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From:
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Date:
July 23, 2013

ARCADIS Project No.:
NJ000604.2013

Subject:
Baseline Ecological Risk Assessment for the O'Connor Disposal Area
Ringwood Mines/Landfill Site, Ringwood, New Jersey

Introduction

On behalf of the Ford Motor Company (Ford), ARCADIS U.S., Inc. (ARCADIS) has prepared this Baseline Ecological Risk Assessment (BERA) for the O'Connor Disposal Area (OCDA) of the Ringwood Mines/Landfill Site (Site). In the United States Environmental Protection Agency (USEPA) letter dated August 2, 2012, the preparation of a BERA was requested based on the potential risks to ecological receptors identified in the June 2012 Revised Screening Level Ecological Risk Assessment (SLERA) for the OCDA (ARCADIS 2012a). This BERA has been prepared as a technical memorandum. The approach for the BERA was presented in the October 10, 2012, letter to USEPA that was approved on October 26, 2012. The memorandum is organized as follows:

- Overview of SLERA
- Refinements to Dose Model
- BERA Risk Characterization
- Conclusions

The Site is located along the northern side of Margaret King Avenue about one-half mile west of Sloatsburg Road in the Borough of Ringwood, in the northeastern corner of Passaic County, New Jersey.

The OCDA is located within the northern portion of the Site just south of the Ringwood State Park and east of the Peters Mine Road, between Peters Mine Road and Park Brook. Overall, the Site covers approximately 500 acres of which the OCDA encompasses only 12 acres. Commercial mining operations occurred on the Site between the 1700s and the 1940s. The OCDA was used as a "slime pond" during active mining operations and later used for waste disposal. Further detail on the historical operation of the OCDA is presented in the SLERA (ARCADIS 2012a).

Similar to the overall Site, the 12 acres of the OCDA is mostly wooded, but contains various access roads and open areas related to historical iron-ore mining operations. While there are no surface water bodies within the limits of the OCDA, Park Brook is located adjacent to the southeastern boundary. Park Brook flows into Furnace Dam Pond (often referred to as Sally's Pond) to the southeast of the Ringwood Site, and subsequently to the Ringwood River about one mile upstream of its confluence with the Wanaque Reservoir. There is also an area of freshwater wetlands slightly within and adjacent to the eastern boundary of the OCDA. As detailed in the SLERA, Park Brook exhibits characteristics of a small, high energy mountain stream when flow is present in its upper reaches. The stream channel has very few low-energy, fine-grained sediment depositional areas and is primarily composed of boulders, cobbles, gravel, and bedrock outcrops. Park Brook exhibits intermittent flow in its upper reaches, upstream of the OCDA. The characteristics of Park Brook adjacent to and immediately downstream of the OCDA begin to transition from characteristics observed in high energy mountain streams to those more typical of lower gradient streams with braided morphology. This portion of Park Brook contains more low-energy, fine-grained sediment depositional areas relative to its upper reaches and exhibits more consistently permanent flow.

Overview of SLERA

A field reconnaissance was conducted by an ARCADIS ecologist on November 30, 2011, to identify potential ecological receptors on and immediately adjacent to the OCDA. Based on the results of this reconnaissance as well as review of the available habitat information described above, it was determined that the OCDA provides terrestrial habitat for avian and mammalian species as well as aquatic habitat. The potential presence of threatened and endangered species was also evaluated, but of those identified in the Natural Heritage Database search and by the United States Fish and Wildlife Service (USFWS), including the barred owl, Cooper's hawk, Indiana bat, and timber rattlesnake, none were identified at the Site. On September 1, 2010, a wood turtle was observed in Park Brook adjacent to the OCDA.

Based on the ecological receptors and habitats identified at the OCDA, namely Park Brook and the forested areas, the primary potentially complete exposure pathways involve constituents of potential ecological concern (COPEC) in surface water, surface soil (defined as the top six inches of soil), and sediment in ecological habitat areas. In addition, the potential exists for COPEC that occur in overburden groundwater within the OCDA to be transported and discharged to surface water bodies, including the nearby forested wetlands and Park Brook. However, for ecological exposures to groundwater to occur, there must be a discharge to surface water. As noted in the SLERA (ARCADIS 2012a), there are a

number of constituents detected in groundwater that were also identified as COPEC in surface water. Potential exposure to these constituents was evaluated through assessment of surface water quality.

The Remedial Investigation conducted for the OCDA, identified semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), and metals as the primary COPEC within and adjacent to the OCDA (ARCADIS 2012b).

The available information described above regarding the potential sources of COPEC and routes and mechanisms of transport was combined with the potential receptor species to develop the Conceptual Site Model (CSM), which defines potentially complete exposure pathways at the OCDA via ingestion of food as well as ingestion of soil, sediment, and water (Figure 1). Based on the CSM, the following assessment and measurement endpoints were identified for the SLERA (ARCADIS 2012a):

Assessment Endpoint No. 1

Do COPEC concentrations in OCDA surface soil pose a potential risk to the sustainability of terrestrial plant and invertebrate communities at the Site?

- *Measurement Endpoint 1:* Compare concentrations of COPEC in surface soil to ecological soil screening levels.

Assessment Endpoint No. 2

Do COPEC concentrations in the aquatic environment pose a potential risk to the sustainability of aquatic plants and benthic invertebrate communities at the Site?

- ***Measurement Endpoint 2a:*** Compare concentrations of COPEC in sediment to freshwater sediment quality guidelines.

- ***Measurement Endpoint 2b:*** Compare concentrations of COPEC in surface water to surface water quality criteria.

Assessment Endpoint No. 3

Do COPEC concentrations in Site surface water pose a potential risk to the sustainability of fish at the Site?

- ***Measurement Endpoint 3:*** Compare concentrations of COPEC in surface water to freshwater surface water quality criteria and calculate hazard quotients (HQs).

Assessment Endpoint No. 4

Do COPEC concentrations in OCDA surface soil pose a potential risk to the sustainability of herbivorous mammal populations at the Site?

- ***Measurement Endpoint 4:*** Compare modeled dietary COPEC exposure to toxicity reference values (TRVs) (calculate HQs) for an herbivorous mammal, meadow vole (*Microtus pennsylvanicus*), using terrestrial habitat at the Site.

Assessment Endpoint No. 5

Do COPEC concentrations in OCDA surface soil or sediment pose a potential risk to the sustainability of insectivorous/vermivorous bird populations at the Site?

- ***Measurement Endpoint 5a:*** Compare modeled dietary exposure to COPECs in soil to TRVs (calculate HQs) for a vermivorous bird, American robin (*Turdus migratorius*), using terrestrial habitat at the Site.

- ***Measurement Endpoint 5b:*** Compare modeled dietary exposure to COPECs in sediment to TRVs (calculate HQs) for an insectivorous bird, tree swallow (*Tachycineta bicolor*), using aquatic habitat at the Site.

Assessment Endpoint No. 6

Do COPEC concentrations in OCDA surface soil pose a potential risk to the sustainability of insectivorous/vermivorous mammal populations at the Site?

- ***Measurement Endpoint 6:*** Compare modeled dietary COPEC exposure to TRVs (calculate HQs) for an insectivorous mammal, short-tailed shrew (*Blarina brevicauda*), using terrestrial habitat at the Site.

Assessment Endpoint No. 7

Do COPEC concentrations in OCDA surface soil or sediment pose a potential risk to the sustainability of terrestrial carnivorous/piscivorous bird populations at the Site?

- ***Measurement Endpoint 7a:*** Compare modeled dietary exposure to COPECs in soil to TRVs (calculate HQs) for a carnivorous bird, red-tailed hawk (*Buteo jamaicensis*), using terrestrial habitat at the Site.

- ***Measurement Endpoint 7b:*** Compare modeled dietary exposure to COPECs in sediment to TRVs (calculate HQs) for a piscivorous bird, great blue heron (*Ardea herodias*), using aquatic habitat at the Site.

Assessment Endpoint No. 8

Do COPEC concentrations in OCDA surface soil or sediment pose a potential risk to the sustainability of carnivorous/piscivorous mammal populations at the Site?

- ***Measurement Endpoint 8a:*** Compare modeled dietary exposure to COPECs in sediment to TRVs (calculate HQs) for a piscivorous mammal, mink (*Neovison vison*), using aquatic habitat at the Site.

- ***Measurement Endpoint 8b:*** Compare modeled dietary exposure to COPECs in soil to TRVs (calculate HQs) for a mammal, red-tailed fox (*Vulpes vulpes*), using terrestrial habitat at the Site.

Assessment Endpoint No. 9

Do COPEC concentrations in OCDA surface soil pose a potential risk to the sustainability of herbivorous bird populations at the Site?

- ***Measurement Endpoint 9:*** Compare modeled dietary exposure to COPECs to TRVs (calculate HQs) for an herbivorous bird, Northern bobwhite quail (*Colinus virginianus*), using terrestrial habitat at the Site.

Direct contact effects to aquatic and terrestrial plants and invertebrates were evaluated in the SLERA by comparing constituent concentrations to screening levels for each media (Assessment Endpoints 1 through 3). For surface water, potential risks to aquatic receptors were associated with bis(2-ethylhexyl) phthalate and cadmium. In sediment from Park Brook, arsenic, copper, and manganese were identified as posing a potential for risk to aquatic invertebrates. In surface soil, arsenic, barium, lead, manganese, selenium, and zinc had HQs greater than 1 for terrestrial plants or invertebrates. There were several constituents in each media that could not be evaluated quantitatively because no ecologically- based screening level (EBSL) was available thereby representing a source of uncertainty for the SLERA (ARCADIS 2012a).

Preliminary dose modeling was conducted in the SLERA for bioaccumulative COPEC to evaluate potential risks to upper trophic level species exposed to surface soil, sediment, and surface water in the OCDA (Assessment Endpoints 4 through 9). Fourteen of the COPEC identified at the OCDA, specifically PCBs, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, and zinc, were identified as potentially bioaccumulative compounds, indicating that food-chain transfer is a potentially complete route of exposure. Bioaccumulative compounds can accumulate in plants and invertebrates, providing an indirect exposure to birds and mammals who feed on them. In turn, these mammalian and avian species can accumulate these compounds from their diet, providing an indirect exposure route to carnivorous species. Several HQs for the meadow vole (antimony, lead, selenium), short-

tailed shrew (antimony, cadmium, lead, nickel), American robin (cadmium, lead, nickel, zinc), red-tailed hawk (lead), and tree swallow (lead, nickel, zinc) exceeded 1 (ARCADIS 2012a) in dose modeling conducted for the OCDA.

Table 1 presents a summary of the assessment endpoints and COPEC that were identified as posing a potential risk based on the SLERA. However, the SLERA relied on conservative, screening-level assumptions that may overestimate potential ecological risk, (ARCADIS 2012a). The objective of this BERA is to provide additional evaluation of these potential risks by considering less conservative, more realistic exposure parameters. Direct exposure risks (i.e., Assessment Endpoint's 1 through 3) will be evaluated using updated exposure point concentrations (EPCs) where possible, and less conservative screening benchmarks. The refined dose modeling will focus on organisms and COPEC that showed no observed adverse effects level (NOAEL) or lowest observed adverse effects level (LOAEL) HQs above 1 in the SLERA.

BERA Refinements to Assessment of Direct Contact Exposure

Direct contact exposures were evaluated in the SLERA by comparing the maximum detected concentration to an EBSL. For the purpose of the BERA, this comparison was conducted using more representative estimates of the actual EPC and less conservative benchmarks when data were available.

For example, the screening criteria for bis(2-ethylhexyl) phthalate used in the SLERA was based on a toxicity study from Mayer and Sanders (1973), which reported an unbounded LOAEL value of 3 micrograms per liter (µg/L). A 10-fold safety factor was applied to this value, resulting in a screening value of 0.3 µg/L (NJDEP 2009; USEPA 2003). However, more recent evidence indicates that the research conducted by Mayer and Sanders (1973) may have been flawed. Specifically, subsequent investigations have not been able to duplicate the results and studies repeating the exposure scenarios consistently report no effects at concentrations closer to 100 µg/L (Rhodes et al. 1995). A search of the USEPA ECOTOX database suggests that bounded no observed effect concentration (NOEC) values for aquatic species range from 77 to 50,000 µg/L considering growth, reproduction, and survival endpoints. Based on this information, the effects-based screening level for bis(2-ethylhexyl) phthalate has been adjusted to 77 µg/L, the lowest NOEC reported in the ECOTOX database. The actual hazard quotient is therefore 0.02, which indicates that risk associated with this constituent is negligible. As a result, bis(2-ethylhexyl) phthalate is no longer considered a constituent of potential ecological concern in surface water at the Site.

Surface water benchmarks for a number of metals (including cadmium, copper, nickel, and zinc) were calculated according to NJDEP guidance (NJDEP 2011) based on water hardness. For the purpose of the conservative screening, the values were calculated to estimate dissolved (i.e., filtered) concentrations, which are assumed to represent the bioavailable fraction in surface water. However, the available surface water data for the OCDA are total concentrations (i.e., unfiltered) for metals. Therefore, the BERA has been revised to compare the metals concentrations in surface water to the estimated total metal (i.e., unfiltered) surface water benchmarks.

In addition, other factors such as the frequency of detection and the site-wide distribution of exceedances were considered. Additional screening was only carried out on constituents that showed elevated HQs in the SLERA (Table 1). A 95% upper confidence level of the mean of the dataset (95% UCL) was used to represent the EPC for each media. Specifically, the 95% UCLs were calculated for datasets that had at least 10 samples and at least five detections. The 95% UCLs were calculated using ProUCL version 4.00.05 (USEPA 2010). For datasets insufficient to calculate 95% UCLs (either too few samples or too few detections), the maximum detected concentrations were retained as the EPC.

Tables 2, 3, and 4 summarize these comparisons for surface water, sediment, and surface soil, respectively.

Refinements to Dose Modeling

To evaluate potential effects to upper trophic level wildlife (e.g., mammals and birds), a refined dose-exposure model was used to estimate the daily intake of COPEC by each receptor:

$$ADD = \frac{\{[(IR_f \times C_f) + (IR_s \times C_s)] \times SUF\}}{BW}$$

Where:

ADD = Average daily dose of COPEC (mg/kg/day)

C_f = Concentration of a COPEC in food (mg/kg)

IR_f = Daily ingestion of food (kg/day)

C_s = Concentration of a COPEC in soil or sediment (mg/kg)

IR_s = Daily incidental ingestion rate of soil or sediment (kg/day)

SUF = Site use factor (unitless)

BW = Body weight (kg)

For the purpose of this BERA, refined dose estimates were calculated for the meadow vole, short-tailed shrew, American robin, red-tailed hawk, and tree swallow as these were the only receptors with NOAEL or LOAEL HQs greater than 1 based on the modeling conducted for the SLERA (ARCADIS 2012a). The analysis focused on the specific constituents (antimony, cadmium, lead, nickel, selenium, and zinc) associated with HQs greater than 1 in the SLERA. EPCs for these constituents in soil and sediment are presented in Table 5. Bioaccumulation factors (BAFs) for soil remain unchanged from the SLERA and are presented in Table 6. As available, biota sediment accumulation factors (BSAFs) for sediment from the literature were used in the refined dose model. BSAFs were available for cadmium, lead, nickel, and zinc and were used as recommended by the authors (Bechtel Jacobs 1998). For antimony and selenium, no BSAFs were available so BAFs were used in the model (USEPA 2007b). Specific refinements to the BERA dose modeling include more realistic TRVs for all receptors and adjustments to the model input parameters for the American robin.

The TRVs used in the dose modeling for each constituent showing a potential risk in the SLERA were evaluated. Most TRVs are based on a single study, with a single organism, and a single constituent form. A few of the TRVs were based on a geometric mean of NOAEL values for reproduction and growth, but these calculations did not consider LOAEL values that may have been available. Therefore, the TRVs used in the SLERA represent a very conservative estimate of potential effects to organisms in the environment. To refine the TRVs for COPEC posing a potential risk in the SLERA, data considered as high quality (i.e., literature selected for Ecological Soil Screening Level [EcoSSL] development following USEPA methodology [2007a]) in each EcoSSL document were evaluated. Focusing on the reproduction and growth endpoints for both mammalian and avian receptors, refined TRVs for antimony, cadmium, lead, nickel, selenium, and zinc were defined as the geometric mean of those toxicological results reported for which both a NOAEL and LOAEL value (i.e., bounded values) were reported. There were no avian studies selected for derivation of an EcoSSL for antimony. Studies used in the calculation of TRVs are presented in Attachment A by constituent. Refined TRVs were used in dose modeling for the meadow vole, short-tailed shrew, American robin, red-tailed hawk, and tree swallow and are presented in Table 7.

In addition to the modifications to the TRVs, specific changes to the exposure assumptions for the American robin were made as described below and presented in Table 8. All other exposure parameters remain unchanged.

Dietary Composition: For the purpose of the SLERA, the robin's diet was assumed to be comprised solely of invertebrates (e.g., worms). This is a conservative assumption because uptake of metals such as lead is typically greater in invertebrates than in plant tissue. For the purpose of this BERA, the dietary composition was modified to more accurately reflect the robin's actual diet, which includes plant material as well as invertebrate tissue. Dietary data reported by Howell (1942) was used to develop these estimates, with a modification recommended by Chapman (1999). Specifically, Chapman notes that the dietary composition reported by Howell (1942) includes a grass component. However, ingestion of grass by robins is likely to be accidental and does not provide dietary value. Therefore, the estimates were adjusted to exclude that component resulting in an assumed composition of 13% plants and 87% invertebrates.

Daily Ingestion Rate: The SLERA assumed the maximum daily ingestion rate reported in the *Wildlife Exposure Factors Handbook* (USEPA 1993). For the purpose of this BERA, a daily ingestion rate developed based on a laboratory study conducted by Levey and Karasov (1989) was considered. As noted for the dietary composition, the values reported by Levey and Karasov (1989) were modified to remove the grass component of the diet (Chapman, 1999) resulting in a more realistic daily ingestion rate of 0.38 kg/kg body weight per day wet weight. Converting the value to correct for body weight yields a daily ingestion rate of 0.029 kg/day wet weight of plants (excluding grass) and invertebrates as shown in the enclosed Table 8.

Soil Ingestion Rate: For the purpose of this BERA, the soil ingestion rate was assumed to be 10% based on data reported in the *Wildlife Exposure Factors Handbook* (USEPA, 1993) value for American woodcock (*Scolopax minor*).

Body Weight: A body weight of 0.0773 kg was assumed based on data reported in the *Wildlife Exposure Factors Handbook* (USEPA 1993).

The refined dose modeling for soil and sediment described above is presented in the enclosed Tables 9 through 13. Hazard quotients for modeling with soil and sediment are presented in Table 14.

BERA Risk Characterization

As previously discussed, direct-contact effects to terrestrial and aquatic plants and invertebrates were evaluated in the BERA by comparing EPCs to conservative screening levels for each media. For surface water, there were insufficient data to calculate a new EPC, so the evaluation is still based on the maximum detected concentration. The results indicate that cadmium is the only constituent that occurs in surface water at concentrations above an EBSL (Table 2). Cadmium was only detected in two samples (ARCADIS 2012a). For sediments, as shown in Table 3, none of the detected concentrations exceed the upper bound screening level (i.e., the severe effect level). In surface soil, the 95% UCL for arsenic, barium, lead, manganese, selenium, and zinc exceeded the screening level and may pose a risk to terrestrial plants or invertebrates (Table 4) as HQs in surface soil above 1 were calculated. As previously noted, there are some constituents that could not be evaluated quantitatively because no EBSL was available, representing a source of uncertainty.

Risks to upper trophic -level receptors potentially exposed to surface soil and sediment were refined in the BERA. As summarized in Table 14, no refined LOAEL HQs exceed 1 for any receptor. NOAEL HQs exceed 1 for cadmium in the short-tailed shrew and lead in the American robin, indicating limited potential for risk.

Conclusions

As previously discussed, the SLERA (ARCADIS 2012a) conducted for the OCDA concluded that there are COPEC in soil, sediment, and surface water that are present at concentrations greater than screening levels indicating a potential risk to terrestrial plants and invertebrates, as well as aquatic plants, benthic invertebrates, and fish. These risks were further evaluated through dose modeling to upper trophic level receptors, which demonstrated that potential ecological risks within the OCDA were associated with dietary exposures of metal COPEC in soil to the meadow vole, short-tailed shrew, American robin, and red-tailed hawk as well as metal COPEC in sediment to the tree swallow. All other potential exposure pathways were determined to have negligible risk. The objective of this BERA was to provide a refined analysis of the potential risks using more realistic exposure assumptions.

The analysis presented in the BERA indicates that the elevated HQs associated with COPEC in soil, sediment, and surface water are very localized. Actual potential risks to plants, aquatic receptors, and invertebrates are therefore likely to be minimal. Similarly, the results of the refined dose modeling for soil and sediment demonstrate that risks associated with potential exposures to ecological receptors including the meadow vole, short-tailed shrew, American robin, red-tailed hawk, and tree swallow in the OCDA are

low; no LOAEL HQs for any receptor or COPEC modeled for soil or sediment exceeded 1. NOAEL HQs exceed 1 for cadmium in the short-tailed shrew and lead in the American robin indicating limited potential for risk. As noted above, NOAEL TRVs are very conservative and, therefore, the LOAEL HQ provides a more appropriate estimate of potential risk.

Based on the results of this BERA, the data indicate that the risks to ecological receptors within the OCDA are low and no further evaluation is warranted.

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1. Site-Specific Conceptual Site Model

Tables:

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5. Exposure Point Concentrations Used in Dose Modeling
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11. Hazard Quotients for American Robin
12. Hazard Quotients for Tree Swallow
13. Hazard Quotients for Red-Tailed Hawk
14. Summary of Hazard Quotients Based on Refined Dose Modeling

Attachments:

A. Bounded NOAEL and LOAEL Values from Avian and Mammalian Reproduction and Growth Studies from USEPA EcoSSL Documents

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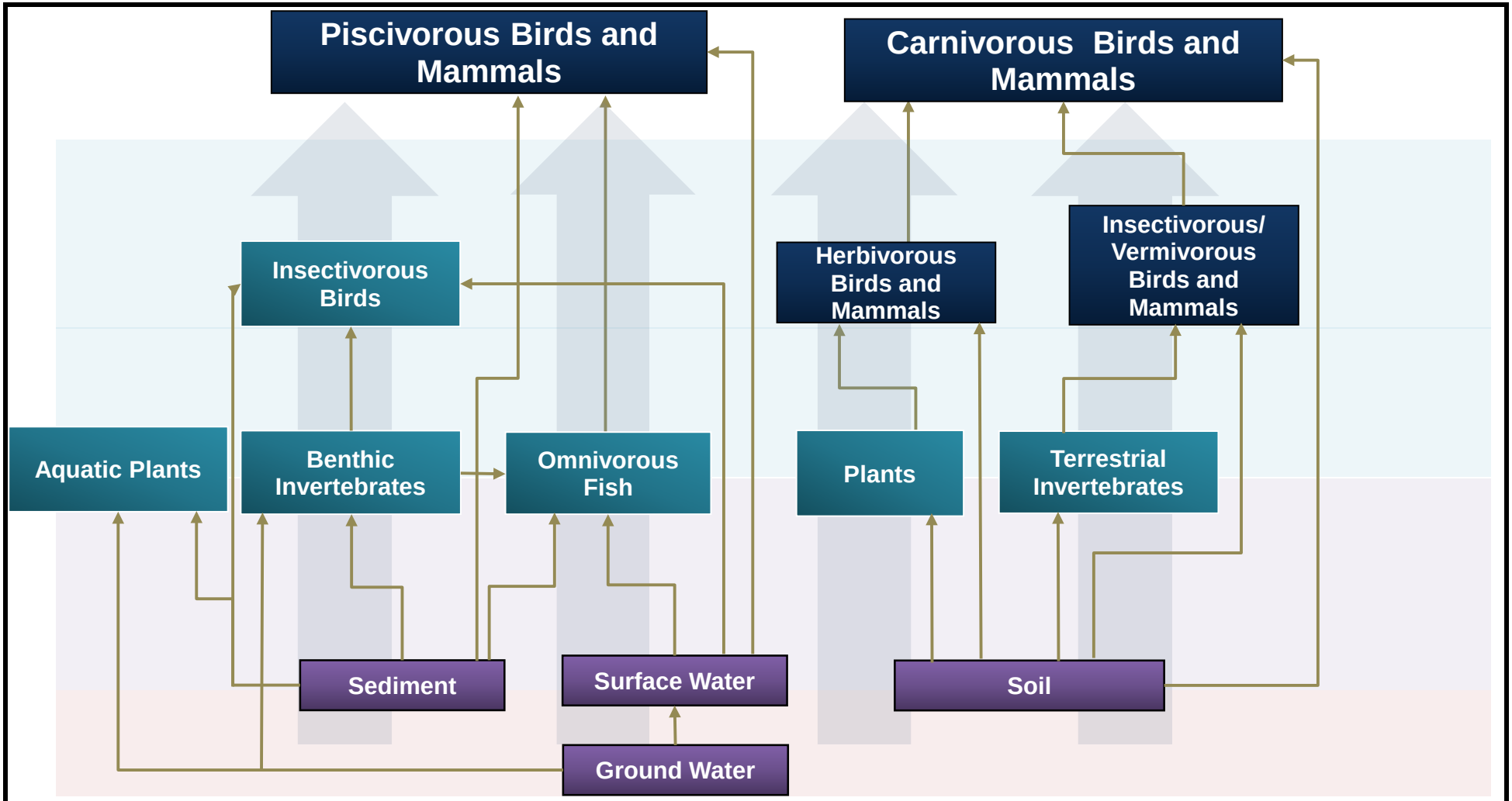

NOTE:

Complete Exposure Pathway

O'Connor Disposal Area - Ringwood Site
Baseline Ecological Risk Assessment

SITE-SPECIFIC CONCEPTUAL SITE MODEL

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FIGURE
1

Fig 1 - OCDA CSM-Ringwood.xlsx
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Table 1. Summary of COPECs and Exposure Pathways Identified in the Screening Level Ecological Risk Assessment as Requiring Further Evaluation
O'Connor Disposal Area, Ringwood, New Jersey

Constituent	ME 1 Direct Contact to Soil Plants and Invertebrates	ME 2a Direct Contact to Sediment Plants and Invertebrates	ME 2b Direct Contact to Surface Water Plants and Invertebrates	ME 3 Direct Contact to Surface Water Fish	ME 4 Dietary Exposure Meadow Vole	ME 5a Dietary Exposure American Robin	ME 5b Dietary Exposure Tree Swallow	ME 6 Dietary Exposure Short-tailed Shrew	ME 7a Dietary Exposure Red-tailed Hawk
SVOCs									
bis(2-Ethylhexyl)phthalate			X	X					
Metals - Total									
Antimony					X			X	
Arsenic	X	X							
Barium	X								
Cadmium			X	X		X		X	
Cobalt									
Copper		X							
Lead	X				X	X	X	X	X
Manganese	X	X							
Nickel						X	X	X	
Selenium	X				X				
Zinc	X					X	X		

Notes:
Only COPEC and pathways associated with at least one HQ>1 are shown.
COPEC = Constituent of potential ecological concern
ME = Measurement endpoint
SVOCs = Semi-volatile organic compounds
X = Chemical had a hazard quotient greater than one for specified measurement endpoint.

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Table 2. Summary of Park Brook BERA Surface Water Hazard Quotients
O'Connor Disposal Area, Ringwood, New Jersey

Constituent	Surface Water EBSL (a)		Surface Water EPC (b)	Hazard Quotient
SVOCs				
Bis(2-ethylhexyl)phthalate	77	(c)	1.2	0.02
Metals - Total (c)				
Cadmium	0.17	(d)	0.3	2

Notes:
Results are reported in micrograms per liter (ug/L).
(a) Surface water EBSLs recommeded by New Jersey Department of Environmental Protection
(b) Insufficient data to calculate upper confidence limit, therefore, maximum detected concentration is presented. Metals results are unfiltered.
(c) Value is lowest NOEC reported for growth, survival, or reproduction endpoints from USEPA ECOTOX Database (http://cfpub.epa.gov/ecotox/quick_query.htm), original study Rhodes et. al. 1995.
(d) Total criteria calculated using the formula: WER $[e^{(0.7409\ (\ln\ [\text{hardness}])-4.719)}]$
where hardness = 51.952 mg/L (average hardness calculated from 2005 surface water samples)
-- = Value not available
BERA = Baseline Ecological Risk Assessment
EBSL = Effects Based Screening Level
EPC = Exposure Point Concentration
NOEC = No Observed Effect Concentration
SVOCs = Semi-volatile Organic Compounds
WER = Water Effect Ratio

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Table 3. Summary of Park Brook BERA Sediment Hazard Quotients
O'Connor Disposal Area, Ringwood, New Jersey

Constituent	Sediment EBSL (a)		Sediment EPC (b)	Hazard Quotient
Metals				
Arsenic	33		15.5	0.47
Copper	110		19.3	0.18
Manganese	1100	(c)	1060	0.96

Notes:
Results are reported in milligrams per kilogram (mg/kg)
(a) Values reported are severe effect levels reported in New Jersey Department of Environmental Protection's Ecological Screening Criteria Table
(b) Insufficient data to calculate upper confidence limit; therefore, maximum detected concentration is presented
(c) Sediment value from National Oceanic and Atmospheric Administration Screening Quick Reference Tables
-- = Value not available
BERA = Baseline Ecological Risk Assessment
EBSL = Effects Based Screening Level
EPC = Exposure point concentration

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Table 4. Summary of BERA Surface Soil Hazard Quotients
O'Connor Disposal Area, Ringwood, New Jersey

Constituent	Soil EBSL (a)		Soil EPC (b)	Hazard Quotient Plants	Hazard Quotient Invertebrates
	Plants	Soil Invertebrates			
Metals - Total					
Arsenic	18	--	39.2	2	--
Barium	--	330	550.7	--	2
Cobalt	13	--	11.97	0.9	--
Copper	70	80	35.7	0.5	0.4
Lead	120	1700	1219	10	0.7
Manganese	220	450	616	3	1
Nickel	38	280	5.38	0.1	0.02
Selenium	0.52	4.1	1.3 c	3	0.3
Zinc	160	120	204	1	2

Notes:
(a) Values presented are EPA's ecological soil screening levels (EcoSSL) (2003)
(b) Upper confidence limit as recommended by ProUCL is presented unless otherwise noted
(c) Data insufficient to calculate upper confidence limit; value is maximum
-- = Value not available
EBSL = Effects Based Screening Level
EPC = Exposure point concentration
mg/kg = Milligrams per kilogram

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Table 5. Exposure Point Concentrations Used in Dose Modeling
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Site-wide Surface Soil (a)		Site-wide Sediment		Site-wide Surface Water	
	Soil EPC (mg/kg)	Basis	Sediment EPC (mg/kg)	Basis	Surface Water (ug/L)	Basis
Antimony	23.8	Maximum (b)	ND	--	6.4	Maximum (b)
Cadmium	5.3	Maximum (b)	ND	--	0.3	Maximum (b)
Lead	1219	UCL	19.6	Maximum (b)	3.7	Maximum (b)
Nickel	5.38	UCL	12.6	Maximum (b)	3.2	Maximum (b)
Selenium	1.3	Maximum (b)	ND	--	ND	--
Zinc	203.6	UCL	76.2	Maximum (b)	8.6	Maximum (b)

Notes:
(a) Surface soil defined as depth interval from 0 to 6 inches below ground surface
(b) Data insufficient to calculate UCL; value is maximum
COPEC = Constituent of potential ecological concern
EPC = Exposure point concentration
mg/kg = Milligrams per kilogram
ND = Not detected in media
UCL = Upper confidence limit as recommended by ProUCL
ug/L = Micrograms per liter
-- = No data available

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Table 6. Summary of BAFs and BSAFs
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Soil (a)			Sediment	
	BAF_{invert}	BAF_{plant}	BAF_{mammal}	$BSAF_{invert}$	
Antimony	Cs	e^(0.938*LN(Cs) - 3.233)	0.001 * 50 * (Cd)	Cs	(a)
Cadmium	e^(0.795*LN(Cs)+2.114)	e^(0.546*LN(Cs)-0.475)	e^(0.4723*LN(Cs)-1.2571)	10^(-0.314+0.513*log(Cs))	(b)
Lead	e^(0.807 * LN(Cs) - 0.218)	e^(0.561*LN(Cs) - 1.328)	e^(0.4422 * LN(Cs) + 0.0761)	10^(-0.864+0.859*log(Cs))	(b)
Nickel	e^(7.033-1.548*LN(Cs))	e^(0.748*LN(Cs)-2.223)	e^(0.4658*LN(Cs)-0.2462)	10^(-0.44+0.695*log(Cs))	(b)
Selenium	e^(0.733*LN(Cs)-0.075)	e^(1.104*LN(Cs)-0.677)	e^(0.3764*LN(Cs)-0.4158)	e^(0.733*LN(Cs)-0.075)	(a)
Zinc	e^(0.328 * LN(Cs) + 4.449)	e^(0.554*LN(Cs) + 1.575)	e^(0.0706 * LN(Cs) + 4.3632)	10^(1.89+0.126*log(Cs))	(b)

Notes:
Source is USEPA (2007b) for all BAFs except for nickel, which is from Sample et al. (1998).
(a) BAF from USEPA 2007b
(b) Bechtel Jacobs 1998
BAF = Bioaccumulation factor
BSAF = Biota-sediment accumulation factor
Cd = Concentration in diet of prey
COPEC = Constituent of potential ecological concern
Cs = Concentration in soil (mg/kg dry weight)
invert = Invertebrate
LN = Natural log

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Table 7. Toxicity Reference Values for Wildlife
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	TRVs (mg/kg/d)							
	Mammals				Birds			
	NOAEL	Notes	LOAEL	Notes	NOAEL	Notes	LOAEL	Notes
Antimony	3.3	(a)	16	(a)	NA		NA	
Cadmium	1.7	(a)	8.7	(a)	1.3	(a)	5.9	(a)
Lead	35	(a)	137	(a)	7.3	(a)	43	(a)
Nickel	10	(a)	33	(a)	15	(a)	21	(a)
Selenium	0.4	(a)	0.8	(a)	0.6	(a)	1.4	(a)
Zinc	146	(a)	895	(a)	89	(a)	154	(a)

Notes:
(a) Geometric mean of NOAEL and LOAEL values for reproduction and growth presented during derivation of Ecological Soil Screening Levels (EcoSSL) (USEPA 2005-2007) as shown in Attachment A.
COPEC = Constituent of potential ecological concern
LOAEL = Lowest observed adverse effects level
mg/kg/d = Miligrams per kilogram per day
NA = Not available
NOAEL = No observed adverse effects level
TRV = Toxicity reference value

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Table 8. Exposure Parameters for Wildlife
O'Connor Disposal Area, Ringwood, New Jersey

Common Name	Scientific Name	Body Weight (kg)	Notes	Dietary Composition (%) (i)			Daily Ingestion Rate (kg/day ww)	Notes	Daily Ingestion Rate (kg/day dw)	Notes	Soil/Sediment Ingestion (%)	Notes	Soil/Sediment Ingestion Rate (kg/day dw)	Notes
				Plants	Inverts	Tissue								
Terrestrial Species														
Meadow vole	*Microtus pennsylvanicus*	0.0369	(a)	100%			0.034900	(a)	0.0115	(a)	2.4%	(f)	0.000276	(h)
Short-tailed shrew	*Blarina brevicauda*	0.015	(b)		100%		0.010140	(d)	0.001622	(e)	3%	(d)	0.000049	(h)
American robin	*Turdus migratorius*	0.077	(c)	13%	87%		0.029	(j)	0.004700	(e)	10%	(g)	0.000470	(h)
Red-tailed hawk	*Buteo jamaicensis*	1.13	(c)			100%	0.111531	(c)	0.03569	(e)	5.7%	(h)	0.002034	(i)
Aquatic Species														
Tree swallow	*Tachycineta bicolor*	0.0202	(a)		100%		0.0352	(a)	0.011600	(a)	<2.0%	(j)	0.000232	(h)

Notes:
(a) Nagy 2001
(b) Sample and Suter 1994
(c) USEPA 1993
(d) Based on shrew and red-tailed hawk (USEPA 2007)
(e) Daily ingestion rates converted to dry weight assuming a moisture content of the following (USEPA 2007):
Inverts: 84%
Tissue: 68%
Plants: 85%
(f) Beyer et al. 1994
(g) Based on American woodcock (Beyer et al. 1994 and USEPA 2007)
(h) Calculated by multiplying the soil ingestion rate times the dry weight daily ingestion rate
(i) American robin dietary composition from Howell (1942) as modified by Chapman (1999)
(j) Levy and Karasov (1989) as modified by Chapman (1999). Value shown is converted from 0.38 kg/kg-bw-d ww to 0.029 kg/day ww by multiplying by body weight
invert = Invertebrate
kg = Kilogram
kg/day dw = Kilograms per day dry weight
kg/day ww = Kilograms per day wet weight
kg/kg-bw-d ww = Kilograms per kilogram body weight per day wet weight

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Table 9. Hazard Quotients for Meadow Vole
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Surface Soil EPC (a) (mg/kg)	Body Weight (kg)	Dietary Composition	BAF_{plant}	C_{plant} (mg/kg)	Daily Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Daily Dietary Dose (mg/kg/d)	TRV (mg/kg/d)		HQ	
			Plants						NOAEL	LOAEL	NOAEL	LOAEL
Antimony	23.8	0.0369	100%	e^(0.938*LN(Cs) - 3.233)	0.771	0.0115	0.000276	0.4184	3.3	16	0.1	0.03
Cadmium	5.3	0.0369	100%	e^(0.546*LN(Cs)-0.475)	1.5	0.0115	0.000276	0.5214	1.7	8.7	0.3	0.06
Lead	1219	0.0369	100%	e^(0.561*LN(Cs) - 1.328)	14.27	0.0115	0.000276	13.5658	35	137	0.4	0.10
Nickel	5.38	0.0369	100%	e^(0.748*LN(Cs)-2.223)	0.381	0.0115	0.000276	0.1591	10.0	33	0.02	0.005
Selenium	1.3	0.0369	100%	e^(1.104*LN(Cs)-0.677)	0.68	0.0115	0.000276	0.2213	0.4	0.8	0.5	0.3
Zinc	203.6	0.0369	100%	e^(0.554*LN(Cs) + 1.575)	91.85	0.0115	0.000276	30.1480	146	895	0.2	0.03

Notes:
(a) Surface soil defined as depth interval from 0 to 6 inches below ground surface
BAF = Bioaccumulation factor
Cplant = Concentration in plant
COPEC = Constituent of potential ecological concern
Cs = Concentration in soil/sediment
EPC = Exposure point concentration
HQ = Hazard quotient
kg = Kilogram
kg/day dw = Kilograms per day dry weight
LN = Natural log
LOAEL = Lowest observed adverse effects level
mg/kg = Milligrams per kilogram
mg/kg/d = Millligrams per kilogram per day
NOAEL = No observed adverse effects level
TRV = Toxicity reference value

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Table 10. Hazard Quotients for Short-Tailed Shrew
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Surface Soil EPC (a) (mg/kg)	Body Weight (kg)	Dietary Composition	BAF_{invert}	C_{invert} (mg/kg)	Daily Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Daily Dietary Dose (mg/kg/d)	TRV (mg/kg/d)		HQ	
			Inverts						NOAEL	LOAEL	NOAEL	LOAEL
Antimony	23.8	0.015	100%	Cs	23.800	0.001622	0.000049	2.6514	3.3	16	0.8	0.2
Cadmium	5.3	0.015	100%	e^(0.795*LN(Cs)+2.114)	31.182	0.001622	0.000049	3.3898	1.7	8.7	**2**	0.4
Lead	1219	0.015	100%	e^(0.807 * LN(Cs) - 0.218)	248.730	0.001622	0.000049	30.8581	35	137	0.9	0.2
Nickel	5.38	0.015	100%	e^(7.033-1.548*LN(Cs))	83.78	0.001622	0.000049	9.0791	10.0	33	0.9	0.3
Selenium	1.3	0.015	100%	e^(0.733*LN(Cs)-0.075)	1.124	0.001622	0.000049	0.1258	0.4	0.8	0.3	0.1
Zinc	203.6	0.015	100%	e^(0.328 * LN(Cs) + 4.449)	489.16	0.001622	0.000049	53.5687	146	895	0.4	0.06

Notes:
(a) Surface soil defined as depth interval from 0 to 6 inches below ground surface
BAF = Bioaccumulation factor
Cinvert = Concentration in invertebrate
COPEC = Constituent of potential ecological concern
Cs = Concentration in soil/sediment
EPC = Exposure point concentration
HQ = Hazard quotient
Invert = Invertebrate
kg = Kilogram
kg/day dw = Kilograms per day dry weight
LN = Natural log
LOAEL = Lowest observed adverse effects level
mg/kg = Milligrams per kilogram
mg/kg/d = Millligrams per kilogram per day
NOAEL = No observed adverse effects level
TRV = Toxicity reference value

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Table 11. Hazard Quotients for American Robin
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Surface Soil EPC (a) (mg/kg)	Body Weight (kg)	Dietary Composition		BAF_{plant}	BAF_{invert}	C_{plant} (mg/kg)	C_{invert} (mg/kg)	Daily Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Daily Dietary Dose (mg/kg/d)	TRV (mg/kg/d)		HQ	
			Plants	Inverts								NOAEL	LOAEL	NOAEL	LOAEL
Antimony	23.8	0.0773	13%	87%	e^(0.938*LN(Cs) - 3.233)	Cs	0.7711789	23.800	0.0047	0.000470	1.4097242	NA	NA	--	--
Cadmium	5.3	0.0773	13%	87%	e^(0.546*LN(Cs)-0.475)	e^(0.795*LN(Cs)+2.114)	1.546	31.182	0.0047	0.000470	1.6938222	1.3	5.9	1	0.3
Lead	1219	0.0773	13%	87%	e^(0.561*LN(Cs) - 1.328)	e^(0.807 * LN(Cs) - 0.218)	14.273	248.730	0.0047	0.000470	20.6811721	7.3	43	**3**	0.5
Nickel	5.38	0.0773	13%	87%	e^(0.748*LN(Cs)-2.223)	e^(7.033-1.548*LN(Cs))	0.381	83.78	0.0047	0.000470	4.4673686	15	21	0.3	0.2
Selenium	1.3	0.0773	13%	87%	e^(1.104*LN(Cs)-0.677)	e^(0.733*LN(Cs)-0.075)	0.679	1.124	0.0047	0.000470	0.0727497	0.59	1.39	0.1	0.05
Zinc	203.6	0.0773	13%	87%	e^(0.554*LN(Cs) + 1.575)	e^(0.328 * LN(Cs) + 4.449)	91.849	489.16	0.0047	0.000470	27.8387312	89	154	0.3	0.2

Notes:
(a) Surface soil defined as depth interval from 0 to 6 inches below ground surface
BAF = Bioaccumulation factor
Cinvert = Concentration in invertebrate
COPEC = Constituent of potential ecological concern
Cplant = Concentration in plant
Cs = Concentration in soil/sediment
EPC = Exposure point concentration
HQ = Hazard quotient
Invert = Invertebrate
kg = Kilogram
kg/day dw = Kilograms per day dry weight
LN = Natural log
LOAEL = Lowest observed adverse effects level
mg/kg = Milligrams per kilogram
mg/kg/d = Millligrams per kilogram per day
NOAEL = No observed adverse effects level
TRV = Toxicity reference value
-- = No data available

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Table 12. Hazard Quotients for Tree Swallow
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Sediment EPC (mg/kg)	Body Weight (kg)	Dietary Composition	$BSAF_{invert}$	C_{invert} (mg/kg)	Daily Ingestion Rate (kg/day dw)	Sediment Ingestion Rate (kg/day dw)	Daily Dietary Dose (mg/kg/d)	TRV (mg/kg/d)		HQ	
			Inverts						NOAEL	LOAEL	NOAEL	LOAEL
Antimony	ND	0.0202	100%	Cs	NA	0.011600	0.000232	NA	NA	NA	--	--
Cadmium	ND	0.0202	100%	10^(-0.314+0.513*log(Cs))	NA	0.011600	0.000232	NA	1.3	5.9	--	--
Lead	19.6	0.0202	100%	10^(-0.864+0.859*log(Cs))	1.8	0.011600	0.000232	1.24	7.3	43	0.2	0.03
Nickel	12.6	0.0202	100%	10^(-0.44+0.695*log(Cs))	2.1	0.011600	0.000232	1.36	15	21	0.09	0.06
Selenium	ND	0.0202	100%	e^(0.733*LN(Cs)-0.075)	NA	0.011600	0.000232	NA	0.6	1.4	--	--
Zinc	76.2	0.0202	100%	10^(1.89+0.126*log(Cs))	134	0.011600	0.000232	77.83	89	154	0.9	0.5

Notes:
BSAF = Biota-sediment accumulation factor
Cinvert = Concentration in invertebrate
COPEC = Constituent of potential ecological concern
Cs = Concentration in soil/sediment
EPC = Exposure point concentration
HQ = Hazard quotient
Invert = Invertebrate
kg = Kilogram
kg/day dw = Kilograms per day dry weight
LN = Natural log
LOAEL = Lowest observed adverse effects level
mg/kg = Milligrams per kilogram
mg/kg/d = Millligrams per kilogram per day
NA = Not appplicable, not a COPEC in this medium
ND = Not detected in media
NOAEL = No observed adverse effects level
TRV = Toxicity reference value
-- = No data available

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Table 13. Hazard Quotients for Red-Tailed Hawk
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	Surface Soil EPC (a) (mg/kg)	Body Weight (kg)	Dietary Composition	$BAF_{mammals}$	$C_{mammals}$ (mg/kg)	Daily Ingestion Rate (kg/day dw)	Soil Ingestion Rate (kg/day dw)	Daily Dietary Dose (mg/kg/d)	TRV (mg/kg/d)		HQ	
			Mammals						NOAEL	LOAEL	NOAEL	LOAEL
Antimony	23.8	1.13	100%	0.001 * 50 * (Cd)	1.1900000	0.03569	0.002034	0.080431814	NA	NA	--	--
Cadmium	5.3	1.13	100%	e^(0.4723*LN(Cs)-1.2571)	0.6253511	0.03569	0.002034	0.029292615	1.32	5.88	0.02	0.005
Lead	1219	1.13	100%	e^(0.4422 * LN(Cs) + 0.0761)	24.9850745	0.03569	0.002034	2.983679665	7.3	43	0.4	0.07
Nickel	5.38	1.13	100%	e^(0.4658*LN(Cs)-0.2462)	1.71	0.03569	0.002034	0.063753787	15	21	0.004	0.003
Selenium	1.3	1.13	100%	e^(0.3764*LN(Cs)-0.4158)	0.7282972	0.03569	0.002034	0.025342913	0.59	1.39	0.04	0.02
Zinc	203.6	1.13	100%	e^(0.0706 * LN(Cs) + 4.3632)	114.27	0.03569	0.002034	3.975485812	89	154	0.04	0.03

Notes:
(a) Surface soil defined as depth interval from 0 to 6 inches below ground surface
BAF = Bioaccumulation factor
Cd = Concentration in diet of prey
Cmammals = Concentration in mammals
COPEC = Constituent of potential ecological concern
Cs = Concentration in soil/sediment
EPC = Exposure point concentration
HQ = Hazard quotient
kg = Kilogram
kg/day dw = Kilograms per day dry weight
LN = Natural log
LOAEL = Lowest observed adverse effects level
mg/kg = Milligrams per kilogram
mg/kg/d = Millligrams per kilogram per day
NA = Not appplicable, not a COPEC in this medium
NOAEL = No observed adverse effects level
TRV = Toxicity reference value
-- = No data available

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Table 14. Summary of Hazard Quotients Based on Refined Dose Modeling
O'Connor Disposal Area, Ringwood, New Jersey

COPEC	HQ Based on Site-specific Surface Soil Samples (a)								HQ Based on Site-specific Sediment Samples	
	Meadow Vole		Short-tailed Shrew		American Robin		Red-tailed Hawk		Tree Swallow	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Antimony	0.1	0.03	0.8	0.2	--	--	--	--	NA	NA
Cadmium	0.3	0.06	**2**	0.4	1	0.3	0.02	0.005	NA	NA
Lead	0.4	0.10	0.9	0.2	**3**	0.5	0.4	0.07	0.2	0.03
Nickel	0.02	0.005	0.9	0.3	0.3	0.2	0.004	0.003	0.09	0.06
Selenium	0.5	0.3	0.3	0.1	0.1	0.05	0.04	0.02	NA	NA
Zinc	0.2	0.03	0.4	0.06	0.3	0.2	0.04	0.03	0.9	0.5

Notes:
(a) Surface soil defined as depth interval from 0 to 6 inches below ground surface
Bold cells indicate an HQ > 1
COPEC = Constituent of potential ecological concern
HQ = Hazard quotient
LOAEL = Lowest observed adverse effects level
NOAEL = No observed adverse effects level
NA = Not appplicable, not a COPEC in this medium
-- = No data available

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Attachment A. Bounded Antimony NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2005a)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Rossi et al. 1987	Rat (Rattus norvegicus)	0.0590	0.590
Growth			
Poon et al. 1998	Rat (Rattus norvegicus)	5.60	42.0
Dieter 1992	Mouse (Mus musculus)	106	161
Geometric Mean of NOAEL and LOAEL		3.3	16

Notes:

a. All growth and reproduction studies presented in USEPA 2005a with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2005a. Ecological Soil Screening Levels for Antimony: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-61. February.

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Attachment A. Bounded Cadmium NOAEL and LOAEL Values from Avian Reproduction and Growth Studies from USEPA (2005b)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Leach et al. 1978	Chicken (Gallus domesticus)	0.593	2.37
Leach et al. 1978	Chicken (Gallus domesticus)	0.593	2.37
Bokori et al. 1996	Chicken (Gallus domesticus)	0.799	2.4
White and Finley 1978	Mallard (Anas platyrhychos)	1.53	21.1
White et al. 1978	Mallard (Anas platyrhynchos)	1.53	21
Growth			
Lefevre et al. 1982	Chicken (Gallus domesticus)	0.708	7.08
Leach et al. 1978	Chicken (Gallus domesticus)	0.826	3.3
Bokori et al. 1996	Chicken (Gallus domesticus)	1.55	4.66
Hill 1979	Chicken (Gallus domesticus)	1.72	3.44
Hill 1974	Chicken (Gallus domesticus)	1.72	3.44
Di Giulio and Scanlon 1984	Mallard (Anas platyrhychos)	12.5	37.6
Geometric Mean of NOAEL and LOAEL		1.3	5.9

Notes:
a. All growth and reproduction studies presented in USEPA 2005b with both NOAEL and LOAEL value reported.
LOAEL = Lowest observed adverse effects level
mg/kg bw/day = Milligrams per kilogram body weight per day
NOAEL = No observed adverse effects level
USEPA = United States Environmental Protection Agency
USEPA. 2005b. Ecological Soil Screening Levels for Cadmium: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-65. March.

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Attachment A. Bounded Cadmium NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2005b)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Webster 1988	Mouse (Mus musculus)	0.0939	15.6
Sorell and Braziano 1990	Rat (Rattus norvegicus)	0.651	4.88
Sutou et al. 1980a	Rat (Rattus norvegicus)	1	10
Sutou et al. 1980b	Rat (Rattus norvegicus)	1	10
Sawicka-Kapusta et al 1994	Mouse (Mus musculus)	1.14	2.28
Ahokas et al 1980	Rat (Rattus norvegicus)	1.57	4.5
Baranski and Sitarek 1987	Rat (Rattus norvegicus)	4	40
Zielinska-Psuja et al. 1979	Rat (Rattus norvegicus)	5.4	54
Sasser et al. 1985	Rat (Rattus norvegicus)	6	10
Machemer and Lorke 1981	Rat (Rattus norvegicus)	6.13	18.4
Wardell et al. 1982	Rat (Rattus norvegicus)	50	75
Growth			
Merali and Singhal 1980	Rat (Rattus norvegicus)	0.1	1
Rastogi et al 1977	Rat (Rattus norvegicus)	0.1	1
Ahokas et al 1980	Rat (Rattus norvegicus)	0.207	1.6
Cousins et al 1977	Rat (Rattus norvegicus)	0.268	1.3
Baranski and Sitarek 1987	Rat (Rattus norvegicus)	0.4	4
Doyle et al. 1974	Sheep (Ovis aires)	0.448	0.909
Ogoshi et al. 1989	Rat (Rattus norvegicus)	0.581	1.2
Perry et al. 1977	Rat (Rattus norvegicus)	0.645	1.6
Yuhas et al 1979	Rat (Rattus norvegicus)	0.77	7.7
Sutou et al. 1980	Rat (Rattus norvegicus)	1	10
Takashima et al 1980	Rat (Rattus norvegicus)	1.04	5.2
Bhattacharyya et al. 1988	Mouse (Mus musculus)	1.08	10.8
Machemer and Lorke 1981	Rat (Rattus norvegicus)	1.84	6.13
Yuyama 1982	Rat (Rattus norvegicus)	2.65	10.6
Lee et al. 1994	Rat (Rattus norvegicus)	3	10
Mitsumori et al. 1998	Rat (Rattus norvegicus)	3.08	15.4
Cousins et al. 1973	Pig (Sus scrofa)	4.05	12
Chetty et al. 1980	Rat (Rattus norvegicus)	4.36	8.71
Koller and Roan 1977	Mouse (Mus musculus)	4.44	44.4
Zielinska-Psuja et al. 1979	Rat (Rattus norvegicus)	5.4	54
Gustafson and Mercer 1984	Rat (Rattus norvegicus)	6.06	15.2

Attachment A. Bounded Cadmium NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2005b)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Ogoshi et al. 1989	Rat (Rattus norvegicus)	8.54	17.1
Exon et al. 1979	Mouse (Mus musculus)	43	85.9
Hamada et al. 1991	Dog (Canis familiaris)	50	100
Geometric Mean of NOAEL and LOAEL		1.7	8.7

Notes:

a. All growth and reproduction studies presented in USEPA 2005b with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2005b. Ecological Soil Screening Levels for Cadmium: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-65. March.

Attachment A. Bounded Lead NOAEL and LOAEL Values from Avian Reproduction and Growth Studies from USEPA (2005c)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Edens and Garlich 1983	Japanese quail (Coturnix japonica)	0.194	1.94
Edens and Garlich 1983	Chicken (Gallus domesticus)	1.63	3.26
Meluzzi et al. 1996	Chicken (Gallus domesticus)	2.69	4.04
Morgan et al. 1975	Japanese quail (Coturnix japonica)	12.6	126
Morgan et al. 1975	Japanese quail (Coturnix japonica)	67	135
Growth			
Edens and Garlich 1983	Japanese quail (Coturnix japonica)	1.56	15.6
Edens and Melvin 1989	Japanese quail (Coturnix japonica)	5.93	59.3
Damron et al. 1969	Chicken (Gallus domesticus)	6.14	61.4
Damron et al. 1969	Chicken (Gallus domesticus)	7.10	71.0
Edens et al. 1976	Japanese quail (Coturnix japonica)	11.1	111
Edens 1985	Japanese quail (Coturnix japonica)	11.2	112
Morgan et al. 1975	Japanese quail (Coturnix japonica)	12.6	126
Morgan et al. 1975	Japanese quail (Coturnix japonica)	14	67
Hoffman et al. 1985	American kestrel (Falco sparverius)	25.0	125
Berg et al. 1980	Chicken (Gallus domesticus)	61.3	123
Geometric Mean of NOAEL and LOAEL		7.3	43

Notes:

a. All growth and reproduction studies presented in USEPA 2005c with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2005c. Ecological Soil Screening Levels for Lead: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-70. March.

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Attachment A. Bounded Lead NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2005c)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Grant et al. 1980	Rat (Rattus norvegicus)	0.71	7
Dilts and Ahokas 1979	Rat (Rattus norvegicus)	1	5
Gandley et al. 1999	Rat (Rattus norvegicus)	2.6	26
Grant et al. 1980	Rat (Rattus norvegicus)	3	6
Dilts and Ahokas 1980	Rat (Rattus norvegicus)	5	10
Jessup and Shott 1969	Rat (Rattus norvegicus)	7.5	74.9
Kimmel et al. 1980	Rat (Rattus norvegicus)	9.1	45
McMurry et al. 1995	Cotton rat (Sigmodon hispidus)	12.4	170
Barratt et al. 1989	Rat (Rattus norvegicus)	18	180
Chowdhury et al. 1984	Rat (Rattus norvegicus)	31.6	63.2
Winder et al. 1984	Rat (Rattus norvegicus)	33.3	111
Miller et al. 1982	Rat (Rattus norvegicus)	41	54.6
Wolfe et al.1996	Rat (Rattus norvegicus)	47.3	82
Sourgens et al. 1987	Rat (Rattus norvegicus)	56	285
Ronis et al. 1998	Rat (Rattus norvegicus)	90.1	270
Wardell et al. 1982	Rat (Rattus norvegicus)	100	150
Eyden et al.1978	Mouse (Mus musculus)	144.0	1440
Maker et al. 1973	Mouse (Mus musculus)	202	506
Maker et al. 1973	Mouse (Mus musculus)	202	506
Cramer et al.1980	Rat (Rattus norvegicus)	276	552
Nathan et al. 1992	Rat (Rattus norvegicus)	294	587
Barrett and Livesey 1983	Rat (Rattus norvegicus)	601	1500
Growth			
Dilts and Ahokas 1979	Rat (Rattus norvegicus)	1	5
Kimmel et al. 1980	Rat (Rattus norvegicus)	1.27	13
Kimmel et al. 1980	Rat (Rattus norvegicus)	5	9
Zheng et al. 1996	Rat (Rattus norvegicus)	5.64	28.2
Hammond et al. 1989	Rat (Rattus norvegicus)	5.8	29
Gruber et al. 1997	Rat (Rattus norvegicus)	11	532
Lorenzo et al. 1978	Rabbit (Oryctolagus cuniculus)	10.7	50.4
Gerber et al.1978	Mouse (Mus musculus)	16.3	163
Barratt et al. 1989	Rat (Rattus norvegicus)	18	180
Wolfe et al.1996	Rat (Rattus norvegicus)	71.5	178
Gelman and Michaelson 1979	Rat (Rattus norvegicus)	75	225
Goyer et al. 1970	Rat (Rattus norvegicus)	120	383

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Attachment A. Bounded Lead NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2005c)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Eyden et al.1978	Mouse (Mus musculus)	136	1360
Sokol et al. 1985	Rat (Rattus norvegicus)	169.0	508.0
Wadi and Ahmad 1999	Mouse (Mus musculus)	187	373
Mykkanen et al. 1980	Rat (Rattus norvegicus)	230	460
Holtzman et al. 1982	Rat (Rattus norvegicus)	400	800
Holtzman et al. 1982	Rat (Rattus norvegicus)	400	800
Maker et al. 1973	Mouse (Mus musculus)	632	1264
Maker et al. 1973	Mouse (Mus musculus)	1260	2530
Geometric Mean of NOAEL and LOAEL		35	137

Notes:

a. All growth and reproduction studies presented in USEPA 2005c with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2005c. Ecological Soil Screening Levels for Lead: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-70. March.

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Attachment A. Bounded Nickel NOAEL and LOAEL Values from Avian Reproduction and Growth Studies from USEPA (2007c)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Growth			
Martinez and Diaz 1996	Chicken (Gallus domesticus)	5.76	11.5
Hill 1979	Chicken (Gallus domesticus)	8.95	17.9
Weber and Reid 1968	Chicken (Gallus domesticus)	28.3	30.2
Weber and Reid 1968	Chicken (Gallus domesticus)	31.0	31.5
Geometric Mean of NOAEL and LOAEL		15	21

Notes:

a. All growth and reproduction studies presented in USEPA 2007c with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2007c. Ecological Soil Screening Levels for Nickel: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-70. March.

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Attachment A. Bounded Nickel NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2007c)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Kakela et al. 1999	Rat (Rattus norvegicus)	1.10	3.31
Pandey and Srivastava 2000	Mouse (Mus musculus)	1.35	2.71
Pandey and Srivastava 2000	Mouse (Mus musculus)	1.70	3.40
Berman and Rehnberg 1983	Mouse (Mus musculus)	85.3	171
Ambrose et al. 1976	Rat (Rattus norvegicus)	164	327
Growth			
Smith et al. 1993	Rat (Rattus norvegicus)	1.33	6.80
Spears and Hatfield 1985	Rat (Rattus norvegicus)	1.47	22.0
O'Dell et al. 1970	Cattle (Bos taurus)	1.64	6.55
O'Dell et al. 1971	Cattle (Bos taurus)	7.00	14.6
Ambrose et al. 1976	Rat (Rattus norvegicus)	9.11	91.1
Whanger 1973	Rat (Rattus norvegicus)	9.49	47.4
Obone et al. 1999	Rat (Rattus norvegicus)	11.7	23
Alexander et al. 1978	Meadow vole (Microtus pennsylvanicus)	29	309
Ambrose et al. 1976	Dog (Canis familiaris)	45.0	112
Berman and Rehnberg 1983	Mouse (Mus musculus)	85.3	171
Dieter et al. 1988	Mouse (Mus musculus)	107.0	148
Geometric Mean of NOAEL and LOAEL		10	33

Notes:

a. All growth and reproduction studies presented in USEPA 2007c with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2007c. Ecological Soil Screening Levels for Nickel: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-70. March.

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Attachment A. Bounded Selenium NOAEL and LOAEL Values from Avian Reproduction and Growth Studies from USEPA (2007d)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Thapar et al. 1969	Chicken (Gallus domesticus)	0.092	0.368
Stanley et al. 1996	Mallard (Anas platyrhynchos)	0.212	0.425
Poley and Moxon 1938	Chicken (Gallus domesticus)	0.214	0.429
Heinz et al. 1989	Duck (Anas platyrhynchos)	0.219	0.438
Ort and Latshaw 1978	Chicken (Gallus domesticus)	0.247	0.412
Hoffman and Heinz 1988	Mallard (Anas platyrhynchos)	0.273	0.546
Albers et al. 1996	Duck (Anas platyrhynchos)	0.644	1.29
Heinz et al. 1987	Mallard (Anas platyrhynchos)	1.03	2.58
Growth			
Jensen 1986	Chicken (Gallus domesticus)	0.0740	0.370
Thapar et al. 1969	Chicken (Gallus domesticus)	0.180	0.721
Hill 1979	Chicken (Gallus domesticus)	0.204	0.408
Echevarria et al. 1988	Chicken (Gallus domesticus)	0.213	0.426
Hill 1974	Chicken (Gallus domesticus)	0.429	0.859
Jensen et al. 1977	Chicken (Gallus domesticus)	0.617	1.23
O'Toole and Raisbeck 1997	Mallard (Anas platyrhynchos)	0.690	1.73
Cantor et al. 1984	Chicken (Gallus domesticus)	0.72	1.44
Hoffman et al. 1991	Mallard (Anas platyrhynchos)	1.13	4.53
Hoffman et al. 1992	Mallard (Anas platyrhynchos)	1.23	4.94
Cantor et al. 1984	Chicken (Gallus domesticus)	1.45	2.90
Heinz et al. 1988	Mallard (Anas platyrhynchos)	1.74	3.48
Heinz et al. 1988	Mallard (Anas platyrhynchos)	2.13	4.26
Heinz et al. 1996	Mallard (Anas platyrhynchos)	4.16	8.32
Heinz et al. 1996	Mallard (Anas platyrhynchos)	5.75	11.5
Jensen et al. 1977	Chicken (Gallus domesticus)	6.34	11.9
Geometric Mean of NOAEL and LOAEL		0.6	1.4

Notes:

a. All growth and reproduction studies presented in USEPA 2007d with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2007d. Ecological Soil Screening Levels for Selenium: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-70. July.

Attachment A. Bounded Selenium NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2007d)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Nobunaga et al. 1979	Mouse (Mus musculus)	0.072	0.145
Nebbia et al. 1987	Rat (Rattus norvegicus)	0.384	0.768
Kezhou et al. 1987	Rat (Rattus norvegicus)	0.388	0.776
Abdo 1994	Rat (Rattus norvegicus)	0.393	0.763
Abdo 1994	Mouse (Mus musculus)	0.735	1.510
Hau et al. 1987	Mouse (Mus musculus)	1.21	6.03
Webster 1979	Mouse (Mus musculus)	2.54	25.4
Hardin et al. 1987	Mouse (Mus musculus)	3.20	6.39
Growth			
Shull and Checke 1973	Rat (Rattus norvegicus)	0.053	0.265
Palmer et al. 1982	Rat (Rattus norvegicus)	0.0838	0.763
Kim and Mahan 2001a	Pig (Sus scrofa)	0.112	0.157
Kim and Mahan 2001b	Pig (Sus scrofa)	0.1	0.27
Mahan and Moxon 1984	Pig (Sus scrofa)	0.143	0.22
Goehring et al. 1984a	Pig (Sus scrofa)	0.146	0.273
Liu et al. 1994	Rat (Rattus norvegicus)	0.151	0.304
Kim and Mahan 2001c	Pig (Sus scrofa)	0.155	0.22
Jenkins and Hidiroglou 1986	Cattle (Bos taurus)	0.17	0.33
Mahan and Magee 1991	Pig (Sus scrofa)	0.170	0.510
Mahan and Magee 1991	Pig (Sus scrofa)	0.183	0.548
McAdam and Levander 1987	Rat (Rattus norvegicus)	0.217	0.435
Goehring et al. 1984b	Rat (Rattus norvegicus)	0.217	0.470
Moxon and Mahan 1982	Pig (Sus scrofa)	0.227	0.340
Tsunoda et al. 2000	Mouse (Mus musculus)	0.240	0.580
LeBoeuf et al. 1985	Rat (Rattus norvegicus)	0.261	0.521
Palmer and Olson 1974	Rat (Rattus norvegicus)	0.274	0.540
Julius et al. 1983	Hamster (Mesocricetus auratus)	0.356	0.712
Kim and Mahan 2001b	Pig (Sus scrofa)	0.367	0.489
Abdo 1994	Rat (Rattus norvegicus)	0.368	0.564
Julius et al. 1983	Hamster (Mesocricetus auratus)	0.374	0.747
Spallholz et al. 1973	Mouse (Mus musculus)	0.384	0.523
Nebbia et al. 1987	Rat (Rattus norvegicus)	0.384	0.768
Kezhou et al. 1987	Rat (Rattus norvegicus)	0.388	0.776
Abdo 1994	Rat (Rattus norvegicus)	0.393	0.763
Halverson et al. 1966	Rat (Rattus norvegicus)	0.425	0.6

Attachment A. Bounded Selenium NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2007d)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Halverson et al. 1966	Rat (Rattus norvegicus)	0.432	0.577
McAdam and Levander 1987	Rat (Rattus norvegicus)	0.435	0.869
McAdam and Levander 1987	Rat (Rattus norvegicus)	0.435	0.869
McAdam and Levander 1987	Rat (Rattus norvegicus)	0.435	0.869
Johnson et al. 2000	Mouse (Mus musculus)	0.438	1.31
Jacobs and Forst 1981a	Rat (Rattus norvegicus)	0.452	0.904
Dausch and Fullerton 1993	Rat (Rattus norvegicus)	0.515	1.540
Beems and van Beek 1985	Hamster (Mesocricetus auratus)	0.610	1.21
Hadjimarkos 1970	Hamster (Mesocricetus auratus)	0.680	0.88
Abdo 1994	Mouse (Mus musculus)	0.735	1.51
Abdo 1994	Mouse (Mus musculus)	0.781	1.23
Jacobs and Forst 1981b	Mouse (Mus musculus)	0.784	1.21
Julius et al. 1983	Hamster (Mesocricetus auratus)	0.810	1.62
Hermann et al. 1991	Rat (Rattus norvegicus)	0.996	1.59
Hermann et al. 1991	Rat (Rattus norvegicus)	0.996	1.59
Jacobs and Forst 1981b	Mouse (Mus musculus)	1.14	2.27
Hardin et al. 1987	Mouse (Mus musculus)	3.20	6.39
Sayato et al. 1993	Mouse (Mus musculus)	10.0	20.0
Geometric Mean of NOAEL and LOAEL		0.4	0.8

Notes:

a. All growth and reproduction studies presented in USEPA 2007d with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2007d. Ecological Soil Screening Levels for Selenium: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-70. July.

Attachment A. Bounded Zinc NOAEL and LOAEL Values from Avian Reproduction and Growth Studies from USEPA (2007e)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Jensen and Maurice 1980	Chicken (Gallus domesticus)	24.7	98.8
Jackson et al. 1986	Chicken (Gallus domesticus)	55	105
Gibson et al. 1986	Chicken (Gallus domesticus)	57.3	66.5
Stevenson et al. 1987	Chicken (Gallus domesticus)	63.9	76.7
Gibson et al. 1986	Chicken (Gallus domesticus)	64	123
Stevenson et al. 1987	Chicken (Gallus domesticus)	67.8	84.8
Growth			
Hamilton et al. 1981	Japanese quail (Coturnix japonica)	43.3	86.6
Jackson et al. 1986	Chicken (Gallus domesticus)	55.0	105
Berg and Martinson 1972	Chicken (Gallus domesticus)	55.3	111
Sandoval et al. 1998	Chicken (Gallus domesticus)	70.6	106
Roberson and Schaible 1960	Chicken (Gallus domesticus)	74.3	111
Roberson and Schaible 1960	Chicken (Gallus domesticus)	74.7	112
Roberson and Schaible 1960	Chicken (Gallus domesticus)	75	150
Roberson and Schaible 1960	Chicken (Gallus domesticus)	75.7	114
Hill 1974	Chicken (Gallus domesticus)	85.9	172
Hamilton et al. 1979	Japanese quail (Coturnix japonica)	86.8	174
Henry et al. 1987	Chicken (Gallus domesticus)	92	185
Gibson et al. 1986	Chicken (Gallus domesticus)	96.9	145
Stevenson et al. 1987	Chicken (Gallus domesticus)	99.1	149
Stevenson et al. 1987	Chicken (Gallus domesticus)	129	194
Dewar et al. 1983	Chicken (Gallus domesticus)	143	286
Vohra and Kratzer 1968	Turkey (Meleagris gallopavo)	148	297
Roberson and Schaible 1960	Chicken (Gallus domesticus)	155	232
Roberson and Schaible 1960	Chicken (Gallus domesticus)	158	237
Southern and Baker 1983	Chicken (Gallus domesticus)	177	354
Oh et al. 1979	Chicken (Gallus domesticus)	252	503
Jackson et al. 1986	Chicken (Gallus domesticus)	367	480
Geometric Mean of NOAEL and LOAEL		89	154

Notes:

a. All growth and reproduction studies presented in USEPA 2007e with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2007e. Ecological Soil Screening Levels for Zinc: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-73. June.

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Attachment A. Bounded Zinc NOAEL and LOAEL Values from Mammalian Reproduction and Growth Studies from USEPA (2007e)

Reference (a)	Test Organism	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)
Reproduction			
Hill et al. 1983	Pig (Sus scrofa)	8.23	82.3
Miller et al. 1989	Cattle (Bos taurus)	37.9	75.9
Ketcheson et al. 1969	Rat (Rattus norvegicus)	181	452
Maita et al. 1981	Rat (Rattus norvegicus)	234	2514
Maita et al. 1981	Mouse (Mus musculus)	458	4927
Maita et al. 1981	Mouse (Mus musculus)	479	4878
Growth			
Hill et. al. 1983	Pig (Sus scrofa)	10.3	103
Brink et al. 1959	Pig (Sus scrofa)	43.5	87.1
Maita et al. 1981	Rat (Rattus norvegicus)	234	2514
Maita et al. 1981	Mouse (Mus musculus)	458	4927
Maita et al. 1981	Mouse (Mus musculus)	479	4878
Pettersen et al. 2002	Mouse (Mus musculus)	1419.0	2838
Geometric Mean of NOAEL and LOAEL		146	895

Notes:

a. All growth and reproduction studies presented in USEPA 2007e with both NOAEL and LOAEL value reported.

LOAEL = Lowest observed adverse effects level

mg/kg bw/day = Milligrams per kilogram body weight per day

NOAEL = No observed adverse effects level

USEPA = United States Environmental Protection Agency

USEPA. 2007e. Ecological Soil Screening Levels for Zinc: Interim Final. USEPA, Washington, D.C. OSWER Directive 9285.7-73. June.

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