200	1,150	22,800	863	73	683	230	9.2	20.7	12.5
11/13/2002	NL-0024	RCD	White Sucker	B	1,370	272	20,900	1,920	39,600	1,240	62.1	1,280	458	101.5	42.1	15.2
11/13/2002	NL-0027	RCD	White Sucker	B	10,700	894	45,800	3,510	74,900	2,690	224	2,100	692	117	59.6	39.9
11/13/2002	NL-0028	RCD	White Sucker	B	13,900	955	43,800	3,370	72,700	2,520	197	2,010	693	123.5	60	37.0
11/13/2002	NL-0029	RCD	White Sucker	B	6,060	594	29,700	2,320	51,500	1,780	146	1,540	528	115	46.3	26.7
5/28/2003	NL-0023	RCD	White Sucker	B	3,690	200	10,800	964	20,600	921	52	506	171	11.6	11.6	9.7
5/28/2003	NL-0024	RCD	White Sucker	B	4,070	280	18,400	1,650	34,700	1,420	86.8	851	285	12.3	26.8	15.9
5/28/2003	NL-0026	RCD	White Sucker	B	2,510	116	6,390	473	9,340	413	26.1	230	83.4	11.8	11.8	5.0
5/28/2003	NL-0027 (Dup of NL-0026)	RCD	White Sucker	B	3,360	153	8,200	625	15,100	622	39.2	305	112	12.05	12.05	7.3
5/28/2003	NL-0028	RCD	White Sucker	B	12,800	1100	55,500	4,390	95,400	3,310	196	2,650	836	9.05	72	40.0
5/28/2003	NL-0029	RCD	White Sucker	B	10,700	864	50,100	3,980	82,900	3,260	234	2,250	761	11.3	75	41.4
5/28/2003	NL-0030	RCD	White Sucker	B	11,100	891	57,100	4,480	115,000	4,040	230	2,470	952	12.45	85.8	45.4
5/28/2003	NL-0031	RCD	White Sucker	B	6,950	342	18,600	1,730	41,300	1,560	82.9	883	341	12.35	36.1	16.6
5/28/2003	NL-0032	RCD	White Sucker	B	14,600	707	36,400	2,760	74,400	2,810	156	1,610	631	11.65	61.1	30.8
5/28/2003	NL-0033	RCD	White Sucker	B	17,100	876	46,900	3,420	86,400	3,450	187	1,750	660	12.5	61.4	36.9
5/28/2003	NL-0034	RCD	White Sucker	B	9,530	473	24,100	2,040	50,300	1,850	106	878	356	12.5	31.9	20.8

Notes:

Shaded results indicate a nondetect; value is one-half of the detection limit

B = Benthic
 Dup = Duplicate
 EPC = Exposure point concentration
 HpCB = Heptachlorobiphenyl
 HxCB = Hexachlorobiphenyl
 ID = Identification
 P = Pelagic
 PeCB = Pentachlorobiphenyl
 pg/kg = Picogram per kilogram
 RCD = Richland Creek Section D
 RCVP = Richland Creek at Vernal Pike
 TCDD = 2,3,7,8-Tetrachloro-p-dioxin
 TeCB = Tetrachlorobiphenyl
 TEF = Toxicity equivalency factor
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-3
CALCULATION OF FISH TISSUE EPCs
3-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Fillet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Fillet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
6/18/2004	Tt-NL3-005	3-mile	Smallmouth Bass	P	170	170	NA	NA	1.1	289	335	1	Fillet	Aroclor	F	NA
6/18/2004	Tt-NL3-006	3-mile	Rock Bass	P	54.4	54.4	1.4	1.4	0.4	193	143	1	Fillet	Congener	F	NA
6/18/2004	Tt-NL3-007	3-mile	Rock Bass	P	120	120	NA	NA	0.5	164	95	1	Fillet	Aroclor	M	NA
			Avg Pelagic			114.8		1.4								
6/18/2004	Tt-NL3-001	3-mile	Northern Hogsucker	B	170	170	NA	NA	0.8	270	219	1	Fillet	Aroclor	M	NA
6/18/2004	Tt-NL3-002	3-mile	Northern Hogsucker	B	106	106	2.3	2.3	0.6	261	196	1	Fillet	Congener	M	NA
6/18/2004	Tt-NL3-003	3-mile	White Sucker	B	300	300	NA	NA	3.6	246	163	1	Fillet	Aroclor	M	NA
6/18/2004	Tt-NL3-004	3-mile	Golden Redhorse	B	140	140	NA	NA	1.3	319	391	1	Fillet	Aroclor	M	NA
6/18/2004	Tt-NL3-004 (Dup)	3-mile	Golden Redhorse	B	170	170	NA	NA	NA	NA	NA	1	Fillet	Aroclor	M	NA
			Avg Benthic			182.8		2.3								

Notes:

µg/kg = Microgram per kilogram
 Avg = Average
 B = Benthic
 Dup = Duplicate
 EPC = Exposure point concentration
 F = Female
 ID = Identification
 M = Male
 NA = Not applicable or not available
 ng/kg = Nanogram per kilogram
 P = Pelagic
 PCB = Polychlorinated biphenyl
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-4
TCDD TEQ EPC CALCULATIONS (pg/kg)
3-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	77 TeCB	81 TeCB	105 PeCB	114 PeCB	118 PeCB	123 PeCB	126 PeCB	156/157 HxCB	167 HxCB	169 HxCB	189 HpCB	Mammalian WHO-TEQ
		Mammalian TEF:			0.0001	0.0001	0.0001	0.0005	0.0001	0.0001	0.1	0.0005	0.00001	0.01	0.0001	
6/18/2004	Tt-NL3-006	3-mile	Rock Bass	P	442	26.3	1,470	118	2,690	115	8.24	94.1	40.3	0.389	6.38	1.4
6/18/2004	Tt-NL3-002	3-mile	Northern Hogsucker	B	702	35.4	3,290	233	5,720	205	10.6	158	55	0.357	7.37	2.3

Notes:

Shaded results indicate a nondetect; value is one-half of the detection limit

B = Benthic
 EPC = Exposure point concentration
 HpCB = Heptachlorobiphenyl
 HxCB = Hexachlorobiphenyl
 ID = Identification
 P = Pelagic
 PeCB = Pentachlorobiphenyl
 pg/kg = Picogram per kilogram
 TCDD = 2,3,7,8-Tetrachloro-p-dioxin
 TeCB = Tetrachlorobiphenyl
 TEF = Toxicity equivalency factor
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-5
CALCULATION OF FISH TISSUE EPCs
5.5-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Fillet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Fillet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
5/28/2003	NL-0049	RCG	Shorthead Redhorse	B	80	80	2.7	2.7	0.4	328	368	1	Fillet	Congener	F	NA
5/28/2003	NL-0050	RCG	Shorthead Redhorse	B	275	275	4.7	4.7	2.9	291	244	1	Fillet	Congener	M	NA
5/28/2003	NL-0051 (Dup of NL-0050)	RCG	Shorthead Redhorse	B	280	280	3.6	3.6	2.3	291	244	1	Fillet	Congener	M	NA
5/28/2003	NL-0052	RCG	Shorthead Redhorse	B	120	120	2.7	2.7	1.2	228	137	1	Fillet	Congener	M	NA
5/28/2003	NL-0053 (Dup of NL-0052)	RCG	Shorthead Redhorse	B	125	125	2.8	2.8	1.7	228	137	1	Fillet	Congener	M	NA
5/28/2003	NL-0054	RCG	Shorthead Redhorse	B	320	160	3.4	1.7	4.9	179	63	1	Whole body	Congener	M	NA
5/28/2003	NL-0055	RCG	Shorthead Redhorse	B	664	332	10	5	4.6	177	59	1	Whole body	Congener	M	NA
5/28/2003	NL-0056	RCG	Shorthead Redhorse	B	360	180	7.5	3.8	3.9	187	81	1	Whole body	Congener	M	NA
			Avg Benthic			192		3.3								

Notes:

µg/kg = Microgram per kilogram
 Avg = Average
 B = Benthic
 Dup = Duplicate
 EPC = Exposure point concentration
 F = Female
 ID = Identification
 M = Male
 NA = Not applicable or not available
 ng/kg = Nanogram per kilogram
 PCB = Polychlorinated biphenyl
 RCG = Richland Creek Section G
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-6
TCDD TEQ EPC CALCULATIONS (pg/kg)
5.5-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	77 TeCB	81 TeCB	105 PeCB	114 PeCB	118 PeCB	123 PeCB	126 PeCB	156/157 HxCB	167 HxCB	169 HxCB	189 HpCB	Mammalian WHO-TEQ
5/28/2003	NL-0049	RCG	Shorthead Redhorse	B	205	32.1	3,390	293	7,550	262	11.7	226	107	11.7	11.7	2.7
5/28/2003	NL-0050	RCG	Shorthead Redhorse	B	1,890	101	6,560	468	12,600	451	20.9	272	119	9.7	9.7	4.7
5/28/2003	NL-0051 (Dup of NL-0050)	RCG	Shorthead Redhorse	B	1,630	85.6	5,670	374	10,400	344	14.7	252	96	1.6	9.3	3.6
5/28/2003	NL-0052	RCG	Shorthead Redhorse	B	522	45.8	3,440	258	7,240	279	12	172	80.4	12.0	12.0	2.7
5/28/2003	NL-0053 (Dup of NL-0052)	RCG	Shorthead Redhorse	B	571	47.6	3,850	289	8,080	296	11.9	198	96.5	11.9	11.9	2.8
5/28/2003	NL-0054	RCG	Shorthead Redhorse	B	1,820	95.5	4,900	381	9,920	411	12.4	229	109	12.4	12.4	3.4
5/28/2003	NL-0055	RCG	Shorthead Redhorse	B	4,070	244	11,900	1,050	26,900	1,070	46.2	635	297	11.5	30.8	10.0
5/28/2003	NL-0056	RCG	Shorthead Redhorse	B	2,350	141	8,910	723	18,700	765	36.9	488	235	11.8	27.9	7.5

Notes:

Shaded results indicate a nondetect; value is one-half of the detection limit

B = Benthic
 EPC = Exposure point concentration
 HpCB = Heptachlorobiphenyl
 HxCB = Hexachlorobiphenyl
 ID = Identification
 PeCB = Pentachlorobiphenyl
 pg/kg = Picogram per kilogram
 RCG = Richland Creek Section G
 TCDD = 2,3,7,8-Tetrachloro-p-dioxin
 TeCB = Tetrachlorobiphenyl
 TEF = Toxicity equivalency factor
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-7
CALCULATION OF FISH TISSUE EPCs
12.7-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Fillet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Fillet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
8/1/2001	FINL0190	RCI	Longear Sunfish	P	200	50	NA	NA	1.18	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0191	RCI	Longear Sunfish	P	250	62.5	NA	NA	0.38	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0192	RCI	Longear Sunfish	P	220	55	NA	NA	0.8	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0193	RCI	Longear Sunfish	P	350	87.5	NA	NA	0.72	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0194	RCI	Longear Sunfish	P	350	87.5	NA	NA	0.94	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0195	RCI	Longear Sunfish	P	100	25	NA	NA	1.05	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0196	RCI	Longear Sunfish	P	300	75	NA	NA	1.8	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0197	RCI	Longear Sunfish	P	260	65	NA	NA	0.7	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0198	RCI	Rock Bass	P	95	95	NA	NA	NA	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0199	RCI	Rock Bass	P	95	95	NA	NA	0.35	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0200	RCI	Spotted Bass	P	135	135	NA	NA	NA	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0201	RCI	Spotted Bass	P	70	70	NA	NA	0.28	NA	NA	NA	Fillet	Aroclor	NA	NA
			Avg. Pelagic			92		NA								
8/1/2001	FINL0187	RCI	Black Redhorse	B	320	160	NA	NA	NA	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0188	RCI	Black Redhorse	B	390	195	NA	NA	2.35	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0189	RCI	Black Redhorse	B	310	155	NA	NA	3.65	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0202	RCI	White Sucker	B	290	145	NA	NA	NA	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0203	RCI	White Sucker	B	340	170	NA	NA	1.99	NA	NA	NA	Whole body	Aroclor	NA	NA
			Avg. Benthic			165		NA								

Notes:

Shaded results indicate a nondetect; value is one-half of the detection limit

µg/kg = Microgram per kilogram
 Avg = Average
 B = Benthic
 EPC = Exposure point concentration
 ID = Identification
 NA = Not applicable or not available
 ng/kg = Nanogram per kilogram
 P = Pelagic
 PCB = Polychlorinated biphenyl
 RCI = Richland Creek Section I
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-8
CALCULATION OF FISH TISSUE EPCs
21.8-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Fillet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Fillet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
8/1/2001	FINL0209	RCJ	Longear Sunfish	P	100	25	NA	NA	0.77	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0210	RCJ	Longear Sunfish	P	120	30	NA	NA	1.41	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0211	RCJ	Longear Sunfish	P	80	20	NA	NA	1.04	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0212	RCJ	Longear Sunfish	P	100	100	NA	NA	1.03	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0213	RCJ	Longear Sunfish	P	95	95	NA	NA	0.39	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0214	RCJ	Longear Sunfish	P	220	220	NA	NA	1.54	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0215	RCJ	Longear Sunfish	P	80	80	NA	NA	2.07	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0216	RCJ	Longear Sunfish	P	90	90	NA	NA	0.45	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0217	RCJ	Rock Bass	P	100	100	NA	NA	NA	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0218	RCJ	Rock Bass	P	85	85	NA	NA	0.46	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0219	RCJ	Spotted Bass	P	44.5	44.5	NA	NA	NA	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0220	RCJ	Spotted Bass	P	80	80	NA	NA	0.46	NA	NA	NA	Fillet	Aroclor	NA	NA
			Avg Pelagic			79.9		NA								
8/1/2001	FINL0204	RCJ	Black Redhorse	B	230	115	NA	NA	2.24	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0205	RCJ	Black Redhorse	B	160	80	NA	NA	1.74	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0206	RCJ	Black Redhorse	B	210	105	NA	NA	4.25	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0207	RCJ	Black Redhorse	B	105	52.5	NA	NA	2.63	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0208	RCJ	Carp	B	85	42.5	NA	NA	2.53	NA	NA	NA	Whole body	Aroclor	NA	NA
			Avg Benthic			79.0		NA								

Notes:

Shaded results indicate a nondetect; value is one-half of the detection limit

µg/kg = Microgram per kilogram
 Avg = Average
 B = Benthic
 EPC = Exposure point concentration
 ID = Identification
 NA = Not applicable or not available
 ng/kg = Nanogram per kilogram
 P = Pelagic
 PCB = Polychlorinated biphenyl
 RCJ = Richland Creek Section J
 TEQ = Toxicity equivalent
 WHO = World Health Organization

TABLE B-9
CALCULATION OF FISH TISSUE EPCs
34.5-MILE SITE
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA

Sampling Date	Sample ID	Location	Fish Type	Feeding Guild	Total PCBs (µg/kg wet weight)	Total PCBs Whole to Fillet (µg/kg wet weight)	WHO TEQ (ng/kg)	WHO TEQ Whole to Fillet (ng/kg)	Lipids	Length	Weight	Number	Type	Comments	Sex	Age (years)
8/1/2001	FINL0228	RCK	Longear Sunfish	P	70	17.5	NA	NA	3.04	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0229	RCK	Longear Sunfish	P	70	17.5	NA	NA	2.51	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0230	RCK	Longear Sunfish	P	75	18.75	NA	NA	1.01	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0231	RCK	Spotted Bass	P	85	85	NA	NA	NA	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0232	RCK	Spotted Bass	P	75	75	NA	NA	0.76	NA	NA	NA	Fillet	Aroclor	NA	NA
8/1/2001	FINL0221	RCK	Black Redhorse	B	70	35	NA	NA	2.69	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0222	RCK	Black Redhorse	B	70	35	NA	NA	1.85	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0223	RCK	Black Redhorse	B	80	40	NA	NA	1.53	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0224	RCK	Carp	B	70	35	NA	NA	2.18	NA	NA	NA	Whole body	Aroclor	NA	NA
8/1/2001	FINL0225	RCK	Carp	B	70	35	NA	NA	0.61	NA	NA	NA	Whole body	Aroclor	NA	NA

Notes:

Shaded results indicate a nondetect; value is one-half of the detection limit

µg/kg = Microgram per kilogram
B = Benthic
EPC = Exposure point concentration
ID = Identification
NA = Not applicable or not available
ng/kg = Nanogram per kilogram
P = Pelagic
PCB = Polychlorinated biphenyl
RCK = Richland Creek Section K
TEQ = Toxicity equivalent
WHO = World Health Organization

TABLE B-10

**CALCULATION OF SURFACE WATER EPCs
NORTH SPRING
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Data File				Variable:	North Spring					
Raw Statistics			Normal Distribution Test						Data	
Number of Valid Samples	14		Shapiro-Wilk Test Statistic	0.815945			2/11/2005	0.32		
Number of Unique Samples	13		Shapiro-Wilk 5% Critical Value	0.874			1/19/2005	0.16	J	
Minimum	0.16		Data not normal at 5% significance level				12/16/2004	0.45		
Maximum	1.4						11/17/2004	0.82		
Mean	0.501429		95% UCL (Assuming Normal Distribution)				10/6/2004	1.4		
Median	0.425		Student's-t UCL	0.658008			9/9/2004	0.88		
Standard Deviation	0.330823						8/6/2004	0.56		
Variance	0.109444		Gamma Distribution Test				7/27/2004	0.43	(7/16/04)	
Coefficient of Variation	0.659761		A-D Test Statistic	0.436963			6/4/2004	0.43		
Skewness	1.774726		A-D 5% Critical Value	0.742093			5/5/2004	0.26		
			K-S Test Statistic	0.214193			4/19/2004	0.35		
Gamma Statistics			K-S 5% Critical Value	0.230368			3/9/2004	0.2		
k hat	3.17858		Data follow gamma distribution				2/12/2004	0.34	(2/13/04)	
k star (bias corrected)	2.545075		at 5% significance level				1/14/2004	0.42		
Theta hat	0.157752									
Theta star	0.197019		95% UCLs (Assuming Gamma Distribution)				Notes:			
nu hat	89.00024		Approximate Gamma UCL				All concentrations are in units of microgram per liter (µg/L).			
nu star	71.26209		Adjusted Gamma UCL				J = Estimated concentration			
Approx.Chi Square Value (.05)	52.82268									
Adjusted Level of Significance	0.03122		Lognormal Distribution Test							
Adjusted Chi Square Value	50.72053		Shapiro-Wilk Test Statistic	0.96962						
			Shapiro-Wilk 5% Critical Value	0.874						
Log-transformed Statistics			Data are lognormal at 5% significance level							
Minimum of log data	-1.832581									
Maximum of log data	0.336472		95% UCLs (Assuming Lognormal Distribution)							
Mean of log data	-0.855767		95% H-UCL	0.716109						
Standard Deviation of log data	0.581422		95% Chebyshev (MVUE) UCL	0.844953						
Variance of log data	0.338051		97.5% Chebyshev (MVUE) UCL	0.995781						
			99% Chebyshev (MVUE) UCL	1.292055						
			95% Non-parametric UCLs							
			CLT UCL	0.64686						
			Adj-CLT UCL (Adjusted for skewness)	0.691671						
			Mod-t UCL (Adjusted for skewness)	0.664997						
			Jackknife UCL	0.658008						
			Standard Bootstrap UCL	0.641026						
			Bootstrap-t UCL	0.774999						
			Hall's Bootstrap UCL	0.8091						
RECOMMENDATION			Percentile Bootstrap UCL	0.654286						
Data follow gamma distribution (0.05)			BCA Bootstrap UCL	0.687857						
Use Approximate Gamma UCL			95% Chebyshev (Mean, Sd) UCL	0.886826						
			97.5% Chebyshev (Mean, Sd) UCL	1.053588						
			99% Chebyshev (Mean, Sd) UCL	1.381159						

TABLE B-11

**CALCULATION OF SURFACE WATER EPCs
SOUTH SPRING
HUMAN HEALTH RISK ASSESSMENT
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Data File				Variable: South Spring					
Raw Statistics			Normal Distribution Test						
Number of Valid Samples	14	Shapiro-Wilk Test Statistic	0.871424				Data		
Number of Unique Samples	14	Shapiro-Wilk 5% Critical Value	0.874			2/11/2005	0.89		
Minimum	0.74	Data not normal at 5% significance level				1/19/2005	0.74		
Maximum	1.85					12/16/2004	1.55		
Mean	1.0875	95% UCL (Assuming Normal Distribution)				11/17/2004	1.4		
Median	0.9375	Student's-t UCL	1.242415			10/6/2004	1.85		
Standard Deviation	0.327307					9/9/2004	1.1		
Variance	0.10713	Gamma Distribution Test				8/6/2004	0.955		
Coefficient of Variation	0.300972	A-D Test Statistic	0.588461			7/27/2004	0.81		
Skewness	1.186061	A-D 5% Critical Value	0.734339			6/4/2004	0.92		
		K-S Test Statistic	0.218111			5/5/2004	0.87		
		K-S 5% Critical Value	0.228522			4/19/2004	1.15		
Gamma Statistics									
k hat	13.54581	Data follow gamma distribution				3/9/2004	0.805		
k star (bias corrected)	10.69075	at 5% significance level				2/12/2004	0.885		
Theta hat	0.080283					1/14/2004	1.3		
Theta star	0.101723	95% UCLs (Assuming Gamma Distribution)							
nu hat	379.2827	Approximate Gamma UCL	1.250822			Notes:			
nu star	299.3411	Adjusted Gamma UCL	1.274498			All concentrations are in units of microgram per liter (µg/L).			
Approx. Chi Square Value (.05)	260.2556								
Adjusted Level of Significance	0.03122	Lognormal Distribution Test							
Adjusted Chi Square Value	255.4209	Shapiro-Wilk Test Statistic	0.919878						
		Shapiro-Wilk 5% Critical Value	0.874						
		Data are lognormal at 5% significance level							
Log-transformed Statistics									
Minimum of log data	-0.30111								
Maximum of log data	0.615186	95% UCLs (Assuming Lognormal Distribution)							
Mean of log data	0.046516	95% H-UCL	1.25643						
Standard Deviation of log data	0.275958	95% Chebyshev (MVUE) UCL	1.4373						
Variance of log data	0.076153	97.5% Chebyshev (MVUE) UCL	1.589642						
		99% Chebyshev (MVUE) UCL	1.888889						
		95% Non-parametric UCLs							
		CLT UCL	1.231386						
		Adj-CLT UCL (Adjusted for skewness)	1.261015						
		Mod-t UCL (Adjusted for skewness)	1.247036						
		Jackknife UCL	1.242415						
		Standard Bootstrap UCL	1.223801						
		Bootstrap-t UCL	1.292561						
		Hall's Bootstrap UCL	1.270551						
RECOMMENDATION									
Data follow gamma distribution (0.05)		Percentile Bootstrap UCL	1.228571						
		BCA Bootstrap UCL	1.271429						
Use Approximate Gamma UCL		95% Chebyshev (Mean, Sd) UCL	1.468801						
		97.5% Chebyshev (Mean, Sd) UCL	1.63379						
		99% Chebyshev (Mean, Sd) UCL	1.95788						

TABLE B-12

SUMMARY OF TOTAL PCB CONCENTRATIONS IN SEDIMENT, SOIL, AND SURFACE WATER

Matrix	Location	Number of Detected Results	Total Number of Results	Detection Frequency (Percent)	Censored Data Only		Detected Data Only		Detected and Censored Data Combined ¹				
					Minimum Concentration	Maximum Concentration	Minimum Concentration	Maximum Concentration	Median Concentration ²	UCL	Distribution ³	Method	EPC
Surface Water	RC43	2	3	67	0.200	0.200	0.101	0.150	0.150	NA	Nonparametric	(4)	0.150
	RCVP	2	4	50	0.020	0.200	0.103	0.104	0.104	0.104	Nonparametric	(2)	0.104
	SW-A	18	22	82	0.200	0.200	0.037	0.475	0.140	0.191	Nonparametric	(2)	0.191
	SW-PreA	8	10	80	0.020	0.200	0.055	1.630	0.290	0.928	Nonparametric	(2)	0.928
Sediment and Soil	BK-A	11	13	85	0.220	0.250	0.170	3.100	0.810	1.768	Gamma	(1)	1.768
	BK-C	1	5	20	0.230	0.250	0.014	0.014	0.240	0.329	Nonparametric	(3)	0.014
	BK-D	0	8	0	0.220	0.270	NA	NA	0.250	NA	NA	NA	NA
	BK-E	2	12	17	0.240	0.310	0.130	0.240	0.260	0.272	Nonparametric	(3)	0.240
	BK-F	0	12	0	0.250	0.280	NA	NA	0.260	NA	NA	NA	NA
	BK-PreA	24	37	65	0.220	0.250	0.009	61.000	1.270	12.466	Nonparametric	(2)	12.466
	FP-A	16	25	64	0.230	0.270	0.120	7.300	0.270	2.270	Nonparametric	(2)	2.270
	FP-B	1	6	17	0.230	0.430	0.220	0.220	0.230	0.417	Nonparametric	(3)	0.220
	FP-PreA	13	26	50	0.230	0.270	0.140	19.000	0.270	4.538	Nonparametric	(2)	4.538
	Sed-A	26	26	100	NA	NA	0.230	3.000	0.553	1.039	Gamma	(1)	1.039
	Sed-B	1	4	25	0.340	0.385	0.032	0.032	0.353	0.547	Nonparametric	(3)	0.032
	Sed-C	0	3	0	0.250	0.280	NA	NA	0.280	NA	NA	NA	NA
	Sed-D	1	7	14	0.230	0.365	0.019	0.019	0.270	0.362	Nonparametric	(3)	0.019
	Sed-E	1	13	8	0.240	0.320	0.027	0.027	0.255	0.269	Nonparametric	(3)	0.027
	Sed-F	3	13	23	0.050	0.290	0.240	0.550	0.260	0.363	Nonparametric	(3)	0.363
	Sed-G	1	9	11	0.050	0.340	0.210	0.210	0.280	0.329	Nonparametric	(3)	0.210

Notes: Units are milligrams per kilogram for sediment and soil and micrograms per liter for surface water.

- 1 Methods used to calculate the UCL were based on the relative sample-size and detection frequency. Calculations of the UCL were only performed for PCBs with at least four sample results and at least one detection. Each of the methods used are summarized below (numbers in parentheses are the method codes listed in the table):
 - (1) Detection frequencies greater than or equal to 85 percent: calculations performed using EPA's ProUCL software package (EPA 2004). Censored (nondetect) values were replaced with one-half of the detection limit.
 - (2) Detection frequencies greater than or equal to 50 percent and less than 85 percent: flipped Kaplan-Meier method in accordance with Helsel (2005).
 - (3) Detection frequencies less than or equal to 25 percent: Monte Carlo methods in accordance with the "bounding" approach described in EPA (2002).
 - (4) No calculations performed for the UCL because there were fewer than four results. The EPC defaulted to the maximum detected concentration.
- 2 Nonparametric calculation based on the rank-ordered original measurements (censored data entered at the detection limit)
- 3 Tested for samples with at least five measurements and detection frequencies greater than or equal to 85 percent using the ProUCL software package (EPA 2004). All other distributions are considered nonparametric.

BK = Bank soil (Sections Pre-A, A, and C through F)
 EPA = U.S. Environmental Protection Agency
 EPC = Exposure point concentration, defined as the lesser of the UCL and the maximum detected concentration or the minimum detection limit in cases where all measurements were nondetect.
 FP = Floodplain soil (Sections Pre-A, A, and B)
 NA = Not applicable or not available
 PCB = Polychlorinated biphenyl
 RC43 = Richland Creek at the State Route 43 bridge (3-mile site)
 RCVP = Richland Creek at Vernal Pike (1-mile site)
 Sed = Sediment (Sections A through G)
 SW = Surface water
 UCL = One-sided upper confidence limit of the mean.

References

Helsel, D. 2005. *Nondetects and Data Analysis: Statistics for Censored Environmental Data*. John Wiley & Sons, Inc., New York, NY.
 U.S. Environmental Protection Agency (EPA). 2002. "Calculating Exposure Point Concentrations at Hazardous Waste Sites." OSWER 9285.6-10. Office of Emergency and Remedial Response. Washington, DC. December.
 EPA. 2004. "ProUCL Version 3.0 User Guide." Prepared by A. Singh, A.K. Singh, and R.W. Maichle for the EPA Technical Support Center, Las Vegas, NV. April.

APPENDIX C

RECEPTOR-SPECIFIC EXPOSURE, RISK, AND HAZARD CALCULATIONS

(Three Pages)

TABLE C-1

**FISH INGESTION EXPOSURES, RISKS, AND HAZARDS
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Location	Fish	PCB				TCDD TEQ				
		ADD	Hazard	LADD	Risk	ADD	Hazard	LADD	Risk	Risk _{EPA Alt}
Adult (18 or more years old)										
1 - Mile	Pelagic	7.8E-06	3.9E-01	3.3E-06	6.7E-06	1.5E-10	1.5E-01	6.4E-11	9.6E-06	6.4E-05
	Benthic	2.3E-05	1.2E+00	9.9E-06	2.0E-05	2.3E-10	2.3E-01	9.8E-11	1.5E-05	9.8E-05
3 - Mile	Pelagic	6.0E-06	3.0E-01	2.6E-06	5.1E-06	7.3E-11	7.3E-02	3.1E-11	4.7E-06	3.1E-05
	Benthic	6.3E-06	3.1E-01	2.7E-06	5.4E-06	7.9E-11	7.9E-02	3.4E-11	5.1E-06	3.4E-05
5.5 - Mile	Pelagic	--	--	--	--	--	--	--	--	--
	Benthic	8.4E-06	4.2E-01	3.6E-06	7.2E-06	1.4E-10	1.4E-01	6.2E-11	9.2E-06	6.2E-05
12.7 - Mile	Pelagic	1.2E-05	6.0E-01	5.2E-06	1.0E-05	--	--	--	--	--
	Benthic	1.4E-05	7.2E-01	6.2E-06	1.2E-05	--	--	--	--	--

Notes:

-- = Not calculated
 ADD = Average daily dose (mg/kg-day)
 LADD = Lifetime average daily dose (mg/kg-day)
 mg/kg-day = Milligram per kilogram per day
 PCB = Polychlorinated biphenyl
 TCDD = Tetrachloro-p-dioxin
 TEQ = Toxicity equivalent
 Risk_{EPA Alt} = U.S. Environmental Protection Agency's alternative TCDD slope factor (see Section 4.2.2).

TABLE C-2

**SURFACE WATER EXPOSURES, RISKS, AND HAZARDS
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Location	Chemical	Ingestion				Dermal Contact			
		ADD	Hazard	LADD	Risk	ADD	Hazard	LADD	Risk
Adult (18 or more years old)									
South Spring	PCB	6.4E-08	3.2E-03	2.7E-08	5.4E-08	5.8E-06	2.9E-01	2.5E-06	4.9E-06
North Spring	PCB	3.4E-08	1.7E-03	1.5E-08	2.9E-08	3.1E-06	1.6E-01	1.3E-06	2.7E-06
Pre-A	PCB	4.7E-08	2.4E-03	2.0E-08	4.0E-08	5.3E-06	2.7E-01	2.3E-06	4.5E-06
A	PCB	9.7E-09	4.9E-04	4.2E-09	8.3E-09	1.3E-06	6.5E-02	5.6E-07	1.1E-06
B	PCB	--	--	--	--	--	--	--	--
C	PCB	--	--	--	--	--	--	--	--
D	PCB	--	--	--	--	--	--	--	--
E	PCB	--	--	--	--	--	--	--	--
F	PCB	--	--	--	--	--	--	--	--
G	PCB	--	--	--	--	--	--	--	--
1 - Mile	PCB	1.1E-08	5.3E-04	4.5E-09	9.1E-09	2.1E-06	1.1E-01	9.1E-07	1.8E-06
3 - Mile	PCB	1.5E-08	7.6E-04	6.5E-09	1.3E-08	4.4E-06	2.2E-01	1.9E-06	3.8E-06
Youth (7 to 18 years old)									
South Spring	PCB	2.8E-07	1.4E-02	4.9E-08	9.7E-08	1.0E-05	5.0E-01	1.7E-06	3.4E-06
North Spring	PCB	1.5E-07	7.7E-03	2.6E-08	5.3E-08	5.4E-06	2.7E-01	9.2E-07	1.8E-06
Pre-A	PCB	2.1E-07	1.1E-02	3.6E-08	7.2E-08	1.1E-05	5.3E-01	1.8E-06	3.6E-06
A	PCB	4.3E-08	2.2E-03	7.4E-09	1.5E-08	2.8E-06	1.4E-01	4.8E-07	9.6E-07
B	PCB	--	--	--	--	--	--	--	--
C	PCB	--	--	--	--	--	--	--	--
D	PCB	--	--	--	--	--	--	--	--
E	PCB	--	--	--	--	--	--	--	--
F	PCB	--	--	--	--	--	--	--	--
G	PCB	--	--	--	--	--	--	--	--
1 - Mile	PCB	3.2E-08	1.6E-03	5.4E-09	1.1E-08	2.7E-06	1.4E-01	4.7E-07	9.4E-07
3 - Mile	PCB	4.5E-08	2.3E-03	7.8E-09	1.6E-08	5.8E-06	2.9E-01	1.0E-06	2.0E-06
Child (1 to 6 years old)									
South Spring	PCB	8.9E-07	4.5E-02	7.6E-08	1.5E-07	1.5E-05	7.4E-01	1.3E-06	2.5E-06
North Spring	PCB	4.8E-07	2.4E-02	4.1E-08	8.3E-08	8.0E-06	4.0E-01	6.9E-07	1.4E-06
Pre-A	PCB	6.6E-07	3.3E-02	5.7E-08	1.1E-07	1.9E-05	9.5E-01	1.6E-06	3.2E-06
A	PCB	1.4E-07	6.8E-03	1.2E-08	2.3E-08	4.7E-06	2.4E-01	4.0E-07	8.1E-07
B	PCB	--	--	--	--	--	--	--	--
C	PCB	--	--	--	--	--	--	--	--
D	PCB	--	--	--	--	--	--	--	--
E	PCB	--	--	--	--	--	--	--	--
F	PCB	--	--	--	--	--	--	--	--
G	PCB	--	--	--	--	--	--	--	--
1 - Mile	PCB	9.9E-08	4.9E-03	8.5E-09	1.7E-08	4.3E-06	2.2E-01	3.7E-07	7.4E-07
3 - Mile	PCB	1.4E-07	7.1E-03	1.2E-08	2.4E-08	9.8E-06	4.9E-01	8.4E-07	1.7E-06

Notes:

-- = Not calculated
 ADD = Average daily dose (mg/kg-day)
 LADD = Lifetime average daily dose (mg/kg-day)
 mg/kg-day = Milligram per kilogram per day
 PCB = Polychlorinated biphenyl

TABLE C-3

**SEDIMENT AND SOIL EXPOSURES, RISKS, AND HAZARDS
NEAL'S LANDFILL
BLOOMINGTON, MONROE COUNTY, INDIANA**

Location	Type		Ingestion				Dermal Contact			
		Chemical	ADD	Hazard	LADD	Risk	ADD	Hazard	LADD	Risk
Adult (18 or more years old)										
Pre-A	Bank Soil	PCB	1.9E-06	9.3E-02	8.0E-07	1.6E-06	1.0E-06	5.2E-02	4.5E-07	8.9E-07
	Floodplain Soil	PCB	6.7E-07	3.3E-02	2.9E-07	5.7E-07	3.7E-07	1.9E-02	1.6E-07	3.2E-07
A	Sediment	PCB	1.3E-07	6.7E-03	5.7E-08	1.1E-07	1.2E-07	5.9E-03	5.1E-08	1.0E-07
	Bank Soil	PCB	2.7E-07	1.3E-02	1.1E-07	2.3E-07	1.5E-07	7.5E-03	6.4E-08	1.3E-07
	Floodplain Soil	PCB	4.0E-07	2.0E-02	1.7E-07	3.4E-07	2.2E-07	1.1E-02	9.6E-08	1.9E-07
	Sediment	PCB	8.5E-09	4.3E-04	3.6E-09	7.3E-09	7.6E-09	3.8E-04	3.3E-09	6.5E-09
B	Floodplain Soil	PCB	6.5E-08	3.3E-03	2.8E-08	5.6E-08	3.7E-08	1.8E-03	1.6E-08	3.1E-08
	Sediment	PCB	--	--	--	--	--	--	--	--
C	Bank Soil	PCB	4.2E-09	2.1E-04	1.8E-09	3.6E-09	2.3E-09	1.2E-04	1.0E-09	2.0E-09
	Sediment	PCB	5.1E-09	2.5E-04	2.2E-09	4.3E-09	4.5E-09	2.3E-04	1.9E-09	3.9E-09
D	Bank Soil	PCB	--	--	--	--	--	--	--	--
	Sediment	PCB	7.2E-09	3.6E-04	3.1E-09	6.2E-09	6.4E-09	3.2E-04	2.8E-09	5.5E-09
E	Bank Soil	PCB	7.1E-08	3.6E-03	3.1E-08	6.1E-08	4.0E-08	2.0E-03	1.7E-08	3.4E-08
	Sediment	PCB	9.6E-08	4.8E-03	4.1E-08	8.2E-08	8.6E-08	4.3E-03	3.7E-08	7.3E-08
F	Bank Soil	PCB	--	--	--	--	--	--	--	--
	Sediment	PCB	5.6E-08	2.8E-03	2.4E-08	4.8E-08	5.0E-08	2.5E-03	2.1E-08	4.3E-08
G	Bank Soil	PCB	--	--	--	--	--	--	--	--
Youth (7 to 18 years old)										
Pre-A	Bank Soil	PCB	8.3E-06	4.2E-01	1.4E-06	2.8E-06	5.1E-06	2.5E-01	8.7E-07	1.7E-06
	Floodplain Soil	PCB	3.0E-06	1.5E-01	5.1E-07	1.0E-06	1.8E-06	9.2E-02	3.1E-07	6.3E-07
	Sediment	PCB	5.9E-07	3.0E-02	1.0E-07	2.0E-07	2.3E-06	1.1E-01	3.9E-07	7.7E-07
	Bank Soil	PCB	1.2E-06	6.0E-02	2.1E-07	4.1E-07	7.3E-07	3.7E-02	1.3E-07	2.5E-07
A	Floodplain Soil	PCB	1.8E-06	9.0E-02	3.1E-07	6.2E-07	1.1E-06	5.5E-02	1.9E-07	3.8E-07
	Sediment	PCB	2.5E-08	1.3E-03	4.3E-09	8.7E-09	9.6E-08	4.8E-03	1.6E-08	3.3E-08
B	Floodplain Soil	PCB	1.9E-07	9.7E-03	3.3E-08	6.7E-08	1.2E-07	6.0E-03	2.0E-08	4.1E-08
	Sediment	PCB	--	--	--	--	--	--	--	--
C	Bank Soil	PCB	1.2E-08	6.2E-04	2.1E-09	4.3E-09	7.6E-09	3.8E-04	1.3E-09	2.6E-09
	Sediment	PCB	1.5E-08	7.5E-04	2.6E-09	5.2E-09	5.7E-08	2.9E-03	9.8E-09	2.0E-08
D	Bank Soil	PCB	--	--	--	--	--	--	--	--
	Sediment	PCB	2.1E-08	1.1E-03	3.7E-09	7.3E-09	8.1E-08	4.1E-03	1.4E-08	2.8E-08
E	Bank Soil	PCB	2.1E-07	1.1E-02	3.6E-08	7.3E-08	1.3E-07	6.5E-03	2.2E-08	4.5E-08
	Sediment	PCB	2.9E-07	1.4E-02	4.9E-08	9.8E-08	1.1E-06	5.4E-02	1.9E-07	3.7E-07
F	Bank Soil	PCB	--	--	--	--	--	--	--	--
	Sediment	PCB	1.7E-07	8.3E-03	2.9E-08	5.7E-08	6.3E-07	3.2E-02	1.1E-07	2.2E-07
G	Bank Soil	PCB	--	--	--	--	--	--	--	--
Child (1 to 6 years old)										
Pre-A	Bank Soil	PCB	2.6E-05	1.3E+00	2.2E-06	4.5E-06	8.7E-06	4.3E-01	7.4E-07	1.5E-06
	Floodplain Soil	PCB	9.4E-06	4.7E-01	8.0E-07	1.6E-06	3.1E-06	1.6E-01	2.7E-07	5.3E-07
	Sediment	PCB	1.9E-06	9.3E-02	1.6E-07	3.2E-07	3.5E-06	1.7E-01	3.0E-07	6.0E-07
	Bank Soil	PCB	3.7E-06	1.9E-01	3.2E-07	6.4E-07	1.2E-06	6.2E-02	1.1E-07	2.1E-07
A	Floodplain Soil	PCB	5.6E-06	2.8E-01	4.8E-07	9.6E-07	1.9E-06	9.4E-02	1.6E-07	3.2E-07
	Sediment	PCB	7.9E-08	4.0E-03	6.8E-09	1.4E-08	1.5E-07	7.4E-03	1.3E-08	2.5E-08
B	Floodplain Soil	PCB	6.1E-07	3.1E-02	5.2E-08	1.0E-07	2.0E-07	1.0E-02	1.7E-08	3.5E-08
	Sediment	PCB	--	--	--	--	--	--	--	--
C	Bank Soil	PCB	3.9E-08	1.9E-03	3.3E-09	6.7E-09	1.3E-08	6.5E-04	1.1E-09	2.2E-09
	Sediment	PCB	4.7E-08	2.4E-03	4.0E-09	8.1E-09	8.8E-08	4.4E-03	7.6E-09	1.5E-08
D	Bank Soil	PCB	--	--	--	--	--	--	--	--
	Sediment	PCB	6.7E-08	3.4E-03	5.7E-09	1.1E-08	1.3E-07	6.3E-03	1.1E-08	2.1E-08
E	Bank Soil	PCB	6.7E-07	3.3E-02	5.7E-08	1.1E-07	2.2E-07	1.1E-02	1.9E-08	3.8E-08
	Sediment	PCB	8.9E-07	4.5E-02	7.7E-08	1.5E-07	1.7E-06	8.4E-02	1.4E-07	2.9E-07
F	Bank Soil	PCB	--	--	--	--	--	--	--	--
	Sediment	PCB	5.2E-07	2.6E-02	4.5E-08	8.9E-08	9.7E-07	4.9E-02	8.4E-08	1.7E-07
G	Bank Soil	PCB	--	--	--	--	--	--	--	--

Notes:

-- = Not calculated
 ADD = Average daily dose (mg/kg-day)
 LADD = Lifetime average daily dose (mg/kg-day)
 mg/kg-day = Milligram per kilogram per day
 PCB = Polychlorinated biphenyl