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MEMORANDUM

To:	John Persico (Geosyntec)
From:	John Samuelian and Judi Durda
Date:	September 14, 2018 (Revision for EPA Review)
Subject:	Rolling Knolls Landfill Feasibility Study – Residual Ecological Risk Evaluation of Alternatives
Project No.:	C1398

Integral Consulting (Integral) prepared this technical memorandum to summarize the results of a residual ecological risk assessment (rERA) conducted in support of the feasibility study (FS) for the Rolling Knolls Landfill Superfund Site. The rERA characterizes risks that could exist following implementation of any one of three remedy Alternatives that incorporate excavation and/or capping elements. These Alternatives were selected for the rERA because implementation would reduce ecological exposures and risks compared to baseline (pre-remedy) conditions.

Alternative 2 (site controls including institutional controls and access restrictions) will not alter baseline ecological risks and therefore was not evaluated in this assessment. Risks under Alternative 1 (No Action) are the base case risks and are used in the rERA to evaluate the risk reduction achieved by each of the other evaluated Alternatives. These are comparable to the risks presented in the baseline ecological risk assessment (BERA; Integral 2016).

The three remedy Alternatives that incorporate excavation and/or capping[1] are as follows:

- Alternatives 3 and 4—Alternative 3 is a capping scenario and Alternative 4 is an excavation and backfill scenario, both with revegetation. These two alternatives focus on three areas of the Site: the 25-acre “Selected Area” on the north side of the landfill, the seven Areas of Particular Concern (APCs) and unvegetated portions of

[1] All Alternatives include site controls as described in the FS.

the landfill outside of these locations (collectively called "Remedy Areas"). These are shown in **Figure 1** and discussed in FS Section 6 and FS Appendix B.

The APCs represent areas with soil chemical concentrations that where three times greater than the Alternative Remediation Standard (discussed in Appendix A to the FS Report). For purposes of the rERA, a one-acre circle centered at each of the APCs was used to identify the soil and biota samples that would be replaced with imputed RL values.

- Alternative 5—Alternative 5 involves capping of all landfill material, with revegetation (**Figure 2**). This also includes 2 APCs located west of the landfill.

During review of the data used to support the rERA, it was determined that there was an inaccuracy in the site-wide hazard quotient (HQ) values reported in the 2016 BERA. **Attachment 1** to this technical memorandum are errata tables for the 2016 BERA showing the reported and corrected HQ results, with supporting documentation. There is no change in the conclusions of the BERA based upon the corrected HQ results.

SYNOPSIS OF APPROACH

The general approach used in the rERA was outlined in an e-mail communication to the U.S. Environmental Protection Agency (EPA) on April 11, 2018,[2] which was subsequently approved with some modifications on April 17, 2018[3] (see **Attachment 2**). In subsequent discussions, EPA requested modifications to the methodology for the rERA that accounts for uncertainty in the exposure and toxicity assumptions from the BERA and to improve risk-related decisions at the Site.

A combination of quantitative and qualitative approaches was used to evaluate residual ecological risks. For the quantitative evaluation, residual risks were calculated using predicted post-remedy exposure point concentrations (EPCs) and the exposure assumptions presented in the BERA (Integral 2016), with the following modifications

- *Soil Invertebrate Methylmercury*: Total mercury was analyzed in the soil invertebrate samples collected during the BERA field program. The BERA assumed that all mercury in soil invertebrates was exclusively in the form of methylmercury. However, typically only 3 to 12% of the total mercury is present in earthworms as methylmercury (Zhang et al. 2009). Therefore for the rERA, 10% of the measured

[2] E-mail communication from John Samuelian, Integral Consulting Inc, to EPA representatives Michael Clemetson, Betsy Donovan, Supinder Kaur, and Stephanie Vaughn

[3] E-mail communication from Betsy Donovan, EPA, to John Persico, Geosyntec Consultants.

total mercury was assumed to be in the form of methylmercury to more accurately reflect potential residual ecological risks at the site.

- *Estimated Vegetation Cyanide Concentrations*: In the BERA the terrestrial vegetation cyanide concentrations were calculated from the soil data using the default Biota Transfer Factor for Vegetation (BTF_{veg}) of 0.9 from USEPA (1999). Plants vary in their uptake, assimilation and degradation of cyanide. Typically plants exposed to cyanide in hydroponic systems (used as surrogate for soil pore water) retained cyanide in their roots with the remaining cyanide metabolized and translocated into the plant as a nitrogen source for plant amino acids (e.g., Ebbs et al 2005, Yu 2015). The latter capability is one reason why phytoremediation of cyanides is a common practice. Some plant species also produce cyanogenic glycosides as a protection against herbivory. Cyanide seldom remains biologically available in soils, however, because it is either complexed by trace metals, metabolized by various microorganisms, or lost through volatilization (ATSDR 2006; Irwin et al. 1997).

  Larsen and co-workers (2005) assessed the toxicity and uptake of cyanide into willow trees[4] to support development of a model that can be used for cyanide phytoremediation. These authors reported that at low soil pore water concentrations (<10 mg/L), cyanide would be rapidly metabolized by willow trees and not accumulated. There was no free cyanide detected in any of the BERA surface water samples (detection limit of 5 µg/L) and total cyanide was detected in only one of the six pond samples (5.4 µg/L) and one of the three landfill perimeter samples (3.4 µg/L)[5]. Therefore it is not anticipated that there would be significant accumulation of cyanides in plants at the Site, and far less than predicted using the BERA BTF_{veg}.

  The results from Larsen et al (2005) can be used as an alternative to the default BTFveg (0.9) for cyanide. Willow trees (as rooted branches) were exposed to no additional cyanide or five test water concentrations (10, 20, 30, 40 and 50 mg/L) in a sand system for 4 days. There was a reduction in plant photosynthesis at 20 mg/L and the plants died at the higher test solution concentrations. The authors calculated a mass balance of the amount of cyanide in the initial and final test solutions, roots, stem and leaves of the plants, and also calculated the loss of cyanide during the test period. If it is assumed that all of the cyanide in the sand-solution mixture is in solution (conservative given the binding potential of cyanide to soils) the ratio of the cyanide masses in the leaves to final solution can approximate the BTF_{veg}. For the 10 and 20 mg/L test solutions (no to some toxicity)

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[4] Willow trees are used as a surrogate for vegetation present at the Site.
[5] See BERA Table 4-1a for the sample specific results.

the BTF_{veg} values (ratios of dry weight plant concentrations to dry weight soil concentrations) ranged from 1.52E-02 to 3.35E-02, with a geometric mean of 2.26E-02. The latter was used as the vegetation cyanide BTF_{veg} for the rERA.

- *Estimated Vegetation Methylmercury Concentrations*: In the BERA the terrestrial vegetation methylmercury concentrations were calculated using the BTF_{veg} for total mercury (0.24) and then assuming the predicted mercury concentration was exclusively in the form of methylmercury. However, lower percentages of methylmercury have been reported in vegetation grown in soils containing total mercury. USEPA (1976) quantified methylmercury in pea plants grown in soils containing mercury in a laboratory study which was used to derive an alternate BTF_{veg} for the rERA.

  USEPA (1976) reported that the methylmercury levels in the pea plants (a commonly used plant toxicity test species) ranged from 0.0021 to 0.0076 mg/kg_{ww} (equivalent to 0.00109 to 0.00443 mg/kg_{dw}, assuming a moisture content of 30%) for plants grown in soils containing 10 to 100 mg/kg_{dw} of total mercury, for 14 days. The alternate BTF_{veg} for the rERA is the geometric mean of the ratios of the plant and soil dry weight concentration (1.67E-04).

- *rERA TRVs*: The BERA used the geometric mean values from the range of reported Lowest Observable Adverse Effect Level (LOAEL) toxicity values from sources such as the EcoSSL dataset for the evaluated chemicals. This is appropriate for the evaluation stage in a BERA but is a conservative approach because the geometric mean corresponds to the lower portion of the range of LOAEL results and is likely to predict toxicity even though exposures are still within an acceptable range. For the rERA, it is preferable to limit the conservatism of the BERA to support EPA's risk-based decision process. Accordingly, at the direction of EPA and to support effective risk-based decision making for the Site, alternative values representing the range of the literature reported TRVs were used for the rERA TRVs to better represent the potential COPEC toxicity.

Residual risks were compared to baseline risks to determine risk reduction (as reflected in a decrease in the calculated HQ of the Alternatives). For the qualitative evaluation, residual risks under these Alternatives were evaluated in the context of the uncertainty in the exposure calculations (e.g., conservative plant uptake factors), observations of the ecological conditions at the site, and reference area conditions.

Post-remedy EPCs for the quantitative evaluations were calculated on a site-wide basis by imputing the reporting limits (RLs) for those samples within the Remedy Areas for Alternatives 3 and 4 or the capped area for Alternative 5, and combining the imputed values with the sample results from outside of these areas to calculate the residual ecological risks for each of the Alternatives.

Evaluated Receptors

The rERA evaluated potential risks to vermivorous birds (i.e., American robin) and vermivorous mammals (i.e., short-tailed shrew), which are the terrestrial BERA receptors that had HQ values above 1 for the terrestrial or wetland habitats. The exposure assumptions for these two receptors used in this rERA are the same as were used in the BERA (**Table 1)**. These assumptions are used in conjunction with the post-remedy EPCs to calculate the average daily dose (ADD) as described in Section 3.7.2 of the BERA.

Evaluated Chemicals

The chemicals evaluated in the rERA are those that have calculated baseline site-wide HQ lowest-observed-adverse-effects level (HQ_{LOAEL}) values greater than 1 and also are present at concentrations above reference area or regional background levels. As shown in **Table 2**, of the 16 chemicals of potential ecological concern (COPECs) that had HQ_{LOAEL} values greater than 1, 13 were also greater than reference area or regional background levels and were retained for the rERA. These are barium, cadmium, chromium, copper, cyanide, lead, mercury[6], nickel, selenium, zinc, total polychlorinated biphenyls (PCBs), PCB toxicity equivalency quotients (PCB-TEQs), and polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran TEQs (PCDD/F-TEQs). Arsenic was not retained for the rERA because the soil EPC (14 mg/kg_{dw}) was similar to the reference area soil EPC (13 mg/kg_{dw}). Vanadium was not retained because the reference area HQ_{LOAEL} was greater than the site HQ_{LOAEL}. Manganese was also excluded from the rERA because it is a commonly occurring cation and an essential nutrient for biota (WHO 2004).

Imputed Reporting Limits and Calculation of Exposure Point Concentrations

Imputed RLs were used to represent the post-remedy COPEC concentrations in the site areas that are within the Remedy Areas for Alternatives 3 and 4 or the capped area for Alternative 5. RLs are the analyte- and sample-specific detection limits that were achieved during the site investigation, and indicate the level of analytical sensitivity achieved as affected by sample characteristics such as moisture content (soils only), analytical dilutions, and other analysis related parameters that affect the reported sample conditions. The use of the RLs in the EPC calculations in the rERA is likely to over-estimate post-remedy

[6] Total mercury was measured in the soil and soil invertebrate samples but was assumed to be 100% methylmercury in the soil invertebrate (and calculated vegetation) samples in the BERA.

concentrations given that the cover/backfill material to be used will meet regulatory requirements for clean fill and/or will be representative of background to the extent native soil is used. A sensitivity assessment for the use of alternate imputed values for non-detects is presented at the end of this technical memorandum.

A two-step process was used to identify the imputed RLs for the PCB-TEQ and PCDD/F-TEQ results. First, the congener-specific estimated detection limits (EDLs)[7] were identified and then these were multiplied by the congener-specific toxicity equivalency factors (TEFs) and then summed on a sample-specific basis to yield the imputed TEQ reporting limits. This approach yields a conservative upper bound for the TEQs because the EPC is calculated assuming all non-detected congeners are present in the sample at their RL levels, whereas in reality, some congeners may not be present at all.

There were instances when the imputed RL for a COPEC was greater than the maximum detected concentration of the COPEC in the sample. This occurred with select COPECs (i.e., selenium, PCDD/F-TEQ$_{avian}$) that were detected at low concentrations. For example, selenium was detected in BERA soil sample SOI010 (0.47 mg/kg) at a concentration that was less than the RL (3.9 mg/kg). Notwithstanding, to be consistent with the approach, the imputed RL for this sample was used in the EPC calculation for the rERA calculations. Accordingly, the approach generates conservative calculated EPCs in the samples evaluated for the different Alternatives.

Table 3 lists the soil and soil invertebrate samples that are within the Remedy Areas for Alternatives 3, 4 and the capped area for Alternative 5. The imputed RLs for these samples are summarized by Alternative in **Table 4.**

The EPCs represent the average media concentrations from the remedial investigation data set plus the additional surface soil (depth interval within the range of 0 to 1 foot below ground surface) and soil invertebrate samples collected to support the BERA. Average media concentrations were used for the rERA consistent with the BERA. ProUCL (v 5.1) was used to calculate the mean or Kaplan-Meier mean values used to derive the EPCs.

The terrestrial vegetation EPCs were calculated from the soil EPCs using the same biota transfer factors (BTF$_{veg}$) as used in the BERA (**Table 5**), except as discussed earlier for cyanide and methylmercury. The BERA soil samples showed a mixture of Aroclor 1254 and 1260, with Aroclor 1254 being the predominant form. Therefore, the Aroclor 1254 BTF$_{veg}$ (6.54E-03 kg$_{dw\text{-}soil}$/kg$_{dw\text{-}veg}$) was used to calculate the terrestrial vegetation EPCs for total PCBs using the soil EPCs in this rERA. For the PCB-TEQ and PCDD/F-TEQ terrestrial vegetation, EPC calculations for the congener-specific concentrations were first calculated

[7] EDLs are the same as the RLs.

from the individual soil and BTF_{veg} values and then multiplied by the congener-specific TEF values to yield the TEQ concentrations.

Consistent with the calculation of EPCs for the site-wide assessment in the BERA, the mean values for the terrestrial and wetland sample results were first calculated separately and then these were combined as the spatially weighted mean value based on the terrestrial and wetland acreages (229 and 198 acres, respectively).[8] The EPCs by media for the evaluated Alternatives are shown **Table 6a**.

Table 6b provides some additional details regarding the types of mean values for the soil or soil invertebrate samples used as the EPC inputs by habitat type. For the soil samples under both Alternatives 3 and 4, and Alterative 5, the terrestrial and wetland EPC input values were all based on the Kaplan-Meier Mean (KM Mean) values calculated using ProUCL.

The KM Mean was also used for most of the soil invertebrate samples[9], with the following exceptions:

- There were single detections for eight of the metals (barium, cadmium, chromium, copper, lead, nickel, selenium, and zinc) for the Alternative 5 terrestrial soil invertebrate EPC input. ProUCL requires more than two detections to calculate the KM Mean. The arithmetic mean of the single detection and one-half the RLs for the remaining samples was used for the Alternative 5 terrestrial EPC soil invertebrate input. In all cases the average EPC input values were less than the detected concentrations.

- *Mercury*: Mercury (as a surrogate for methylmercury) was detected in only 2 of the 13 soil invertebrate samples collected to support the BERA (see BERA Table 4-8). Due to the low detection frequency, ProUCL did not calculate a KM Mean for soil invertebrates when the detected mercury results were replaced with the imputed RL under Alternatives 3 and 4. In this case, the mean was the average of the detected values and one-half the RLs of the remaining samples, consistent with how the analytical results were summarized in the BERA. All of the wetland soil invertebrate sample results for Alternative 3 and 4 were non detect for mercury, so it was set to zero for the area-weighted EPC. Use of one-half RL values for mercury

[8] These acreage values correspond to the extent of investigation area, which was larger than the landfill itself. See BERA (Section 3.7.2 and Table 3-5) for additional detail.
[9] There are seven soil invertebrate samples for the terrestrial area and six soil invertebrate samples from the wetland area.

in the wetland soil invertebrate samples is discussed in the sensitivity analysis section.

There was no detectable mercury for both the terrestrial and wetland EPC inputs under Alternative 5 so these were set to zero as the EPC.

- *Total PCBs*: The single detected result was used for the wetland EPC input for both Alternative 3 and 4, and Alternative 5. This was because the RLs were greater than the detected results and the average of the detected values and one-half the RL values would have yielded an average EPC input value greater than the detected value.

- *PCB-TEQ and PCDD/F-TEQ*: The arithmetic mean of the single detection and one-half the RLs for the remaining samples was used under Alternative 3 and 4 wetland EPC input, and for both the wetland and terrestrial EPC inputs for Alternative 5. As discussed above, ProUCL requires more than one detection to calculate the KM Mean.

Ecological Risk Hazard Quotient Calculations

HQs were calculated in the same manner as presented in the BERA using the equation shown below:

$$HQ = \frac{ADD}{TRV}$$

Where:

HQ	=	hazard quotient
ADD	=	average daily dose
TRV	=	toxicity reference value for the COPEC

HQs are calculated for the site baseline condition and also for each of the evaluated Alternative.

RESIDUAL ECOLOGICAL RISK EVALUATION RESULTS

This section summarizes the HQ_{LOAEL} results for each of the evaluated Alternatives. The relative reduction in the HQ values are calculated as the percent difference relative to the Alternative 1 (No Action) baseline condition. If the HQ_{LOAEL} values are greater than 1 for the evaluated Alternatives, then an assessment of the uncertainty in the HQ, including how the underlying TRV_{LOAEL} value was derived, is evaluated. The HQ_{LOAEL} results are also evaluated in the context of the reference area (terrestrial) HQ_{LOAEL} results and the ecological setting at the site.

Table 8 presents the rERA HQ_{LOAEL} results by receptor, chemical, and evaluated Alternative. The HQ_{LOAEL} values for the BERA reference area samples are also provided in this table. HQ_{LOAEL} results are all reported to one significant digit in this table. The detailed risk calculations (similar to Appendix H tables from the BERA) are provided in **Attachment 3**.

The HQ_{LOAEL} results varied across the chemicals for these two receptors due to differences in exposure (i.e., diets) and TRV_{LOAEL} values. The following definitions were used for the discussion of the HQ_{LOAEL} results:

- Values less than or equal to 1: Includes values that are less than 1 and those that round to 1 when one significant digit is reported (e.g., 1.3 rounds to 1).
- Values greater than 1: Includes values that round to greater than 1 when one significant digit is reported (e.g., 1.8 rounds to 2).

The key results are summarized below by Alternative.

Alternatives 3 and 4 Evaluation

As identified earlier, Alternatives 3 and 4 include either capping or excavating, respectively, both with revegetation of the "Remedy Area", which includes the 25-acre "Select Area" located on the north side of the landfill, and APCs and unvegetated areas. Both Alternatives have the same impact on residual ecological risk and were combined for this discussion.

Overall, risks under Alternatives 3 or 4 are reduced by up to 62% across the evaluated COPECs for the two receptors. Residual HQ_{LOAEL} values are above 1 for two COPECs for the robin and none for the shrew (the HQ above 1 for PCDD-F for both receptors is simply an artifact of the ProUCL calculation and does not reflect potential post-remedy risks), but overall, the level of calculated risks is not likely to represent a significant risk post-remedy, given the conservative nature of the exposure calculations and the underlying TRVs. The receptor-specific HQ results and the assessment of the HQ results in the context of ecological setting are discussed below.

American Robin

HQ_{LOAEL} values are reduced up to 61% relative to the base case for all of the evaluated COPECs except for PCDD/F-TEQ_{avian} for the American robin under Alternatives 3 and 4.

The HQ_{LOAEL} values for nine COPEC inorganics (cadmium, chromium, copper, cyanide, lead, methylmercury, nickel, selenium, and zinc) and total PCBs, were all less than one, indicating no site-specific risk impacts from these chemicals under this Alternative.

The HQ_{LOAEL} values for three COPECs were greater than 1 under this alternative; barium, PCDD/F-TEQ_{avian}, and PCB-TEQ_{avian}. Given the conservative nature of the exposure calculations there is high confidence that HQ values in this range do not indicate ecological risk. In addition, the PCDD/F-TEQ_{avian} HQ_{LOAEL} value was similar to the reference HQ_{LOAEL}, indicating no site-specific risk impacts from this chemical. The HQ_{LOAEL} results for these three COPECs are discussed more fully below.

- **Barium**. Barium had an HQ_{LOAEL} of 4 post-remedy, which was 22% lower than the base case HQ_{LOAEL} value (5) and was greater than the reference area HQ_{LOAEL}. About 60% of the total barium dose was derived from consumption of soil invertebrates, 32% from vegetation consumption and the remaining 8% from soil consumption (see Attachment 3). The vegetation barium concentrations were estimated using a conservative BTF_{veg} uptake factor that does not account for site-specific bioavailability. For example, barium reacts with metal oxides in soil (ATSDR 2007) reducing its bioavailability for uptake. In fact, under typical environmental conditions, barium displaces other adsorbed alkaline earth metals from oxides of manganese, silicon and titanium. These collective processes and fate will contribute to a reduced bioavailability of barium in terrestrial systems. The BERA and rERA both assumed that barium was fully bioavailable in soils, however the data from the soil invertebrates shows that barium concentrations are well less than soil concentrations, suggesting that barium has reduced soil bioavailability and/or is not readily absorbed by the organisms. Barium sulfate – which is one of the most common forms of barium in soils (ATSDR 2006) – is generally insoluble and not sorbed in the gut (Casarett and Klaassen 2008) nor toxic to wildlife (Raisbeck et al. 2011).

  Due to the conservative approach to characterizing toxicity, barium is very unlikely to pose an ecological risk to vermivorous birds under these Alternatives.

- **PCB-TEQ_{avian}**. PCB-TEQ_{avian} had an HQ_{LOAEL} of 2 post-remedy which is 57% lower than the base case and greater than the reference area HQ_{LOAEL}. About 66% of the total PCB-TEQ_{avian} dose was derived from consumption of soil invertebrates, about 5% from vegetation consumption and the remainder from soil consumption (see Attachment 3).

  The calculated results for PCB-TEQ_{avian} are likely overestimated due to the conservative nature of the exposure calculations and the available toxicity data used to derive the TRVs: First, about 30% of the calculated dose was derived from soil consumption and it was assumed that all of the PCBs would be available for uptake.

All of the dose calculations assume that the dioxin-like PCB congeners (used to calculate the PCB-TEQ$_{avian}$) are in a fully bioavailable form in the soils. However, this is highly conservative given that the bioavailability of organic chemicals decreases over time from soils (e.g., Alexander 2000), and that the individual dioxin-like PCB congeners have different partitioning potential to soils.

Second, the PCB-TEQ$_{avian}$ TRV$_{LOAEL}$ used in the rERA (1.4E-04 mg/kg-day) is the same as that used in the BERA. The TRV$_{LOAEL}$ was based on a single study by Nosek et al. (1992) that evaluated the toxicity and reproductive effects of a single PCDD/F congener (2,3,7,8-TCDD) on ring-necked pheasants. As discussed in Appendix A of the BERA, there were reproductive effects (reduced egg production and hatchability) for the maximum intraperitoneal injection dose only (1 µg/kg$_{bw}$ per week) after 10 weeks of exposure. Though useful for a toxicological assessment, exposure by intraperitoneal injection is fully bioavailable and therefore more conservative than exposure to environmental media via oral ingestion. Sample et al (1996) used these results to derive the TRV$_{LOAEL}$ of 1.4E-04 mg/kg$_{bw}$-day by converting the weekly dose to a daily equivalent and assuming a body weight of 1 kg.

It is well known that avian species vary in their sensitivities to TCDD based on biochemical endpoints. For example, Head and co-workers (2008) reported that ring-necked pheasants are up to nearly 5 times more sensitive to TCDD than passerine species such as the Eastern bluebird when using biochemical endpoints. Therefore, these results indicate that the TRV$_{LOAEL}$ is likely biased low (which would bias high the HQ$_{LOAEL}$) for the evaluated avian receptor.

Consequently, PCB-TEQ$_{avian}$ is very unlikely to pose an ecological risk to vermivorous birds under these Alternatives.

- **PCDD/F-TEQ$_{avian}$.** PCDD/F-TEQ$_{avian}$ had an HQ$_{LOAEL}$ of 4 post-remedy which is about 33% larger than the base case and which is similar to the reference area HQ$_{LOAEL}$. About 8% of the total PCDD/F-TEQ$_{avian}$ dose was derived from consumption of soil invertebrates, 90% from vegetation consumption and the remainder from soil consumption (see Attachment 3).

  The calculated results for PCDD/F-TEQ$_{avian}$ are likely overestimated due to the conservative nature of the exposure calculations and the available toxicity data used to derive the TRVs: First, the PCDD/F-TEQ$_{avian}$ TRV$_{LOAEL}$ used in the rERA (1.4E-04 mg/kg-day; see Appendix A of the BERA for additional discussion) and was based on a single study, as discussed in the prior PCB-TEQ$_{avian}$ HQ$_{LOAEL}$ evaluation. Second, the imputed RL for PCDD/F-TEQ$_{avian}$ was higher than the detected concentrations at the site, so calculated risks for PCDD/F-TEQ_{avian} are an artifact of the way ProUCL calculated the KM Mean values when the imputed RL values were used. Given that post-remedy concentrations will not increase after remediation, the EPCs used in the rERA for this COPEC is not an accurate estimate of post-remedy conditions compared to baseline. Lastly, 90% of the total ADD was related to consumption of vegetation which was estimated using conservative BTF_{veg} uptake factors.

Consequently, PCDD/F-TEQ_{avian} is unlikely to pose an ecological risk to vermivorous birds under these Alternatives.

Overall, these results indicate it is very unlikely the COPECs will pose a significant site-specific risk to vermivorous birds under Alternatives 3 and 4.

Short-tailed Shrew

The post remedy HQ_{LOAEL} values round to 1 or are below 1 for all of the COPECs for this receptor under Alternatives 3 and 4. HQ_{LOAEL} values are reduced up to 62% relative to the base case for 11 of the 12 COPECs for the short-tailed shrew under Alternatives 3 and 4. The exception was PCDD/F-TEQ_{mammal}, which showed a 53% increase relative to the base case. As noted with the American robin, the increased HQ_{LOAEL} value for this COPEC relative to the base case is simply an artifact of the ProUCL calculation and does not reflect potential post-remedy risks.

Overall, these results indicate that COPECs are not likely to pose a significant site-specific risk to vermivorous mammals under Alternatives 3 and 4.

Summary of Alternatives 3 and 4

Implementation of Alternative 3 or 4 would reduce calculated risks for sensitive receptors by up to 62% across the evaluated COPECs. All of the HQ_{LOAEL} values were less than or equal to one for the vermivorous mammals. For the vermivorous avian species, the HQ_{LOAEL} values for nine of the ten COPEC inorganics (cadmium, chromium, copper, cyanide, lead, methylmercury, nickel, selenium, and zinc) and total PCBs, were all less than one, indicating no site-specific risk impacts from these chemicals under this Alternative. The HQ_{LOAEL} values for three COPECs (barium, PCDD/F-TEQ_{avian}, and PCB-TEQ_{avian}) were above 1 but overall there is high confidence that this level of calculated risks represents only low potential risk, given the conservative nature of the exposure calculations and the available toxicity data used to derive the TRVs.

Under Alternatives 3 and 4, the existing ecological habitats within the Remedy Areas, which includes old field habitat, some mature tree stands, and some peripheral wetlands would be eliminated and replaced with maintained grassy areas, which have lower ecological value than the existing vegetated habitats outside of the exposed fill areas.[10] In addition, some small areas of potential habitat for the federally threatened and State endangered bog turtle and blue spotted salamander[11], as well as mature trees that are potential roosting habitat for the federally threatened and State endangered Indiana bat, would be lost permanently under these Alternatives.

Alternative 5 Evaluation

FS Alternative 5 includes use of site controls and capping of all landfill material, and two APCs (located in the surface/debris area; see **Figure 2**), with revegetation. As such, this Alternative would cover the existing landfill soils with clean borrow material. Exposure to landfill soils containing organic chemicals (total PCBs, PCB-TEQ, and PCDD/F-TEQ) would be eliminated, and exposures to metals in surface soils would be reduced to levels comparable to or lower than reference conditions, depending on the source of the cover material.

Table 8 presents the HQ_{LOAEL} values for the evaluated COPECs based on imputed RLs for soils underlying the Alternative 5 cap and areas outside of the cap (e.g., portions of the surface/debris area west of the ponds). The receptor-specific HQ results and the assessment of the HQ results in the context of ecological setting are discussed below.

American Robin

For the American robin, HQ_{LOAEL} values are reduced to more than 99% (value rounded up to 100% in **Table 8**) relative to the base case across all of the COPECs. The HQ_{LOAEL} values for nine COPEC inorganics (cadmium, chromium, copper, cyanide, lead, methylmercury, nickel, selenium, and zinc) and two COPEC organics (total PCBs and $PCB\text{-}TEQ_{avian}$) were less than one, indicating no site-specific risk impacts from these chemicals under this Alternative.

The HQ_{LOAEL} values for two COPECs (barium and $PCDD/F\text{-}TEQ_{avian}$) were greater than 1 under this alternative. The HQ_{LOAEL} results for these two COPECs are discussed more fully below.

- **Barium**. Barium had an HQ_{LOAEL} of 2 post-remedy, which was 58% lower than the base case HQ_{LOAEL} value (5) and was greater than the reference area HQ_{LOAEL}. About 72% of the total barium dose was derived from consumption of soil

[10] As discussed in the FS, the non-vegetated exposed fill area is approximately 2 acres in size.
[11] A blue spotted salamander was observed west of the Select Area during the BERA field investigation but its habitat preference is similar to that of bog turtles (see BERA Appendix D, Figure D4-1).

invertebrates, 22% from vegetation consumption and the remaining 6% from soil consumption (see Attachment 3). The same factors causing conservatism in the HQ_{LOAEL} value that were discussed under Alternative 3 and 4 for barium are relevant for this alternative.

Consequently, barium is unlikely to pose an ecological risk to vermivorous birds under this Alternative.

- **PCDD/F-TEQ$_{avian}$**: PCDD/F-TEQ$_{avian}$ had an HQ_{LOAEL} of 2 post-remedy which is 37% lower than the base case and also lower than the reference area HQ_{LOAEL}. About 32% of the total PCDD/F-TEQ$_{avian}$ dose was derived from consumption of soil invertebrates, about 68% from vegetation consumption and the remainder (<1%) from soil consumption (see Attachment 3). The same factors causing conservatism in the HQ_{LOAEL} value that were discussed under Alternative 3 and 4 for PCDD/F-TEQ$_{avian}$ are relevant for this alternative.

  Consequently, PCDD/F-TEQ$_{avian}$ is unlikely to pose an ecological risk to vermivorous birds under these Alternative.

Short-tailed Shrew

The HQ_{LOAEL} values are reduced to below 1 for all of the evaluated COPECs for this receptor under this alternative. Ten of the 12 HQ_{LOAEL} values are reduced to more than 99% (value rounded up to 100% in **Table 8**) relative to the base case across all of the COPECs. As discussed earlier, the increases in the HQ_{LOAEL} values for selenium and PCDD/F-TEQ$_{mammal}$ are artifacts of how the EPCs were calculated and do not reflect potential post-remedy risks.

Summary Alternative 5

The HQ_{LOAEL} values are reduced for all COPECs (except selenium) in Alternative 5 compared to Alternatives 3 and 4 due to the larger areal extent of the cap. As was the case for the other Alternatives, some of the calculated post remedy risks were slightly above a risk quotient threshold of 1, but most of the risks are at or near those found in reference areas and/or within the bounds of the uncertainty in the risk calculations.

Under this Alternative, however, the existing ecological habitats of the entire landfill surface, which includes old field habitat, mature tree stands, and wetlands would be eliminated and replaced with maintained grassy areas, which have lower ecological value than the existing vegetated habitats outside of the exposed fill areas.[12] In addition, some small areas of potential habitat for the federally threatened and State endangered bog turtle and blue spotted salamander, as well as mature trees that are potential roosting habitat for the federally threatened and State endangered Indiana bat, would be lost permanently under this Alternative. Overall, given habitat and species disturbances, the overall net ecological benefit implementing Alternative 5 is reduced compared to Alternatives 3 and 4.

Sensitivity Analysis

A key parameter of the rERA was the use of the RLs (or equivalent) as the imputed values for non-detect results for the evaluated alternatives. To determine the sensitivity of the selected imputed value, the EPCs and ADD values for soil invertebrates for barium and PCB-TEQ were recalculated using the following as imputed values: Half-RLs or zero values. Barium and PCB-TEQ were selected since the relative contribution of soil invertebrate ingestion to the total ADD was greater than 50% and these COPECs had HQ_{LOAEL} values greater than one for the Alternative 3 and 4 scenario for the American Robin[13].

Table 9 compares the soil invert EPCs (EPC_{invert}) and ADD (ADD_{invert}) using the imputed RL and two alternate imputed values for the two COPECs. Although the EPC_{invert} and ADD_{invert} values decline with decreasing RL values, the two COPECs differ in their relative responses to the different imputed values. Barium appears to be more sensitive, declining by 23% when zeros are used in lieu of RLs for the non-detect results. The equivalent decline is 11% for $PCB\text{-}TEQ_{avian}$. Although use of alternate imputed values result in lower ADD_{invert} values there would be a moderate reduction in the calculated HQ_{LOAEL} values when different imputed values are used. The overall conclusions of the rERA are unlikely to change if different imputed values were used when HQ_{LOAEL} values are greater than 2.

Methylmercury in Soil Invertebrates: As discussed earlier, all of the wetland soil invertebrate sample results for Alternative 3 and 4 were non detect for mercury. A value of zero for the wetland soil invertebrate results in conjunction with the KM_{mean} for the terrestrial soil invertebrate mercury results to calculate the EPC_{invert} for Alternative 3 and 4. A value of zero was used for the wetland soil invertebrate results to be consistent with Alternative 5 which had no detections for mercury in either terrestrial or wetland areas, and therefore had an EPC_{invert} value of zero. To determine whether this approach would substantively change the risk results, the wetland soil invertebrate results were re-calculated for

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[12] As discussed in the FS, the non-vegetated exposed fill area is approximately 2 acres in size.

[13] Although the HQ_{LOAEL} for $PCDD/F\text{-}TEQ_{avian}$ was 4 for this receptor under Alternatives 3 and 4 the relative contribution from soil invertebrates was only 8% so it was not used for the sensitivity analysis.

Alternative 3 and 4 using half the detection limit for the wetland samples. The methylmercury input values are shown in the table below.

	Soil Invert EPC with Zero Value for Wetland Sample	Soil Invert EPC with Half-DL Value for Wetland Sample
EPC-Terrestrial	0.0493	0.0493
EPC-Wetland	0	0.00473
Weighted EPC_{invert}	0.0264	0.0286

Use of a Half-DL substitution for the EPC-wetland increases the Weighted EPC_{invert} by about 8%. The methylmercury HQ_{LOAEL} values are well below one for both receptors (**Table 8**) so this slight increase will not result in any changes to the overall conclusion that methylmercury risks are not significant for this scenario.

Residual Ecological Risks and Ecological Setting of the Site

Overall, the rERA calculations indicate that implementation of the selected remedy will reduce the calculated HQs to below levels of concern. There is in fact high confidence in this finding given that even under baseline conditions considered in the BERA, the ecological habitat survey indicates that the site is supporting a varied ecological community typical of these types of habitats in New Jersey.

The ecological habitat assessment performed as part of the BERA (see Appendix D) indicated that although portions of the landfill surface are heavily disturbed (e.g., thin soil layer, landfill material at the surface), there are well-vegetated terrestrial areas and wetland areas bordering the main landfill (and proximal to the Great Swamp National Wildlife Refuge) that are currently supporting average and higher value habitats (see Table D4-1 in BERA Appendix D). The vegetative cover in the terrestrial areas of the landfill are similar an "old field" mixtures of plant species.

Species common to mixed forest and shrub habitats of New Jersey were observed (or evidence of their presence was identified, such as scat) during the field investigation. Terrestrial species observed or heard include a variety of passerines, raptors, and small (e.g., chipmunk, squirrel) and medium size mammals (e.g., red fox and groundhogs). Tracks and scat throughout the site suggest abundant raccoon, deer, and evidence of black bear activity. Large and small burrow holes were observed in the upland vegetated areas and near the edges of the wetlands throughout the course of the field investigation.

The wetland and aquatic habitats are predominantly present on the perimeter of the landfill outside of the areas associated with Alternatives 3, 4, and 5. Aquatic and semi-aquatic wildlife were observed during the 2016 ecological site assessment and BERA field sampling event. A wide variety of frog species and salamanders utilize the wetland and pond environments at the site. An adult of the New Jersey endangered blue-spotted salamander was observed to the west side of one of the west site ponds. Overall, suitable habitat exists for amphibians, turtles, and avian species at wetland habitats located on the western, southern, and northeastern landfill perimeter.

Overall, even without remediation, the habitat at the site is supporting a varied ecological community typical of these types of habitats in New Jersey.

CONCLUSIONS

There is high confidence that each of the proposed Alternatives analyzed in the rERA will reduce post-remedy ecological risks to a level unlikely to result in ecological impact from COPECs, though some negative habitat impacts could be associated with Alternative 5. Virtually all of the calculated residual HQs are below 1, and the few that are above 1 are not anticipated to be associated with adverse ecological effects. This marginal potential risk coupled with the conservative assumptions used to calculate exposure provides high confidence that these numbers indicate an overall low potential post-remedy risk to robins and other vermivorous birds. The ecological habitat survey indicates that the site currently supports a varied ecological community typical of these types of habitats in New Jersey. The presence of a varied ecological community coupled with the reduced risks predicted under each of the Alternatives, results in high confidence that that any potential residual ecological risk following remedy implementation is negligible.

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