INTERIM FINAL

Addendum to the Interim Final Preliminary Remediation Goals Report: Oxbow Area

Centredale Manor Restoration Project Superfund Site North Providence, Rhode Island

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September 2011

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Addendum to the Interim Final Preliminary Remediation Goals Report: Oxbow Area, Part I Human Health

CENTREDALE MANOR RESTORATION PROJECT SUPERFUND SITE
NORTH PROVIDENCE, RHODE ISLAND

Submitted to:

Department of the Army
U.S. Army Corps of Engineers
New England Division

Under Contract to:

BATTELLE
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TABLE OF CONTENTS

TABLES

LIST OF ACRONYMS

BHHRA	Baseline Human Health Risk Assessment
COC	Chemical of Concern
COPC	Chemical of Potential Concern
HHRA	Human Health Risk Assessment
HI	Hazard Index
MACTEC	MACTEC Engineering and Consulting, Inc.
NCP	National Hazardous Substances and Pollution Contingency Plan
10^{-6}	one in one million
10^{-4}	one in ten thousand
PRG	Preliminary Remediation Goals
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objectives
RfD	Reference Dose
RIDEM	Rhode Island Department of Environmental Management
RME	Reasonable Maximum Exposure
TCDD	Tetrachlorodibenzo-p-dioxin
TEQ	Toxic Equivalence
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

MACTEC Engineering and Consulting, Inc. (MACTEC) is pleased to provide this report documenting the derivation of human health risk-based preliminary remediation goals (PRGs) for direct contact with surface soil at the Oxbow Area, which is a component of the Centredale Manor Restoration Project Superfund Site (hereafter referred to as the Site) in North Providence, Rhode Island. Risk-based PRGs were developed for Oxbow Area surface soils based on findings from the *Supplemental Baseline Human Health and Ecological Risk Assessment: Oxbow Area Floodplain Soil and Sediment, Part I – Human Health* (MACTEC and Battelle, 2011), hereafter referred to as the human health risk assessment or HHRA, to support remedial decision making. Those exposure pathways are identified below.

1.1 DOCUMENT THE NEED FOR PRGS – SUMMARY OF BASELINE HUMAN HEALTH RISK ASSESSMENT RESULTS

The *Supplemental Baseline Human Health and Ecological Risk Assessment: Oxbow Area Floodplain Soil and Sediment, Part I – Human Health* (MACTEC and Battelle, 2011) evaluated the human health risks associated with potential exposures to surficial soils for a Passive Recreational Visitor at the Oxbow Area. The Passive Recreational Visitor is not the same as the Visiting Angler or Resident evaluated in the Baseline Human Health Risk Assessment (BHHRA). The Passive Recreational Visitor was only evaluated for direct contact to surface soil, whereas the Visiting Angler or Resident was evaluated in the BHHRA for fish consumption and direct contact with surface water, sediment and bank soil at and adjacent to the Woonasquatucket River. The Passive Recreational Visitor was evaluated separately for two different exposure areas, the human health concern area and the general area. The HHRA characterized human health cancer and noncancer risks associated with incidental ingestion and dermal contact with surface soils. Risks were calculated for each chemical in soil, and risks for all chemicals evaluated were summed into a cumulative receptor risk for surficial soils. The HHRA evaluated only a Reasonable Maximum Exposure (RME) scenario.

In the HHRA, the results from the carcinogenic risk assessment were compared to acceptable risk ranges established by the USEPA. The USEPA's guidelines, established in the National Hazardous Substances and Pollution Contingency Plan (NCP) identify acceptable exposure levels as those concentration levels "that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} [one in ten thousand] and 10^{-6} [one in one million] using information on the

relationship between dose and response" (USEPA, 1990). The selection of the actual upper limit cancer risk target is a risk management decision that can vary on a case-by-case basis. This PRG document is intended to provide information to support that decision.

The HHRA also included an evaluation of noncarcinogenic risks. As defined by USEPA (USEPA, 1989), a hazard index (HI) of less than 1 indicates that noncarcinogenic toxic effects are unlikely. An HI greater than 1 indicates a greater possibility of a noncarcinogenic toxic effect occurring, but the circumstances must be evaluated on a case-by-case basis. USEPA typically considers the need for remediation if the HI is greater than one.

Table ES-1 of the HHRA presents the risks calculated for the Passive Recreational Visitor at the Oxbow Area. The Passive Recreational Visitor was evaluated in two different exposure areas, the human health concern area and the general area. As shown in Table ES-1, for both the general area and the human health concern area, among the age groups evaluated, the child age group has the highest non-cancer HI. The HIs do not have a single, dominant chemical contributor. The HIs for the child in the human health concern area and the general area are 0.1 and 0.2, respectively.

As shown in Table ES-1 of the HHRA, the total (summed across age groups) soil cancer risk for the Passive Recreational Visitor in the human health concern area is 4×10^{-6}. Ingestion of soil by the child receptor contributes the largest cancer risk among exposure pathways. The largest chemical contributor to cancer risk is arsenic.

As shown in Table ES-1 of the HHRA, the total (summed across age groups) soil cancer risk for the Passive Recreational Visitor in the general area is 6×10^{-5}. Ingestion of soil by the child receptor contributes the largest cancer risk among exposure pathways. The largest chemical contributor to cancer risk is the dioxin toxic equivalence (TEQ).

For both exposure areas, the human health concern area and the general area, the HI is below the Superfund HI Threshold of 1. In addition, for both exposure areas, the total cancer risk for the Passive Recreational Visitor is within the Superfund cancer risk range of 1×10^{-4} to 1×10^{-6}. However, one of the RAOs identified in the Feasibility Study (Battelle, 2010) is to prevent direct contact to floodplain soil that would result in excess lifetime cancer risk above the Rhode Island Department of Environmental Management (RIDEM) limit of 1×10^{-5}. The total cancer risk for the human health concern area is below this limit. However, the total cancer risk for the general

area exceeds the RIDEM cancer risk limit so risk-based PRGs were developed for this area for those soil chemicals of concern (COCs) with individual contributing cancer risk greater than 1 x 10^{-6}.

1.2 CHEMICALS OF CONCERN FOR EACH OF THE MEDIA

The results and conclusions of the HHRA have identified the chemicals that most significantly contribute to human health risks for the direct contact pathway. Chemicals with cancer risk greater than 1 x 10^{-6} and/or Hazard Quotient greater than 1 are referred to as Chemical of Concern (COCs). Risk-based PRGs have been developed for the identified COCs. As indicated in RAGS Part D, the concentration associated with a lifetime cancer risk of 1 x 10^{-6} is considered a point of departure in evaluating remedial requirements. Subsequently, other factors are considered to determine where within the acceptable risk range the actual remediation goals for a given COC will be established. The surface soil COCs for the general area include arsenic, benzo(a)pyrene, and dioxin TEQ based on cancer risk. No COCs were identified for non-cancer effects. For those identified surface soil COCs, the PRGs were developed for various risk levels (cancer risk of 10^{-6}, 10^{-5}, 10^{-4}, and non-cancer hazard quotients of 0.1, 1, and 10).

The human health risk-based PRGs for the general area surface soil have been developed using the procedures and calculations identified for soils as described in the *Interim Final Preliminary Remediation Goals Report, Part I – Human Health* (MACTEC, 2005). The development of risk-based PRGs has been conducted consistently with *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual, Part B, Development of Risk-based Preliminary Remediation Goals, Interim* (USEPA, 1991) and Part D, *Standardized Planning, Reporting and Review of Superfund Risk Assessments, Final* (USEPA, 2001). The PRGs are also being developed consistent with the USEPA's *Risk Assessment Guidance for Superfund (RAGS): Part D, Volume I - Human Health Evaluation Manual (Part D, Standardized Planning, Reporting and Review of Superfund Risk Assessments) Final* (USEPA, 2001). PRGs can be either generic or site-specific; however, site-specific PRGs are more appropriate for use in the remedial decision-making process. Therefore, the PRGs developed for the Site have been based on the site-specific HHRA that has been conducted for the Site and the physical and chemical conditions at the Site.

2.0 TECHNICAL APPROACH AND PROCEDURE FOR DEVELOPMENT OF PRGs

Section 2 presents the technical approach and procedure for the calculation of human health risk-based PRGs for surface soil at the Oxbow general area. Following the description of the technical approach and procedures, the documentation of the derivation of and the presentation of the human health risk-based PRGs is included in Section 3 of the document. The PRGs for direct contact with surface soil have been calculated using RAGS Part B equations or modified RAGS Part B equations. The modifications to the RAGS Part B equations were made to account for the evaluation of two or three age groups in the calculation of cumulative receptor risk. The equations used in the calculation of those direct exposure PRGs are presented in Table 1.

2.1 SURFACE SOIL PRGS BASED ON DIRECT CONTACT EXPOSURES

The HHRA identified arsenic, benzo(a)pyrene, and dioxin TEQ as the only COCs for surface soils at the Oxbow general area. The direct contact-based surface soil PRGs are calculated by rearranging the equations from the HHRA, setting the cancer risk equal to the target cancer risk or the target hazard quotient, and solving for the surface soil concentration. The cancer risk-based PRG incorporates exposures (incidental ingestion and dermal contact) for all three age groups. The Hazard Quotient-based PRG is calculated separately for each age group, since the Hazard Quotients are not additive or cumulative among the age groups. The equations used to calculate the PRGs (at three cancer risk levels and at three Hazard Quotient values) are shown in the PRG calculation tables that are presented in Section 3.0 below. These equations are consistent with RAGS Part B equations, but have been modified to account for the three age groups that have been evaluated in the HHRA. Those tables also document the exposure assumptions and toxicity values used in the calculations.

3.0 CALCULATION AND PRESENTATION OF PRGs

The direct contact-based surface soil PRGs for the Passive Recreational Visitor are presented and documented in Table 1. That table presents the exposure parameters, the toxicity values, and the equations that have been used to calculate those PRGs. All of these PRGs (without all of the supporting documentation) are summarized in Table 2. In that table, for each COC in surface soil, PRGs associated with target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4} as well as PRGs associated with noncancer Hazard Quotients of 0.1, 1, and 10 are presented.

4.0 DISCUSSION OF UNCERTAINTIES

The uncertainties in the calculated human health risk-based PRGs are generally similar to those identified for the risk estimates for the *Supplemental Baseline Human Health and Ecological Risk Assessment: Oxbow Area Floodplain Soil and Sediment, Part I – Human Health* (HHRA). Those uncertainties, briefly summarized, include:

- Not all COCs are necessarily "site-related". It appears that some of the COCs, such as arsenic, although associated with risks sufficient to identify them as COCs, may not be associated with releases at the Oxbow Area but may rather be associated with other regional sources.
- Toxicity Data for Dioxins. Based on information in USEPA's Reassessment Document for Dioxin, the cancer slope factor for 2,3,7,8- tetrachlorodibenzo-p-dioxin (TCDD) that was utilized for dioxin-TEQ in the HHRA and in the derivation of the surface soil PRGs could be revised, possibly upwards, by a factor of approximately 6.4. Such a revision would suggest that the cancer risk-based PRGs should be lowered by a factor of approximately 6.4. This would likely result in dioxin-TEQ PRGs that are below reported background conditions for the Site.
- The values for receptor-specific exposure parameters such as soil contact rates and soil ingestion rates have been identified in a conservative manner. Default USEPA residential values have been applied to this passive recreational scenario. Values have been identified based on available guidance and professional judgment. In risk assessment, when values are assigned in lieu of actual measurements, there is some uncertainty in the values, and that uncertainty may have an impact on the results of the risk assessment. In that context, the exposure estimates and associated risk estimates in this assessment would likely be overestimated rather than underestimated. Some factors that were not specifically addressed in the calculations could result in lower risk estimates.
- The exposure frequency of 26 days per year was used for the general area because it is assumed that the general area is more difficult to access and a less desirable area for recreational activities than the human health concern area. There is some uncertainty in this assumption. Recently there appears to be some evidence of a more frequent activity such as deep rutted terrain and freshly exposed soils. The use of a 26 day per year exposure frequency may underestimate exposure and overestimate the PRGs.
- Non-cancer risk was not quantitatively evaluated for potential exposures to dioxins and furans. There is not currently a published USEPA oral reference dose (RfD) available for 2,3,7,8-TCDD, or any other dioxin or furan congener. USEPA has concluded that the current average dioxin exposure to the human population is greater than the RfDs that would be calculated based on available data. USEPA, therefore, concluded that RfD values would not be informative for safety assessment (USEPA, 2000). Non-cancer effects such as effects on reproduction and development, suppression of the immune system, and chloracne (USEPA, 2000) have been associated with these compounds in animal studies and it is likely that similar effects might occur with human exposure. Therefore, the non-cancer risk associated with potential exposure to dioxins and furans are understated in the HHRA and are not quantitatively evaluated in the development of the PRGs.

5.0 COMPARISON OF PRGS TO BACKGROUND CONDITIONS

Consistent with the results of the HHRA, some of the calculated surface soil PRGs for the COCs are lower than the representative surface soil concentrations at the upstream background area, Greystone Mill Pond.

For arsenic, the soil PRGs at target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4} are 4.7 mg/kg, 47 mg/kg, and 467 mg/kg and the associated non-carcinogenic effects based PRGs (for the child) at hazard quotient of 0.1, 1, and 10 respectively are 29 mg/kg, 291 mg/kg, and 2914 mg/kg. In the four background soil samples, arsenic concentrations ranged from 5.58 mg/kg to 12.2 mg/kg with an arithmetic mean concentration of 7.72 mg/kg. With the exception of the PRG based on 10^{-6} cancer risk (4.7 mg/kg), all PRGs are above the arithmetic mean arsenic concentration in surface soil at the background area. The Rhode Island Remediation Regulations contain a soil direct-exposure criterion for arsenic for residential land use of 7 mg/kg, which is based on a conservative estimate of the Rhode Island soil background concentration. It should be noted that arsenic concentrations in surface soil are very similar to those reported for the surface soils in the background area, suggesting there may be little or no Site impact on surface soil in the Oxbow Area.

For benzo(a)pyrene, the soil PRGs at target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4} are 0.21 mg/kg, 2.1 mg/kg, and 21 mg/kg and the associated non-carcinogenic effects based PRGs (for the child) at hazard quotient of 0.1, 1, and 10 respectively are 2,316 mg/kg, 23,157 mg/kg, and 231,573 mg/kg. In the four background soil samples, benzo(a)pyrene concentrations ranged from 2.29 mg/kg to 3.42 mg/kg with an arithmetic mean of 3.08 mg/kg. The PRGs based on 10^{-6} and 10^{-5} cancer risk are below the arithmetic mean benzo(a)pyrene concentration in surface soil at the background area. The PRG based on 10^{-4} cancer risk is above the arithmetic mean benzo(a)pyrene concentration in surface soil at the background area.

For dioxin TEQ, the surface soil PRGs at target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4} are 0.000053 mg/kg, 0.00053 mg/kg and 0.0053 mg/kg. These PRGs can also be expressed as 0.053 parts per billion, 0.53 parts per billion, and 5.3 parts per billion. In the four background soil samples, dioxin TEQ concentrations ranged from 0.0000379 mg/kg to 0.000109 mg/kg. This range of concentrations can also be expressed as 0.0379 parts per billion to 0.109 parts per billion. The arithmetic mean floodplain soil dioxin TEQ concentration at the background area is 0.05 parts per billion. The dioxin-TEQ PRGs set at a cancer risk target of 10^{-6} is below the maximum dioxin

TEQ concentration reported in soils at the background area. The dioxin-TEQ PRGs set at target cancer risks of 10^{-5} and 10^{-4} are above the range of reported dioxin TEQ concentrations in surface soil at the background area.

6.0 COMPARISON OF SITE CONCENTRATIONS TO PRGS

In order to provide a general sense of the distribution of COC surface soil concentrations relative to the calculated surface soil PRGs, the following text indicates the frequency at which concentrations of COCs in Oxbow general area surface soil are above the corresponding cancer risk-based PRGs (at target cancer risk of 10^{-6}) and non-cancer risk-based PRGs (hazard quotient equal to one).

For arsenic, 10 of 19 surface soil samples have arsenic concentrations above the surface soil PRG set at the target cancer risk of 10^{-6}. None of the detected arsenic concentrations are above the surface soil PRG set at the target hazard quotient of one. For benzo(a)pyrene, 12 of the 18 surface soil samples have benzo(a)pyrene concentrations above the surface soil PRG set at the target cancer risk of 10^{-6}. None of the detected benzo(a)pyrene concentrations are above the surface soil PRG set at the target hazard quotient of one. For dioxin-TEQ, 17 of 22 surface soil samples have dioxin TEQ concentrations above the surface soil PRG set at the target cancer risk of 10^{-6}.

7.0 REFERENCES

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TABLES

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Table 1
Derivation of Surface Soil Based Human Health Preliminary Remediation Goals - Direct Contact

Oxbow Preliminary Remediation Goals Report - Oxbow Area - Human Health
Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

SCENARIO TIMEFRAME: CURRENT/FUTURE
MEDIUM: SOIL
EXPOSURE MEDIUM: SURFACE SOIL

EXPOSURE ROUTE	RECEPTOR POPULATION	RECEPTOR AGE	EXPOSURE POINT	PARAMETER CODE	PARAMETER DEFINITION	VALUE	UNITS	RATIONALE/ REFERENCE
INGESTION	PASSIVE RECREATIONAL VISITOR	ADULT (ages 19 and above)	OXBOW	IR-S	INGESTION RATE OF SOIL	100	mg/day	USEPA, 1994
				FI	FRACTION INGESTED	1	unitless	Professional Judgement
				EF	EXPOSURE FREQUENCY	26	day/yr	Professional Judgement[1]
				ED	EXPOSURE DURATION	12	yr	USEPA, 1994[2]
				BW	BODY WEIGHT	70	kg	USEPA, 1994
				AT-C	AVERAGING TIME (CANCER)	25550	day	USEPA, 1989
				AT-N	AVERAGING TIME (NONCANCER)	4380	day	USEPA, 1989
				ADAF	AGE DEPENDENT ADJUSTMENT FACTOR	1	unitless	USEPA, 2005[3]
				CF	CONVERSION FACTOR	0.000001	kg/mg	
		ADOLESCENT (ages 7 - 18)	OXBOW	IR-S	INGESTION RATE OF SOIL	100	mg/day	USEPA, 1994
				FI	FRACTION INGESTED	1	unitless	Professional Judgement
				EF	EXPOSURE FREQUENCY	26	day/yr	Professional Judgement[1]
				ED	EXPOSURE DURATION	12	yr	USEPA, 1994[2]
				BW	BODY WEIGHT	45	kg	USEPA, 1997[4]
				AT-C	AVERAGING TIME (CANCER)	25550	day	USEPA, 1989
				AT-N	AVERAGING TIME (NONCANCER)	4380	day	USEPA, 1989
				ADAF	AGE DEPENDENT ADJUSTMENT FACTOR	2.5	unitless	USEPA, 2005[3]
				CF	CONVERSION FACTOR	0.000001	kg/mg	
		CHILD (ages 1 - 6)	OXBOW	IR-S	INGESTION RATE OF SOIL	200	mg/day	USEPA, 1994
				FI	FRACTION INGESTED	1	unitless	Professional Judgement
				EF	EXPOSURE FREQUENCY	26	day/yr	Professional Judgement[1]
				ED	EXPOSURE DURATION	6	yr	USEPA, 1994[2]
				BW	BODY WEIGHT	15	kg	USEPA, 1994
				AT-C	AVERAGING TIME (CANCER)	25550	day	USEPA, 1989
				AT-N	AVERAGING TIME (NONCANCER)	2190	day	USEPA, 1989
				ADAF	AGE DEPENDENT ADJUSTMENT FACTOR	4.2	unitless	USEPA, 2005[3]
				CF	CONVERSION FACTOR	0.000001	kg/mg	
DERMAL	PASSIVE RECREATIONAL VISITOR	ADULT (ages 19 and above)	OXBOW	AF	ADHERENCE FACTOR	0.07	mg/cm2	USEPA, 2001[5]
				AbF	ABSORPTION FACTOR	chemical-specific	unitless	USEPA, 2001[6]
				SA	SKIN SURFACE AREA AVAILABLE FOR CONTACT	5700	cm2/day	USEPA, 2001[7]
				EV	EVENT DAY	1	unitless	Professional Judgement
				EF	EXPOSURE FREQUENCY	26	day/yr	Professional Judgement[1]
				ED	EXPOSURE DURATION	12	yr	USEPA, 1994[2]
				BW	BODY WEIGHT	70	kg	USEPA, 1994
				AT-C	AVERAGING TIME (CANCER)	25550	day	USEPA, 1989
				AT-N	AVERAGING TIME (NONCANCER)	4380	day	USEPA, 1989
				ADAF	AGE DEPENDENT ADJUSTMENT FACTOR	1	unitless	USEPA, 2005[3]
				CF	CONVERSION FACTOR	0.000001	kg/mg	
		ADOLESCENT (ages 7 - 18)	OXBOW	AF	ADHERENCE FACTOR	0.2	mg/cm2	USEPA, 2001[5]
				AbF	ABSORPTION FACTOR	chemical-specific	unitless	USEPA, 2001[6]
				SA	SKIN SURFACE AREA AVAILABLE FOR CONTACT	4800	cm2/day	USEPA, 1997[8]
				EV	EVENT DAY	1	unitless	Professional Judgement
				EF	EXPOSURE FREQUENCY	26	day/yr	Professional Judgement[1]
				ED	EXPOSURE DURATION	12	yr	USEPA, 1994[2]
				BW	BODY WEIGHT	45	kg	USEPA, 1997[4]
				AT-C	AVERAGING TIME (CANCER)	25550	day	USEPA, 1989
				AT-N	AVERAGING TIME (NONCANCER)	4380	day	USEPA, 1989
				ADAF	AGE DEPENDENT ADJUSTMENT FACTOR	2.5	unitless	USEPA, 2005[3]
				CF	CONVERSION FACTOR	0.000001	kg/mg	
		CHILD (ages 1 - 6)	OXBOW	AF	ADHERENCE FACTOR	0.2	mg/cm2	USEPA, 2001[5]
				AbF	ABSORPTION FACTOR	chemical-specific	unitless	USEPA, 2001[6]
				SA	SKIN SURFACE AREA AVAILABLE FOR CONTACT	2800	cm2/day	USEPA, 2001[7]
				EV	EVENT DAY	1	unitless	Professional Judgement
				EF	EXPOSURE FREQUENCY	26	day/yr	Professional Judgement[1]
				ED	EXPOSURE DURATION	6	yr	USEPA, 1994[2]
				BW	BODY WEIGHT	15	kg	USEPA, 1994
				AT-C	AVERAGING TIME (CANCER)	25550	day	USEPA, 1989
				AT-N	AVERAGING TIME (NONCANCER)	2190	day	USEPA, 1989
				ADAF	AGE DEPENDENT ADJUSTMENT FACTOR	4.2	unitless	USEPA, 2005[3]
				CF	CONVERSION FACTOR	0.000001	kg/mg	

Table 1
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Oxbow Preliminary Remediation Goals Report - Oxbow Area - Human Health
Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

SCENARIO TIMEFRAME: CURRENT/FUTURE
MEDIUM: SOIL
EXPOSURE MEDIUM: SURFACE SOIL

EXPOSURE ROUTE	RECEPTOR POPULATION	RECEPTOR AGE	EXPOSURE POINT	PARAMETER CODE	PARAMETER DEFINITION	VALUE	UNITS	RATIONALE/ REFERENCE

USEPA, 1989. "Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)"; Office of Emergency and Remedial Response; EPA-540/1-89/002 (interim final); Washington, D.C., December.
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USEPA, 2005. "Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens, Risk Assessment Forum; EPA/630/R-03/003F; Washington, D.C. March.
1 - Value based on exposure during wading, swimming, and walking/exploring banks (1 day per week May - October).
2 - The total RME exposure duration is 30 years, consistent with USEPA, 1994. The allocation of exposure duration for the three age groups is based on professional judgement.
3 - ADAF is only used for carcinogenic chemicals that operate with a mutagenic mode of action (only benzo(a)pyrene for these COPCs).
4 - Values are the average of 50th percentile body weights for males and females ages 7 through 18.
5 - Values for residential exposure to soil used as conservative estimate of potential soil adherence associated with recreational walking/exploring.
6 - Values are provided (Table 3-4 of USEPA, 2001) for arsenic, cadmium, chlordane, 2,4-D, DDT (used for DDD, DDE), TCDD, lindane (used for other BHC isomers), PAHs, PCBs, and pentachlorophenol. A single value is listed for all other SVOCs. No values are listed for VOCs, other pesticides, or other inorganics and, subsequently, no value will be assigned to the AbF term for COPCs falling into those categories.
7 - Values for residential exposure to soil used as conservative estimate of potential surface area exposed to soil during recreational walking/exploring.
9 - Values are the average of 50th percentile body surface areas (sum of areas for face, hands, forearms, lower legs, and feet) for males in the various age groups indicated.
mg - milligrams
cm2 - square centimeters
kg - kilograms

Based on cancer risk,

$$PRG_{soil,c} = \frac{TR_{soil}}{\left[\left[\left(\frac{CSF_o \times ADAF \times IR_{child} \times FI \times EF_{child} \times ED_{child} \times CF}{BW_{child} \times AT}\right) + \left(\frac{CSF_o \times ADAF \times IR_{olderchild} \times FI \times EF_{olderchild} \times ED_{olderchild} \times CF}{BW_{olderchild} \times AT}\right) + \left(\frac{CSF_o \times ADAF \times IR_{adult} \times FI \times EF_{adult} \times ED_{adult} \times CF}{BW_{adult} \times AT}\right)\right] + \left[\left(\frac{CSF_d \times ADAF \times AF \times AbF \times CF \times EV_{child} \times ED_{child} \times EF_{child} \times SA_{child}}{BW_{child} \times AT}\right) + \left(\frac{CSF_d \times ADAF \times AF \times AbF \times CF \times EV_{olderchild} \times ED_{olderchild} \times EF_{olderchild} \times SA_{olderchild}}{BW_{olderchild} \times AT}\right) + \left(\frac{CSF_d \times ADAF \times AF \times AbF \times CF \times EV_{adult} \times ED_{adult} \times EF_{adult} \times SA_{adult}}{BW_{adult} \times AT}\right)\right]\right]}$$

COMPOUND OF POTENTIAL CONCERN	ORAL SLOPE FACTOR (mg/kg/day)-1	DERMAL SLOPE FACTOR (mg/kg/day)-1	DERMAL ABSORPTION FACTOR [AbF]	PRG ELCR = 10^{-4} (mg/Kg)	PRG ELCR = 10^{-5} (mg/Kg)	PRG ELCR = 10^{-6} (mg/Kg)
Arsenic	1.5	1.5	0.03	467	47	4.7
Benzo(a)pyrene	7.3	7.3	0.13	21.2	2.1	0.21
Dioxin-TEQ	150000	150000	0.001	0.0053	0.00053	0.000053

TRsoil - Target Risk
ELCR - Excess Lifetime Cancer Risk

Based on non-cancer risk,

$$PRG_{soil,nc} = \frac{THI_{soil}}{\left[\left(\frac{CF \times IR_{agegroup} \times FI \times EF_{agegroup} \times ED_{agegroup}}{RfD_o \times BW_{agegroup} \times AT}\right) + \left(\frac{AF \times AbF \times CF \times EV_{agegroup} \times ED_{agegroup} \times EF_{agegroup} \times SA_{agegroup}}{RfD_d \times BW_{agegroup} \times AT}\right)\right]}$$

COMPOUND OF POTENTIAL CONCERN	ORAL CHRONIC REFERENCE DOSE (mg/kg/day)	DERMAL CHRONIC REFERENCE DOSE (mg/kg/day)	DERMAL ABSORPTION FACTOR [AbF]	PRG ADULT HI = 0.1 (mg/Kg)	PRG ADULT HI = 1 (mg/Kg)	PRG ADULT HI = 10 (mg/Kg)	PRG ADOLESCENT HI = 0.1 (mg/Kg)	PRG ADOLESCENT HI = 1 (mg/Kg)	PRG ADOLESCENT HI = 10 (mg/Kg)	PRG CHILD HI = 0.1 (mg/Kg)	PRG CHILD HI = 1 (mg/Kg)	PRG CHILD HI = 10 (mg/Kg)
Arsenic	0.0003	0.0003	0.03	263	2633	26329	147	1471	14714	29	291	2914
Benzo(a)pyrene	0.03	0.03	0.13	19412	194118	1941185	8431	84306	843057	2316	23157	231573
Dioxin-TEQ	ND	ND	0.001	---	---	---	---	---	---	---	---	---

THI - Target Hazard Index
HI - Hazard Index
NA - not available
--- No PRG calculated

Table 2
Preliminary Remediation Goals - Surface Soil Direct Contact

Oxbow Preliminary Remediation Goals Report - Oxbow Area - Human Health
Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

COMPOUND OF POTENTIAL CONCERN	PRG ELCR = 10-4 (mg/Kg)	PRG ELCR = 10-5 (mg/Kg)	PRG ELCR = 10-6 (mg/Kg)	PRG ADULT HI = 0.1 (mg/Kg)	PRG ADULT HI = 1 (mg/Kg)	PRG ADULT HI = 10 (mg/Kg)	PRG ADOLESCENT HI = 0.1 (mg/Kg)	PRG ADOLESCENT HI = 1 (mg/Kg)	PRG ADOLESCENT HI = 10 (mg/Kg)	PRG CHILD HI = 0.1 (mg/Kg)	PRG CHILD HI = 1 (mg/Kg)	PRG CHILD HI = 10 (mg/Kg)
Arsenic	467	47	4.7	263	2633	26329	147	1471	14714	29	291	2914
Benzo(a)pyrene	21	2.1	0.21	19412	194118	1941185	8431	84306	843057	2316	23157	231573
Dioxin-TEQ	0.0053	0.00053	0.000053	---	---	---	---	---	---	---	---	---

Interim Final

Addendum to the Interim Final Preliminary Remediation Goals Report: Oxbow Area, Part II Ecological

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

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September 2011

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The Business of Innovation

TABLE OF CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

BAF	Bioaccumulation factor
BERA	Baseline ecological risk assessment
BMF	Biomagnification factor
BSAF	Biota-soil accumulation factor
BW	Body weight
CBR	Critical body residue
COCs	Chemicals of concern
4,4'- DDD	4,4,'-dichlorodiphenyldichloroethane
4,4'- DDE	4,4'-dichlorodiphenyldichloroethylene
dw	Dry weight
g	Gram
HI	Hazard index
HQ	Hazard quotient
IR	Ingestion rate
kg	Kilogram
LOAEL	Lowest observed adverse effects level
MATC	Maximum allowable toxicant concentration
mg	Milligram
NOAEL	No observed adverse effects level
PCB	Polychlorinated biphenyl
PRG	Preliminary remediation goal
SFF	Site foraging frequency
SLERA	Screening Level Ecological Risk Assessment
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEQ	Toxic equivalency
THQ	Target hazard quotient
TOC	Total organic carbon
TRV	Toxicity reference value
USACE	United States Army Corps of Engineers
ww	Wet weight

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1.0 INTRODUCTION

Ecologically-based Preliminary Remediation Goals (PRGs) were derived for the Oxbow Area floodplain soils based on risks identified in the *Interim Final Supplemental Baseline Human Health and Ecological Risk Assessment: Oxbow Area Floodplain Soil and Sediment, Part II: Ecological Risk Assessment* (MACTEC and Battelle, 2011); hereinafter "Supplemental BERA". The Oxbow Area is a wooded wetland area that is part of the Centredale Manor Restoration Project Superfund Site (hereinafter referred to as "the Site") immediately west of the Woonasquatucket River below the Allendale Dam (Figure 1). The Supplemental BERA also evaluated floodplain soil exposures in wooded wetland areas to the east of the Oxbow Area (along the eastern bank of the Woonasquatucket River) and in a couple isolated wetland areas downstream from the Oxbow area and adjacent to Lyman Mill Pond (Figure 2), and the PRGs developed herein are applicable to these areas as well.

A process similar to that employed to develop PRGs for other exposure areas and Site media was used to ensure that consistent and comparable information was provided for risk management decision making. Ecologically-based PRGs for other impacted media at the Site (e.g., sediment, Allendale Pond floodplain soils) are documented in the Interim Final Preliminary Remediation Goals Report Part II (MACTEC, 2005) based on risks identified in the Baseline Ecological Risk Assessment (BERA) for the Site (MACTEC, 2004). PRGs were calculated for chemicals of concern (COCs) in floodplain soil and biota based on risks to the most sensitive receptors identified for each exposure pathway and/or endpoint evaluated in the Supplemental BERA (MACTEC and Battelle, 2011). The PRGs that were developed for the Oxbow Area floodplain soil relate specifically to bioaccumulation hazards, which are the primary hazards posed by the COCs to ecological receptors at the Site. These PRGs were developed to update those derived based on the results of the screening level ecological risk assessment (SLERA) performed for the *Addendum to the Interim Final Baseline Risk Assessment: Oxbow Area, Part II – Ecological Health* (MACTEC and Battelle, 2006). PRGs were not developed for Oxbow Area sediments because sediment exposures, which occur within the shrub-scrub habitat in the lower Oxbow, were only evaluated qualitatively in the Supplemental BERA. It is anticipated that sediment PRGs developed for Lyman Mill Pond (MACTEC, 2005) will be appropriate for identifying necessary remedial actions in the portions of the Oxbow Area evaluated that contain sediments.

1.1 Summary of the Addendum to the Baseline Ecological Risk Assessment Results

The Supplemental BERA (MACTEC and Battelle, 2011) evaluated the risks associated with potential exposures of ecological receptors to surficial floodplain soils in the Oxbow Area. Figure 2 depicts the locations within the Oxbow Area that were sampled to estimate exposures and quantify risks to ecological receptors. Risks were evaluated based on direct contact with and/or incidental ingestion of surface soil and the consumption of contaminated biota. Three assessment endpoints were evaluated:

1. Protection and maintenance (i.e., survival, growth, and reproduction) of floodplain invertebrate communities which serve as a forage base for wildlife.
2. Protection and maintenance of vermivorous (i.e., earthworm-feeding) mammal and bird populations.
3. Protection and maintenance of omnivorous mammal populations.

Results of the Supplemental BERA (MACTEC and Battelle, 2011) indicate that ecological receptors are possibly or probably at substantial risk of harm from exposure to site-related COCs in floodplain soil or in biological tissue residues as follows:

Assessment Endpoint 1, Protection and Maintenance of the Floodplain Soil Invertebrate Community.

- Based on a comparison average floodplain soil concentrations to macroinvertebrate screening benchmarks, the soil macroinvertebrate community occurring within the Oxbow Area may be at risk of harm (i.e., hazard index [HI] exceeds 1.0) due to direct exposure to pesticides (including 4,4'-DDT, 4,4-DDE, 4,4'-DDD, dieldrin, lindane [gamma-chlordane], and endrin) (HI = 62), metals (including chromium, copper, manganese, mercury, vanadium, zinc, and potentially aluminum [depending on soil pH]) (HI = 94), and PAHs (HI=13) in floodplain soil (see Table ES-2 in MACTEC and Battelle [2011]). The total risk (HI=170) is similar to direct exposure risks for soil macroinvertebrates in Allendale Pond floodplain soils (HI=170) and two times lower than those estimated in the BERA for Lyman Mill Pond (HI=230) for the BERA, and risks to soil macroinvertabrates at all three areas are below background risks at Greystone Mill Pond (HI=850) (see Table ES-2 in MACTEC and Battelle [2011]). The higher exposure risk at Greystone Mill Pond is being driven by higher floodplain soil concentrations of metals and PAHs.
- Estimated body burdens of bioaccumulated metals, primarily cadmium, lead, manganese, nickel, vanadium, zinc, and possibly aluminum (depending on soil pH, which affects the bioavailability of aluminum for uptake by soil invertebrates) appear to pose a substantial risk of harm to soil macroinvertebrates (no observable adverse effects level [NOAEL]-based HI = 770 and lowest observable adverse effects level [LOAEL]-based HI = 120 with aluminum, and HIs = 30 and 28 without HQs for aluminum). However, risks are substantially lower than risks from body burdens of metals for soil macroinvertebrates exposed to floodplain soil at Allendale Pond, Lyman Mill Pond, and Greystone Mill Pond.
- An evaluation of the soil macroinvertebrate community study conducted to support the BERA suggests that the macroinvertebrate fauna is most likely comparable to other exposure areas at the Site and is not distinguishable from the upriver background area.

Assessment Endpoint 2, Protection and Maintenance of Vermivorous Wildlife Populations.

- Vermivorous mammal and bird populations that occur within the Oxbow Area appear to be at risk of harm due to direct exposure to Site-related contaminants in floodplain soil and prey items. Dioxin as toxic equivalency (TEQ) is the most substantial contributor to the estimated total risks to vermivorous mammals, contributing approximately 51% of the total risk, followed by metals. Pesticides are the most substantial contributor to the estimated total risks to vermivorous birds, followed by TEQ, contributing approximately 45% and 26% to the estimated total risk, respectively. In addition, based on modeled tissue concentrations, consumption of contaminated earthworm prey may result in elevated tissue residues in these receptors, potentially resulting in adverse reproductive effects (i.e., bioaccumulation hazard). Although risks to vermivorous wildlife in the exposure areas evaluated for the BERA are also from exposure to dioxins and metals, risks from dietary exposure estimated for Allendale Pond and Lyman Mill Pond for the BERA are up to two times lower than risks at the Oxbow Area. Risks to vermivorous mammals in the Oxbow Area are 2.5 times higher than background; however, risks to vermivorous birds are similar to background.
- Modeled tissue burdens for pesticides and 2,3,7,8-TCDD in avian eggs and 2,3,7,8-TCDD in mammal liver tissue as a result of potential dietary exposures pose a substantial risk of harm to vermivorous wildlife species. Risks are similar to those at Allendale Pond, but are two to three times higher than previously estimated risks from exposure to Lyman Mill Pond sediment. Estimated background risks are insignificant.

Assessment Endpoint 3, Protection and Maintenance of Omnivorous Wildlife Populations.

- Omnivorous mammal populations that forage within the study area are not at substantial risk of harm from exposure to Site-related contaminants in floodplain soil and terrestrial prey items. This is consistent with risks from exposure to Allendale Pond and Lyman Mill Pond floodplain soil estimated for the BERA.

1.2 Ecological Chemicals of Concern for Oxbow Area Floodplain Soil

Table 1 provides a summary of the PRGs that were developed for each endpoint receptor. In general, the COCs for which PRGs were developed are those that resulted in the highest incremental risk for a given species relative to background risks (as summarized in the incremental risk tables in the Supplemental BERA). These chemicals include dioxins and furans, pesticides (4,4'-DDT, 4,4'-DDE, dieldrin, and lindane), and several inorganic compounds (aluminum, antimony, copper, and nickel). Although a toxic equivalency (TEQ) approach was previously used to derive a single PRG for dioxins and furans (MACTEC, 2005), 2,3,7,8-TCDD accounted for a majority of the hazard associated with ecological exposure to dioxins and furans (ranging up to greater than 90 percent of the total TEQ in individual floodplain soil samples; see Figure C-2A in Appendix C of the Supplemental BERA [MACTEC and Battelle, 2011]).

PRGs were developed based on the measurement endpoints used in the Supplemental BERA. For the earthworm receptor, PRGs were developed using (1) soil screening benchmarks protective of soil invertebrates and (2) tissue threshold concentrations based on literature-derived critical body residues (CBRs). PRGs for vermivorous wildlife were developed in two ways as well: (1) using the exposure dose model to back-calculate protective media concentrations and (2) using tissue threshold concentrations based on literature-derived CBRs.

2.0 TECHNICAL APPROACH AND PROCEDURE FOR DEVELOPMENT OF PRGS

Site-specific PRGs were developed based on the conclusions of the Supplemental BERA and the physical and chemical conditions at the Oxbow Area. PRGs were developed consistent with *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual* (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991).

In general, floodplain soil PRGs for ecological receptors were derived by dividing the risk threshold concentrations for prey tissue by site-specific biota-soil accumulation factors (BSAFs) appropriate for each receptor of concern. Risk threshold concentrations for earthworm tissue were divided by the appropriate BSAFs to derive floodplain soil PRGs protective of these endpoint receptors. BSAFs were derived using the geometric mean concentration of the total organic carbon (TOC) normalized floodplain soil concentrations and the lipid-normalized biota tissue concentrations[1].

For each COC, for a given endpoint receptor and measurement endpoint, PRGs were calculated for both NOAEL and LOAEL endpoints when available. The geometric mean of the NOAEL and LOAEL values (i.e., Maximum Allowable Toxicant Concentration [MATC]) was also calculated. For each of these benchmarks (i.e., NOAEL, LOAEL, and MATC), PRGs were calculated based on target HQ values of 0.1, 1.0, and 10.

[1] For organic COCs only; in the case of inorganic COCs, geometric means for non-normalized data were used.

Specific procedures used to derive PRGs for each of the endpoint receptors of concern are detailed in the following sections.

2.1 Procedure for Development of Floodplain Soil PRGs Protective of Earthworms and Other Soil Invertebrates

The following procedure was used to develop floodplain soil PRGs protective of floodplain soil invertebrates for the COCs identified in Table 1.

Ecological earthworm tissue PRGs were developed for each of the COCs based on literature-derived CBRs.

Earthworm tissue PRGs based on the literature-derived CBRs were calculated using NOAEL- and LOAEL-based CBR values and the geometric mean of these values as follows:

$$PRG_{earthworm} = THQ * CBR \qquad \text{Equation 1}$$

where:

$PRG_{earthworm}$	=	PRG for earthworm tissue (mg COC/kg earthworm tissue)
THQ	=	Target Hazard Quotient for the COC based on tissue residue effects (dimensionless); PRGs were calculated using THQs of 0.1, 1.0, and 10.
CBR	=	Critical Body Residue (mg COC/kg earthworm tissue). NOAEL- and LOAEL-based CBR values presented in Table 5 of the Supplemental BERA (MACTEC and Battelle, 2011). The MATC-based CBR is the geometric mean of the NOAEL- and LOAEL-based values.

The CBR-based PRGs for nickel in earthworm tissue are presented in Table 2. Floodplain soil concentrations for organic COCs based on these protective tissue residues were then calculated by dividing the $PRG_{earthworm}$ values by the estimated average earthworm tissue lipid concentration and the corresponding BSAF presented in the Supplemental BERA (Table 3)[2]:

$$PRG_{soil} = \frac{PRG_{earthworm} * [TOC]_{soil}}{BSAF * [Lipid]_{earthworm}} \qquad \text{Equation 2}$$

where:

PRG_{soil}	=	PRG for floodplain soil that is protective of soil invertebrates (mg COC/kg soil).
BSAF[3]	=	Biota-Soil Accumulation Factor (g organic carbon in soil/g lipid in earthworm)
$[TOC]_{soil}$	=	Average TOC concentration in Oxbow soil reported as dry weight mg organic carbon/kg soil)
$[Lipid]_{earthworm}$	=	Average lipid concentration in Lyman Mill earthworm tissues (mg lipid/kg earthworm tissue)

[2] The earthworm BSAFs were derived assuming that the typical lipid percentage in Oxbow floodplain earthworms is 2.7% based on the average of Lyman Mill earthworm samples collected to support the BERA (Table 20; MACTEC, 2004). A floodplain soil TOC of 8.1% was also used based on the average of 28 floodplain surface soil samples collected in the Oxbow Area (MACTEC and Battelle, 2011).

[3] This term was developed as a means of quantifying organic contaminant uptake by biota from the sediment medium; however, the application to floodplain soils is appropriate and straightforward.

$PRG_{earthworm}$ = PRG for earthworm tissue (mg COC/kg earthworm tissue)

To calculate PRGs for inorganic COCs in floodplain soil, bioaccumulation factors (BAFs) (i.e., ratio of non-normalized COC concentration in earthworm tissue by non-normalized chemical concentration in floodplain soil) were used:

$$PRG_{soil} = \frac{PRG_{earthworm}}{BAF} \quad \text{Equation 3}$$

The PRGs were calculated based on target HQ values of 0.1, 1.0, and 10. Floodplain soil PRGs based on protection of soil invertebrates using tissue CBRs are presented in Table 3.

Ecological invertebrate soil PRGs were developed for each of the COCs based on literature-derived soil screening benchmarks.

Floodplain soil PRGs based on the literature-derived CBRs were calculated using soil screening values as follows:

$$PRG_{soil} = THQ * TRV \quad \text{Equation 4}$$

where:

PRG_{soil} = PRG for floodplain soil that is protective of soil invertebrates (mg COC/kg soil).
THQ = Target Hazard Quotient for the COC based on tissue residue effects (dimensionless); PRGs were calculated using THQs of 0.1, 1.0, and 10.
TRV = Toxicity Reference Value (mg COC/kg soil). Literature-based soil screening values are presented in Table 4 of the Supplemental BERA (MACTEC and Battelle, 2011).

PRGs based on use of these soil screening levels are presented in Table 4.

2.2 Procedure for Development of Floodplain Soil PRGs Protective of Vermivorous Wildlife

The following procedure was used to develop floodplain soil PRGs protective of vermivorous (i.e., earthworm-feeding) wildlife for the COCs identified in Table 1.

Ecological earthworm tissue PRGs were developed for each COC that are protective of the effects to American woodcock embryos (eggs).

Ecological earthworm tissue PRGs were developed that are protective of the American woodcock embryos based on CBRs as follows:

$$PRG_{egg} = THQ * CBR \quad \text{Equation 5}$$

where:

PRG_{egg} = PRG for woodcock eggs (mg COC/kg egg tissue).

THQ = Target Hazard Quotient for the COC based on tissue residue effects (dimensionless); PRGs were calculated using THQs of 0.1, 1.0, and 10.
CBR = Critical Body Residue (mg COC/kg egg tissue). NOAEL- and LOAEL-based CBR values presented in Table 10 of the Supplemental BERA (MACTEC and Battelle, 2011). The MATC-based CBR is the geometric mean of the NOAEL- and LOAEL-based values.

CBR-based egg tissue PRGs are presented in Table 5. Protective COC concentrations in food (earthworm tissue) were estimated using the protective avian egg tissue concentration and Biomagnification Factors (BMFs) as follows:

$$PRG_{earthworm} = \frac{PRG_{egg} * [Lipid]_{earthworm}}{BMF * [Lipid]_{egg}} \quad \text{Equation 6}$$

where:

$PRG_{earthworm}$ = PRG for earthworm tissue that is protective of woodcock embryos associated with a bioaccumulation hazard (mg COC/kg soil)
PRG_{egg} = PRG for woodcock eggs as calculated in Equation 6 (mg COC/kg egg tissue).
$[Lipid]_{earthworm}$ = Average lipid concentration in Lyman Mill earthworm tissues (kg lipid/kg earthworm tissue)
BMF = Biomagnification Factor (kg earthworm lipid/kg egg lipid)
$[Lipid]_{egg}$ = Average lipid concentration in woodcock embryo tissues (kg egg lipid/kg egg tissue)

The COC-specific BMFs were calculated as follows:

$$BMF = \frac{[C]_{egg,\ln}}{[C]_{earthworm,\ln}} \quad \text{Equation 7}$$

where:

BMF = Biomagnification Factor (g earthworm lipid/g egg lipid)
$[C]_{egg,ln}$ = Lipid-normalized COC concentration in woodcock egg tissue reported as wet weight (mg COC/kg lipid in egg tissue)
$[C]_{earthworm,ln}$ = Lipid-normalized COC concentration in earthworm tissue reported as wet weight (mg COC/kg lipid in earthworm tissue)

PRGs for earthworm tissue based on this endpoint, along with the BMFs, are presented in Table 6. Equation 2 was then used to calculate the corresponding floodplain soil PRGs (Table 7).

A similar approach was employed to calculated floodplain soil PRGs based on protective tissue concentrations in mammalian liver tissue. Equations 5 and 6 were modified with the PRG_{egg} term replaced with a corresponding PRG_{liver} term and Tables 8, 9, and 10 present the derived PRGs for mammal liver, earthworm tissue, and floodplain soil, respectively, based on this endpoint.

Ecological earthworm tissue PRGs were developed for each of the COCs based on exposure dose modeling.

Ecological earthworm tissue PRGs were developed that are protective of the American woodcock and short-tailed shrew earthworm ingestion pathway for each COC in earthworm tissue as follows:

$$PRG_{soil} = \frac{THQ * TRV * BW}{\left(BAF_{plant} * IR_{food} * P_{plant} * SFF\right) + \left(\frac{BSAF_{ew} * [Lipid]_{ew}}{[TOC]_{soil}} * IR_{food} * P_{ew} * SFF\right) + \left(IR_{soil} * SFF\right)}$$ Equation 8

where:

PRG_{soil}	=	PRG for floodplain soil that is protective of wildlife (mg COC/kg soil).
THQ	=	Target Hazard Quotient for the COC based on tissue residue effects (dimensionless); PRGs were calculated using THQs of 0.1, 1.0, and 10.
TRV	=	Toxicity Reference Value. Receptor-specific literature-based toxicity threshold value. NOAEL and LOAEL-based TRV values were obtained from Table D-4 (Appendix D) of the BERA (MACTEC, 2004). The MATEC-based TRV is the geometric mean o f the NOAEL- and LOAEL-based values.
BW	=	Receptor body weight (0.2 kg, woodcock; 0.017 kg, shrew). Literature –based value obtained from Table I-2 of the BERA (MACTEC, 2004).
BAF_{plant}	=	Bioaccumulation Factor between soil and edible portions of plants consumed by the receptor (µg COC plant tissue [ww]/µg COC soil [dw])
IR_{food}	=	Food (earthworm) ingestion rate (0.082 kg/day, woodcock; 0.013 kg/day, shrew). Literature-based value obtained from Table I-2 of the BERA (MACTEC, 2004).
P_{plant}	=	Percentage of plant types in the diet
SFF	=	Site Foraging Frequency (unitless); fraction of time receptor is assumed to forage at the site.
$BSAF_{ew}$	=	Earthworm-Soil Accumulation Factor (g organic carbon in soil/g lipid in earthworm)
$[TOC]_{soil}$	=	Average TOC concentration in Oxbow soil reported as dry weight mg organic carbon/kg soil)
$[Lipid]_{ew}$	=	Average lipid concentration in Lyman Mill earthworm tissues (mg lipid/kg earthworm tissue)
P_{ew}	=	Percentage of earthworms in the diet of the receptor
IR_{soil}	=	Ingestion rate of soil (associated with typical foraging activities); kg (dw) per day.

Floodplain soil PRGs that are protective of the dietary exposure pathway to floodplain avian and mammalian receptors are presented in Tables 11 and 12, respectively.

3.0 CALCULATION AND PRESENTATION OF ECOLOGICAL PRGS

Table 13 summarizes the PRG values calculated for each receptor and endpoint evaluated in the Supplemental BERA for the Oxbow Area. Values presented are based on the MATC TRVs for THQs of 0.1, 1.0, and 10. The calculations for the PRGs using the NOAEL- and LOAEL-based TRVs can be found in Tables 2 through 12. As described in the previous section, PRGs estimated using CBRs and soil screening benchmarks for earthworms were not included in the derivation of the final ecological PRG. Consequently, the ecological PRG for each COC was determined as the lower of the two sets of values calculated for birds and mammals (based on residue- and dose-modeling approaches). For each COC, the

lowest, most conservative (i.e., receptor/endpoint combination requiring the most stringent degree of remediation) PRG is highlighted. These values are compared to PRGs calculated for human receptors to identify the overall PRG for each COC (Table F-2A of Appendix F to the Feasibility Study Addendum [Battelle, In Progress]).

4.0 DISCUSSION OF UNCERTAINTIES

Uncertainties associated with the calculated ecological PRGs are generally similar to those identified for the risk estimate in the Supplemental BERA. These uncertainties are summarized below.

- There are uncertainties associated with the CBR values used to develop floodplain soil PRGs for earthworms, woodcock eggs, and mammalian liver cells; they are neither site-specific nor specific to the particular receptors being evaluated. See below for a specific discussion regarding the mammalian CBR for 2,3,7,8-TCDD.
- The PRGs developed in this report may not be protective of exposures to early life stages of sensitive amphibians and invertebrates. Surface water exposures were not evaluated in the Supplemental BERA because there are no surface water analytical data available to evaluate exposure to this environmental media. With the exception of the former river channel and the scrub-shrub habitat, the majority of the Oxbow Area does not typically contain standing water except seasonally when isolated ponded areas are formed following flooding events. Based on a wetland delineation and functional assessment conducted by the United States Army Corps of Engineers (USACE, 2008), it is possible that vernal pools are present within the Oxbow and that seasonal exposures to sensitive aquatic organisms could occur.
- There are uncertainties associated with the actual plant tissue concentrations in the Oxbow Area because floodplain soil PRGs protective of the short-tailed shrew were calculated using literature-based plant BAFs rather than site-specific plant tissue data. In addition, a plant BAF was not available for 2,3,7,8-TCDD. Therefore, the PRG developed for this contaminant accounts only for the dietary exposure associated with the consumption of contaminated earthworms and soil incidental to foraging activities. As a result, the derived PRG for this receptor may be under-protective, although the plant consumption pathway is not anticipated to represent a substantial portion of the overall exposure to this receptor, because plants constitute only a small percentage of the shrew's diet (USEPA, 1993; Hamilton, 1941, Whitaker and Ferraro, 1963).
- There are uncertainties associated with the 2,3,7,8-TCDD TRV for the short-tailed shrew. The selected TRV is based on a chronic study in which 2,3,7,8-TCDD was administered to rats in their diet (Table D-4 in the BERA [MACTEC, 2004]) and female fertility and neonatal survival measured. This study was selected as most appropriate because it evaluated relevant measurement endpoints, exposures were of chronic duration, and involved the administration of the contaminant in the diet. However, the rat may be more or less sensitive to 2,3,7,8-TCDD dietary exposures than the shrew and other small wild mammals.
- Compared to the avian CBRs, there are relatively large uncertainties associated with the mammalian tissue CBRs used in the assessment. Residue-based CBRs for the short-tailed shrew are based on a study by Leonards *et al.* (1997) that evaluated adverse effects associated with a range of organochlorine compounds in mink liver tissue. Potential concerns with this study are related to the need for inter-specific extrapolation, the effects (histological) observed, and the lack of similar toxicological data. A review of Table 13 indicates that the mammalian CBR endpoint was selected as the lowest ecological PRG only in the case of 2,3,7,8-TCDD. The PRG based on the mammalian dose assessment is approximately 3.5 times higher than that based on the mammalian residue-based analysis. Due to these uncertainties and given that the other wildlife

receptor appears to be less sensitive than the shrew, deriving the overall ecological PRG using the dose-model rather than the CBR value for 2,3,7,8-TCDD would be a reasonable alternative.

- Uncertainties are associated with the BSAFs and BMFs used in the PRG calculations due to variability in detected concentrations of COCs in floodplain soil or earthworm tissue collected from different locations throughout the study area. The BSAFs were reasonably consistent among the exposure areas, suggesting that the data utilized in BSAF and PRG development were appropriate. No literature-based earthworm BSAF was identified to evaluate the reasonableness of the site-specific values used in this assessment.
- It is believed that the uncertainties associated with the floodplain PRGs developed for soil invertebrates are relatively large compared to those based on wildlife endpoints. Moreover, the TRVs used to establish PRGs protective of direct contact exposures are based on conservative soil screening levels that are not appropriate for establishing cleanup levels. As a result, it is recommended that PRGs based on these endpoints not be used to establish cleanup goals for the Oxbow Area.

5.0 COMPARISON OF PRGS TO BACKGROUND CONDITIONS

Table 13 compares floodplain soil PRGs calculated for the short-tailed shrew and American woodcock to chemical concentrations detected in the upstream background area (Greystone Mill Pond). Ecological PRGs were identified as the lowest avian or mammalian PRG calculated for each COC. Background concentrations are highlighted wherever the value exceeds the identified ecological PRG (for a given THQ).

PRGs that are lower than background concentrations may represent unrealistic remediation goals. Using a THQ of either 0.1 or 1.0, MATC-based floodplain soil PRGs for 4,4'-DDE, antimony, and copper are below the respective average background conditions. With the exception of copper, all ecological PRGs based on a THQ of 10 are above average background conditions.

It is important to note that the average background floodplain soil concentration of 0.000017 µg/g 2,3,7,8-TCDD is different from the dioxin TEQ of 0.00005 µg/g. Although 2,3,7,8-TCDD typically comprises over 90 percent of the TEQs in site media, this is not the case for background floodplain soils at the Site (MACTEC and Battelle, 2011).

Ecological PRGs derived in this report and background values for floodplain soil are presented in Table F-2A of Appendix F to the Feasibility Study Addendum (Battelle, In Progress) along with the human health PRGs developed by MACTEC (Part I of this report).

6.0 COMPARISON OF SITE CONCENTRATIONS TO ECOLOGICAL PRGS

This section provides a brief discussion of the distribution of COC soil concentrations relative to the calculated floodplain soil PRGs. Figure 2 presents the locations for the floodplain soil samples evaluated in the Supplemental BERA (MACTEC and Battelle, 2011). The results of a comparison between Site concentrations and ecological PRGs are summarized in Table 14.

With the exception of 4,4'-DDT, the detected concentrations at the majority of floodplain soil sampling locations exceed the lowest ecological PRGs (Table 14). The concentrations of 4,4'-DDT in Oxbow floodplain soils are less than the lowest ecological PRG at all but one location (i.e., RES-SS-12-556). No PRG is exceeded at sampling locations SS_G-06 and SS_G-33, and only one PRG value is exceeded at

SS_G-02 (copper), SS_G-05 (2,3,7,8-TCDD), SS_G-15 (2,3,7,8-TCDD), and SS_G-26 (2,3,7,8-TCDD). No discernable pattern in exceedances was identified across the various locations.

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TABLES

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Table 1
Summary of Preliminary Remediation Goals Developed for Ecological Receptors

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

Receptor	Risk Basis	Chemicals of Concern[a]
Soil Invertebrates[b]	Soil Screening Benchmarks	4,4'-DDT, 4,4'-DDE, **dieldrin**, **lindane**, **aluminum**, copper
	Estimated tissue residue	**Nickel**
Vermivorous Wildlife – American Woodcock	Food chain exposure dose modeling (earthworm consumption)	Dioxins and furans, 4,4'-DDT, 4,4-DDE
	Estimated egg tissue residue	Dioxins and furans, 4,4-DDE
Vermivorous Wildlife – Short-tailed Shrew	Food chain exposure dose modeling (earthworm consumption)	Dioxins and furans, antimony, copper
	Estimated liver tissue residue	Dioxins and furans

Footnotes:

a. Preliminary remediation goals (PRGs) were developed for those Chemicals of Concern (COCs) with incremental risk based on maximum concentration-based HQs greater than one, which in combination contribute at least 95% of the total risk.

b. PRGs were identified for soil invertebrates for comparison purposes only. The Supplemental BERA relied solely on available screening benchmarks to evaluate potential ecological risks to this receptor category and it is unlikely that these benchmarks constitute an appropriate basis for establishing PRGs. **Bolded** constituents are those that were identified as a COC for this receptor group only.

Table 2
Derivation of Preliminary Remediation Goals for Earthworm Tissue Based on Critical Body Residue Values

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Soil Invertebrates
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{earthworm} = THQ * CBR$$

$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)
THQ = Target Hazard Quotient (unitless)
CBR = Critical Body Residue (ug/g; wet weight basis)

Critical Body Residues (CBRs)[a]

Chemical of Concern	Units	NOAEL	LOAEL	MATC
Nickel	ug/g	0.59	0.59	0.59

Calculated Earthworm Tissue PRGs

Chemical of Concern	Basis	NOAEL			LOAEL			MATC		
	THQ	0.1	1	10	0.1	1	10	0.1	1	10
Nickel		0.059	0.59	5.9	0.059	0.59	5.9	0.059	0.59	5.9

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC - (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.
PRG - Preliminary Remediation Goal

a. Values obtained from Table 5 in the Supplemental BERA for Oxbow Area (MACTEC and Battelle, 2011) and BERA (MACTEC, 2004; Table G-1)

Table 3
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Earthworm Critical Body Residue Values

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Soil Invertebrates
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{soil} = \frac{PRG_{earthworm}}{BAF}$$ for inorganics

PRG_{soil} = Floodplain Soil PRG (ug/g; dry-weight basis)
$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)
BAF = Bioaccumulation Factor (g soil/g tissue)

$$PRG_{soil} = \frac{PRG_{earthworm} * [TOC]_{soil}}{BSAF * [Lipid]_{earthworm}}$$ for organics

PRG_{soil} = Floodplain Soil PRG (ug/g; dry-weight basis)
$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)
TOC_{soil} = Average Total Organic Carbon concentration in Oxbow soil (ug/g; dry-weight basis)[c]
BSAF = Biota Soil Accumulation Factor (g soil [dw]/g tissue [ww])
$Lipid_{earthworm}$ = Average lipid concentration in Lyman Mill earthworm tissue (ug/g; wet-weight basis)[d]

Calculated Earthworm Tissue PRGs[a]

Chemical of Concern	Basis	NOAEL			LOAEL			MATC		
	THQ	0.1	1	10	0.1	1	10	0.1	1	10
Nickel		0.059	0.59	5.9	0.059	0.59	5.9	0.059	0.59	5.9

Calculated Floodplain Soil PRGs

Chemical of Concern	BAF[b]	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
Nickel	1.7		0.030	0.30	3.0	0.030	0.30	3.0	0.030	0.30	3.0

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.
PRG - Preliminary Remediation Goal

a. Values as presented in Table 2.
b. Mean Biota Soil Accumulation Factors (BSAFs presented in Table J-8 of the BERA (MACTEC, 2004) and Table 3 of the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 201
c. Average TOC in 28 floodplain surface soil samples collected in the Oxbow Area; as indicated in Table 2a, concentrations range from 0.9 to 36%.
Selected value: **8.1%**
c. Average earthworm lipid content measured in the three earthworm samples collected from the Lyman Mill Pond exposure area during the June 2001 field sampling program.
Selected value: **2.7%**

Table 4
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Invertebrate Soil Screening Values

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Soil Invertebrates
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	Screening Benchmark

$$PRG_{soil} = THQ * TRV$$

PRG_{soil} = Floodplain Soil PRG (ug/g; dry-weight basis)
THQ = Target Hazard Quotient (unitless)
TRV = Soil Toxicity Reference Value(ug/g; dry-weight basis)
PRG - Preliminary Remediation Goal

			Target Hazard Quotient		
Chemical of Concern	**TRV[a]**	**Units**	**0.1**	**1.0**	**10**
4,4'-DDT	0.0025	ug/g	0.00025	0.0025	0.025
4,4'-DDE	0.0025	ug/g	0.00025	0.0025	0.025
Dieldrin	0.00050	ug/g	0.000050	0.00050	0.0050
Lindane	0.00005	ug/g	0.0000050	0.000050	0.00050
Aluminum	600	ug/g	60	600	6000
Copper	80	ug/g	8.0	80	800

a. Soil TRVs based on lowest available invertebrate screening benchmark values as summarized in the BERA (MACTEC, 2004; Table D-3) and in the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011).

Table 5
Derivation of Preliminary Remediation Goals for Woodcock Tissue Based on Critical Body Residues for Woodcock Eggs

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	American Woodcock
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{egg} = THQ * CBR$$

PRG_{egg} = Woodcock egg PRG (ug/g; wet-weight basis)
THQ = Target Hazard Quotient (unitless)
CBR = Critical Body Residue (ug/g; wet weight basis)

Critical Body Residues (CBRs)[a]

Chemical of Concern	Units	NOAEL	LOAEL	MATC
2,3,7,8-TCDD	ug/g	0.000070	0.0012	0.00029
4,4'-DDE	ug/g	0.01	0.10	0.032

Calculated Woodcock Egg PRGs

Chemical of Concern	Basis	NOAEL			LOAEL			MATC		
	THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD		0.0000070	0.000070	0.00070	0.00012	0.0012	0.012	0.000029	0.00029	0.0029
4,4'-DDE		0.001	0.01	0.1	0.010	0.10	1.0	0.003	0.03	0.3

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.
PRG - Preliminary Remediation Goal

a. Values obtained from Table 10 in the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011); NOAEL (reported as "-" in the cited report) value for 4,4'-DDE derived using a 0.1 LOAEL to NOAEL extrapolation factor.

Table 6
Derivation of Preliminary Remediation Goals for Earthworm Tissue Based on Critical Body Residues for Woodcock Eggs

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	American Woodcock
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{earthworm} = \frac{PRG_{egg} * [Lipid]_{earthworm}}{BMF * [Lipid]_{egg}}$$

$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)
PRG_{egg} = Woodcock egg PRG (ug/g; wet-weight basis)[a]
$Lipid_{egg}$ = Percent lipid content of woodcock egg (g/g; wet-weight basis)[b]
$Lipid_{earthworm}$ = Percent lipid content of earthworm tissue (g/g; wet-weight basis)[c]
BMF = Biomagnification Factor (g earthworm lipid/g egg lipid)
PRG - Preliminary Remediation Goal

Calculated Earthworm Tissue PRGs

Chemical of Concern	BMF[d]	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD	6.99		0.00000035	0.0000035	0.000035	0.0000059	0.000059	0.00059	0.0000014	0.000014	0.00014
4,4'-DDE	13.3		0.000026	0.00026	0.0026	0.00026	0.0026	0.026	0.000082	0.00082	0.0082

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.

a. Values as calculated in Table 5.
b. Estimated as average lipid percentage in gull eggs as reported by Braune and Norstrom (1989)
Selected value[a]: **7.7%**
c. Estimated as average earthworm lipid percentage in 3 Lyman Mill samples collected to support the BERA (MACTEC, 2004).
Selected value[a]: **2.7%**
d. Values obtained from Table 10 in the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011)

Table 7
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Critical Body Residues for Woodcock Eggs

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	American Woodcock
EXPOSURE MEDIUM:	Floodplain soil
RISK BASIS:	CBR Threshold

$$PRG_{soil} = \frac{PRG_{earthworm} * [TOC]_{soil}}{BSAF * [Lipid]_{earthworm}}$$

PRG_{soil} = Floodplain Soil PRG (ug/g; dry-weight basis)
$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)[a]
BSAF = Biota-Soil Accumulation Factor (g organic carbon in soil/g lipid in earthworm)[b]
TOC_{soil} = Average TOC concentration in Oxbow soil reported as dry weight ug organic carbon/g soil)[c]
$Lipid_{earthworm}$ = Average lipid concentration in Lyman Mill earthworm tissues (ug lipid/g earthworm tissue)[d]

Calculated Earthworm Tissue PRGs[a]

Chemical of Concern	BMF	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD	6.99		0.00000035	0.0000035	0.000035	0.0000059	0.000059	0.00059	0.0000014	0.000014	0.00014
4,4'-DDE	13.3		0.00003	0.0003	0.003	0.00026	0.0026	0.026	0.00008	0.0008	0.008

Calculated Floodplain Soil PRGs

Chemical of Concern	BSAF[b]	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD	0.252		0.0000042	0.000042	0.00042	0.000072	0.00072	0.0072	0.000017	0.00017	0.0017
4,4'-DDE	0.545		0.0001	0.001	0.01	0.0014	0.014	0.14	0.0005	0.005	0.05

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.

a. Values as calculated in Table 6.
b. Values obtained from Table 3 in the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011)
c. Average TOC in 28 floodplain surface soil samples collected in the Oxbow Area; as indicated in Table 2a, concentrations range from 0.9 to 36%.
Selected value: **8.1%**
d. Estimated as average earthworm lipid percentage in 3 Lyman Mill samples collected to support the BERA (MACTEC, 2004).
Selected value: **2.7%**

Table 8
Derivation of Preliminary Remediation Goals for Short-tailed Shrew Tissue Based on Critical Body Residues

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Short-tailed Shrew
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{liver} = THQ * CBR$$

PRG_{liver} = Mammal liver PRG (ug/g; wet-weight basis)
THQ = Target Hazard Quotient (unitless)
CBR = Critical Body Residue (ug/g; wet weight basis)

Critical Body Residues (CBRs)[a]

Chemical of Concern	Units	NOAEL	LOAEL	MATC
2,3,7,8-TCDD	ug/g	0.00015	0.00023	0.00019

Calculated Mammal Liver PRGs

Chemical of Concern	Basis	NOAEL			LOAEL			MATC		
	THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD		0.000015	0.00015	0.0015	0.000023	0.00023	0.0023	0.000019	0.00019	0.0019

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.
PRG - Preliminary Remediation Goal

a. Values obtained from Table 11 in the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011) and Table G-1 of the BERA (MACTEC, 2004)

Table 9
Derivation of Preliminary Remediation Goals for Earthworm Tissue Based on Critical Body Residues for Shrew Liver Tissue

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Short-tailed Shrew
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{earthworm} = \frac{PRG_{liver} * [Lipid]_{earthworm}}{BMF * [Lipid]_{liver}}$$

$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)
PRG_{liver} = Mammal liver PRG (ug/g; wet-weight basis)[a]
$Lipid_{earthworm}$ = Percent lipid content of earthworm tissue (g/g; wet-weight basis)[b]
$Lipid_{liver}$ = Percent lipid content of mammal liver (g/g; wet-weight basis)[c]
BMF = Biomagnification Factor (g earthworm lipid/g liver lipid)[a]
PRG - Preliminary Remediation Goal

Calculated Earthworm Tissue PRGs

Chemical of Concern	BMF[d]	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD	11		0.00000082	0.0000082	0.000082	0.0000013	0.000013	0.00013	0.0000010	0.000010	0.00010

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.

a. Values as calculated in Table 8.
b. Estimated as average earthworm lipid percentage in 3 Lyman Mill samples collected to support the BERA (MACTEC, 2004).
Selected value: **2.7%**
c. Estimated as the average lipid percentage in five otter liver samples (Leonards *et al.* , 1997)
Selected value: **4.4%**
d. Values obtained from Table 11 in the Addendum to the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011)

Table 10
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Critical Body Residues for Shrew Liver Tissue

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Short-tailed Shrew
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	CBR Threshold

$$PRG_{soil} = \frac{PRG_{earthworm} * [TOC]_{soil}}{BSAF * [Lipid]_{earthworm}}$$

PRG_{soil} = Floodplain Soil PRG (ug/g; dry-weight basis)
$PRG_{earthworm}$ = Earthworm Tissue PRG (ug/g; wet-weight basis)[a]
TOC_{soil} = Average TOC concentration in Oxbow soil reported as dry weight ug organic carbon/g soil)[b]
$Lipid_{earthworm}$ = Average lipid concentration in Lyman Mill earthworm tissues (ug lipid/g earthworm tissue)[c]
BSAF = Biota-Soil Accumulation Factor (g organic carbon in soil/g lipid in earthworm)

Calculated Earthworm Tissue PRGs[a]

Chemical of Concern	BMF	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD	11		0.00000082	0.0000082	0.000082	0.0000013	0.000013	0.00013	0.0000010	0.000010	0.00010

Calculated Floodplain Soil PRGs

Chemical of Concern	BSAF[d]	Basis	NOAEL			LOAEL			MATC		
		THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD	0.252		0.000010	0.00010	0.0010	0.000015	0.00015	0.0015	0.000012	0.00012	0.0012

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.

a. Values as calculated in Table 9.
c. Average TOC in 28 floodplain surface soil samples collected in the Oxbow Area; as indicated in Table 2a, concentrations range from 0.9 to 36%.
Selected value: **8.1%**
c. Estimated as average earthworm lipid percentage in 3 Lyman Mill samples collected to support the BERA (MACTEC, 2004).
Selected value: **2.7%**
d. Values obtained from Table 3 in the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011)

Table 11
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Woodcock Dietary Exposures

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	American Woodcock
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	Food Chain Dose Modeling

$$PRG_{soil} = \frac{THQ * TRV * BW}{\left(BAF_{plant} * IR_{food} * P_{plant} * SFF\right) + \left(\frac{BSAF_{ew} * [Lipid]_{ew}}{[TOC]_{soil}} * IR_{food} * P_{ew} * SFF\right) + \left(IR_{soil} * SFF\right)}$$

Parameter Symbol	Parameter Definition	Units	Value[c]	Note
PRG_{soil}	Floodplain soil PRG protective of the woodcock	ug/g	Calculated	
THQ	Target Hazard Quotient	unitless	0.1, 1.0, 10	
TRV	Literature-based Toxicity Reference Value	ug/g-day	COC-specific	a
BAF_{plant}	Literature-based plant Biota Accumulation Factor	g (dw soil)/g (ww tissue)	COC-specific	b
$BSAF_{ew}$	Earthworm Biota-Soil Accumulation Factor	g (soil TOC)/g (tissue lipid)	COC-specific	c
IR_{food}	Ingestion Rate of Food	kg-day	0.082	d
IR_{soil}	Ingestion Rate of Soil	kg-day	0.012	assumption
P_{plant}	Percent plants in diet	unitless	0%	e
P_{ew}	Percent earthworms in diet	unitless	100%	e
SFF	Site Foraging Frequency	unitless	100%	f
BW	Body Weight	kg	0.2	g
$[Lipid]_{ew}$	Lipid concentration in earthworm tissue	g (lipid)/g (tissue)	2.7%	h
$[TOC]_{soil}$	Total organic carbon concentration in soil	g (TOC)/g (soil)	8.1%	i

Chemical Specific Parameters

Chemical of Concern	Toxicity Reference Values[a]			Plant BAF[b]		Earthworm BSAF[j]	
	Units	NOAEL	LOAEL	MATC	Units	Value	Units	Value
2,3,7,8-TCDD	ug/g-d	0.000014	0.00014	0.000044	g_{soil}/g_{tissue}	0	g_{soil}/g_{tissue}	0.252
4,4'-DDT	ug/g-d	0.0028	0.028	0.0089	g_{soil}/g_{tissue}	0.0014	g_{soil}/g_{tissue}	0.21
4,4'-DDE	ug/g-d	0.0028	0.028	0.0089	g_{soil}/g_{tissue}	0.00096	g_{soil}/g_{tissue}	0.55

Table 11
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Woodcock Dietary Exposures

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.

Chemical of Concern	Basis	Calculated Floodplain Soil PRGs								
		NOAEL			LOAEL			MATC		
	THQ	0.1	1	10	0.1	1	10	0.1	1	10
2,3,7,8-TCDD		0.000015	0.00015	0.0015	0.00015	0.0015	0.015	0.000047	0.00047	0.0047
4,4'-DDT		0.0032	0.032	0.32	0.032	0.32	3.2	0.010	0.10	1.0
4,4'-DDE		0.0021	0.021	0.21	0.021	0.21	2.1	0.0066	0.066	0.66

Notes:

a. Values from Table D-4 (Appendix D of the BERA (MACTEC, 2004).
b. Values from Table J-1 (Appendix J) of the BERA (MACTEC, 2004) & Addendum to Interim Final BERA: Oxbow Area, Table C.2-1 (MACTEC and Battelle, 2006)
c. Values from Table 19 of the BERA (MACTEC, 2004) & Tables C.1-1,C.1-3, 8 & 10 from the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011)
d. USEPA, 1993.
e. Whitaker and Feraro, 1963.
f. Buckner, 1966.
g. Guilday, 1957.
h. Estimated as average earthworm lipid percentage in 3 Lyman Mill samples collected to support the BERA (MACTEC, 2004).
i. Average TOC in 28 floodplain surface soil samples collected in the Oxbow Area; concentrations range from 0.9 to 36%.
Values from Table 3 (Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011))
j.

Table 12
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Shrew Dietary Exposures

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

RECEPTOR:	Short-tailed Shrew
EXPOSURE MEDIUM:	Floodplain Soil
RISK BASIS:	Food Chain Dose Modeling

$$PRG_{soil} = \frac{THQ * TRV * BW}{\left(BAF_{plant} * IR_{food} * P_{plant} * SFF\right) + \left(\frac{BSAF_{ew} * [Lipid]_{ew}}{[TOC]_{soil}} * IR_{food} * P_{ew} * SFF\right) + \left(IR_{soil} * SFF\right)}$$

Parameter Symbol	Parameter Definition	Units	Value[c]	Note
PRG_{soil}	Floodplain soil PRG protective of the shrew	ug/g	Calculated	
THQ	Target Hazard Quotient	unitless	0.1, 1.0, 10	
TRV	Literature-based Toxicity Reference Value	ug/g-day	COC-specific	a
BAF_{plant}	Literature-based plant Biota Accumulation Factor	g (dw soil)/g (ww tissue)	COC-specific	b
$BSAF_{ew}$	Earthworm Biota-Soil Accumulation Factor	g (soil TOC)/g (tissue lipid)	COC-specific	c
IR_{food}	Ingestion Rate of Food	kg-day	0.013	d
IR_{soil}	Ingestion Rate of Soil	kg-day	0.00064	assumption
P_{plant}	Percent plants in diet	unitless	14%	e
P_{ew}	Percent earthworms in diet	unitless	85%	e
SFF	Site Foraging Frequency	unitless	100%	f
BW	Body Weight	kg	0.017	g
$[Lipid]_{ew}$	Lipid concentration in earthworm tissue	g (lipid)/g (tissue)	2.7%	h
$[TOC]_{soil}$	Total organic carbon concentration in soil	g (TOC)/g (soil)	8.1%	i

Chemical Specific Parameters

Chemical of Concern	Toxicity Reference Values[a]				Plant BAF[b]		Earthworm BSAF[J]	
	Units	NOAEL	LOAEL	MATC	Units	Value	Units	Value
2,3,7,8-TCDD	ug/g-d	0.0000010	0.000010	0.0000032	g_{soil}/g_{tissue}	0	g_{soil}/g_{tissue}	0.252
Antimony	ug/g-d	0.026	0.26	0.082	g_{soil}/g_{tissue}	0.002	g_{soil}/g_{tissue}	0.699
Copper	ug/g-d	0.420	4.20	1.33	g_{soil}/g_{tissue}	0.097	g_{soil}/g_{tissue}	0.098

Table 12
Derivation of Preliminary Remediation Goals for Floodplain Soil Based on Shrew Dietary Exposures

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
MATC (Maximum Allowable Toxicant Concentration) is calculated as the geometric mean of the NOAEL and LOAEL values.

		Calculated Floodplain Soil PRGs								
Chemical of Concern	**Basis**	**NOAEL**			**LOAEL**			**MATC**		
	THQ	**0.1**	**1**	**10**	**0.1**	**1**	**10**	**0.1**	**1**	**10**
2,3,7,8-TCDD		0.0000011	0.000011	0.00011	0.000011	0.00011	0.0011	0.0000035	0.000035	0.00035
Antimony		0.014	0.14	1.4	0.14	1.4	14	0.044	0.44	4.4
Copper		0.608	6.08	60.8	6.08	60.8	608	1.92	19.2	192

Notes:

a. Values from Table D-4 (Appendix D of the BERA (MACTEC, 2004).
b. Values from Table J-1 (Appendix J) of the BERA (MACTEC, 2004) & Supplemental BERA: Oxbow Area, Table C.2-1 (MACTEC and Battelle, 2011)
c. Values from Table 19 of the BERA (MACTEC, 2004) & Tables C.2-4, 9 & 10 from the Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011)
d. USEPA, 1993.
e. Whitaker and Feraro, 1963.
f. Buckner, 1966.
g. Guilday, 1957.
h. Estimated as average earthworm lipid percentage in 3 Lyman Mill samples collected to support the BERA (MACTEC, 2004).
i. Average TOC in 28 floodplain surface soil samples collected in the Oxbow Area; as indicated in Table 2a, range from 0.9 to 36%.
Values from Table 3 (Supplemental BERA: Oxbow Area (MACTEC and Battelle, 2011))
j.

Table 13
Summary of Ecologically-Derived Preliminary Remediation Goals

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

Chemical of Concern	Receptor/Endpoint: Soil Invertebrate CBR[a]	Soil Invertebrate SSL[b]	Avian CBR[c]	Avian DOSE[d]	Mammal CBR[e]	Mammal DOSE[f]	Lowest Ecological PRG[g]	Floodplain Soil Background[h]	Selected PRG Basis
THQ = 0.1									
2,3,7,8-TCDD	-	-	0.000017	0.000047	0.000012	**0.0000035**	0.0000035	**0.000017**	Mammalian-Dose Assessment
4,4'-DDT	-	0.00025	-	**0.010**	-	-	0.010	0.0085	Avian-Dose Assessment
4,4'-DDE	-	0.00025	**0.00046**	0.0066	-	-	0.0005	**0.013**	Avian-CBR
Dieldrin	-	0.000050	-	-	-	-		0.0063	*No Ecological PRG*
Lindane	-	0.0000050	-	-	-	-		-	*No Ecological PRG*
Aluminum	-	60	-	-	-	-		16000	*No Ecological PRG*
Antimony	-	-	-	-	-	**0.044**	0.044	**0.62**	Mammalian-Dose Assessment
Copper	-	8.0	-	-	-	**1.9**	1.9	**205**	Mammalian-Dose Assessment
Nickel	0.030	-	-	-	-	-		-	*No Ecological PRG*
THQ = 1.0									
2,3,7,8-TCDD	-	-	0.00017	0.00047	0.00012	**0.000035**	0.000035	0.000017	Mammalian-Dose Assessment
4,4'-DDT	-	0.0025	-	**0.10**	-	-	0.10	0.0085	Avian-Dose Assessment
4,4'-DDE	-	0.0025	**0.0046**	0.066	-	-	0.005	**0.013**	Avian-CBR
Dieldrin	-	0.00050	-	-	-	-		0.0063	*No Ecological PRG*
Lindane	-	0.000050	-	-	-	-		-	*No Ecological PRG*
Aluminum	-	600	-	-	-	-		16000	*No Ecological PRG*
Antimony	-	-	-	-	-	**0.44**	0.44	**0.62**	Mammalian-Dose Assessment
Copper	-	80	-	-	-	**19.2**	19.2	**205**	Mammalian-Dose Assessment
Nickel	0.30	-	-	-	-	-		-	*No Ecological PRG*
THQ = 10									
2,3,7,8-TCDD	-	-	0.0017	0.0047	0.0012	**0.00035**	0.00035	0.000017	Mammalian-Dose Assessment
4,4'-DDT	-	0.025	-	**1.0**	-	-	1.00	0.0085	Avian-Dose Assessment
4,4'-DDE	-	0.025	**0.046**	0.66	-	-	0.046	0.013	Avian-CBR
Dieldrin	-	0.0050	-	-	-	-		0.0063	*No Ecological PRG*
Lindane	-	0.00050	-	-	-	-		-	*No Ecological PRG*
Aluminum	-	6000	-	-	-	-		16000	*No Ecological PRG*
Antimony	-	-	-	-	-	**4.4**	4.4	0.62	Mammalian-Dose Assessment
Copper	-	800	-	-	-	**192**	192	**205**	Mammalian-Dose Assessment
Nickel	3.0	-	-	-	-	-		-	*No Ecological PRG*

Table 13
Summary of Ecologically-Derived Preliminary Remediation Goals

Centredale Manor Restoration Project Superfund Site
North Providence, Rhode Island

Notes:
All units in ug/g (ppm).

a. Ecological PRGs based on residue-based benchmarks for soil invertebrates are presented in Table 3.
b. Ecological PRGs based on soil screening benchmarks for soil invertebrates are presented in Table 4.
c. Ecological PRGs based on residue-based benchmarks for avian embryos are presented in Table 7.
d. Ecological PRGs based on residue-based benchmarks for avian vermivores are presented in Table 11.
e. Ecological PRGs based on residue-based benchmarks for mammal tissue are presented in Table 10.
f. Ecological PRGs based on residue-based benchmarks for mammalian vermivores are presented in Table 12.
g. As discussed in the text, only the wildlife-based endpoints were used to develop the ecological PRGs.
h. Average soil concentrations in Greystone floodplain soil samples (Table 67 in the Baseline Ecological Risk Assessment [MACTEC, 2004]); shaded values are higher than lowest PRG.
i. No background soil datum is available.

Table 14

Summary of Oxbow Concentrations of Contaminants of Concern Compared in Floodplain Surface Soil with Ecologically-Derived Preliminary Remediation Goals

Floodplain Soil Sampling Location	Contaminants of Concern					Footnote
	TCDD	DDE	DDT	Antimony	Copper	
Ecological PRG[a]	**3.5E-05**	**4.6E-03**	**1.0E-01**	**4.4E-01**	**1.9E+01**	
CMS-raceway	1.3E-03	-	-	-	-	b
LPX-FP-4004	1.1E-03	5.1E-03	3.0E-03	5.6E-02	3.3E+01	
LPX-FP-4007	9.9E-06	3.2E-02	4.3E-02	2.1E-01	8.6E+01	
LPX-SD-4405	4.3E-03	-	-	-	-	
LPX-SD-4406	1.8E-03	-	-	-	-	
LPX-SD-4407	2.1E-03	4.2E-02	2.8E-03	2.8E+00	7.3E+01	
RES-10-005	5.2E-05	3.1E-02	6.6E-03	4.1E-01	3.2E+01	c
RES-SS-10-042	5.5E-05	4.1E-03	4.1E-03	3.8E+01	2.4E+03	d
RES-SS-10-044	3.4E-05	3.3E-02	1.2E-02	3.8E+00	8.2E+01	e
RES-SS-10-604	2.6E-05	1.3E-02	7.8E-03	3.8E-01	4.6E+01	f
RES-SS-11-011	4.4E-06	2.7E-03	2.7E-03	6.0E-01	2.9E+01	g
RES-SS-11-012	3.0E-06	2.1E-02	2.7E-02	2.5E+00	2.5E+02	h
RES-SS-12-556	1.5E-05	1.0E+00	1.3E+00	3.1E+00	7.3E+01	i
RES-11-419-02	1.4E-04	-	-	-	-	
RES-12-560-01	-	5.2E-03	4.6E-03	6.0E-01	3.0E+01	
RES-12-560-02	-	5.4E-03	5.3E-03	6.5E-01	4.1E+01	
SS_G-01	6.4E-03	3.7E-03	3.9E-02	4.6E-01	4.7E+01	j
SS_G-02	3.1E-06	1.8E-03	6.0E-04	2.7E-01	3.1E+01	
SS_G-03	2.3E-04	1.7E-03	1.8E-03	2.4E-01	2.1E+01	
SS_G-04	4.9E-04	5.8E-03	3.0E-03	9.7E-01	4.6E+01	
SS_G-05	4.5E-05	1.2E-03	4.7E-04	4.5E-02	6.2E+00	
SS_G-06	8.0E-06	1.0E-03	2.0E-03	5.6E-02	7.1E+00	
SS_G-07	2.1E-03	1.2E-02	1.2E-02	6.4E-01	2.4E+01	
SS_G-08	5.9E-04	6.3E-03	1.0E-02	6.4E-01	2.2E+01	
SS_G-09	2.3E-03	1.4E-02	2.7E-02	1.3E+00	3.8E+01	
SS_G-14	3.9E-04	1.9E-03	6.1E-03	4.9E-01	1.6E+01	
SS_G-15	3.9E-04	1.7E-03	4.0E-03	4.0E-01	1.1E+01	
SS_G-18	1.2E-03	6.5E-03	1.8E-02	9.6E-01	3.3E+01	
SS_G-23	1.0E-03	5.3E-03	1.7E-02	5.6E-01	4.1E+01	
SS_G-26	5.9E-04	2.6E-03	5.4E-03	2.4E-01	1.5E+01	
SS_G-29	6.2E-03	6.2E-03	2.8E-02	7.1E-01	4.6E+01	k
SS_G-30	1.2E-06	3.6E-02	5.2E-02	3.2E+00	9.2E+01	
SS_G-31	2.4E-06	8.5E-03	5.3E-02	1.4E+00	1.2E+02	
SS_G-32	1.3E-04	8.8E-03	1.4E-02	2.5E-01	3.5E+01	
SS_G-33	5.8E-08	1.1E-03	1.2E-03	1.3E-01	1.6E+01	
WRL-SD-2038	6.1E-04	2.1E-03	6.1E-03	2.7E-01	2.9E+01	

Table 14

Summary of Oxbow Concentrations of Contaminants of Concern Compared in Floodplain Surface Soil with Ecologically-Derived Preliminary Remediation Goals

Notes:

Dashes indicate that analyte was analyzed; units in ug/g (ppm).

a. Shaded cells indicate locations where concentration exceeds preliminary remediation goal (PRG), based on a Target Hazard Quotient (THQ) of one (1). PRGs presented in Table 13.

b. Average of CMS-217, -218, -219, -458, and -459 (TCDD only)

c. Average of RES-SS-10-005-01, -02, and -03 (TCDD only)

d. Average of RES-SS-10-042-01, -02, and -03 (TCDD only)

e. Average of RES-SS-10-044-01, -02, and -03 (TCDD only)

f. Average of RES-SS-10-604-01, -02, and -03 (TCDD only)

g. Average of RES-SS-11-011-01, -02, and -03 (TCDD only)

h. Average of RES-SS-11-012-01, -02, and -03 (TCDD only)

i. Average of RES-SS-12-556-01 and -02 (TCDD only)

j. Average of SS_G-01, SS_G-01-01, -02, and -03

k. Average of SS_G-29, SS_G-29-01, and -02

FIGURES

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Figure 1. Site Locus Map

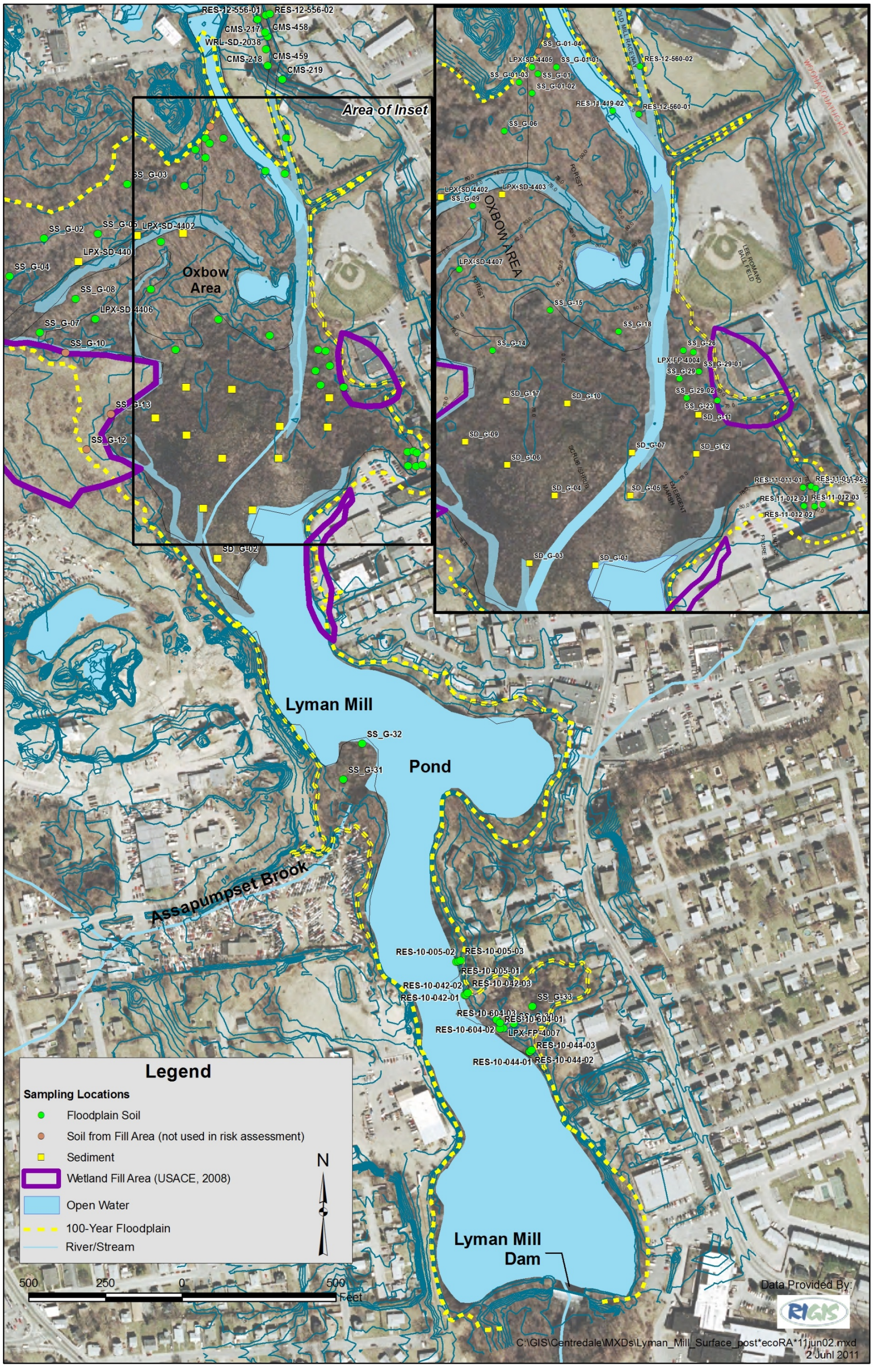

Figure 2. Sample Locations in the Oxbow Area and Associated with Lyman Mill Pond Floodplain Soils