APPENDIX A

SITE-SPECIFIC AQUATIC WILDLIFE SCREENING LEVEL EXPOSURE EVALUATION

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A.1 INTRODUCTION

The following sections present the methodology and results of the risk assessment for benthic invertebrates and fish in Turkey Creek. The benthic invertebrate community lives in constant and direct contact with sediment and, therefore, may be directly impacted by the constituents of concern (COCs). Benthic invertebrates have vital functions within the ecosystem, including serving as a prey base for higher trophic level organisms and cycling of nutrients. The fish community lives in constant and direct contact with surface water. Indirect exposures are also possible via interaction with sediment and through the food web. The fish community dominates the aquatic ecosystem, in terms of biomass, and small- to medium-sized fish serve as a prey base for mature aquatic-feeding wildlife.

Risk to aquatic species was evaluated using measured concentrations of PAHs and dioxins in surface sediment, pore water and surface water. Analyses of concentrations in benthic invertebrate tissue and whole fish provided an additional line of evidence in the exposure assessment.

A.2 PAHs EVALUATION

Potential risk to benthic invertebrates from sediment and pore water was evaluated using the Equilibrium Partitioning Sediment Benchmark (ESB) toxic units approach (EPA 2009). Final Chronic Values (FCV) for PAHs were derived using the National Water Quality Criteria (WQC) Guidelines as the toxicity endpoints. The FCVs are chemical concentrations in water that are protective of the presence of aquatic life.

A.2.1 SEDIMENT EVALUATION

ESB Toxic Units Procedure

Sediment and pore water samples were collected from locations 1 through 10 in November and December 2009. An additional 50 sediment samples were collected in the biologically active zone (0 to 1 foot below the creek bottom) to delineate PAHs around the location 5 and 6 area where evidence of NAPL was observed. The ESB toxic units for PAHs are determined as follows:

$C_{OC,PAHi,MAXi}$ = organic carbon normalized maximum sediment concentration of a PAH, provided in *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures* (EPA, 2003)

Organic carbon normalized sediment concentration $C_{OC,PAHi}$ (ug/kg) = PAHi (ug/kg) x 1 kg/1000g x fraction total organic carbon (TOC)

$$ESBTU_{FCV} = \sum \frac{C_{OC,PAHi}}{C_{OC,PAHi,MAXi}}$$

Toxicity to benthic invertebrates is considered possible if the sum of toxic units of the PAH_{34} exceeds 1.0 (EPA 2003).

Total Organic Carbon

A total of seven (7) samples in the 0 to 1 foot interval were tested for percent total organic carbon in the areas of Locations 5 and 6.

Sample Location	**TOC %**
TC-SED-5 (0.5-1.0)	3.138
TC-SED-5 Dup (0.5-1.0)	2.933
TC-SED-6WV (0-0.75)	0.112
TC-SED-6VV (0-1)	0.368
TC-SED-6TV (0-0.5)	0.173
TC-SED-6QV (0-1)	1.560
TC-SED-6 (0.5-1.0)	0.185
Average	**1.210**

The average of the TOCs were used in the calculation of organic carbon normalized sediment concentrations.

Uncertainty Factor Calculation

"Total PAHs" required for deriving the ESB for PAH mixtures is defined as the sum of the $ESBTU_{FCV}$ values for a minimum of the 34 PAHs (EPA, 2003). The use of fewer than 34 PAHs may underestimate the total toxicological contribution of the PAH mixtures. As an alternative to measuring all PAHs, it may be possible to estimate the total PAH concentration in sediments using a subset including the commonly measured PAHs. During the second phase of the investigation, only 17 PAHs were analyzed in sediment due to time and cost constraints; therefore, the sediment and pore water data from locations 1 through 10 were used to calculate a site-specific uncertainty factor to account for the contribution of additional PAH compounds.

The sediment and pore water sampling results for PAH_{34} and PAH_{17} at locations 1 through 10 were compared as follows:

Sediment Comparison:

LOCATION	TOTAL PAHs (17) ug/kg	TOTAL PAHs (35) ug/kg	TOXIC UNITS 17 PAHs	TOXIC UNITS 35 PAHs	% DIFF	FACTOR
TC-SED-1	70.8	89.5	0.0266	0.0334	25.5%	1.25
TC-SED-2	117.7	217.6	0.0839	0.1461	74.0%	1.74
TC-SED-3	323.9	474.9	0.0662	0.0970	46.5%	1.46
TC-SED-4	215.2	332.7	0.1030	0.1579	53.3%	1.53
TC-SED-5	1124	1731	0.0441	0.0682	54.7%	1.55
TC-SED-5 Dup	946.5	1448.5	0.0407	0.0617	51.8%	1.52
TC-SED-6	494	835.9	0.3626	0.6071	67.4%	1.67
TC-SED-7	83.1	104	0.0943	0.1160	23.1%	1.23
TC-SED-8	140.5	210.5	0.0692	0.0999	44.3%	1.44
TC-SED-9	90.6	111.5	0.0530	0.0639	20.5%	1.21
TC-SED-10	316.9	460.2	0.1456	0.2050	40.8%	1.41
MAXIMUM					**74.0%**	**1.74**

Pore Water Comparison:

LOCATION	TOTAL PAHs (17) ug/L	TOTAL PAHs (35) ug/L	TOXIC UNITS 17 PAHs	TOXIC UNITS 35 PAHs	% DIFF	FACTOR
TC-PW-1	0.645	0.849	0.0499	0.0779	56.2%	1.56
TC-PW-2	0.269	0.381	0.0104	0.0242	131.6%	2.32
TC-PW-3	23.044	24.033	0.5185	0.6652	28.3%	1.28
TC-PW-3 Dup	22.169	23.107	0.4970	0.6320	27.2%	1.27
TC-PW-4	3.788	4.721	0.2546	0.3812	49.8%	1.50
TC-PW-5	1.15	1.468	0.1264	0.1803	42.7%	1.43
TC-PW-6	4973.2	7200.8	495.79	919.27	85.4%	1.85
TC-PW-6A	146.86	224.96	10.17	18.11	78.1%	1.78
TC-PW-6B	1.936	2.028	0.0528	0.0706	33.6%	1.34
TC-PW-7	5.858	8.674	0.2509	0.5312	112%	2.12
TC-PW-8	1.791	2.302	0.2244	0.3174	41.5%	1.41
TC-PW-9	9.712	10.349	0.6308	0.7619	20.8%	1.21
TC-PW-10	0.693	0.982	0.0652	0.1030	58.0%	1.58
MAXIMUM					**132%**	**2.32**

Location PW-2 exhibited the largest difference in toxic units between the PAH_{17} and PAH_{34} of 132%. Adding a safety factor of 20 percent yields a site-specific uncertainty factor of 2.8.

Sediment Toxic Unit Results

All sum of toxic units results for samples collected within the 0-1 foot interval during the investigation to delineate PAHs around Locations 5 and 6 were multiplied by the 2.8 uncertainly

factor. The toxic units calculation is provided in Table A-1, a summary of the results is provided as follows:

LOCATION	DEPTH (FT)	TOXIC UNITS	TU x 2.8 FACTOR
Original Samples			
TC-SED-5	0.5-1	0.177	NA
TC-SED-5 Dup	0.5-1	0.150	NA
TC-SED-6	0.5-1	0.093	NA
Additional Samples			
TC-SED-5A	0-1	0.153	0.428
TC-SED-5B	0-1	0.000	0.000
TC-SED-5C	0.5-1	0.033	0.091
TC-SED-5DV	0.5-1	0.030	0.085
TC-SED-6A	0.5-1	0.000	0.000
TC-SED-6A	0-0.5	0.000	0.000
TC-SED-6B	**0.5-1**	**1.331**	**3.726**
TC-SED-6B	**0-0.5**	**0.764**	**2.138**
TC-SED-6BV	0-1	0.224	0.627
TC-SED-6C	**0.4-0.75**	**1.178**	**3.297**
TC-SED-6C	**0-0.4**	**118.075**	**330.610**
TC-SED-6C	**0-1**	**162.628**	**455.358**
TC-SED-6CV	0-0.7	0.000	0.000
TC-SED-6D	0-0.75	0.000	0.000
TC-SED-6DV	0-1	0.000	0.000
TC-SED-6F	**0-1**	**119.475**	**334.531**
TC-SED-6FV2	**0-0.25**	0.110	0.309
TC-SED-6FV2	**0.25-0.5**	**0.651**	**1.824**
TC-SED-6GV2	0-1	0.000	0.000
TC-SED-6H	**0.5-1**	**20.135**	**56.378**
TC-SED-6H	**0-0.5**	**15.191**	**42.534**
TC-SED-6I	**0.5-1**	**20.750**	**58.101**
TC-SED-6I	**0-0.5**	**2.731**	**7.647**
TC-SED-6J	0.5-1	0.035	0.099
TC-SED-6J	0-0.5	0.083	0.234
TC-SED-6K	0.5-1.2	0.296	0.828
TC-SED-6K	0-0.5	0.000	0.000
TC-SED-6L	0.7-1.2	0.000	0.000
TC-SED-6L	0-0.7	0.000	0.000
TC-SED-6LV	0-1	0.006	0.016
TC-SED-6OV	0-1	0.000	0.000
TC-SED-6PV2	0-1	0.058	0.164
TC-SED-6EP	0-0.25	0.000	0.000
TC-SED-6QV	0-1	0.015	0.043
TC-SED-6RV	0-1	0.163	0.458
TC-SED-6SV	0-1	0.375	1.050
TC-SED-6TV	0-1	0.011	0.032
TC-SED-6VV	0-1	0.044	0.122
TC-SED-6W	0.5-1.5	0.000	0.000

LOCATION	DEPTH (FT)	TOXIC UNITS	TU x 2.8 FACTOR
TC-SED-6W	0-0.5	0.000	0.000
TC-SED-6WV	**0-0.75**	**1.486**	**4.161**
TC-SED-6WV2	**0-1**	**2.420**	**6.775**
TC-SED-6XV	**0-1.25**	**36.854**	**103.190**
TC-SED-6YV	0-1	0.005	0.014
TC-SED-6YV2	**0-0.5**	**0.678**	**1.898**
TC-SED-6ZV	0-1	0.023	0.063

As shown on the table, 16 samples at 9 locations have a sum of toxic units value exceeding 1. The sample locations, as well as locations where a sheen was observed in sediment encompasses an area of approximately 4,000 square feet.

A.2.2 PORE WATER EVALUATION

The method for determining the total PAH toxic units in pore water samples is as follows:

$$ESBTU_{FCV} = \sum \frac{PAHi\ (ug/L)}{FCVi\ (ug/L)}$$

Where,

FCVi = chemical-specific Final Chronic Value

The sum of toxic units calculations are provided in Table A-1, a summary of the results for pore water are provided below.

Pore Water Sample	Total PAH Toxic Units
TC-PW-1	0.08
TC-PW-2	0.02
TC-PW-3	0.67
TC-PW-3 Dup	0.63
TC-PW-4	0.38
TC-PW-5	0.18
TC-PW-6	919.27
TC-PW-6A	18.11
TC-PW-6B	0.07
TC-PW-7	0.53
TC-PW-8	0.32
TC-PW-9	0.76
TC-PW-10	0.10

As with sediment, toxicity to benthic invertebrates is considered possible if the sum of toxic units of the PAH_{34} exceeds 1.0. The sum of toxic units for two samples showing the highest total PAH values (TC-PW-6 and TC-PW-6A) exceeded one.

A.2.3 WHOLE FISH AND RANGIA TISSUE

Samples of whole fish and the clam ((*Rangia cuneata*) were collected and analyzed as part of this screening risk evaluation because they may serve as food for wildlife in the area. *Rangia* tissue was evaluated because this species is a good representative of benthic organisms, it is plentiful in the creek, and the samples are easy to collect. Fish species used in the evaluation include largemouth bass (*Micropterus salmoides*), pumpkinseed bream (*Lepomis gibbosus*), channel catfish (*Ictalurus punctatus*), hogchoker (*Trinectes maculatus*), pogie (*Brevoortia patronus*), striped mullet *(Mugil cephalus),* orangespotted sunfish (*Lepomis humilis*), and mosquitofish (*Gambusia affinis).* Because the primary objective of the fish analyses was to evaluate exposure to mammals and avian receptors (described in Appendix B), the analyses included whole fish.

In *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures* (2003) EPA determined a concentration of 2.24 micromoles total PAHs per gram lipid (umol/g lipid) is an "acceptable" tissue concentration which provides the same level of protection as an FCV. Tissue PAH concentrations in Rangia and fish were converted from wet weight umol/g lipid using the following:

$$\sum \text{Concentration (umol/g lipid)} = \frac{\text{Concentration in Tissue (ug/kg)}}{\text{Molecular weight (g/mol) x fraction lipid x 1000}}$$

The calculations are provided on Table A-3. The sum of the whole fish and clam tissue concentrations is summarized as follows:

Species	Sample ID	Sum of umol PAHs/g lipid
Largemouth Bass (*Micropterus salmoides*)	BASS-1	0.00985
Pumpkinseed Bream *(Lepomis gibbosus)*	BREAM-1	0.0206
Pumpkinseed Bream *(Lepomis gibbosus)*	BREAM-3	0.0188
Channel Catfish (*Ictalurus punctatus)*	CATFISH-1	0.00555
Hogchoker (*Trinectes maculatus*)	HOG-1	0.0151
Pogie (*Brevoortia patronus*)	POGEY-1	0.024
Pogie (*Brevoortia patronus*)	POGEY-3	0.0192
Pogie (*Brevoortia patronus*)	POGEY-4	0.021
Hogchoker (*Trinectes maculatus*), Striped Mullet *(Mugil cephalus),* Orangespotted Sunfish (*Lepomis humilis*)]	Comp-1	0.25
Comp-2 [Largemouth Bass (*Micropterus salmoides*), Orangespotted Sunfish (*Lepomis humilis*), Mosquitofish (*Gambusia affinis)*]	Comp-2	0.173

Species	Sample ID	Sum of umol PAHs/g lipid
Clam (*Rangia cuneata*)	TC-RG-11	0.0824
	TC-RG-12	0.0419
	TC-RG-13	0.0573
	TC-RG-14	0.0441

The sum of PAHs included used the full value of the reporting limit for non-detects. As indicated on the table, the concentrations of PAHs in whole fish and clams are below the acceptable tissue concentration of 2.24 umol/g lipid proposed in the EPA guidance.

A.3 DIOXIN EVALUATION

The sediment, pore water, surface water and aquatic wildlife tissue results were calculated using the toxic equivalent (TEQ) approach. A TEQ is developed for each sample as the sum of the dioxin-like toxicity of the dioxin/furan congeners to yield a single concentration equivalent to the toxicity of a similar concentration of 2,3,7,8-TCDD.

Within the TEQ method, each dioxin compound is assigned a Toxic Equivalency Factor, or TEF (see the table below). This factor denotes a given dioxin compound's toxicity relative to 2,3,7,8-TCDD, which is assigned the maximum toxicity designation of one. Other dioxin compounds are given equal or lower numbers, with each number roughly proportional to its toxicity relative to that of 2,3,7,8-TCDD. Developed by the World Health Organization, TEFs are used extensively by scientists and governments around the world. The dioxin TEQs were calculated as follows:

$TEQ = SUM(TEF_i[Congener]_i)$

The following World Health Organization Toxic Equivalency Values (WHO TEFs) were used:

ANALYTE	FISH TEQ[(1)]
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.5
1,2,3,6,7,8-HxCDD	0.01
1,2,3,7,8,9-HxCDD	0.01
1,2,3,4,6,7,8-HpCDD	0.001
OCDD	0.0001
2,3,7,8-TCDF	0.05
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1

ANALYTE	FISH TEQ(1)
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001

(1) Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. M Van den Berg, et al., 1998

The dioxin results have been expressed as dioxin 2,3,7,8-TCDD TEQs setting the value of non-detected constituents to zero and half the detection limit. The TEQ calculations for sediment, pore water, surface water and biota are provided in Tables A-4 through A-7. A discussion of the results is provided in the following sections.

A.3.1 SEDIMENT SCREENING

TEQ values were calculated using the TEFs for fish on the sediment samples collected in November 2009. The TEQs using zero for non-detects are compared to the values calculated using ½ the detection limit. The complete results are presented in Table A-4, the TEQs are summarized below.

The resulting TEQ values were compared to the 60 ng/kg screening level presented in the EPA 1993 *Interim Report on Data and Methods for Assessment of 2,3,7,8-tetrachlorodibenzo-p-dioxin Risks to Aquatic Life and Associated Wildlife (EPA/600/R-93/055)* as follows:

Sample Location	TEQ - Half Detection Limit	TEQ - Zero for Non-Detects
	ng/kg	
TC-SED-1	1.52	1.45
TC-SED-2	0.64	0.51
TC-SED-3	2.14	2.13
TC-SED-4	0.42	0.30
TC-SED-5	6.97	6.79
TC-SED-5 Dup	2.50	2.16
TC-SED-6	0.68	0.54
TC-SED-7	0.66	0.54
TC-SED-8	2.05	1.99
TC-SED-9	0.73	0.63
TC-SED-10	2.43	2.42
Fish Screening	**60**	

As indicated on the table above, none of the recalculated TEQs using half the detection limited exceeded the EPA screening level of 60 ng/kg.

A.3.2 CREEK WATER SCREENING

EPA Region 4 Ecological Screening Guidance (EPA 2001) provides a chronic screening value of 10 pg/L for 2,3,7,8-TCDD (dioxin) in surface water. The following sections present an evaluation of pore water and surface water data to evaluate the potential impact to fish.

A.3.2.1 Pore Water

The following table presents the TEQ values calculated using the TEFs for fish on the pore water samples collected in November 2009. The TEQs using zero for non-detects are compared to the values calculated using ½ the detection limit. The complete results are presented in Table A-5, the TEQs are summarized as follows:

Sample Location	TEQ - Half Detection Limit	TEQ - Zero for Non-Detects
	pg/L	
TC-PW-1	0.72	0.01
TC-PW-2	1.12	0.35
TC-PW-3	0.96	0.21
TC-PW-3 Dup	0.96	0.14
TC-PW-4	0.39	0.06
TC-PW-5	0.42	0.03
TC-PW-6A	1.17	0.33
TC-PW-6B	3.23	0.06
TC-PW-7	0.38	0.02
TC-PW-8	0.36	0.02
TC-PW-9	2.15	0.60
TC-PW-10	0.49	0.02

As shown on the table, the highest calculated TEQ is 3.23 pg/L, below the EPA Region 4 ecological chronic screening value of 10 pg/L for 2,3,7,8-TCDD (dioxin).

A.3.2.2 Surface Water

The following table presents the TEQ values calculated using the TEFs for fish on the surface water samples collected in June 2010. The TEQs using zero for non-detects are compared to the values calculated using ½ the detection limit. The complete results are presented in Table A-6, the TEQs are summarized as follows:

Sample Location	TEQ - Half Detection Limit	TEQ - Zero for Non-Detects
	pg/L	
TC-SW-11	1.17	0.12
TC-SW-12	0.98	0.11
TC-SW-13	1.47	0.10
TC-SW-14	2.87	2.01
TC-SW-15	1.15	0.11

As shown on the table, the highest calculated TEQ is 2.87 pg/L, below the EPA Region 4 ecological chronic screening value of 10 pg/L for 2,3,7,8-TCDD (dioxin). Note that sample TC-SW-14 was west of the Washington Street/Rippy Road Bridge over Turkey Creek, upstream of the facility.

A.3.3 TISSUE TEQ CALCULATIONS

The following table presents the 2,3,7,8-TCDD (dioxin) TEQ values calculated using the TEFs for fish on the clam tissue and whole fish samples collected in June and July 2010. The TEQs calculated using zero for non-detects are compared to the values calculated using ½ the detection limit. The complete results are presented in Table A-7, the TEQs are summarized as follows:

SAMPLE ID	Half Detection Limit	Zero for Non-Detects	Area Collected
	ng/kg		
TC-RG-11 6/24/2010	0.15	0.0092	Mouth of Creek
TC-RG-12 6/24/2010	0.20	0.053	Location 6 Area
TC-RG-13 6/24/2010	0.17	0.005	Location 2 Area
TC-RG-14 7/21/2010	0.79	0.76	West of Bridge Upstream
Comp-1 7/9/2010	0.091	0.023	Specimens Collected Across Entire Area
Comp-2 7/9/2010	0.18	0.14	Specimens Collected Across Entire Area
BREAM-2 7/20/2010	1.29	1.19	Composite of Specimens from Location 6 to Mouth of Creek
POGEY-2 7/20/2010	1.26	1.24	Mouth of Turkey Creek
CATFISH-1 7/21/2010	10.17	10.12	West of Bridge Upstream

Dioxin TEQs in fish ranged from 0.091 (onsite composite) to 10.17 ng/kg (upstream catfish). The highest dioxin TEQ in Rangia was collected from location TC-TG-14, west of the Washington Street/Rippy Road Bridge over Turkey Creek, upstream of the facility.

In addition, these values were used to estimate the intake of dioxins via food consumption for the avian and mammalian wildlife exposure evaluation.

TABLES