while exceedences of the chronic LOAEL effect level indicates adverse effects are likely to this species.

2.4.16 Avian Terrestrial Omnivore Survival, Reproduction, and Growth

The American robin inhabits forested areas but prefers to forage in open areas containing herbaceous vegetation. The diet of the robin varies seasonally but includes a high proportion of vegetation (primarily seeds and fruits which is disperses) as well as animal matter (invertebrates such as insects and worms). Home ranges are also fairly small for the robin. The American robin represents a ground-feeding avian omnivorous species that might be exposed to site contaminants that accumulate in both plants and invertebrates. Estimated contaminant exposure doses will be compared to chronic survival, reproductive, or growth effect levels (NOAELs and LOAELs) reported in the literature. Exccedences of the chronic NOAEL effect levels indicate effects are possible to individuals while exceedences of the chronic LOAEL effect level indicates adverse effects are likely to this species.

3.0 ANALYSIS

The analysis component of the risk assessment consists of assessing the exposure of the selected measurement receptors to the COCs (Exposure Assessment) and determining the toxicity of the COCs to the receptors (Toxicity Assessment).

3.1 Exposure Assessment

Exposure represents the contact (including ingestion) of a measurement receptor with a COC through the various exposure pathways identified in Section 2.4. Exposure to community measurement receptors (i.e., aquatic water invertebrates, fish, benthic invertebrates and amphibian larvae) is simply represented by the concentrations of COCs within the media of concern that the particular community inhabits. Surface water (dissolved and total) and sediment contaminant concentrations (mean and maximum) are provided in Attachment I. These concentrations are assumed to represent exposure point concentrations for these community receptors.

Exposure to contaminants via the food chain is evaluated by modeling exposure to the selected indicator species or measurement receptors (kingfisher, mink, Canada goose, muskrat, meadow vole, spotted sandpiper, little brown bat, green frog, woodcock, short-tailed shrew, mallard, raccoon, deer mouse and robin). The exposure scenarios developed in the Problem Formulation place measurement receptors within exposure pathways that are most likely to contribute to contaminant intake.

The belted kingfisher and mink may be exposed to contaminants that have bioaccumulated within fish and large macroinvertebrates. The Canada goose, muskrat and meadow vole may be exposed to soil contaminants through direct ingestion and through consumption of vegetation that have accumulated contaminants through plant uptake. The spotted sandpiper, little brown bat, short-tailed shrew and American woodcock may consume contaminants directly through soil ingestion or indirectly via the consumption of invertebrates that are in direct contact with contaminated soil. The mallard, raccoon, deer mouse and American robin would be exposed to site contaminants through the ingestion of both vegetation and invertebrates that are in direct contact with contaminated soil. The purpose of the exposure assessment is to formulate these exposure pathways into algorithms that can predict an estimate of total exposure.

The methods and calculations required for quantification of exposure doses are described within this section. Exposure to contaminants at the site by the selected indicator species is estimated by the following equation:

$$ED = [(S_{conc} \times S_{diet}) + (P_{conc} \times P_{diet}) + (I_{conc} \times I_{diet}) + (F_{conc} \times F_{diet})] (FIR) (AUF) + (W_{con})(WIR)(AUF)$$

Where:

ED	=	Exposure Dose (mg/kg-body weight-day);
S_{conc}	=	Soil (or sediment) contaminant concentration (mg/kg);
S_{diet}	=	% of diet soil comprises;
P_{conc}	=	Plant contaminant concentration (mg/kg);
P_{diet}	=	% of diet plants comprise;
I_{conc}	=	Invertebrate contaminant concentration (mg/kg);
I_{diet}	=	% of diet invertebrates comprise;
F_{conc}	=	Fish contaminant concentration (mg/kg);
F_{diet}	=	% of diet fish comprise;
FIR	=	Food ingestion rate (kg/kg-body weight-day);
W_{con}	=	Surface water (total) contaminant concentration (mg/L);
WIR	=	Water ingestion rate (L/kg BW-day); and,
AUF	=	Area use factor (% of home range comprised of habitat evaluated).

Dietary information for each of the 14 measurement receptor species was generally obtained from U.S. EPA Wildlife Exposure Factors Handbook (U.S. EPA, 1993a) or, for the little brown bat, from Sample et al. (1997). Specifically, food and water ingestion rates, dietary composition (relative percentage of vegetation, invertebrates, and/or fish in the diet as well as soil/sediment ingestion rates) and home ranges were obtained from these sources. Model inputs for the measurement receptor species are presented in Table 9.

3.1.1 COC Concentrations in Plants

Concentrations of COCs in vegetation were determined by multiplying the mean and maximum soil/sediment concentrations by an appropriated plant uptake factor. Plant uptake factors for organic constituents were derived from Travis and Arms (1988) and from Baes et al. (1984) for inorganic constituents. Plant uptake bioaccumulation factors are presented in Attachment II. Additionally, plant COC concentrations were converted from a dry weight to a wet weight basis since the food ingestion rates are based on wet weight. A conversion factor of 0.1 was used based on plants containing 90 percent water content (Baes et al., 1984).

Table 9. Model Inputs for Selected Measurement Receptor Species – Pownal Tannery Study Area

Measurement Receptors	Ingestion Rate - Food (kg/kg BW-day)	Ingestion Rate - Water (kg/kg BW-day)	Soil/Sediment % Diet	Vegetation % Diet	Invertebrates % Diet	Fish % Diet	AUF Pond	AUF Seeps/ Meadow	AUF Lagoons (Aquat.)	AUF Lagoons (Terrest.)	AUF River
Belted Kingfisher	0.5	0.11	0	0	41	59	0.5	n/a	n/a	n/a	1.0
Mink	0.22	0.11	1	1	13	85	0.2	n/a	n/a	n/a	1.0
Canada Goose	0.033	0.037	8.2	91.8	0	0	0.04	n/a	0.02	n/a	0.2
Muskrat	0.34	0.098	3	97	0	0	1.0	n/a	1.0	n/a	1.0
Meadow Vole	0.35	0.21	2.4	97.6	0	0	n/a	1.0	n/a	1.0	n/a
Spotted Sandpiper	0.68	0.17	18.1	0	81.9	0	1.0	n/a	1.0	n/a	1.0
Little Brown Bat	1.12	0.16	0	0	100	0	0.4	n/a	0.2	n/a	1.0
American Woodcock	0.77	0.1	10.4	9.9	80.5	0	n/a	0.3	n/a	1.0	n/a
Short-tailed Shrew	0.62	0.223	8.6	12.8	78.6	0	n/a	1.0	n/a	1.0	n/a
Mallard	0.23	0.058	1	24.8	74.2	0	0.04	n/a	0.02	n/a	0.2
Raccoon	0.19	0.083	9.4	53.2	37.4	0	0.3	n/a	0.2	n/a	1.0
Deer Mouse	0.45	0.34	1	41	58	0	n/a	1.0	n/a	1.0	n/a
American Robin	1.52	0.14	2.5	43.5	54	0	n/a	1.0	n/a	1.0	n/a

Notes: AUFs based on following home range requirements and following approximate sizes of habitat types:

Landfill Pond: 3.6 acres
Landfill Seeps/Wet Meadow: 3.5 acres
Lagoon (Aquatic): 2.1 acres
Lagoon (Terrestrial): 16.2 acres
Hoosic River: 1.6 miles (20 acres)

Belted Kingfisher: 0.5 miles
Mink: 19.5 ac.
Canada Goose: 100 ac.
Muskrat: 0.4 ac.
Meadow Vole: 0.02 ac.
Spotted Sandpiper: 0.6 ac.
Little Brown Bat: 10.0 ac. (est.)

American Woodcock: 11.2 ac.
Short-tailed Shrew: 1.0 ac.
Mallard: 100 ac.
Raccoon: 13.25 ac.
Deer Mouse: 0.25 ac.
American Robin: 0.4 ac.

3.1.2 COC Concentrations in Invertebrates

The transfer of soil and sediment non-ionic organic COCs into the tissues of terrestrial and aquatic invertebrates was based on a model in which these constituents are partitioned between soil/sediment organic carbon and tissue lipids (Markwell et al., 1989; Menzie et al., 1992). COC uptake into invertebrate tissue for organic constituents is directly related to the ratio of insect lipid content (four percent; Roeder, 1953) and the fraction of organic carbon in soil/sediment as well as the octanol-water partitioning coefficient of each COC. Bioaccumulation factors for invertebrates present within each of the habitats assessed are presented in Attachment II.

The concentrations of inorganic COCs within invertebrate tissues were determined from previously reported bioaccumulation factors for earthworm's (soil) and benthic invertebrates (sediment). Uptake factors (90^{th} percentile) reported in Sample et al. (1998) were used to determine terrestrial invertebrate concentrations of inorganic COCs while biota-sediment accumulation factors (BSAFs) reported in Bechtel Jacobs (1998) were used to calculate benthic invertebrate concentrations. The inorganic invertebrate bioaccumulation factors are presented in Attachment II. Similar to the dry weight:wet weight conversion conducted for plants, invertebrate COC concentrations for both organic and inorganic constituents were converted from a dry weight to a wet weight basis since the food ingestion rates are based on wet weight. A conversion factor of 0.25 was used (Beyer and Gish, 1980).

3.1.3 COC Concentrations in Fish

Biota-sediment accumulation factors (BSAFs) represent transfer coefficients that describe the relationship between contaminants in biota and sediment. Fish BSAFs represent the contaminant concentration in fish (normalized by lipid content of the fish) to the concentration of the contaminant in the sediment (normalized by organic carbon content of the sediment). The BSAFs are only applicable to nonionic organic contaminants. BSAFs used to derive fish tissue concentrations for organic COCs were obtained from U.S. EPA (1997b) and are presented in Attachment II.

Fish BSAFs for inorganic COCs are not available in the literature. Fish tissue concentrations for inorganic COCs were derived by applying a fish bioconcentration factor (BCF) to filtered (i.e., dissolved) surface water inorganic concentrations as detailed in U.S. EPA (1999a). BCFs were first obtained from U.S. EPA (1999a) if available, and then from Barnthouse et al. (1988). The BCFs for fish are presented in Attachment II.

3.1.4 Exposure Doses

Exposure doses to each of the 14 indicator species were estimated using the model parameters presented in Table 9 and contaminant concentrations (mean and maximum) presented in Attachment I for media of concern. Mean and maximum total exposure doses are presented in Attachment II.

3.2 Toxicity Assessment

Toxicity of COCs is assessed by the selection of appropriate toxicity reference values (TRVs) for each of the measurement receptors. Community-level TRVs are media specific (i.e., concentration in surface water or sediment) while TRVs for measurement receptor species are provided in terms of dose ingested. The selected TRVs for each measurement receptor are identified and discussed below.

3.2.1 Fish/Water Invertebrate TRVs

TRVs for fish and/or aquatic invertebrates present within the surface water bodies of the Pownal Tannery Study Area were obtained from the following sources: available acute and chronic ambient water quality criteria (U.S. EPA, 1999b; U.S. EPA, 1991a) and secondary values from Great Lakes Water Quality Initiative as reported in Suter and Tsao, 1996. The selected chronic and acute surface water TRVs are presented in Table 10 for each COC.

Water hardness is important in determining ambient water quality criteria (AWQC) for some metals. The average water hardness values for each of the sampled surface water bodies (Hoosic River, lagoons, and landfill pond/seeps) was used in determining the appropriate TRVs for these metals.

3.2.2 Amphibian TRVs

Amphibian larvae present within the ponded areas of surface water at the lagoons and the landfill pond/seeps may potentially be exposed to surface water COCs. A search of amphibian toxicity data for each COC present at these locations was conducted in the scientific literature (Pauli et al., 2000). Available toxicity data are primarily limited to acute studies relating to mortality or development of immature (i.e., larvae) amphibians. The lowest reported No Observable Adverse Effect Level (NOAEL) or Lowest Observable Adverse Effect Level (LOAEL) was selected as the preferred amphibian larvae TRV. For some COCs, the lack of NOAEL and LOAEL data required selecting toxicity data associated with lethal effects to larvae. The use of these studies is discussed in Section 4.5 (Uncertainty Analysis). The TRVs for amphibian larvae are presented in Table 11.

3.2.3 Benthic Invertebrate TRVs

Criteria, guidelines and benchmarks were obtained from various regulatory agencies for COCs detected in sediments within the Pownal Tannery Study Area as well as through the equilibrium partitioning (EqP) approach for organic contaminants. Sediment quality criteria (EPA, 1993b) have been developed for a limited number of organic contaminants and were selected as benthic invertebrate TRVs if available. Sediment guidelines developed by Swartz (1999) for PAH mixtures or by the National Oceanic and Atmospheric Administration (NOAA) or Ontario Ministry of the Environment (MOE) for other COCs were then used to assess potential adverse impacts to the macrobenthic community from sediment contamination. The EqP approach (EPA,

Table 10. TRVs for Surface Water COCs – Pownal Tannery Study Area					
COC	**Chronic RV (ug/L)**	**Duration & Endpoint**	**Acute TRV (ug/L)**	**Duration & Endpoint**	**Reference**
Acetone	1,500	Tier II SCV	28,000	Tier II SAV	Suter and Tsao, 1996
2-Butanone	14,000	Tier II SCV	240,000	Tier II SAV	Suter and Tsao, 1996
Toluene	9.8	Tier II SCV	120	Tier II SAV	Suter and Tsao, 1996
Bis(2-ethylhexyl)phthalate	3	Tier II SCV	27	Tier II SAV	Suter and Tsao, 1996
1,2,3,4,6,7,8-HpCDD	-	-	-	-	-
1,2,3,4,6,7,8-HpCDF	-	-	-	-	-
1,2,3,4,7,8-HxCDF	-	-	-	-	-
1,2,3,6,7,8-HxCDF	-	-	-	-	-
1,2,3,7,8-PeCDD	-	-	-	-	-
2,3,7,8-TCDF	-	-	-	-	-
OCDD	-	-	-	-	-
OCDF	-	-	-	-	-
Aluminum	87	AWQC (CCC)	750	AWQC (CMC)	U.S. EPA, 1999b
Antimony	30	AWQC (proposed CCC)	88	AWQC (proposed CMC)	U.S. EPA, 1991
Arsenic (Filtered)	150	AWQC (CCC)	340	AWQC (CMC)	U.S. EPA, 1999b
Barium	4	Tier II SCV	110	Tier II SAV	Suter and Tsao, 1996
Beryllium	0.66	Tier II SCV	35	Tier II SAV	Suter and Tsao, 1996
Cadmium (Filtered)	2.2	*AWQC (CCC)	4.3	*AWQC (CMC)	U.S. EPA, 1999b
Chromium (Filtered)	74	*AWQC (CCC)	570	*AWQC (CMC)	U.S. EPA, 1999b
Cobalt	23	Tier II SCV	1,500	Tier II SAV	Suter and Tsao, 1996
Copper (Filtered)	9	*AWQC (CCC)	13	*AWQC (CMC)	U.S. EPA, 1999b
Iron	1000	AWQC (CCC)	-	-	U.S. EPA, 1991
Lead (Filtered)	2.5	*AWQC (CCC)	65	*AWQC (CMC)	U.S. EPA, 1999b
Manganese	120	Tier II SCV	2,300	Tier II SAV	Suter and Tsao, 1996
Mercury (Filtererd)	0.77	*AWQC (CCC)	1.4	*AWQC (CMC)	U.S. EPA, 1999b
Nickel (Filtered)	52	*AWQC (CCC)	470	*AWQC (CMC)	U.S. EPA, 1999b
Selenium	5	AWQC (CCC)	-	-	U.S. EPA, 1999b
Silver (Filtered)	-	-	3.4	*AWQC (CMC)	U.S. EPA, 1999b
Thallium	12	Tier II SCV	110	Tier II SAV	Suter and Tsao, 1996
Vanadium	20	Tier II SCV	280	Tier II SAV	Suter and Tsao, 1996
Zinc (Filtered)	120	*AWQC (CCC)	120	*AWQC (CMC)	U.S. EPA, 1999b

NOTES: SCV - Secondary Chronic Value SAV - Secondary Acute Value
CCC - Criteria Continuous Concentration represents highest concentration aquatic life can be exposed for extended time (4 days) without adverse effects.
CMC - Criteria Maximum Concentration represents highest concentration aquatic life can be exposed for short time (1 hour average) without adverse effects.
* Based on water hardness. Value presented assumes hardness of 100 mg/L, however, values are adjusted based on site-specific water hardness.

Table 11. Amphibian TRVs for Surface Water COCs – Pownal Tannery Study Area			
COC	**TRV (ug/L)**	**Duration & Endpoint**	**Reference**
Acetone	10,000	LOAEL – Frog larvae development	Pauli et al., 2000
2-Butanone	2,000	LOAEL – Frog behavior	Pauli et al., 2000
Toluene	390	LC-50 - Frog embryo	Pauli et al., 2000
Bis(2-ethylhexyl)phthalate	-	-	-
1,2,3,4,6,7,8-HpCDD	-	-	-
1,2,3,4,6,7,8-HpCDF	-	-	-
1,2,3,4,7,8-HxCDF	-	-	-
1,2,3,6,7,8-HxCDF	-	-	-
1,2,3,7,8-PeCDD	-	-	-
2,3,7,8-TCDF	-	-	-
OCDD	-	-	-
OCDF	-	-	-
Aluminum	50	LC-50 – Toad embryo/larvae	Pauli et al., 2000
Antimony	300	LC-50 - Toad embryo/larvae	Pauli et al., 2000
Arsenic	40	LC-50 - Toad embryo/larvae	Pauli et al., 2000
Barium	-	-	-
Beryllium	3,150	LC-50 – Salamander larvae	Pauli et al., 2000
Cadmium	106	NOAEL – Salamander larvae mortality	Pauli et al., 2000
Chromium	1,000	LOAEL – Newt larvae genotoxicity	Pauli et al., 2000
Cobalt	50	LC-50- Toad larvae	Pauli et al., 2000
Copper	20	NOAEL – Toad larvae development	Pauli et al., 2000
Iron	20,000	NOAEL – Toad larvae development	Pauli et al., 2000
Lead	750	LOAEL – Frog larvae behavior	Pauli et al., 2000
Manganese	1,420	LC-5O – Toad embryo/larvae	Pauli et al., 2000
Mercury	0.16	LOAEL – Frog embryo/larvae mortality	Pauli et al., 2000
Nickel	50	LC-50 – Toad embryo/larvae	Pauli et al., 2000
Selenium	90	LC-50 – Toad embryo/larvae	Pauli et al., 2000
Silver	4.1	LC-50 – Toad larvae	Pauli et al., 2000
Thallium	110	LC-50 – Toad embryo/larvae	Pauli et al., 2000
Vanadium	-	-	-
Zinc	100	NOAEL – Toad larvae development	Pauli et al., 2000

NOTES:
- No data available

LC-50: Lethal concentration to 50% of test organisms (test duration generally 4 days).
NOAEL: No Observable Adverse Effect Level
LOAEL: Lowest Observed Adverse Effect Level

1993b; Jones et al., 1997) and other available guidelines (WADE, 1994; Ingersoll et al., 1996; U.S.EPA regional guidelines as cited in Hull and Suter, 1994) were also used if sediment quality criteria, NOAA or MOE guidelines were unavailable. The sediment TRVs selected for the benthic invertebrate community are presented in Table 12.

Swartz (1999) presents consensus sediment quality guidelines for polycyclic aromatic hydrocarbons (PAHs) as expressed as a mixture concentration (i.e., total PAHs) and their causal effects on sediment toxicity and benthic community perturbations. The Threshold Effect Concentration (TEC) represents a total PAH concentration (290 ug/g organic carbon) at which lower concentrations of total PAHs are unlikely to cause adverse effects on the benthic community. The median effect concentration (MEC) represents a median concentration 1,800 ug/g organic carbon) of the effects ranges reported. Each of these values is adjusted by the organic carbon content of the sediment within the area of concern (equilibrium partitioning approach as described below).

NOAA sediment guidelines (Buchman, 1999) incorporate conservative Threshold Effect Levels (TELs) as well as Probable Effect Levels (PELs) where adverse impacts are expected (Buchman, 1999). The NOAA guidelines were developed from a data set of studies that correlated sediment contaminant concentrations with effects to biota (or absence of adverse effects to biota). The TEL represents the geometric mean of the 15^{th} percentile concentration of the toxic effects data set and the median of the no-effect data set. The TEL represents a screening level concentration where impacts to the benthic community are expected to occur only infrequently. The PEL is the geometric mean of the 50^{th} percentile of toxic effects data and the 85^{th} percentile of the non-impacted results and represents a concentration where adverse impacts are likely.

MOE sediment guidelines (Persaud et al., 1993) were also developed from a review of available freshwater data regarding contaminant concentrations (observed or predicted) and biological effects on benthic biota. These data were sorted and the Lowest Effect Level (LEL) and Severe Effect Level (SEL) were identified. The LEL represents a concentration that has no effect on the majority of benthic species and is similar to the TEL established by NOAA. The SEL represents a concentration that may adversely affect most sediment-dwelling organisms (similar to the NOAA PEL). The SELs guidelines for organic contaminants are normalized to the sediment organic carbon content (EqP approach).

The EqP approach was also used to calculate sediment quality benchmarks for non-ionic organic contaminants (EPA, 1993b). Calculating a benchmark using the EqP approach requires that the organic carbon content of the sediment be known and that an organic-carbon-water partitioning coefficient and a surface water criteria or effects level for each contaminant be identified. The EqP approach is based on a correlation between contaminant concentrations in sediment, on an organic carbon basis, to their corresponding concentrations in the interstitial pore water of the sediment. The EqP approach assumes that the partitioning of the contaminant between the sediment and interstitial water are in equilibrium.

Table 12. TRVs for Sediment COCs – Pownal Tannery Study Area			
COC	TEL/LEL/ Chronic TRV	PEL/SEL/ Acute TRV	Reference
VOCs (ug/kg)			
1,2,4-Trichlorobenzene	9,600*	60,100*	Jones et al., 1997, Suter and Tsao, 1996
1,2-Dichlorobenzene	330*	6,100*	Jones et al., 1997, Suter and Tsao, 1996
1,4-Dichlorobenzene	340*	4124*	Jones et al., 1997, Suter and Tsao, 1996
Acetone	14.3*	-	U.S. EPA, 1999
2-Butanone	270*	4,680*	Jones et al., 1997, Suter and Tsao, 1996
Carbon Disulfide	0.85*	16*	Jones et al., 1997
Methyl Acetate	-	-	-
Methylene Chloride	370*	4,400*	Jones et al., 1997, Suter and Tsao, 1996
Tetrachloroethylene	410*	3,460*	Jones et al., 1997, Suter and Tsao, 1996
Tetrahydrofuran	-	-	-
Toluene	50*	600*	Jones et al., 1997, Suter and Tsao, 1996
Xylene (Total)	160*	2,765*	Jones et al., 1997, Suter and Tsao, 1996
SVOCs (ug/kg)			
2,2-oxybis(1-Chloropropane)	-	-	-
2,4-Dichlorophenol	-	-	-
2,4-Dimethylphenol	29	-	Jones et al., 1997
2-Methylnaphthalene	See Total PAHs	See Total PAHs	EPA -
2-Nitroaniline	-	-	-
2-Nitrophenol	-	-	-
4-Chloro-3-methylphenol	-	-	-
4-Chloroaniline	-	-	-
4-Methylphenol	670	-	Jones et al., 1997
4-Nitrophenol	-	-	-
Acenaphthene	see Total PAHs	see Total PAHs	-
Acenaphthylene	-	-	-
Anthracene	see Total PAHs	see Total PAHs	-
Benzaldehyde	-	-	-
Benzo(a)anthracene	see Total PAHs	see Total PAHs	-
Benzo(a)pyrene	see Total PAHs	see Total PAHs	-
Benzo(b)fluoranthene	see Total PAHs	see Total PAHs	-
Benzo(g,h,i)perylene	see Total PAHs	see Total PAHs	-
Benzo(k)fluroanthene	see Total PAHs	see Total PAHs	-
Bis(2-chloroethoxy)methane	-	-	-
Bis(2-chloroethyl)ether	-	-	-
Bis(2-ethylhexyl)phthalate	890,000*	-	Jones et al., 1997
Caprolactam	-	-	-
Carbazole	-	-	-
Chrysene	see Total PAHs	see Total PAHs	-
Dibenzo(a,h)anthracene	see Total PAHs	see Total PAHs	-
Dibenzofuran	420*	7,400*	Jones et al., 1997, Suter and Tsao, 1996
Di-n-butylphthalate	11,000*	-	Jones et al., 1997
Di-n-octylphthalate	100000*	-	Jones et al., 1997
Diethylphthalate	600*	5,200*	Jones et al., 1997, Suter and Tsao, 1996

Table 12. TRVs for Sediment COCs – Pownal Tannery Study Area			
COC	**TEL/LEL/ Chronic TRV**	**PEL/SEL/ Acute TRV**	**Reference**
Fluoranthene	2,900*	see Total PAHs	EPA, 1993b
Fluorene	see Total PAHs	see Total PAHs	-
Indeno(1,2,3-cd)pyrene	see Total PAHs	see Total PAHs	-
Isophorone	-	-	-
N-Nitroso-di-n-propylamine	-	-	-
Naphthalene	see Total PAHs	see Total PAHs	-
Nitrobenzene	321*	-	U.S. EPA, 1999a
Pentachlorophenol	360	-	Jones et al., 1997
Phenanthrene	850*	see Total PAHs	EPA, 1993
Pyrene	see Total PAHs	see Total PAHs	-
Total PAHs	290*	18,000*	Swartz, 1999
Pesticides/PCBs (ug/kg)			
4,4-DDD	3.54	8.51	Buchman, 1999
4,4-DDE	1.42	6.75	Buchman, 1999
4,4-DDT	8	710*	Persaud et al., 1993
Aldrin	2	80*	Persaud et al., 1993
alpha-BHC	6	100*	Persaud et al., 1993
alpha-Chlordane	4.5	8.9	Buchman, 1999
Aroclor 1242	170*	3,880*	Jones et al., 1997, Suter and Tsao, 1996
Aroclor 1248	1000*	17,200*	Jones et al., 1997, Suter and Tsao, 1996
Aroclor 1254	810*	14,700*	Jones et al., 1997, Suter and Tsao, 1996
Aroclor 1260	4,500,000*	-	Jones et al., 1997
beta-BHC	5	210*	Persaud et al., 1993
delta-BHC	120*	-	Jones et al., 1997
Dieldrin	52*	-	EPA, 1993b
Endosulfan II	5.5*	-	Jones et al., 1997
Endosulfan Sulfate	5.5*	-	Jones et al., 1997
Endrin	20*	-	EPA, 1993b
Endrin Aldehyde	2.67	62.4	Buchman, 1999
Endrin Ketone	2.67	62.4	Buchman, 1999
gamma-BHC (Lindane)	0.94	1.38	Buchman, 1999
gamma-Chlordane	4.5	8.9	Buchman, 1999
Heptachlor	68*	1,250*	Jones et al., 1997, Suter and Tsao, 1996
Heptachlor Epoxide	0.6	2.74	Buchman, 1999
Methoxychlor	19*	-	Jones et al., 1997
Dioxins (ng/kg)			
1,2,3,4,6,7,8-HpCDD	-	-	-
1,2,3,4,6,7,8-HpCDF	-	-	-
1,2,3,4,7,8,9-HpCDF	-	-	-
1,2,3,4,7,8-HxCDD	-	-	-
1,2,3,4,7,8-HxCDF	-	-	-
1,2,3,6,7,8-HxCDD	-	-	-
1,2,3,6,7,8-HxCDF	-	-	-
1,2,3,7,8,9-HxCDD	-	-	-
1,2,3,7,8,9-HxCDF	-	-	-

Table 12. TRVs for Sediment COCs – Pownal Tannery Study Area			
COC	TEL/LEL/ Chronic TRV	PEL/SEL/ Acute TRV	Reference
1,2,3,7,8-PeCDD	-	-	-
1,2,3,7,8-PeCDF	-	-	-
2,3,4,6,7,8-HxCDF	-	-	-
2,3,4,7,8-PeCDF	-	-	-
2,3,7,8-TCDD	102*	-	U.S. EPA, 1999a
2,3,7,8-TCDF	-	-	-
OCDD	-	-	-
OCDF	-	-	-
Metals (mg/kg)			
Aluminum	14,000	-	Ingersoll et al., 1996
Antimony	64	-	WA DE, 1994
Arsenic	5.9	17	Buchman, 1999
Barium	20	-	Hull and Suter, 1994
Beryllium	-	-	-
Cadmium	0.6	3.5	Buchman, 1999
Chromium	37.3	90	Buchman, 1999
Chromium(Hexavalent)	-	-	-
Cobalt	-	-	-
Copper	35.7	197	Buchman, 1999
Cyanide	0.1	-	Hull and Suter, 1994
Iron	20,000	40,000	Persaud et al., 1993
Lead	35	91	Buchman, 1999
Manganese	460	1,100	Persaud et al., 1993
Mercury	0.174	0.486	Buchman, 1999
Nickel	18	35.9	Buchman, 1999
Selenium	0.1	-	WA DE, 1994
Silver	4.5	-	WA DE, 1994
Thallim	-	-	-
Vanadium	-	-	-
Zinc	123	315	Buchman, 1999

* Benchmark calculated via equilibrium partitioning approach assuming 1% foc.

3.2.4 Wildlife TRVs

Wildlife toxicity reference values (TRVs) were selected to evaluate potential affects of the estimated exposure doses received by the selected avian and mammalian measurement receptor species. Because toxicity data for the selected receptor species are unavailable, it is necessary to extrapolate toxicity data from other species, usually laboratory test animals. However, the test endpoints for the laboratory species must be significant to the measurement receptor species under field conditions. Endpoints that were considered significant for this risk assessment included adverse effects on growth, reproduction, and survival that are most likely to result in adverse effects to wild populations of receptors. Other endpoints (e.g., liver damage) were selected if more significant endpoints were unavailable. These other endpoints were primarily used for VOCs and several PAHs. TRVs selected for each COCs (detected across all media of concern) for mammals and birds are presented in Table 13.

Table 13. TRVs for Bird and Mammal Measurement Receptors – Pownal Tannery Study Area

COC	Study Duration	Endpoint	Test Species	NOAEL TRV (mg/kg-BW-day)	LOAEL TRV (mg/kg-BW-day)	Reference
VOCs						
Acetone	5 days - acute	Mortality	Japanese Quail	52	-	Hill and Camardese, 1986
	90 days - subchronic	Liver/kidney damage	Rat	10	50	Sample et al., 1996
Benzene	>6 days gestation-chronic	Reproduction	Mouse	26.36	263.6	Sample et al., 1996
2-Butanone	2 generations - chronic	Reproduction	Rat	1,771	4,571	Sample et al., 1996
Carbon Disulfide	-	-	-	-	-	-
Methyl Acetate	-	-	-	-	-	-
Methylene Chloride	2 years - chronic	Liver histology	Rat	5.85	50	Sample et al., 1996
Tetrachloroethylene	6 weeks - subchronic	Hepatotoxicity	Mouse	1.4	7	Sample et al., 1996
Tetrahydrofuran	-	-	-	-	-	-
Toluene	12 days gestation-chronic	Reproduction	Mouse	26	260	Sample et al., 1996
Xylene (Total)	15 days gestation-chronic	Reproduction	Mouse	2.1	2.6	Sample et al., 1996
SVOCs						
1,2,4-Trichlorobenzene	-	-	-	-	-	-
1,2-Dichlorobenzene	1,4-Dichlorobenzene toxicity value used as surrogate					
1,4-Dichlorobenzene	192 days - chronic	Mortality	Rat	18.8	-	Verschueren, 1977
2,2-oxybis(1-Chloropropane)	-	-	-	-	-	-
2,4-Dichlorophenol	LD50	Mortality	Rat	5.8	-	Verschueren, 1977
2,4-Dimethylphenol	LD50	Mortality	Mouse	4	-	Sax, 1984
2-Methynaphthalene	See low molecular weight PAHs					
2-Nitroaniline	LD50	Mortality	Deer Mouse	3.75	-	Schafer and Bowles, 1985
2-Nitrophenol	-	-	-	-	-	-
4-Chloro-3-methylphenol	-	-	-	-	-	-
4-Chloroaniline	-	-	-	-	-	-
4-Methylphenol	6 months - chronic	Reproduction	Mink	219.2	-	Sample et al., 1996
4-Nitrophenol	-	-	-	-	-	-
Acenaphthene	see low molecular weight PAHs					
Acenaphthylene	see low molecular weight PAHs					
Anthracene	see low molecular weight PAHs					
Benzaldehyde	LD50	Mortality	Deer Mouse	0.47	-	Schafer and Bowles, 1985
Benzo(a)anthracene	see high molecular weight PAHs					
Benzo(a)pyrene	>7days gestation-chronic	Reproduction	Mouse	1.0	10	Sample et al., 1996

Table 13. TRVs for Bird and Mammal Measurement Receptors – Pownal Tannery Study Area

COC	Study Duration	Endpoint	Test Species	NOAEL TRV (mg/kg-BW-day)	LOAEL TRV (mg/kg-BW-day)	Reference
Benzo(b)fluoranthene	see high molecular weight PAHs					
Benzo(g,h,i)perylene	see high molecular weight PAHs					
Benzo(k)fluroanthene	see high molecular weight PAHs					
Bis(2-chloroethoxy)methane	-	-	-	-	-	-
Bis(2-chloroethyl)ether	LD50	Mortality	Rat	0.075	-	Verschueren, 1977
Bis(2-ethylhexyl)phthalate	4 weeks - chronic	Reproduction	Ringed Dove	1.1	-	Sample et al., 1996
	105 days - chronic	Reproduction	Mouse	18.3	183.3	Sample et al., 1996
Caprolactam	-	-	-	-	-	-
Carbazole	LD50	Mortality	Rat	5	-	EPA, 1986
Chrysene	see high molecular weight PAHs					
Dibenzo(a,h)anthracene	see high molecular weight PAHs					
Dibenzofuran	see low molecular weight PAHs					
Di-n-butylphthalate	4 weeks - chronic	Reproduction	Ringed Dove	0.11	1.1	Sample et al., 1996
	105 days - chronic	Reproduction	Mouse	550	1833	Sample et al., 1996
Di-n-octylphthalate	105 days - chronic	-	Mouse	7,500	-	EPA, 1999a
Diethylphthalate	105 days - chronic	Reproduction	Mouse	4583	-	Sample et al., 1996
Fluoranthene	see high molecular weight PAHs					
Fluorene	see low molecular weight PAHs					
Indeno(1,2,3-cd)pyrene	see high molecular weight PAHs					
Isophorone	LD50	Mortality	Rat	3.45	-	ATSDR, 1988
N-Nitroso-di-n-propylamine	-	-	-	-	-	-
Naphthalene	see low molecular weight PAHs					
Nitrobenzene	LD50	Mortality	Rat	0.64	-	Sax, 1984
Pentachlorophenol	8 weeks - chronic	Growth	Chicken	44	88.000	EPA, 1999b
	181 days - chronic	Reproduction	Rat	4	13.0	EPA, 1999b
Phenanthrene	see low molecular weight PAHs					
Pyrene	see high molecular weight PAHs					
High Molecular Wt. PAHs	>7days gestation-chronic	Reproduction	Mouse	1.0	10	Sample et al., 1996
Low Molecular Wt. PAHs	7 months - chronic	Liver Effects	Mallard	40	400	Patton and Dieter, 1980
	90 days - chronic	Liver Effects	Mouse	5.3	53	ATSDR, 1995
Pesticides/PCBs						
4,4-DDD	-	-	-	-	-	-
4,4-DDE	5 days - acute	Mortality	Japanese Quail	0.845	-	Hill and Camardese, 1986

Table 13. TRVs for Bird and Mammal Measurement Receptors – Pownal Tannery Study Area

COC	Study Duration	Endpoint	Test Species	NOAEL TRV (mg/kg-BW-day)	LOAEL TRV (mg/kg-BW-day)	Reference
	5 weeks - subchronic	-	Rat	1.0	-	EPA, 1999a
4,4-DDT	5 years - chronic	Reproduction	Brown Pelican	0.0028	0.028	Sample et al., 1996
	2 years - chronic	Reproduction	Rat	0.8	4.0	Sample et al., 1996
Aldrin	5 days - acute	Mortality	Japanese Quail	0.061	-	Hill and Camardese, 1986
	3 generations - chronic	Reproduction	Rat	0.2	1.0	Sample et al., 1996
alpha-BHC	90 days - chronic	Reproduction	Japanese Quail	0.56	2.25	Sample et al., 1996
	4 generations - chronic	Reproduction	Rat	1.6	3.2	Sample et al., 1996
	331 days - chronic	Reproduction	Mink	0.014	0.14	Sample et al., 1996
alpha-Chlordane	84 days - chronic	Mortality	Red-winged Blackbird	2.14	10.7	Sample et al., 1996
	6 generations - chronic	Reproduction	Mouse	4.6	9.2	Sample et al., 1996
Aroclor 1242	2 generations - chronic	Reproduction	Screech Owl	0.41	-	Sample et al., 1996
	7 months - chronic	Reproduction	Mink	0.069	0.69	Sample et al., 1996
Aroclor 1248	14 months - chronic	Reproduction	Rhesus Monkey	0.01	0.1	Sample et al., 1996
	5 days - acute	Mortality	Japanese Quail	4.74	-	Hill and Camardese, 1986
Aroclor 1254	17 weeks - chronic	Reproduction	Ringed-necked Pheasant	0.18	1.8	Sample et al., 1996
	12 months - chronic	Reproduction	Oldfield Mouse	0.068	0.68	Sample et al., 1996
	4.5 months - chronic	Reproduction	Mink	0.14	0.69	Sample et al., 1996
Aroclor 1260	5 days - acute	Mortality	Japanese Quail	2.16	-	Hill and Camardese, 1986
beta-BHC	90 days - chronic	Reproduction	Japanese Quail	0.56	2.25	Sample et al., 1996
	4 generations - chronic	Reproduction	Rat	1.6	3.2	Sample et al., 1996
	331 days - chronic	Reproduction	Mink	0.014	0.14	Sample et al., 1996
delta-BHC	90 days - chronic	Reproduction	Japanese Quail	0.56	2.25	Sample et al., 1996
	4 generations - chronic	Reproduction	Rat	1.6	3.2	Sample et al., 1996
	331 days - chronic	Reproduction	Mink	0.014	0.14	Sample et al., 1996
Dieldrin	2 years - chronic	Reproduction	Barn Owl	0.077	-	Sample et al., 1996
	3 generations - chronic	Reproduction	Rat	0.02	0.2	Sample et al., 1996
Endosulfan I	4 weeks - chronic	Reproduction	Rat	0.15	-	Sample et al., 1996
	30 days - subchronic	Reproduction	Gray Partridge	10	-	Sample et al., 1996
Endosulfan II	4 weeks - chronic	Reproduction	Rat	0.15	-	Sample et al., 1996
	30 days - subchronic	Reproduction	Gray Partridge	10	-	Sample et al., 1996
Endosulfan Sulfate	Endosulfan toxicity values used as surrogate					
Endrin	>200 days - chronic	Reproduction	Mallard	0.3	-	Sample et al., 1996

Table 13. TRVs for Bird and Mammal Measurement Receptors – Pownal Tannery Study Area

COC	Study Duration	Endpoint	Test Species	NOAEL TRV (mg/kg-BW-day)	LOAEL TRV (mg/kg-BW-day)	Reference
	>83 days - chronic	Reproduction	Screech Owl	0.01	0.1	Sample et al., 1996
	120 days - chronic	Reproduction	Mouse	0.092	0.92	Sample et al., 1996
Endrin Aldehyde	Endrin toxicity values used as surrogate					
Endrin Ketone	Endrin toxicity values used as surrogate					
gamma-BHC (Lindane)	8 weeks - chronic	Reproduction	Mallard	2	20	Sample et al., 1996
	3 generations - chronic	Reproduction	Rat	8	-	Sample et al., 1996
gamma-Chlordane	84 days - chronic	Mortality	Red-winged Blackbird	2.14	10.7	Sample et al., 1996
	6 generations - chronic	Reproduction	Mouse	4.6	9.2	Sample et al., 1996
Heptachlor	5 days - acute	Mortality	Japanese Quail	65	-	Hill and Camardese, 1986
	60 days - subchronic	Mortality	Rat	0.0025	-	EPA, 1999a
	181 days - chronic	Reproduction	Mink	0.1	1	Sample et al., 1996
Heptachlor Epoxide	Heptachlor toxicity values used as surrogate					
Methoxychlor	>6 days gestation-chronic	Reproduction	Rat	100	200	EPA, 1999b
Dioxins						
2,3,7,8-TCDD	10 weeks - chronic	Reproduction	Ring-necked Pheasant	0.000014	0.00014	Sample et al., 1996
	3 generations	Reproduction	Rat	0.000001	0.00001	Sample et al., 1996
Metals						
Aluminum	4 months - chronic	Reproduction	Ringed Dove	109.7	-	Sample et al., 1996
	1 year - chronic	Growth	Rat	1.93	19.3	EPA, 1999a
Antimony	60 days - subchronic	Reproduction	Rat	0.143	1.43	EPA, 1999b
Arsenic	7 months - chronic	Mortality	Brown-headed Cowbird	2.46	7.38	Sample et al., 1996
	128 days - chronic	Mortality	Mallard	5.14	12.84	Sample et al., 1996
	2 years - chronic	Growth, Development	Rat	4.6	9.3	EPA, 1999b
Barium	4 weeks - subchronic	Mortality	Chicken	20.8	41.7	Sample et al., 1996
	16 months - chronic	Growth	Rat	5.1	-	Sample et al., 1996
Beryllium	lifetime - chronic	Longevity	Rat	0.66	-	Sample et al., 1996
Cadmium	90 days - chronic	Reproduction	Mallard	1.4	14	EPA, 1999b
	6 weeks - chronic	Reproduction	Rat	1	10	Sample et al., 1996
Chromium	10 months - chronic	Reproduction	Black Duck	1	5	Sample et al., 1996
	90 days - chronic	Reproduction	Rat	2737	-	Sample et al., 1996
Chromium(Hexavalent)	1 year - chronic	Body Weight	Rat	3.28	-	Sample et al., 1996

Table 13. TRVs for Bird and Mammal Measurement Receptors – Pownal Tannery Study Area

COC	Study Duration	Endpoint	Test Species	NOAEL TRV (mg/kg-BW-day)	LOAEL TRV (mg/kg-BW-day)	Reference
Cobalt	-	-	-	-	-	-
Copper	10 weeks - chronic	Growth, Mortality	Chicken	47	61.7	Sample et al., 1996
	357 days - chronic	Reproduction	Mink	11.7	15.14	Sample et al., 1996
Cyanide	LD50	Mortality	American Kestrel	0.04	-	EPA, 1999a
	2 years - chronic	-	Rat	24	-	EPA, 1999a
Iron	-	-	-	-	-	-
Lead	7 months - chronic	Reproduction	American Kestrel	3.85	-	Sample et al., 1996
	12 weeks - chronic	Reproduction	Japanese Quail	1.13	11.3	Sample et al., 1996
	3 generations - chronic	Reproduction	Rat	8	80	Sample et al., 1996
Manganese	75 days - chronic	Growth	Japanese Quail	977	-	Sample et al., 1996
	224 days - chronic	Reproduction	Rat	88	284	Sample et al., 1996
Mercury	1 year - chronic	Reproduction	Japanese Quail	0.45	0.9	Sample et al., 1996
	20 months - chronic	Mortality	Mouse	13.2	-	Sample et al., 1996
	6 months - chronic	Reproduction	Mink	1	-	Sample et al., 1996
Nickel	90 days - chronic	Mortality, Growth	Mallard	77.4	107	Sample et al., 1996
	3 years - chronic	Reproduction	Rat	53.5	107	EPA, 1999b
Selenium	78 days - chronic	Reproduction	Mallard	0.5	1.0	Sample et al., 1996
	1 year - chronic	Reproduction	Rat	0.2	0.33	Sample et al., 1996
Silver	14 days - subchronic	-	Mallard	178	-	EPA, 1999a
	125 days - chronic	Hypoactivity	Mouse	0.375	3.75	EPA, 1999a
Thallium	LD50	Mortality	European Starling	0.35	-	Schafer, 1972
	60 days - subchronic	Reproduction	Rat	0.0131	-	EPA, 1999a
Vanadium	12 weeks - chronic	Mortality, Weight	Mallard	11.4	-	Sample et al., 1996
	30 days - chronic	Growth	Chicken	1.5	2.2	EPA, 1999b
	60 days - chronic	Reproduction	Rat	0.5	5	EPA, 1999b
Zinc	44 weeks - chronic	Reproduction	Chicken	14.5	131	Sample et al., 1996
	16 days gestation-chronic	Reproduction	Rat	200	410	EPA, 1999b

- No toxicity data available.

Table 14. Toxicity Equivalency Factors (TEFs) for Dioxins/Furans – Pownal Tannery Study Area			
Class	**Dioxin/Furan Analyte**	**Mammal TEF**	**Bird TEF**
Dibenzo-p-dioxins	2,3,7,8-TCDD	1	1
	1,2,3,7,8-PeCDD	1	1
	1,2,3,4,7,8-HxCDD	0.1	0.05
	1,2,3,6,7,8-HxCDD	0.1	0.01
	1,2,3,7,8,9-HxCDD	0.1	0.1
	1,2,3,4,6,7,8-HpCDD	0.01	0.001
	OCDD	0.0001	0.0001
Dibenzofurans	2,3,7,8-TCDF	0.1	1
	1,2,3,7,8-PeCDF	0.05	0.1
	2,3,4,7,8-PeCDF	0.5	1
	1,2,3,4,7,8-HxCDF	0.1	0.1
	1,2,3,6,7,8-HxCDF	0.1	0.1
	1,2,3,7,8,9-HxCDF	0.1	0.1
	2,3,4,6,7,8-HxCDF	0.1	0.1
	1,2,3,4,6,7,8-HpCDF	0.01	0.01
	1,2,3,4,7,8,9-HpCDF	0.01	0.01
	OCDF	0.0001	0.0001

The lowest chronic No Observable Adverse Effect Level (NOAEL), if available for avian and mammalian species was selected for assessing the effects of exposure by the measurement receptor species. If a chronic NOAEL was unavailable, then the chronic Lowest Observable Adverse Effect Level (LOAEL) of acute lethal value (e.g., LD50) reported in the scientific literature were adjusted by an uncertainty factor of 0.1 and 0.01 to derive a TRV equivalent to a chronic NOAEL (Calabrese and Baldwin, 1993).

Selected NOAEL and LOAEL toxicity values are unavailable for most PAHs. Therefore, TRVs for high molecular weight PAHs (HPAHs) and low molecular weight PAHs (LPAHs) were used to assess potential toxicity for PAHs within these groupings. For LPAHs, decreased liver enzyme activity and increased liver weight and blood flow to the liver were the only available endpoints found in the literature (Eisler, 1987). The significance of these endpoints to wild populations may not be as relevant as adverse effects on reproduction. No HPAH TRV was found for avian species in the literature review.

TRVs are also unavailable for most of the dibenzo-p-dioxin and dibenzofuran isomers. Therefore, Toxicity Equivalency Factors (TEFs) were used to equate toxicity of dioxin/furan isomers with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) which is the most toxic and extensively studied isomer. TEFs for birds and mammals used for each of the dioxin/furan isomers are presented in Table 14 (Van den Berg et al., 1998). TEFs for each of the wildlife measurement receptor species are presented in Attachment II.