SITE-SPECIFIC
PRELIMINARY REMEDIATION GOALS
(CLEANUP GOALS)
FOR
TITTABAWASSEE RIVER FLOODPLAIN SOIL

TITTABAWASSEE RIVER, SAGINAW RIVER & BAY SUPERFUND SITE IN MICHIGAN

AUGUST 2014

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ACRONYMS

4-PeCDF	2,3,4,7,8-pentachlorodibenzofuran
ABS_d	Dermal Absorption Coefficient
ARARs	Applicable or Relevant and Appropriate laws and regulations
CSF	cancer slope factor
Dioxin	can refer to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), dioxins and furans, or include other dioxin-like chemicals (DLCs)
D/Fs	dioxins and furans
DLC	dioxin-like chemicals
Dow	The Dow Chemical Company
EFH	EPA's *Exposure Factors Handbook*
EPA	United States Environmental Protection Agency
EROD	7-ethoxyresorufin-O-deethylase
Floodplain	8-year floodplain of the Tittabawassee River
HQ	Hazard Quotient
IRIS	Integrated Risk Information System
kg	kilogram
LADD	Lifetime Average Daily Dose
LOAEL	lowest-observed-adverse-effect level
MDEQ	Michigan Department of Environmental Quality
NREPA	Natural Resources and Environmental Protection Act (Michigan)
NHANES	National Health and Nutrition Examination Survey
NTCRA	non-time critical removal action
OHEA	Office of Health and Environmental Assessment (EPA)
PBPK	physiologically-based pharmacokinetic
PCBs	polychlorinated biphenyls
pg	picogram
ppt	parts per trillion
PRGs	Preliminary Remediation Goals
RBA	Relative Bioavailability
RfD	Reference Dose
RME	reasonable maximum exposure
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	2,3,7,8-tetrachlorodibenzofuran
TEQ	toxic equivalence
TSH	Thyroid Stimulating Hormone
UCL	upper confidence limit
UMDES	University of Michigan Dioxin Exposure Study
WHO	World Health Organization

1.0 INTRODUCTION

The objective of this document is to present the technical basis for the site-specific Preliminary Remediation Goals (PRGs) for human direct contact exposure (i.e., ingestion and dermal contact) to Dioxin contamination in soil in the 8-year floodplain of the Tittabawassee River (Floodplain) at the Tittabawassee River, Saginaw River & Bay site in Michigan. These site-specific PRGs were developed by the United States Environmental Protection Agency (EPA), in consultation with the Michigan Department of Environmental Quality (MDEQ).

PRGs are concentration goals for chemicals for specific medium (e.g., soil) and land use combinations at Superfund sites. There are two general sources of chemical-specific PRGs: (1) concentrations based on Applicable or Relevant and Appropriate laws and regulations (ARARs) and (2) concentrations based on risk calculations. The PRGs developed in this document are reference soil concentrations derived from site-specific risk-based calculations to provide protective human health risk levels for potential direct contact exposure to soils within the Floodplain. Regulations for corrective action in Part 111 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), MCL 324.20101 *et seq* and the associated environmental protection standards under Part 201 of NREPA are considered ARARs for the Floodplain. Those regulations allow for the use of either generic soil cleanup numbers or the development of protective site-specific values. MDEQ has made a preliminary determination that the PRGs proposed herein are site-specific values that meet their Part 111 and 201 ARARs for direct human contact to soil. PRGs are not necessarily final soil concentrations which can be achieved for every location along the Floodplain. However, they are expected to serve as reference soil concentrations to identify locations where response actions would be undertaken including: soil removal/ disposal; soil covers/ barriers; and land use management/ institutional controls.

The Floodplain is part of the larger Tittabawassee River, Saginaw River & Bay site. At this time, EPA, working with MDEQ, is addressing the Floodplain as a non-time critical removal action (NTCRA). The Dow Chemical Company (Dow) is conducting site investigations and developing documents, under a 2010 Settlement Agreement, with the Agencies' oversight. The expected response options were briefly described in the *Tittabawassee River Floodplain Soil Alternatives Array* (Dow 2013) and are described in more detail in the *Tittabawassee River Floodplain Response Proposal* (Dow 2014). The Floodplain NTCRA is part of a larger site-wide management plan. The management approach for the site includes developing a set of prioritized actions intended to quickly reduce exposure to, and/or transport of, impacted media. A residual risk assessment will be completed to assess the effectiveness of the response actions and to determine whether there is a need for further actions in the Floodplain. At this time, EPA anticipates that the residual risk assessment for the Floodplain will be conducted after some upstream cleanup is done, but that it will occur before all Floodplain cleanup is complete. In accordance with Superfund law and regulations, public comment will be taken on the Floodplain Response Proposal (which is an engineering evaluation/cost analysis) and the PRGs before the Action Memorandum is signed by EPA, in consultation with MDEQ.

The term "Dioxin" can refer to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), dioxins and furans, or include other dioxin-like chemicals (DLCs). Four terms are used in this document:

- Dioxin is used as a general or umbrella term;
- D/F(s) refers to dioxins and furans only;
- DLC refers to dioxin-like chemicals which include D/Fs and other dioxin-like chemicals such as coplanar polychlorinated biphenyls (PCBs);
- TCDD refers specifically to 2,3,7,8-tetrachlorodibenzo-p-dioxin.

D/Fs and DLCs are found as mixtures in environmental samples. Many of these chemicals act through a common mechanism(s) with both demonstrated and assumed additive toxicity. As a result, a total toxic equivalence (TEQ) approach is used in accordance with EPA guidance and Michigan regulations (EPA 2010a). EPA and MDEQ will compare the D/F TEQ (i.e., measured Floodplain soil concentration) to the proposed PRGs. Current understanding of the D/F TEQ is based on sampling primarily conducted between 2006 and 2008 that measured D/F, and additional sampling will be conducted, as needed. Approximately 10,000 D/F samples were assessed from about 2,000 locations in the Floodplain. A subset of the samples was analyzed for dioxin-like coplanar PCBs and they were not detected in Floodplain soil. Consequently, PCBs could be disregarded as contaminants for developing PRGs based on Dioxin TEQ.

Because of the variety of land use activities and potential human receptor groups along the Floodplain, multiple potential PRGs values were evaluated as reference levels along the Floodplain. PRGs are derived from the application and combination of the following factors:

A) Identification of the land uses along the Floodplain (e.g., maintained residential property; unmaintained property; agricultural land).

B) Identification of human exposure groups and applicable exposure scenarios (e.g., child soil exposure at a residential property; adult soil exposure at occupational locations).

C) Definition and selection of the exposure factors which are needed to estimate the level of soil contact and contaminant intake for the specific exposure scenarios (e.g., exposure frequency, exposure duration, ingestion and dermal intake rates; bioavailability of contaminant from soil). Numerical values for exposure factors can be selected based on site-specific information and studies as well as non-specific "default" exposure assumptions obtained from EPA and/or MDEQ guidance documents or published literature reference data.

D) Information on the toxicity of dioxin. EPA and MDEQ have performed an extensive review of the health effects of dioxin in humans and in experimental animal models which support the understanding of human toxicity. The toxicity review resulted in the development of numerical toxicity factors which can be used to estimate health risks from the cancer and non-cancer effects of dioxin exposure. Dioxin can cause both human cancer and non-cancer effects. Consequently, both a cancer slope factor (CSF) and a non-cancer Reference Dose (RfD) are needed to characterize the health effects of dioxin and to derive PRGs for cancer and non-cancer effects.

The selected exposure factors and toxicity factors described above are combined into standardized algorithms (equations) which calculate soil PRG values which the Agencies consider to be protective target goals for human health from soil direct contact. In addition, based on risk guidance and practice by EPA and MDEQ, two PRG values should be evaluated for a given exposure scenario:

A) PRGs for the non-cancer endpoint are derived based on achieving a target Hazard Quotient (HQ) of 1 (one). If a measured soil concentration at given location is below the non-cancer PRG, that location is considered unlikely to pose a significant human health risk for the applicable exposure scenario.

B) PRGs will also be assessed for the cancer risk endpoint. Under EPA risk assessment practice, cancer risk PRGs are derived for a 1E-6 (1 in 1 million) to 1E-4 (1 in 10,000) excess individual lifetime cancer risk range (as cited in the EPA *National Contingency Plan;* EPA 1991a). EPA's preference is to establish initial PRGs based on a cancer risk of 1E-6. However, final PRG levels may differ as long as they reflect a cancer risk within the target risk range and a non-cancer PRG reflecting a HQ of 1 (EPA, 1997).

2.0 LAND USE AND EXPOSURE SCENARIOS

2.1 Land Uses in the Floodplain

There are about 4,500 acres in the Floodplain spread along both sides of 21 miles of the lower Tittabawassee River. The Floodplain includes land adjacent to the river that experiences flooding when the river water levels rise above the banks of the river. River water levels typically rise during heavy rainfall events or spring snow melt periods. Based on site investigation results (i.e., the spatial change in D/F TEQ levels) , the portion of the Tittabawassee River floodplain that is generally flooded at least once every 8 years (the "8-year floodplain") will be the focus of response alternatives developed for the Floodplain (ATS 2009). The 8-year floodplain boundary was delineated by Dow using topography and aerial photographs taken during the March 2004 flood event. The 8-year floodplain boundary is not a "bright line" and the actual boundary will be refined as needed during design, based on the actual D/F TEQ levels at a property. Additionally, riverbank areas are included as part of the Floodplain for the purposes of this evaluation.

Land along the Floodplain of the Tittabawassee River is associated with multiple current and expected future land uses. The diversity and distribution of current land use in the Floodplain is illustrated on Figure 1. Additionally, EPA evaluated how the public would like to see the Floodplain used in the future, and those results are shown on Figure 2. As indicated by Figure 1, a significant portion (approximately 54%) of the Floodplain is currently associated with undeveloped natural landscape and/or heavily forested land with low human use activity. Approximately 18% of land is in active agricultural use for crop production and 16% of landscape is covered by the Shiawassee National Wildlife Refuge. The remaining land uses (approximately 12%) can be categorized into more frequent human use activity areas including currently maintained residential land (5%), public parks/recreational areas (3%), and commercial/retail property (4%). Federal, State and local regulations include some restrictions on future development in the Floodplain. As shown on Figure 2, in the future the public wants to maintain or increase natural areas, parks and recreational areas, and the Refuge (EPA 2013).

For the purpose of developing PRG values for the soil contact exposure pathway, consideration was given to the various current and potential future land uses in the Floodplain, the expected level of human activity in each land use type, and the expected distribution of sensitive receptor populations across the land uses. Based on that review, the Floodplain land uses were categorized into two general types for the purpose of evaluating PRGs:

A) Maintained Residential Areas – Current residential properties may have portions in the Floodplain that are maintained for frequent residential activity including open spaces for gardening, playing, or recreational activity. This is the land use type for which the sensitive young child receptor (i.e., age 1 to 6 years) is expected to experience the highest frequency and opportunity for direct soil contact exposure (EPA 2002). It should be noted that it is typical for the houses and house perimeters to be out of the Floodplain and to have soil D/F levels much lower than D/F levels within the Floodplain (see Figure 3).

B) Other Land Use Areas – all other Floodplain land use types associated with possible direct soil contact exposure for receptors. Based on the expected types of activities and the expected frequency of human activity, these land use types were subdivided as follows for consideration in developing PRGs:
   1) Residential Unmaintained Land – Current residential properties with portions clearly **not** maintained for frequent residential activity. Residential unmaintained Land is expected to be characterized by woodlots, brush, wetlands and other areas not subject to regular mowing or other maintenance.
   2) Other Unmaintained Land – Current Floodplain areas that are generally low use and unmaintained, typically wooded or brushy. These areas constitute the bulk of the floodplain acreage. These areas will have less frequent human exposure and the most frequent potential receptors for soil contact exposure would be recreating and/or trespassing older children or teenagers.
   3) Agricultural Land – Lands currently or historically used for crop production. The potential exposed receptor is an adult farm worker who has direct contact with soil during activities such as plowing, seeding, and harvesting.
   4) Shiawassee National Wildlife Refuge – Land dedicated to conservation management. The receptor with the highest potential for exposure is an adult worker on the Refuge.
   5) Park Land – Lands available for open public access and recreation that could have other attractive features such as ball fields, play areas and/or trails. Children and adult recreators would have exposure, but the receptors with the most frequent opportunity for direct soil contact are expected to be adult site workers.
   6) Commercial Land – Typically, the Floodplain portion of many commercial properties would be considered Other Unmaintained Land. These areas include a subset of lands available for public access and recreation (e.g., a golf course) where children, teenagers, and adults could be exposed. However, the receptor with the most frequent opportunity for soil contact is expected to be an adult site worker.

2.2 Exposure Scenarios

According to EPA guidance, the quantitative estimation of health risk is made by developing Exposure Scenarios which are defined by a combination of the following:

- Identification of a human receptor for the chemical contaminant;
- Identification of the receptor location and activity which leads to contaminant exposure;
- Definition of the exposure pathway(s) which result in chemical contaminant contact followed by intake or absorption;
- Selection of quantitative exposure factors and parameters which are used to calculate an estimate of the dose of the chemical contaminant over the appropriate time period;
- Application of the chemical contaminant Toxicity Factor which is combined with the calculated dose to derive the risk level.

2.3 Exposure Receptors, Activities, and Pathways

The following situations require evaluation based on the land uses described earlier:

A) Maintained Residential Areas - Direct soil contact exposure leads to contaminant intake and absorption through the pathways of incidental soil ingestion and dermal exposure to outdoor soils and indoor dust. For evaluating the non-cancer risk endpoint, this is the land use type for which the sensitive young child receptor (i.e., age up to 6 years) is expected to experience the highest frequency and opportunity for direct soil contact exposure. For evaluating the cancer risk endpoint, the sensitive receptor is a resident assumed to live at a residential location for a total exposure duration of 30 years, with potential exposure time age-averaged over child and adult time periods up to age 30 (EPA 2002).

B) Residential Unmaintained Land - Direct soil contact exposure leads to contaminant intake and absorption through the pathways of incidental soil ingestion and dermal exposure to outdoor soils and indoor dust. For evaluating the non-cancer risk endpoint, this is the land use type for which an older child (age 7-11 years) and teenager (age 12-20 years) are expected to experience a higher frequency and opportunity for direct soil contact exposure compared to a young child.

C) Park Land and Other Unmaintained Land - Direct soil contact exposure leads to contaminant intake and absorption through the pathways of incidental soil ingestion and dermal exposure to outdoor soils. For evaluating the non-cancer risk endpoint of a recreator, an older child (age 7-11 years) and teenager (age 12-20 years) are expected to experience the highest frequency and opportunity for direct soil contact exposure.

D) Agricultural Land, Refuge Land, Park Workers, and Commercial Land - Direct soil contact exposure leads to contaminant intake and absorption through the pathways of incidental soil ingestion and dermal exposure to outdoor soils. The receptor requiring evaluation is an adult worker (age 21 and older) for whom the non-cancer and cancer risk endpoint applies. For evaluating the cancer risk endpoint, the adult worker is assumed to have Floodplain soil exposure for a duration of 25 years.

2.4 Exposure Factors and Parameters

As explained earlier (Section 2.2), quantitative exposure factors and parameters are needed to calculate an estimate of the dose of the chemical contaminant over the appropriate time period. Two types of exposure factors are employed for risk evaluation: generic or default values and site-specific values. Default values are used for factors that can be estimated from population statistics (e.g., body weight; dermal surface area) or human activity studies (e.g., soil ingestion rate; residential exposure duration). Factors which were assigned default values are shown in Tables 1 and 2.

Site-specific values are derived from local/regional information or studies which are valid to apply to the specific circumstances at the site, to reduce uncertainty or variability in the risk evaluation. The site-specific exposure factors and parameters are also summarized in Tables 1 and 2, and discussed in detail below. Based on evaluation of the Floodplain exposure scenarios and available information, the following exposure factors were selected to be defined using site-specific information or studies.

2.4.1 Exposure Frequency

Soil and dust exposure frequency are both evaluated on a site-specific basis. Outdoor days include both soil and dust exposure. Indoor days include only dust exposure. These exposure frequencies apply to both the ingestion and dermal components.

2.4.1.1 Local Climate – Determining Outdoor vs. Indoor Exposure Frequency

Local climate data is used to assign outdoor soil exposure frequency to only those days without snow cover (e.g., <1 inch) and/or without frozen soil (e.g., soil temperature >32°F). These endpoints are used to determine the reasonable maximum exposure (RME) for the following reasons: 1) the studies that serve as the basis of the soil ingestion rates were conducted primarily in the summer or fall, but did not exclude days of inclement weather or days without outdoor play time; and 2) days with precipitation events may also represent days with outdoor activities depending on timing and amount of precipitation, and type of outdoor activity. Therefore, the conditions of snow cover and/or frozen soils are used to define the number of days with only indoor dust exposure.

The available local climate data (NOAA 2010 and MSU 2010) for the 2005-2009 period indicate the number of days with either snow cover or frozen soils (≤32°F) to be 90 days (88.8-91.8 days as a range to account for days with missing data), resulting in 275 days (365 minus 90 days) when the soil is not frozen or there is less than an inch of snow cover. Consequently, the site-specific value selected for outdoor exposure days for the PRG derivations is 260 days per year (275 minus 15 days assumed to be spent away from home). This site-specific exposure frequency value is actually greater than the MDEQ Statewide default value of 245 days per year. The site-specific value for indoor only exposure days for the PRGs derivation is the 90 days per year with either snow cover or frozen soils.

2.4.1.2 Residential Exposure Scenarios – Apportioning Outdoor Exposure Days

As discussed above, the site-specific value for outdoor exposure days is 260 days per year. EPA and MDEQ applied this exposure frequency in two ways while calculating the PRGs for residential exposure scenarios (see Section 4): 1) First, PRGs were calculated for the sensitive young child receptor assuming that all 260 days of outdoor exposure could take place on residential soil with some amount of contamination. 2) Second, once that PRG was calculated, the 260 days of outdoor exposure were apportioned to account for different expected land uses (and concentrations) within a residential property.

The site-specific residential exposure scenario considers the variation in soil concentration data and exposure potential for most of the Floodplain residential properties. Houses are generally not in the Floodplain. The typical residential property on the Tittabawassee River floodplain has three different types of areas where direct contact soil exposure may occur (See Figure 3):

- An area around the house perimeter outside the Floodplain that has low soil concentrations that are less than 50 parts per trillion (ppt). (Zone A-1 on Figure 3)
- Maintained Residential Areas within the Floodplain that upon completion of the cleanup will meet the proposed Maintained Residential PRG. (Zone B)
- Residential unmaintained land within the 8-year floodplain with varying Dioxin concentrations. Upon completion of the cleanup, these areas will meet the proposed Other Land Use Areas PRG. (Zone C)

Exposure frequency is used to represent proportional amount of exposure time spent in the different areas described above. The amount of time spent in each of these areas was considered for different age groups for the residential receptors as follows and as summarized in Table 3 below:

- Young child receptor (1-6 years) – the RME is considered to spend most of the time around the house and in the maintained area within the 8-year floodplain. Less time is spent in the unmaintained or other use areas, and then only when accompanied by older sibling or adult. The expectation is that a young child would not be allowed to play unsupervised in unmaintained areas adjacent to the river.
- Older child receptor (6-12 years) and teenage receptor (12-21 years) – the RME is considered to have more independence to play/spend time in unmaintained and other land use areas in the

Floodplain, including weekends during the school year and five out of seven days per week when school is not in session, with the remainder of the days split between the house perimeter outside the Floodplain and the maintained areas within the Floodplain.

- Adult receptor (>21 years) – the RME is considered to spend weekend days in the unmaintained area, with the remainder of the days split between the house perimeter outside the Floodplain and the maintained areas within the Floodplain.

Receptor Age Group	Total Outdoor Exposure Frequency (days/year)	Exposure Frequency for Residential Area Outside Floodplain (days/year)	Exposure Frequency for Maintained Residential Area Inside Floodplain (days/year)	Exposure Frequency for Residential Unmaintained or Other Land Use Area Inside Floodplain (days/year)
Young child (1-6 years)	260	121 (47%)	121 (47%)	18 (7%)
Older child (7-11 years)	260	76.5 (29%)	76.5 (29%)	107 (41%)
Teenager (12-21 years)	260	76.5 (29%)	76.5 (29%)	107 (41%)
Adult (>21 years)	260	93 (36%)	93 (36%)	74 (28%)

Table 3: Apportioning Outdoor Exposure Days for Residents

For most residential properties in the Tittabawassee River floodplain these RME scenarios are adequately protective. A very few residential properties are almost completely inside the Floodplain; therefore soil around the house perimeter may have elevated TEQ. However, most of these residences have already been cleaned up by complete excavation and backfill with clean soil at background levels. In addition, there may be a very few non-residential property uses that do not fit the exposures considered for the Other Land Use PRG. For these properties, a property specific evaluation may be necessary to determine an exposure scenario that takes into consideration greater exposure to contamination in the Floodplain. Alternatively the proposed PRGs for the Maintained Residential and Other Land Use areas may be appropriate in such cases.

2.4.1.3 Exposure Frequency for Non-Residential Scenarios

For non-residential property, an adult worker scenario assumes a person who attends a workplace located where all of the potential soil exposure is within the impacted Floodplain. The worker was assessed for 186 days of outdoor soil exposure (five days per week for the 260 days based on the climate data; Section 2.4.1.1) and 245 days of indoor dust exposure (i.e., 245 total work days split into 186 days with both outdoor soil/indoor dust exposure and 59 days with only indoor dust exposure).

2.4.2 Partition of Soil Exposure: Outdoor Soil and Indoor Dust

Estimates of total daily incidental soil ingestion exposure are typically modeled or assumed to be composed of soil from two sources: outdoor soil and indoor dust. A subset of annual days will only have indoor dust exposure. Consequently, an estimate for indoor daily dust exposure (ingestion and dermal) is needed. Dust is composed partially of outdoor soil transported into the home by various processes (e.g., tracking on shoes or clothes; pet traffic; open doors and windows). No verified sources of data to derive a site-specific value or site-specific partition ratio of outdoor soil to indoor dust could be found. Consequently, a partition ratio of forty five-fifty five (45:55) between soil and dust exposure was selected based on the recommendation found in the EPA *Exposure Factors Handbook* (EFH) (EPA, 2011). This ratio is included in the calculations for soil exposure on outdoor days, with all of the exposure for indoor days coming from indoor dust only.

The EFH recommended partition ratio of forty five-fifty five (45:55) between outdoor soil and dust exposure relates to soil ingestion. Because appropriate data is not currently available, the EFH does not recommend a partition ratio for soil and dust exposure via dermal contact. However, based on professional judgment, the Agencies believe that some split between soil and dust exposure for outdoor days is also appropriate for dermal contact. For the purposes of the Floodplain PRG calculations, the ingestion partition ratio of forty five-fifty five was also used for soil and dust exposure via dermal contact on outdoor exposure days (i.e., 260 days/year). This is discussed further in Section 5.0, Uncertainties and Sensitivity Analysis.

2.4.3 Dust Concentration

After determining that indoor dust should be modeled as a separate source of contaminant exposure, EPA and MDEQ sought an approach for how a site-specific Dioxin TEQ concentration in indoor dust could best be determined. The University of Michigan Dioxin Exposure Study (UMDES) collected site-specific data from residential properties in the Floodplain for both indoor dust and outdoor soil (UMDES 2008). This data has been considered for determining appropriate indoor dust concentrations for exposure related to the soil contamination. Options for using the available data include: 1) a dust-to-soil ratio; and 2) use of the dust concentration data directly (i.e., 95% upper confidence limit or UCL of the mean concentration).

A dust-to-soil ratio has been considered for other sites to address indoor dust concentrations, so this approach was explored first using the UMDES data. The UMDES developed a linear regression model that resulted in a dust-to-soil ratio of 0.2. However, the Agencies do not believe that this linear regression model should be used to develop the site-specific PRG because the model is not transparent and may be confounded with collinear parameters and sampling weights, and consequently, may not be acceptable for determining the appropriate dust/soil concentration ratio. Additionally, paired soil/dust data is not available from UMDES, only summary statistics. Since most of the properties along the Tittabawassee River floodplain have large variations in soil concentrations, using a dust-to-soil ratio from summary statistics is challenging. Therefore, using a dust-to-soil ratio to estimate dust concentrations does not appear to be the preferred approach for this site.

Another approach would be to use the dust concentration data directly, instead of a dust-to-soil ratio. The UMDES analyzed dust from 207 Floodplain residences. The Agencies have opted to use a fixed Dioxin TEQ dust concentration based on this dataset (mean = 35 ppt, median = 15 ppt, 95% UCL of the mean = 50 ppt). The Agencies typically use a 95% UCL of the mean to represent the concentration data for an individual exposure unit. Consequently, a value of 50 ppt is used as the dust Dioxin TEQ concentration for the derivation of PRGs.

2.4.4 Oral Bioavailability / Ingestion Absorption Efficiency

Oral bioavailability is the proportion of an ingested chemical that is absorbed from the gastrointestinal tract into the bloodstream and tissues. Bioavailability of D/F from contaminated soil could be influenced by several factors including the source of the D/F, the soil type, and weathering. If there is evidence that the bioavailability of the D/F in soil compared to that of the test medium in the critical study on which the RfD and/or CSF are based is less than 100%, then an adjustment to the bioavailability is appropriate (EPA 2010b). The ratio of D/F bioavailability in site soil compared to the D/F bioavailability of a non-soil reference medium is referred to as the Relative Bioavailability (RBA) and becomes the basis for a site-specific adjustment factor.

EPA issued a report which reviewed the available information from the published literature on the bioavailability of dioxins in soil (EPA 2010b). This review included the Dow rat and swine pilot and follow-up studies (Budinsky et al, 2008). The primary objectives of the EPA literature review and data analysis were to: 1) Identify and summarize the best available studies that could be used for estimating RBA in soils that contain multiple D/F congeners; 2) Determine if data from the best studies are adequate to conclude that RBA for D/Fs in soil is less than 100%; and 3) Determine if data from the studies are adequate to recommend a quantitative nationwide default RBA value (e.g., central tendency; high-end) for application to site-specific risk assessments. The Report identified three well conducted studies in which quantitative RBA estimates were made for soils containing multiple congeners and for soils tested in more than one species (Budinsky et al. 2008; Finley et al. 2009; Wittsiepe et al. 2007).

The analysis of the studies supported the following conclusions: 1) The RBA of D/F mixtures in soils can be expected to be less than 100% based on comparison to a lipid or organic solvent used as the reference material (e.g., corn oil); 2) Available estimates of soil dioxin RBA are not adequate for recommending a nationwide default RBA value to use in risk assessments as an alternative to 100% or actual site-specific values; 3) RBA varies with the level of congener chlorination in a manner that suggests species differences for the RBA of chlorinated congeners; and 4) The available data and protocols are not adequate to determine a preferred animal model for predicting soil RBA in humans.

One of EPA's conclusions is that current information is not sufficient to determine a preferred animal model or bioassay protocol for predicting soil RBA in humans. Part of that determination is based on conflicting results observed for RBA with increasing levels of dioxin chlorination. Rodents appear to have lower soil RBA with increasing chlorination. Based on the available swine studies, including the Dow studies, swine appear to have higher soil RBA with increasing dioxin chlorination (Budinsky et al. 2008). The EPA Report also made a case that RBA studies in swine should be considered as valid for making estimates of RBA in soil. The Report states: *"While it is not an objective of this report to evaluate a preferred animal model, there are several potential strengths with using swine for estimating RBA of dioxins in soil. As demonstrated for lead bioavailability, similarities between the physiology and anatomy of juvenile swine and human gastrointestinal tracts make swine a suitable model for predicting RBA in humans (USEPA 2007). However, it is important to note that juvenile swine are appropriate for estimating lead bioavailability because the primary concern is exposure to young children, as compared to PCDD/Fs where all life stages are of interest. Swine and rats also differ in the distribution of absorbed PCDD/Fs. Similar to humans, swine accumulate higher levels in adipose tissue relative to the liver, whereas, the distribution in rats tends to show the opposite trend (Budinsky et al. 2008; Thoma et al. 1989, 1990)."* (EPA 2010b; page 28).

Consequently, EPA and MDEQ performed a more detailed review of bioavailability studies conducted in rats and swine by Dow on a soil sample from the Tittabawassee River floodplain.

First, the Agencies reviewed the data on D/F distribution in floodplain soil samples and concluded that the selected test soil evaluated for bioavailability by Dow was adequately representative of the floodplain soils of concern. Dow provided evidence showing that a high proportion of the D/F TEQ measured in floodplain soils is strongly associated with particulate anthropogenic black carbon that was produced and released downstream into the Tittabawassee River during the chloralkali production process (Chai et al., 2011). In addition, Chai et al. (2007) measured specific surface areas of bulk floodplain soils and their sub-fractions and their associated D/F TEQs. No correlation was observed between D/F TEQ distribution and the higher specific surface areas present in the finer sub-fractions of the soil. The Floodplain soil data support the conclusion that, at this site, the anthropogenic black carbon and the D/F TEQ adsorbed to black carbon control bioavailability; and natural organic matter (which can vary by soil type) is much less important (ATS, 2007; Chai et al, 2007).

Second, the Agencies reviewed the Dow studies on RBA of D/F congeners in soil using two animal models, Sprague-Dawley rats and juvenile swine. The studies were designed to measure the bioavailability of the five D/F congeners which contribute the highest portion of TEQ (> 90%) for the Floodplain soils (Dow, 2005). The following is a summary of the pilot studies conducted in rats and swine, and a follow-up study conducted in rats with the Floodplain soil (Dow 2006).

A) The pilot study measured liver and adipose tissue D/F congener levels in soil-fed animals and control animals. The objectives were to evaluate the study designs including the number of animals per dose group and to confirm the analytical methods necessary to detect the D/Fs retained in the liver and adipose tissue of both animals. Soil was administered for 30 days as a soil/feed mixture for rats and as soil wrapped in a dough ball for swine. The control animals ingested matched doses of the same five congeners in a corn oil vehicle. (The dosing for control rats included a corn oil reference. The control swine were dosed with corn oil vehicle in a gelatin capsule which was wrapped in a dough ball.) The results estimated the RBA for individual congeners based on the comparison between the fraction of the dose retained by the soil-fed group and the vehicle-dose group. Then a TEQ-weighted estimate of RBA for each species was obtained by weighting the individual congener RBA estimates by their respective contribution to the TEQ concentration of the floodplain soil sample.

B) The pilot study included measurement of 7-ethoxyresorufin-O-deethylase (EROD) which is linked to liver cytochrome P450 enzyme activity. The purpose was to evaluate whether a different level of enzyme induction was occurring between the soil-fed animals and the control animals. The control group rats showed higher EROD activity compared to soil fed rats. The higher EROD induction in the controls led to speculation that the observed RBA estimates may be elevated because control rats experienced increased metabolic activity which could result in faster elimination of the D/F congeners in the control rats. (No significant differences in hepatic EROD activity were observed among the swine treatment groups.)

C) A follow-up study in rats with the Floodplain soil and several dose-matched corn oil controls was designed to evaluate whether the increased EROD activity was influencing the RBA results (Dow, 2006). The follow-up study demonstrated that when controls with similar dose and EROD activity were used to estimate RBA, the results were not different from those of the pilot study for four of the five congeners. The only congener that appeared to be significantly elevated in the pilot study was 2,3,7,8-tetrachlorodibenzofuran (TCDF). Because TCDF is known to have a much shorter half-life than the other D/F congeners, it is more likely to have increased elimination. Since TCDF is an important congener for the Tittabawassee River floodplain soil, it was concluded that the rat pilot study data should not be used. Only the follow-up study data for the rat should be used. The follow-up study had two control doses (50% and 80% of the soil fed dose) that appeared to match the EROD activity measured in the soil fed rats. Consequently, it was determined that an average of the RBA calculated using each of these two controls would be appropriate to use for the rat data.

D) One of the important conclusions of the follow-up study was that there appeared to be a true difference in RBA between rats and swine. It is not clear whether the difference could be due to species absorption differences and/or soil dosing differences (i.e., soil mixed with normal feed for rats vs. soil within dough balls given as a bolus intake for swine).

Consequently, at the present time, it is not clear which animal model would better represent the human oral bioavailability of dioxin in Floodplain soil. Therefore, EPA and MDEQ concluded that it would be appropriate to use an average of the two species RBA results for the Floodplain soil.

Since the bioavailability from soil must be evaluated relative to the test medium for the critical toxicity study, the appropriate values to use for the Tittabawassee River floodplain are:

A) For the EPA non-cancer RfD - use the oil gavage control in rats and the dough-ball control in the swine.

B) For the EPA and MDEQ CSFs - the test medium was rodent feed for the rat study which serves as the basis for both the current EPA and MDEQ CSFs. Therefore, a soil bioavailability relative to rat feed is appropriate for dioxin cancer risk assessment with the current CSFs. (For floodplain soils, the 2,3,4,7,8-pentachlorodibenzofuran (4-PeCDF) congener contributes more to the TEQ (32-38%) than any of the other congeners and appears on average to be representative of the TEQ oral bioavailability in the rat. Therefore, using the relative bioavailability of 4-PeCDF between the feed reference and the oil gavage reference to adjust the TEQ- weighted relative bioavailability for use with the CSF is appropriate.)

The final consideration for the bioavailability values is how to address different congeners that are contributing to the TEQ. A TEQ-weighted average from the five congeners evaluated in the bioavailability study is used to represent the total TEQ bioavailability. That approach is valid for the following reasons: a) the five congeners in the test soil contributed 92% of the TEQ for the soil that was used in the bioavailability study; and b) the five congeners tested for bioavailability represent 87-89% of the average TEQ for the large collection of Tittabawassee River floodplain soil samples. The distribution of the five congeners in the test soil is provided in Table 4 and compared to the average congener distribution of soil samples collected along the Tittabawassee River floodplain.

As a result of the above considerations, the oral bioavailability values were derived as follows. For the RBA to use with the 2012 EPA RfD:

- Compute the average of the reported TEQ-weighted rat RBA values from the follow-up study using the 50% (0.5x) and 80% (0.8x) oil gavage controls.
- Compute the average of the reported TEQ-weighted swine RBA values at both half the detection level and the full detection level, and
- Use the average of the rat and swine averages.

For the RBA to use with the CSFs:

- Compute the average of the reported TEQ-weighted rat RBA values from the follow-up study using the 50% (0.5x) and 80% (0.8x) oil gavage controls adjusted by dividing by the feed relative to oil gavage control for 4-PeCDF.
- Compute the average of the reported TEQ-weighted swine relative to dough ball bioavailability values at both half the detection level and the full detection level, and
- Use the average of the rat and swine averages.

These values are displayed in Table 5. The values recommended for the Tittabawassee River floodplain as best available information for oral bioavailability are:

- 0.43 (43%) relative to oil bioavailability for use with the 2012 EPA RfD; and
- 0.51 (51%) relative to feed bioavailability for use with either the EPA or MDEQ CSF.

2.4.5 Dermal Absorption Efficiency (ABS_d)

Dermal Absorption (also known as "Percutaneous Absorption") refers to the amount of chemical that can enter into the body's circulatory system after application to the skin. Dermal absorption is the translocation of a substance across the skin to the point where it is introduced into the circulation via the capillaries which perfuse the dermis. The process entails sequential diffusion of the chemical through two differentially selective barriers commonly referred to as the "stratum corneum" and the "epidermis." The stratum corneum is the outer layer of cornified non-viable cells which provides the primary barrier to chemical translocation. Chemical substances must diffuse through the lipid-rich intercellular matrix of the stratum corneum in order to reach the thicker viable epidermis layer. The stratum corneum is the rate-limiting diffusion barrier for hydrophilic (water soluble and ionic) substances; and the epidermis is the rate-limiting diffusion barrier for the lipophilic (fat soluble/water insoluble) substances.

Dermal absorption of organic compounds such as TCDD, PCBs, and some pesticides can be extensive when they are applied to skin in neat solutions. Absorption has also been measured, but at a considerably lower rate, for some of these chemicals when applied to skin in a soil matrix (e.g., TCDD, PCBs, benzo[a]pyrene). EPA evaluated the original experimental studies on TCDD dermal absorption to the skin of rats *in vivo* and to rat and human excised skin preparations *in vitro* (EPA 1992). The available studies indicated that a higher level of total TCDD absorption over a specified time period was observed for low organic carbon soils (0.45%) spiked with radiolabeled TCDD compared to high organic carbon soils (11%). Based on the results of the absorption studies on rats *in vivo* and rat and human excised skin preparations *in vitro*, the human dermal absorption rate was estimated from the following relationship:

$$\textit{Human in vivo ABS} = \frac{(\textit{Human in vitro ABS}) \times (\textit{Rat in vivo ABS})}{(\textit{Rat in vitro ABS})}$$

The approach above assumes that the ratio of *in vivo* to *in vitro* measured absorption fractions for a specific contaminant will be the same in humans as in animal species. The validity of this approach depends on similarities in skin structure and pharmacokinetic processes between animals and humans. Recognizing unavoidable differences between mammalian species, the above relationship is still considered to be the best available approach for making the human dermal absorption estimate based on experimental studies under controlled conditions.

Based on EPA's evaluation of the best available published studies, the following range was recommended for the dermal absorption efficiency estimate for TCDD in soil: 0.1 % to 3%. The high end of the range was recommended for soils with low organic carbon content, and the low end of the range for soils with high organic carbon content (EPA 1992).

Since the original evaluation, EPA performed and published an additional study which is suitable for updating the original recommendation for TCDD dermal absorption (EPA 2008a). The purpose of the new study was to conduct a more complete set of experiments using fully characterized soil and including intravenous administration, rat *in vitro* skin testing, and human skin *in vitro* testing. The experiments were designed to allow comparison of the following experimental conditions: *In vivo* and *in vitro* experiments; TCDD applied in neat form and in soil; absorption across intact *in vitro* rat and human skin samples; and absorption from soil with low and high organic carbon contents. Ultimately, the study discusses dermal absorption efficiencies that should be considered when evaluating human exposure to TCDD contaminated soils.

In the updated EPA study, eight groups of dermal absorption measurements were conducted (two rat *in vivo*; six rat *in vitro* or human *in vitro samples*). TCDD was applied in neat solution (high dose at 250 $\mu g/cm^2$ and low dose at 10 ng/cm^2) or sorbed on a low total organic soil (0.5%) or high total organic soil (11%) at 1 ppm (10 ng TCDD/10 mg $soil/cm^2$). Risk assessments generally assume that dermal absorption from a single soil exposure occurs for up to 24 hours (i.e., soil remains on skin up to 24 hours; EPA 2004). After a 24 hour exposure time, the percent of TCDD dose absorbed compared to the starting TCDD dose on low organic soil was 7.9% (rat *in vivo*), 3.8% (rat *in vitro*) and 0.5% (human *in vitro*). The percent of dose absorbed from TCDD on high organic soil was 0.1% (human *in vitro*). Human skin was observed to be three to four times less permeable to TCDD than rat skin across a range of doses and exposure times. Using the algorithm mentioned previously, the human skin *in vivo* absorption efficiency was estimated to be 1.0% for the low organic soil. After adjustments to account for differences between *in vitro* and *in vivo* results and adjusting for application to monolayer loads, the 24-hour TCDD absorption value recommended for human skin was 1.9% from low organic soil and 0.24% from high organic soil.

Consequently, for the purpose of deriving PRG values a dermal ABS_d value of 0.02 (i.e., 2.0% rounded up from 1.9%) was used for the following reasons:

1) The 2% value is recommended for soils with low organic carbon content. The average total organic carbon content for Tittabawassee River Floodplain soils is < 1% which corresponds well with the low organic carbon content soil from the EPA 2008 study.
2) The 2% value is considered to be the best available dermal absorption estimate for human skin for application to a risk assessment employing the 2012 EPA non-cancer RfD. The EPA non-cancer RfD value is based on epidemiology studies on TCDD exposure where the measured human serum TCDD level resulted from the likely combination of oral and dermal absorption pathways.

2.4.6 Skin Surface Area Parameter

In order to account for dioxin contaminant intake through dermal exposure, values need to be selected for the parameter known as skin surface area. The parameter is needed for estimating contaminant absorption through the dermal pathway and is dependent on the type of receptor (e.g., child, adult) and the exposure scenario under consideration (e.g., residential, worker).

EPA has reviewed the published studies and other available information on skin surface area in order to provide recommendations for incorporating this parameter into Superfund risk assessments. Two factors need to be evaluated in order to derive a value for the skin surface area parameter: 1) Total body surface area; and 2) Fraction of total body surface area attributed to specific exposed body parts. These two factors are combined to estimate the surface area available for exposure.

The recommendations for total body surface area are presented in the EFH, Chapter 7: Dermal Exposure Factors (EPA 2011). The EFH reviews the latest National Health and Nutrition Examination

Survey (NHANES) empirical data on body surface area and presents the metadata by age groups. The recommendations for fractions of total body surface area attributed to body parts are presented in the EPA *Risk Assessment Guidance for Superfund: Supplemental Guidance for Dermal Risk Assessment Part E Final* (EPA 2004).

The above data sources were consulted in order to derive estimates of exposed skin surface area classified by the receptor group and exposure scenario. In addition, EPA, in consultation with MDEQ, determined which body parts would be expected to present exposed skin surfaces under the climate conditions and activity practices expected in the Floodplain areas. The combinations of receptor groups/exposure scenarios and the skin surface estimates are shown in the table below:

Receptor/Exposure Scenario	**Total Body Surface Area* (sq cm)**	**Body Parts Available for Exposure**	**Exposed Skin Surface Area* (sq cm)**
Young Child/Residential/Recreational	6840	face, neck, hands, forearms, lower legs	2052
Older Child/Residential/Recreational	10800	face, neck, hands, forearms, lower legs, feet	3920
Teenager/ Residential/Recreational	17150	face, neck, hands, forearms, lower legs, feet	6260
Adult/Residential/Recreational	19780	face, neck, hands, forearms, lower legs	5618
Adult/Worker	19780	face, neck, hands, forearms	3026

Table 6: Skin Surface Areas
*Details of the derivation are presented in Appendix A

2.4.7 Body Weight Parameter

In order to make estimates of dioxin contaminant intake, values need to be selected for the body weight of each receptor group. Body weight values are used in the calculation of average daily dose for the non-cancer endpoint and lifetime average daily doses for the cancer risk endpoint.

EPA has reviewed the published studies and other available information on body weight in order to provide recommendations for incorporating this parameter into Superfund risk assessments. The primary EPA data review and recommendation documents to inform the body weight parameter include: 1) *Child-Specific Exposure Factors Handbook* (2008b), Chapter 8: Body Weight; and 2) *Exposure Factors Handbook* (EPA 2011), Chapter 8: Body Weight Studies. Reference 1 describes the EPA review of the NHANES data (1999-2006) on body weight and presents the recommended metadata for a number of age groups for children up to age 21. This reference recommends treating the adult as a person 21 years of age or older. Reference 2 describes the EPA review of the NHANES data (1999-2006) on body weight for adults and presents the recommended metadata for a number of adult age groups.

The above data sources were consulted in order to derive estimates of body weight classified by the receptor group and the corresponding age range needed for calculating contaminant dose estimates. The combinations of receptor groups and body weights are shown in the table below:

Receptor Group	Age Range	Body Weight (kilograms) *
Young Child	1 – 6	16.2
Older Child	7 – 11	31.8
Teenager	12 – 21	63.4
Adult	21 – 70	81.8

Table 7: Body Weights
*Details of the derivation are presented in Appendix B

For the adult body weight shown above, the high end of adult age is truncated at 70 years because the calculation of Lifetime Average Daily Dose (LADD) is defined to correspond to a lifetime age of 70 years. The LADD is a parameter needed to calculate the cancer risk component of a PRG value (EPA 1989; 1991b).

3.0 DIOXIN TOXICITY

When information is available for multiple adverse effects of a hazardous substance, an evaluation of both cancer and non-cancer adverse health effects is necessary to determine the most sensitive effect for developing PRGs (EPA 1991b).

3.1 Non-Cancer Reference Dose

Relatively new information regarding prenatal and postnatal health effects attributed to dioxin exposure and changes in risk assessment practices have resulted in the necessity to more closely consider the potential for non-cancer adverse effects in developing the current PRGs. Based on this information, EPA developed an oral RfD that was finalized in February 2012 and posted to the Integrated Risk Information System (EPA, 2012a). The associated toxicity assessment published at the same time is the final version of the non-cancer portion of the EPA *Reanalysis of Key Issues Related to Dioxin Toxicity and Response to National Academy of Sciences (NAS) Comments*, *Volume 1* (EPA, 2012b). The 2012 EPA RfD is the best available information for assessment of non-cancer endpoints. In addition, because the adverse effects captured by the RfD are related to early-life exposures, the appropriate sensitive receptor is a child. Therefore, a young child receptor is used to develop the non-cancer direct contact PRGs.

EPA derived the 2012 RfD of 7.0E-10 mg/kg-day based on two human epidemiology studies demonstrating altered thyroid function (Baccarelli et al, 2008) and impaired adult male reproductive function (Mocarelli et al, 2008) associated with prenatal and postnatal exposure to TCDD, respectively. The Baccarelli study evaluated serum Thyroid Stimulating Hormone (TSH) levels in neonates born to mothers who were exposed to TCDD 17-29 years prior to pregnancy because of a 1976 chemical plant explosion in Seveso, Italy. The adverse effect was identified as an increase in TSH levels above the World Health Organization standard of 5 µ-units TSH per mL of serum, which indicated dysregulation of thyroid hormone metabolism. The Mocarelli study reported decreased adult sperm concentrations and decreased motile sperm counts in men who were 1-9 years old in 1976 at the time of initial exposure to TCDD from the Seveso accident.

The 2012 RfD uses intake rates derived using the Emond et al. (2005) human physiologically-based pharmacokinetic (PBPK) model from serum concentrations reported in the studies. For the Baccarelli et al. study, EPA used the study's regression model to estimate a maternal plasma TCDD concentration at the neonatal TSH level of concern, and the Emond human PBPK model under the gestational scenario to determine the maternal intake rate lowest-observed-adverse-effect level (LOAEL) of 2.4 $\times 10^{-8}$ mg/kg-day. For the Mocarelli et al. study, since it was not clear whether the effects were related to the peak exposure or to the average exposure, EPA used the average of the estimated intake rates for both to derive an intake rate LOAEL of 2.0 x 10^{-8} mg/kg-day. EPA decided that the two studies could be regarded as co-critical studies with a LOAEL converging around the value of 2.0 x 10^{-8} mg/kg-day. To derive the RfD value, the LOAEL was adjusted downward by a 30x uncertainty factor: 10 for the LOAEL and 3 for the possibility of within human variability.

3.2 Cancer Slope Factor

EPA is concerned with addressing potential cancer risk for dioxin exposure. However, EPA has not yet determined a final CSF for evaluating cancer risk. EPA is continuing with development of a new final CSF as part of the ongoing *EPA Dioxin Reassessment/Reanalysis* (EPA 2009). That effort will take some additional time, and no projected completion date is available. In the absence of a final dioxin CSF, EPA policy calls for conducting reviews of the available EPA and non-EPA sources of scientific information to determine if an appropriate interim CSF value can be recommended for use in Superfund risk assessments. Priority will be given to those sources of information that are publicly available, have a transparent analysis of original data, and which have been subjected to peer review (EPA 2003). On that basis, EPA identified two candidates for use as valid interim CSF values:

A) EPA's Office of Health and Environmental Assessment (EPA 1985) developed an oral cancer slope factor of 1.56E-04 $(pg/kg\text{-}day)^{-1}$. This was based on the combined incidence of lung, palate, and nasal carcinomas, and liver hyperplastic nodules or carcinomas in female rats in the study by Kociba et al. (1978).

B) California EPA (CalEPA 1986 and2002) developed an oral cancer slope factor of 1.3E-04 $(pg/kg\text{-}day)^{-1}$. This was based on the occurrence of hepatocellular adenomas and carcinomas in male mice in a study by the National Toxicology Program (NTP 1982).

EPA cited the value from OHEA as the preferred value to use as an interim CSF because it is derived from the evaluation of all tumors types confirmed in the test animals (EPA 2009).

3.3 EPA Policy for Application of Dioxin Toxicity Factors for Development of PRGs

For the goal of applying the best current science as the basis for its cleanup actions, EPA announced that the Agency will use the final RfD for TCDD to address cleanup projects under Superfund. Application of the new RfD will apply to the development of site-specific PRGs. The following statement is found at **http://www.epa.gov/superfund/health/contaminants/dioxin/dioxinsoil.html**

> "Dioxin-contaminated sites cleaned up based on the new non-cancer RfD are not expected to need additional cleanup when a new EPA cancer toxicity value for dioxin is published in EPA's Integrated Risk Information System (IRIS). This is because we anticipate that dioxin cleanup levels based on the new non-cancer RfD will be within the cancer risk range currently used by EPA's Superfund and RCRA cleanup programs."

4.0 DERIVATION OF PRG VALUES

PRGs were calculated for a variety of direct contact Floodplain soil exposure scenarios. The calculations followed standard EPA and MDEQ algorithms and used a combination of both standard default and the site-specific input parameters discussed herein. Potential PRGs were calculated to assess both non-cancer risks to meet a HQ = 1 and cancer risks to meet EPA's risk range. Additionally, under MDEQ risk assessment regulations (Part 201 of NREPA), cancer risks are assessed for 1E-5 (1 in 100,000) using a CSF derived from EPA's Great Lakes Water Quality Initiative for TCDD (EPA 1995).

Based on these calculations, EPA and MDEQ are proposing two site-specific PRGs for the Floodplain soil: 1) Maintained Residential Areas; and 2) Other Land Use Areas. The PRGs are based on the most sensitive receptor and exposure scenario within each land use. Thus, the PRGs will be protective for all other direct contact receptors/scenarios.

4.1 Maintained Residential Areas PRG

For Maintained Residential Areas of the Floodplain, EPA and MDEQ are recommending a PRG of 250 ppt TEQ.

The most sensitive receptor and endpoint for the Maintained Residential Areas of the Floodplain is a young child for non-cancer effects. The proposed PRG is based on calculated values to achieve a HQ of 1, assuming that all of the child's soil exposure is to the maintained portion of the property in the Floodplain. The calculations are shown in Appendix C. The proposed cleanup level for Maintained Residential Areas is 250 ppt TEQ based on the site-specific assumptions described in this memorandum, adjusted to account for exposures to other areas of the residential property and other uncertainties. PRGs were calculated for older residents and for cancer endpoints, and the calculated values were less stringent than 250 ppt TEQ.

4.2 Other Land Use Areas PRG

For Other Land Use Areas of the Floodplain, EPA and MDEQ are recommending a PRG of 2,000 ppt TEQ. This PRG will apply to direct contact exposure in: Residential Unmaintained Land; Other Unmaintained Land; Agricultural Land; Shiawassee National Wildlife Refuge; Park Land; and Commercial Land.

The most sensitive receptor and endpoint for the Other Land Use areas is also a young child for non-cancer effects. The calculated value to achieve a HQ of 1 is 2,000 ppt. This value is based on the site-specific assumptions described in this memorandum, including the apportionment of time in various areas discussed in Section 2.4.1.2. PRGs (cancer and non-cancer) were calculated for older residents and adult workers, and the calculated values were less stringent than 2,000 ppt. PRGs were also quantitatively calculated for older children, teen or adult recreators, and those values are less stringent than the residents of the same age group.

5.0 UNCERTAINTIES AND SENSITIVITY ANALYSIS

Both EPA and MDEQ have published documentation regarding the uncertainties associated with toxicity factors, the default exposure factors and parameters, and the algorithms used to calculate PRGs. All of those uncertainties apply to the site-specific PRGs calculated herein. This discussion will focus on uncertainties and some sensitivity analyses around the three most significant site-specific exposure factors and parameters: Exposure Frequency; Dust Concentration; and Oral Bioavailability. Additionally, although the factor is not as significant, there is also a discussion of the uncertainties associated with partitioning dermal exposure between outdoor soil and indoor dust on outdoor exposure days.

5.1 Exposure Frequency

Recent local climate data supports the site-specific value for outdoor exposure days of 260 days per year (Section 2.4.1.1). EPA and MDEQ believe that this is the best available information to use at this time. However, Executive Order 13653 of November 1, 2013, among other things, directs Federal Agencies to integrate consideration of climate change in managing lands and waters (FedCenter 2013). The Order calls for “adaptive learning, in which experiences serve as opportunities to inform and adjust future actions.” The Superfund program is consistent with the concept of adaptive learning. As discussed above, this Floodplain response action is a NTCRA. In the future, a remedial decision(s) will be made for the Floodplain. Climate change will be considered, as needed, as a component of the remedial decision-making. Superfund also requires a Five-Year Review, during which the continued protectiveness of remedies is evaluated. EPA anticipates that if there is significant climate change in the Floodplain that calls into question the site-specific exposure frequency, it can be evaluated in the Five-Year Review.

Of more immediate concern is the apportionment of outdoor exposure days between the house perimeter, maintained area in the Floodplain, and unmaintained area in the Floodplain (Section 2.4.1.2). The Floodplain is characterized by residential properties which are large and complex with opportunities for multiple use patterns and occupancy rates. There are currently no default exposure frequency factors which can be assigned to a multi-use property. Therefore, professional judgment needs to be applied, considering site-specific circumstances.

For a number of reasons, EPA and MDEQ believe that the partitioning used to calculate the Other Land Use PRG is a conservative approach. First, there is another zone where residents may contact soil – the non-house perimeter (e.g., unmaintained areas) outside of but adjacent to the Floodplain, which have soil TEQ concentrations that are significantly below the 250 ppt TEQ PRG (Zone A-2 on Figure 3). However, to provide a conservative evaluation, this area was excluded from the apportionment of outdoor exposure days. Second, there are periods when the Floodplain is inaccessible due to flooding. The Agencies did not try to reduce the frequency of outdoor day exposure because of “flood days.” Rather, EPA and MDEQ believe that this adds another degree of conservatism to the calculations. Third, in the PRG calculations time is split evenly between the maintained residential areas in and out of the Floodplain. An argument could be made that in many cases more time is spent around the house perimeter, outside of the Floodplain. During implementation of interim response action exposure controls at Floodplain properties, residents were interviewed about their use of the Floodplain. Generally, the reported frequency of use is less than (and sometimes much less than) the exposure frequency included in the PRG calculations. Although this information is informative, the interviews were not conducted as a formal survey, so the results are considered to be an anecdotal line of evidence.

As discussed in Section 4, potential non-cancer health effects were the driver behind the PRGs. Unlike carcinogenic compounds where EPA has established an acceptable risk range, for non-carcinogenic chemicals the HQ does not reflect a range (i.e., HQ = 1). However, it is reasonable to consider the HQ within the framework of uncertainties related to the RfD. In the discussion of uncertainty included in EPA’s definition of the RfD, EPA defines the RfD as:

> “…an estimate (with uncertainty spanning perhaps an order of magnitude) of daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime...” (EPA 2012c)

Because there is this range of uncertainty around the RfD, and other uncertainties, the Agencies have conducted a quantitative sensitivity analysis around the apportionment of outdoor exposure days between the house perimeter, maintained area in the Floodplain, and unmaintained area in the Floodplain (Zones A-1, B, and C on Figure 3). Standard algorithms that calculate the HQ were applied, the PRG values presented in Section 4 were held constant, and the exposure frequency in different property zones was varied. The results are shown in Table 8. As discussed in Section 2.4.1.2 above, the young child is considered to spend most of the time around the house and in the maintained area within the 8-year floodplain. Although this sensitivity analysis calculates HQs for up to 10% of the young child's time spent in the unmaintained portions of the Floodplain, EPA and MDEQ do not believe that this is likely at this particular site – the results are simply to present risk management information. From a risk management perspective, EPA and MDEQ believe that this sensitivity analysis supports the reasonableness of the site-specific exposure frequencies used to calculate the PRGs.

Young Child – Unmaintained Exposure Frequency (% of soil exposure time) Zone C	Proportion of Exposure Frequency to Maintained Areas In vs. Out of Floodplain (Zone B:Zone A-1)	Calculated HQ
5%	50:50	0.91
7%	50:50	1.00
10%	50:50	1.15
5%	25:75	0.78
7%	25:75	0.88
10%	25:75	1.03

Table 8: HQ Sensitivity Analysis Varying the Apportionment of Outdoor Exposure Days
(shaded row shows selected input parameters)

5.2 Dust Concentration

As discussed in Section 2.4.3, EPA and MDEQ determined that using the 95% UCL of the mean of the UMDES dust concentration data directly was the appropriate approach. This resulted in a value of 50 ppt TEQ used as the dust concentration for the derivation of PRGs. In order to guarantee confidentiality for the study participants (a very typical approach), the UMDES data set does not provide location-specific dust data, only summary statistics. Subsequent to when the UMDES data was collected, interim response activities were offered to floodplain properties owners that were intended to reduce indoor dust concentrations (e.g., duct/ carpet/hard surface cleaning activities) at many of the residential properties. These interim response activities may have reduced house dust concentrations, where implemented. Thus, use of the UMDES data is expected to be a conservative estimate of current conditions.

The Agencies evaluated another line of evidence to support the site-specific dust concentration value. EPA took a limited number of dust samples from Floodplain residences in areas where exposure was considered to be potentially elevated. These areas are called Exposure Units. Dust from residences in Exposure Units 2, 4, 5, and 6 had an average value of about 21 ppt TEQ, a median of 15 ppt, and no sample exceeded 50 ppt. Because EPA's sampling was biased to try to evaluate some of the highest potential exposures, EPA and MDEQ believe that this line of evidence supports the use of the 50 ppt dust concentration as a conservative value.

5.3 Oral Bioavailability

As discussed in Section 2.4.4, EPA and MDEQ elected to use 0.43 RBA for use with the 2012 EPA RfD in the calculation of non-cancer PRGs, and the Agencies believe that this is the most appropriate use of the site-specific bioavailability studies. The 0.43 RBA is based on an average of the rat (0.59) and swine (0.27) RBAs, shown in Table 5.

Similar to the analysis done for the exposure frequency, the Agencies have conducted a quantitative sensitivity analysis around use of the site-specific oral RBAs. Standard algorithms that calculate the HQ were applied, the PRG values presented in Section 4 were held constant, and the RBA was varied. The results are shown in Table 9. From a risk management perspective, EPA and MDEQ believe that this sensitivity analysis supports the reasonableness of the site-specific PRGs based on the average oral RBA.

	Maintained Residential PRG Calculated HQ	Other Land Use PRG Calculated HQ
RBA 0.27	0.62	0.66
RBA 0.43	0.93	1.00
RBA 0.59	1.25	1.34

Table 9: HQ Sensitivity Analysis Varying the Oral RBA
(shaded row shows selected input parameter)

5.4 Partition of Dermal Exposure: Outdoor Soil and Indoor Dust

As discussed in Section 2.4.2, the EFH does not recommend a partition ratio for soil and dust exposure via dermal contact. For the purposes of the Floodplain PRG calculations, the ingestion partition ratio of forty five-fifty five was also used for soil and dust exposure via dermal contact on outdoor exposure days. The Agencies believe that, similar to ingestion, it only makes sense that some dermal exposure will come from outdoor soil and some from dust. However, because there is no accepted reference to cite, the Agencies conducted a sensitivity analysis around this factor, evaluating potential impacts on the HQ from other dermal apportionment approaches.

As discussed in Section 4.1, the PRG for the Maintained Residential Areas of the Floodplain is based on a young child for non-cancer effects. The calculated value to achieve a HQ of 1 is 276 ppt TEQ (rounded to 280 ppt TEQ). This value is based on the site-specific assumptions described in this memorandum (including a ratio of forty five-fifty five for soil and dust exposure via dermal contact on outdoor exposure days) and assumes that all of the child's soil exposure is to the maintained portion of the property in the Floodplain (see Appendix C). However, EPA and MDEQ set the proposed cleanup level for Maintained Residential Areas at 250 ppt to account for exposures to other areas of the residential property and other uncertainties. If 100% of dermal exposure on outdoor days was to soil, the 250 ppt Maintained Residential Areas PRG would equate to a HQ of 1. If 100% of dermal exposure on outdoor days was to soil, the 2,000 ppt Other Land Use Areas PRG would equate to a HQ of 1.1

In evaluating this uncertainty, it is important to remember that on the indoor only days, 100% of dermal exposure is attributed to dust. On those cold or snowy indoor days, no adjustment was made to the surface area exposed. This is a conservative approach, in that it is likely that more of the body would be covered with clothing.

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TABLE 1: Input Parameters Used for Computing Non-Cancer PRGs for Exposure of Residents to Dioxin in Soil

Parameter (description)	Units	Default Value	Site-Specific Value
THQ (target hazard quotient)	dimensionless	1	1
RfD_o (oral reference dose)	pg/kg-day	0.7	0.7
EF (exposure frequency)	days/yr	350	350, includes[a] 260 "outdoor" 90 "indoor"
ED (exposure duration) (young child)	years	6	5[a]
ED (exposure duration) (older child)	years	NA	5[a]
ED (exposure duration) (teenager)	years	NA	10[a]
ED (exposure duration) (adult)	years	24	10[a]
BW (body weight – young child)	kg	15	16.2 [b]
BW (body weight – older child)	kg	NA	31.8 [b]
BW (body weight – teenager)	kg	NA	63.4 [b]
BW (body weight – adult)	kg	70	81.8 [b]
AT (averaging time) (young child)	days	2190	1825
AT (averaging time) (older child)	days	NA	1825
AT (averaging time) (teenager)	days	NA	3650
AT (averaging time) (adult)	days	8760	3650
IR_{soil} (soil ingestion rate) (young child) Outdoor days: 45% soil:55% dust Indoor days: 100% dust	mg/day	200	200[c] 90 soil + 110 dust 200 dust
IR_{soil} (soil ingestion rate) (older child, teenager, adult) Outdoor days: 45% soil:55% dust Indoor days: 100% dust	mg/day	NA	100[c] 45 soil + 55 dust 100 dust
Dust concentration	ppt TEQ	NA	50[d]
ABS_{GI} (gastrointestinal absorption fraction)	pg absorbed/ pg ingested	1	1
SA (skin surface area exposed) (young child)	cm^2	2690	2052[e]
SA (skin surface area exposed) (older child)	cm^2	NA	3920[e]
SA (skin surface area exposed) (teenager)	cm^2	NA	6260[e]

SA (skin surface area exposed) (adult)	cm^2	6032	5618[e]
AF (dermal adherence factor) (young child)	mg/cm^2	0.2	0.2
AF (dermal adherence factor) (older child)	mg/cm^2	NA	0.2
AF (dermal adherence factor) (teenager)	mg/cm^2	NA	0.07
AF (dermal adherence factor) (adult)	mg/cm^2	0.07	0.07
ABS_d (dermal absorption fraction)	pg absorbed/ pg on skin	0.03	0.02[f]
EV (dermal exposure frequency)	events/day	1	1
RBA (relative bioavailability)	dimensionless	1	0.43[g]
RSC (relative source contribution)	dimensionless	1	1

Notes: NA (Not Available)

a. Section 2.4.1
b. Section 2.4.7
c. Section 2.4.2
d. Section 2.4.3
e. Section 2.4.6
f. Section 2.4.5
g. Section 2.4.4

TABLE 2: Input Parameters Used for Computing Non-Cancer PRGs for Exposure of Adult Worker to Dioxin in Soil

Parameter (description)	Units	Default Value	Site-Specific Value
THQ (target hazard quotient)	dimensionless	1	1
RfD_o (oral reference dose)	pg/kg-day	0.7	0.7
EF (exposure frequency)	days/yr	250	245[a] 186 "outdoor" 59 "indoor only"
ED (exposure duration)	years	25	25
BW (body weight)	kg	70	81.8 [b]
AT (averaging time)	days	9125	9125
IR_{soil} (soil ingestion rate) Outdoor days: 45% soil:55% dust Indoor days: 100% dust	mg/day	100	100 45 soil + 55 dust 100 dust
Dust concentration	ppt TEQ	NA	50[c]
ABS_{GI} (gastrointestinal absorption fraction)	pg absorbed/ pg ingested	1	1
SA (skin surface area exposed)	cm^2	3300	3026[d]
AF (dermal adherence factor)	mg/cm^2	0.2	0.2
ABS_d (dermal absorption fraction)	pg absorbed/ pg on skin	0.03	0.02[e]
EV (dermal exposure frequency)	events/day	1	1
RBA (relative bioavailability)	dimensionless	1	0.43[f]
RSC (relative source contribution)	dimensionless	1	1

Notes: NA (Not Available)

a. Section 2.4.1
b. Section 2.4.7
c. Section 2.4.3
d. Section 2.4.6
e. Section 2.4.5
f. Section 2.4.4

TABLE 4: Congener Distribution of Test Soil and Floodplain Soil

		Floodplain Bioavailability Study Soil	Floodpain soil data from database 1613 TRP_RT Data above 90 ppt (GeoMorph data)		
		THT02769	Surface Interval	Start Depth <1 ft	Full Thickness Depth
	TEF	Average Concentration % TEQ	Average Concentration % ETEQ	Average Concentration % ETEQ	Average Concentration % ETEQ
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1	0.7%			
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1	0.8%			
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	0.1	0.06%			
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	0.1	0.3%			
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	0.1	0.12%			
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	0.01	0.6%			
Octachlorodibenzo-p-dioxin	0.0003	0.2%			
2,3,7,8-Tetrachlorodibenzofuran	0.1	33%	32%	33%	34%
1,2,3,7,8-Pentachlorodibenzofuran	0.03	5.0%	4.2%	4.3%	4.2%
2,3,4,7,8-Pentachlorodibenzofuran	0.3	41%	38%	38%	38%
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1	11%			
1,2,3,4,7,8-Hexachlorodibenzofuran + 1,2,3,6,7,8-Hexachlorodibenzofuran	0.1		13%	13%	12%
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1	2.5%			
1,2,3,7,8,9-Hexachlorodibenzofuran	0.1	1.5%			
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1	2.1%			
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01	1.1%			
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01	0.1%			
Octachlorodibenzofuran	0.0003	0.06%			
Sum % Bioaval Study Cong		92%	87%	88%	89%

Floodplain Soil Congeners Tested	congener distributions THT02769 % Soil TEQ	% Relative Bioavailability Values							
		RAT - Follow-Up Study				Swine			
		Soil vs. 0.5 Oil Gav.		Soil vs. 0.8 Oil Gav.		1/2 D.L.		D.L.	
		Liver+ Adipose	C.V.	Liver+ Adipose	C.V.	Liver+ Adipose	C.V.	Liver+ Adipose	C.V.
2,3,7,8-TCDF	33%	54	16	62	13	22	26	23	25
1,2,3,7,8-PeCDF	5%	55	13	57	11	30	46	34	29
2,3,4,7,8-PeCDF	41%	62	13	56	8.1	27	13	27	13
1,2,3,4,7,8-HxCDF	11%	62	14	56	8.4	35	12	35	12
1,2,3,6,7,8-HxCDF	3%	67	15	61	10	37	9	37	9
2005 WHO TEQ-Weighted (THT02769)	**0.92**	**59**		**58**		**27**		**27**	
Average for each species (relative bioavailability to gavage oil)		**59**				**27**			
Average of both species (relative bioavailability to gavage oil)		**43**							
Average for each species (relative bioavailability to feed)		**75**				**27**			
Average of both species (relative bioavailability to feed)		**51**							

C.V. – coefficient of variation

TABLE 5: Relative Bioavailability for Tittabawassee River Floodplain Test Soil and Animal Feed Intake

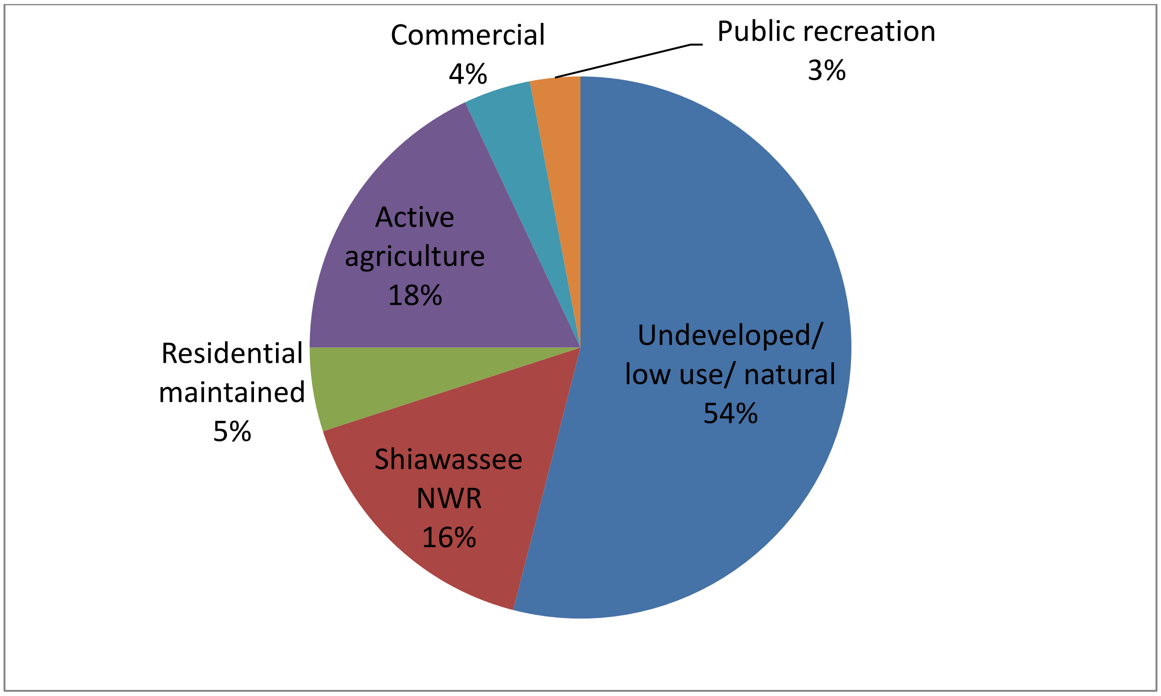

Figure 1: Current Land Use in the Floodplain

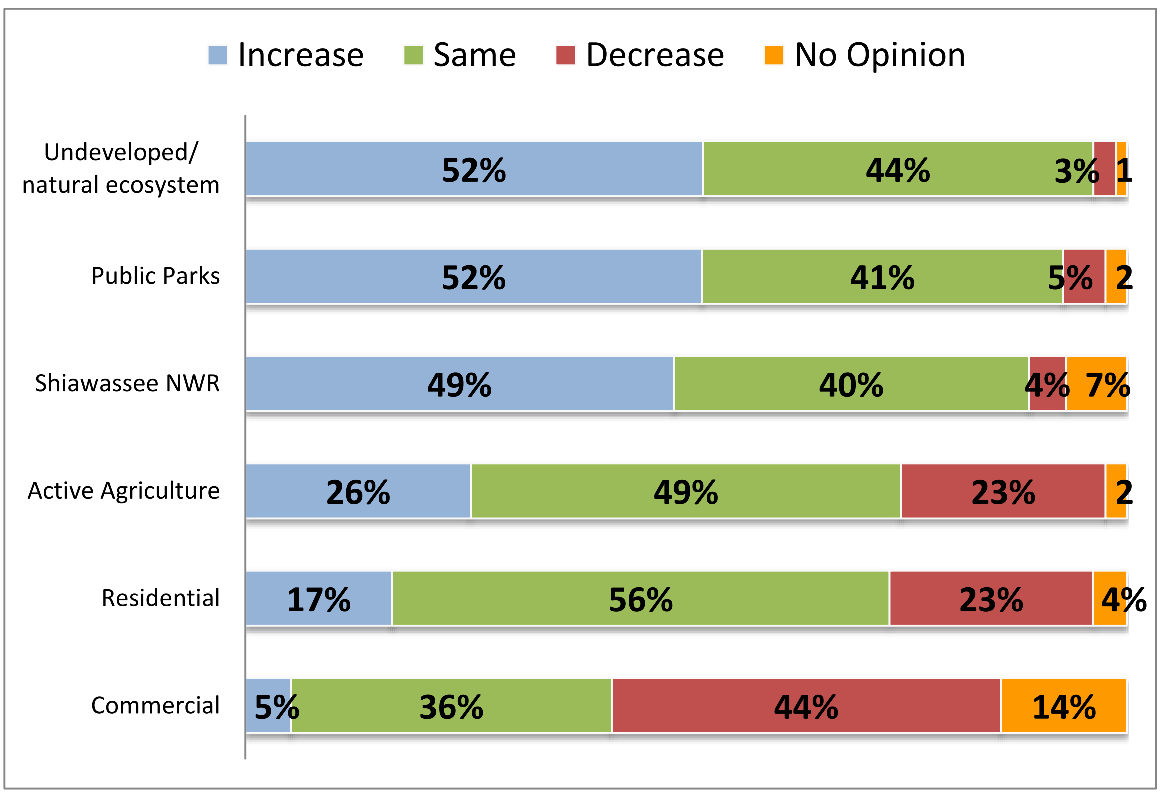

Figure 2: Desired Future Land Use in the Floodplain

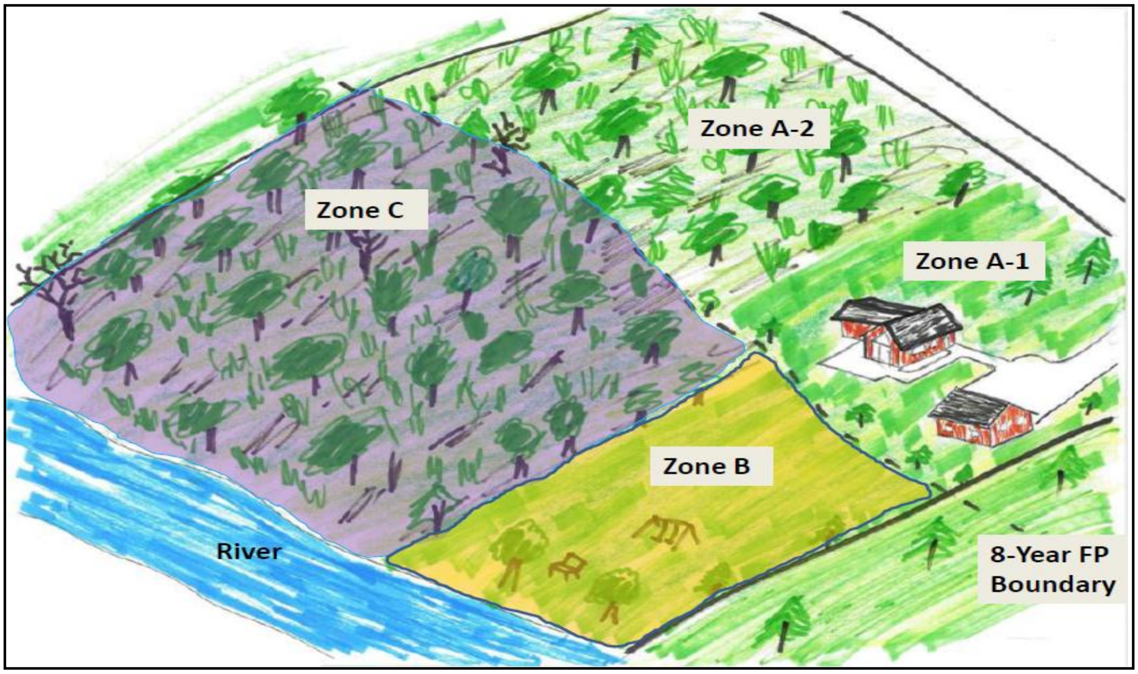

Figure 3: Areas Where Residents May Be Exposed to Soil

Zone A: Outside the 8-year floodplain, where levels are at or below 50 ppt
Zone B: The Maintained Residential PRG of 250 ppt would apply
Zone C: The Other Land Use PRG of 2,000 ppt would apply

NOTE: This is a cartoon of one type of residential property layout. Many residential property boundaries do not extend all the way to the river or are not maintained to the river. A property-by-property plan will be developed.

APPENDIX A Review of Exposed Skin Surface Area Parameter for All Receptor Groups

There are five receptor groups which need Skin Surface Area values selected for evaluation of the cancer risk and/or noncancer endpoint components of the Preliminary Remediation Goal (PRG) determinations. The Receptor Groups are designated as: Young Children, Older Children, Teenagers, Adult Residents and Adult Workers. The following analysis reviews and calculates Skin Surface Area parameters for all receptor groups expected to frequent the 8-Year Floodplain zone.

The primary EPA Superfund/OSWER guidance and metadata documents to inform dermal exposure are the following:

1) *RAGS Part E: Supplemental Guidance for Dermal Risk Assessment Part E Final* (July 2004)
   Exhibit C-1: "Body Part-Specific Surface Area Calculations (Children)"

2) *Exposure Factors Handbook* (2011); Chapter 7: Dermal Exposure Factors
   Table 7-1 and Table 7-9: Recommended values for Total Body Surface area for children and adults (male and female combined)

Total Body Surface Area

Young Children (Combined data for Male and Female):

Existing EPA guidance regards the youngest group of children capable of self-mobility to areas where soil contact could occur are between the ages of 1 year and up 6 years (EPA 2002).

The 2011 EFH reviews the latest NHANES empirical data on Total Body Surface Area and presents the recommended metadata by age groups in Table 7-1 and 7-9;

1 to 2 years = 0.53 square meters
2 to 3 years = 0.61 square meters
3 to 6 years = 0.76 square meters

Calculated Weighted Mean =

$$\frac{0.53 + 0.61 + 0.76 + 0.76 + 0.76}{5} = 0.684 \text{ square meters} = \mathbf{6840 \text{ square centimeters}}$$

Older Children (Combined data for Male and Female):

Older Children are included in this evaluation because it is probable that would they be the child receptor group making the most frequent visits to the "Residential Non-Maintained" portions of residential properties within the 8-Year Tittabawassee River Floodplain including accessible areas along the River front. Although this group does not appear to be formally defined in EPA guidance, available EPA data on age differences would suggest an age range of 7 years through 11 years.

The EFH reviews the latest NHANES empirical data on Total Body Surface Area and presents the recommended metadata by age groups in Tables 7-1 and 7-9;

For this age range, only a single Total Body Surface Area estimate is available:

7 to 11 years = 1.08 square meters

Weighted Mean = 1.08 square meters = **10800 square centimeters**

Teenagers (Combined data for Male and Female):

Existing EPA guidance does not appear to define a specific age range for a Teenager receptor group. Skin surface area parameters were derived earlier for Young Children and Older Children (age range 1 year through 11 years). The EPA Exposure Factors Handbook (2011) and the EPA Child-Specific Exposure Factors Handbook (2009) appear to define the "Adult" receptor as anyone older than 21 years. Therefore, the Teenager will be defined for this review as the receptor group in the age range of 12 through 21 years old.

The 2011 EFH reviews the latest NHANES empirical data on Total Body Surface Area and presents the recommended metadata by age groups in Table 7-1 and 7-9;

12 to 16 years = 1.59 square meters
17 to 21 years = 1.84 square meters

Calculated Weighted Mean =

$$\frac{[5(1.59) + 5(1.84)]}{10} = 1.715 \text{ square meters} = \textbf{17150 square centimeters}$$

Adults (Combined data for Male and Female):

As described earlier, EPA guidance appears to define the Adult as a person older than 21 years of age. The EFH reviews the latest NHANES empirical data on Total Body Surface Area and presents the recommended metadata for the Adult age group in Table 7-9;

21 to 30 years = 1.93 square meters
31 to 40 years = 1.97 square meters
41 to 50 years = 2.01 square meters
51 to 60 years = 2.00 square meters
61 to 70 years = 1.98 square meters

Calculated Weighted Mean =

$$\frac{[10(1.93) + 10(1.97) + 10(2.01) + 10(2.00) + 10(1.98)]}{50} = 1.978 \text{ square meters} = \textbf{19780 square centimeters}$$

Body Part-Specific Surface Area

In order to estimate surface area available for exposure, the estimates of Total Body Surface Area need to be combined with estimates of Body-Part Specific Surface Area for the age group under study.

The RAGS Part E document provides the most comprehensive recommendations for body part- specific surface areas for application to expected exposure scenarios:

Exhibit C-1: Body Part-Specific Surface Area Calculations (Children and Adult)

Mean Fractions of Total Body Surface Area attributed to Age-Weighted Body Part:

	Face	Neck	Arms	Forearms	Hands	Legs	Lower Legs	Feet
Children 1 to 6:	0.047	0.036	0.133	0.060	0.055	0.248	0.102	0.069
Children 7 to 11:	0.037	0.025	0.126	0.057	0.053	0.292	0.117	0.074
Teenager 12 to 21:	0.028	0.021	0.138	0.062	0.054	0.321	0.128	0.072
Adult 21 to 70:	0.022	0.016	NA	0.065	0.050	NA	0.131	0.067

Estimated Surface Areas for Exposure Scenarios

The above recommendations may be combined to provide estimated Dermal Surface Areas for application to various exposure scenarios.

1) Based on consultation with Michigan DEQ, Young Children engaged in play or recreational activity in the Maintained Residential Area and Residential Unmaintained Area are assumed to have the following body parts available for dermal exposure to soil:

Face, Neck, Forearms, Hands, and Lower Legs;

For Young Children age 1 through age 6, the calculated exposed Dermal Surface Area is:

[(0.047 + 0.036 + 0.060 + 0.055 + 0.102)] x 6840 sq cm = **2052 square centimeters**;

2) Based on consultation with Michigan DEQ, Older Children engaged in play or recreational activity in the Maintained Residential Area and Residential Unmaintained Area are assumed to have the following body parts available for dermal exposure to soil:

Face, Neck, Forearms, Hands, Lower Legs and Feet;

For Older Children age 7 through 11, the calculated exposed Dermal Surface Area is:

[(0.037 + 0.025 + 0.057 + 0.053 + 0.117 + 0.074)] x 10800 sq cm = **3920 square centimeters**;

3) Based on consultation with Michigan DEQ, Teenagers engaged in play or recreational activity in the Maintained Residential Area and Residential Unmaintained Area are assumed to have the following body parts available for dermal exposure to soil:

Face, Neck, Forearms, Hands, Lower Legs and Feet;

For Teenagers, the calculated exposed Dermal Surface Area is:

[(0.028 + 0.021 + 0.062 + 0.054 + 0.128 + 0.072)] x 17150 sq cm = **6260 square centimeters**;

4) Based on consultation with Michigan DEQ, Adult residents engaged in any activity in the Maintained Residential Area and Residential Unmaintained Area are assumed to have the following body parts available for dermal exposure to soil:

Face, Neck, Forearms, Hands, and Lower Legs;

For Adults, the calculated exposed Dermal Surface Area is:

[(0.022 + 0.016 + 0.065 + 0.050 + 0.131)] x 19780 sq cm = **5618 square centimeters**;

5) Based on consultation with Michigan DEQ, Adult workers engaged in a work activity or attending a workplace in the Floodplain Area are assumed to have the following body parts available for dermal exposure to soil:

Face, Neck, Forearms, Hands;

For Adults, the calculated exposed Dermal Surface Area is:

[(0.022 + 0.016 + 0.065 + 0.050)] x 19780 sq cm = **3026 square centimeters**;

APPENDIX B Review of Body Weight Parameter for All Receptor Groups

There are four receptor groups which need Body Weight values selected for evaluation of the cancer risk and/or noncancer endpoint components of the Preliminary Remediation Goal (PRG) determinations. The Receptor Groups are designated as: Young Children, Older Children, Teenagers, and Adults. The following analysis reviews and calculates Body Weight parameters for all receptor groups expected to frequent the 8-Year Floodplain zone.

The primary EPA Superfund/OSWER recommendation and metadata documents to inform the Body Weight parameter are the following:

1) *Child-Specific Exposure Factors Handbook* (2008); Chapter 8: Body Weight
   Table 8-1 and 8-3: Recommended Values for Body Weight (Children)

2) *Exposure Factors Handbook* (2011); Chapter 8: Body Weight Studies
   Table 8-1 and Table 8-3: Recommended Values for Body Weight (Adults)

<u>Young Children</u> (Combined data for Male and Female):

Existing EPA guidance regards the youngest group of children capable of self-mobility to areas where soil contact could occur are between the ages of 1 year and up 6 years (EPA 2002).

Reference #1 above describes the U.S. EPA review of the National Health and Nutrition Examination Survey (NHANES) data (1999-2006) on Body Weight and presents the recommended metadata by age groups in Tables 8-1 and 8-3;

1 to 2 years = 11.4 kilograms
2 to 3 years = 13.8 kilograms
3 to 6 years = 18.6 kilograms

Calculated Weighted Mean =

$$\frac{11.4 + 13.8 + 18.6 + 18.6 + 18.6}{5} = 16.2 \text{ kilograms}$$

<u>Older Children</u> (Combined data for Male and Female):

Older Children are included in this evaluation because it is probable that would they be the child receptor group making the most frequent visits to the “Non-Maintained” portions of properties within the 8-Year Tittabawassee River Floodplain including accessible areas along the River front.   Although this group does not appear to be formally defined in EPA guidance, available EPA data on age differences would suggest an age range of 7 years through 11 years.

Reference #1 above describes the U.S. EPA review of the NHANES data (1999-2006) on Body Weight and presents the recommended metadata by age groups in Table 8-1 and 8-3;

For this age range, only a single Body Weight estimate is available:

7 to 11 years = 31.8 kilograms

Teenagers (Combined data for Male and Female):

Existing EPA guidance does not appear to define a specific age range for a Teenager receptor group. The EPA Exposure Factors Handbook (2011) and the EPA Child-Specific Exposure Factors Handbook (2008) appear to define the "Adult" receptor as anyone older than 21 years. Therefore, the Teenager will be defined for this review as the receptor group in the age range of 12 through 20 years old.

Reference #1 above describes the U.S. EPA review of the NHANES data (1999-2006) on Body Weight and presents the recommended metadata by age groups in Table 8-1 and 8-3;

12 to 16 years = 56.8 kilograms
17 to 20 years = 71.6 kilograms

Calculated Weighted Mean =

$$\frac{[5(56.8) + 4(71.6))}{9} = 63.4 \text{ kilograms}$$

Adults (Combined data for Male and Female):

As described earlier, EPA guidance appears to define the Adult as a person older than 21 years of age.

Reference #2 above describes the U.S. EPA review of the NHANES data (1999-2006) on Body Weight for Adults and presents the recommended metadata by age groups in Table 8-1 and 8-3;

21 to 30 years = 78.4 kilograms
31 to 40 years = 80.8 kilograms
41 to 50 years = 83.6 kilograms
51 to 60 years = 83.4 kilograms
61 to 70 years = 82.6 kilograms

Weighted Mean =

$$\frac{(78.4 + 80.8 + 83.6 + 83.4 + 82.6)}{5} = 81.8 \text{ kilograms}$$

NOTE: In the Adult body weight evaluation above, the high end of Adult age is truncated at 70 years because the calculation of Lifetime Average Daily Dose (LADD) is defined to correspond to a lifetime age of 70 years. The LADD is a parameter needed to calculate the cancer risk component of a PRG value [Reference: *Risk Assessment Guidance for Superfund*; Part A and Part B (1989; 1991)].

APPENDIX C Calculation of the Soil PRG for Maintained Residential Land

For potential exposure of a child resident to D/F on Maintained Residential Land, the recommended PRG is based on a Hazard Quotient not exceeding a value of 1. For evaluating the non-cancer risk endpoint, this is the land use type for which the sensitive young child receptor (i.e., age up to 6 years) is expected to experience the highest Average Daily Dose (ADD) due to direct contact soil exposure (see Section 2.3).

To obtain a Hazard Quotient of 1.0, the following relationship holds:

$$HQ = 1 = \frac{\text{Average Daily Dose (ADD)}}{\text{Reference Dose (RfD)}} = \frac{0.7 \text{ pg/kg-day}}{0.7 \text{ pg/kg-day}}$$

Based on the above relationship, the allowable ADD may be equated to an allowable RfD. For Maintained Residential Land along the river floodplain, the total soil contact exposure to the receptor is the sum of two components, exposure to the fixed dust concentration and exposure to soil (see Section 2.4.2). That relationship is represented in terms of an allowable RfD as follows:

Allowable RfD = RfD(fixed dust) + RfD(soil)

0.7 pg/kg-day = RfD(fixed dust) + RfD(soil)

RfD(fixed dust) is calculated as:

RfD(fixed dust) = RfD(dust-ingestion) + RfD(dust-dermal)

RfD(dust-ingestion) = RfD(dust-ingestion-indoor days) + RfD(dust-ingestion-outdoor days)

RfD(dust-ingestion) =

$$\frac{FD \times EF_{ID} \times ED \times IR \times RBA \times CF}{BW \times AT_{nc}} + \frac{FD \times EF_{OD} \times ED \times IR \times fCR_{dust} \times RBA \times CF}{BW \times AT_{nc}}$$

RfD(dust-dermal) = RfD(dust-dermal-indoor days) + RfD(dust-dermal-outdoor days)

RfD(dust-dermal) =

$$\frac{FD \times EF_{ID} \times ED \times SSA \times AF \times ABS \times CF}{BW \times AT_{nc}} + \frac{FD \times EF_{OD} \times ED \times fCR_{dust} \times SSA \times AF \times ABS \times CF}{BW \times AT_{nc}}$$

Where:

FD = 50 ng/kg (Fixed Dust concentration)

EF_{ID} = 90 days/year (Exposure Frequency – Indoor Days)

EF_{OD} = 260 days/year (Exposure Frequency – Outdoor Days)

ED = 5 years (Exposure Duration)

fCR_{dust} = 0.55 (Dust Fraction of Contact Rate for combined soil-dust exposure)

IR = 200 mg/day (Ingestion Rate for soil + dust)

RBA = 0.43 (Oral Relative Bioavailability for D/F soil)

CF = 0.001 (Units Conversion Factor)

SSA = 2052 cm^2 (Skin Surface Area Exposed)

AF = 0.2 mg/cm^2 (Dermal Adherence Factor for soil)

ABS = 0.02 (Dermal Absorption Efficiency for D/F in soil)

BW = 16.2 kg (Body Weight of child)

AT_{nc} = 1825 days (Averaging Time for non-cancer endpoint)

Then:

RfD(fixed dust) = RfD(dust-ingestion) + RfD(dust-dermal)

RfD(fixed dust) = (0.065 + 0.104) + (0.006 + 0.010) = 0.185 pg/kg-day

Then:

Allowable RfD(soil) = 0.7 pg/kg-day - 0.185 pg/kg-day = 0.515 pg/kg-day

Then:

$$\text{PRG (Soil)} = \frac{\text{THQ} \times \text{RfD}_{soil} \times \text{AT}_{nc} \times \text{BW} \times \text{RSC} \times \text{CF1} \times \text{CF2}}{(\text{EF} \times \text{ED}) \times [(\text{fCR}_{soil} \times \text{IR} \times \text{RBA}) + (\text{fCR}_{soil} \times \text{SSA} \times \text{AF} \times \text{ABS})]}$$

PRG (Soil) = 276 ng/kg (276 parts per trillion)

Where:

PRG (Soil) = Preliminary Remediation Goal Concentration for Soil (ng/kg)

THQ = 1 (Target Hazard Quotient)

RfD(soil) = 0.515 pg/kg-day (Allowable RfD for deriving soil PRG)

AT_{nc} = 1825 days (Averaging Time for non-cancer endpoint)

BW = 16.2 kg (Body Weight of child)

RSC = 1 (Relative Source Contribution)

CF1 = 1.0E+06 mg/kg (Units Conversion Factor #1)

CF2 = 1.0E-03 ng/pg (Units Conversion Factor #2)

RSC = 1 (Relative Source Contribution)

EF = 260 days/year (Exposure Frequency)

ED = 5 years (Exposure Duration)

fCR_{soil} = 0.45 (Soil Fraction of Contact Rate for combined soil-dust exposure)

IR = 200 mg/day (Ingestion Rate for soil + dust)

RBA_{oral} = 0.43 (Oral Relative Bioavailability for D/F soil)

SSA = 2052 cm^2 (Skin Surface Area Exposed)

AF = 0.2 mg/cm^2-day (Dermal Adherence Factor for soil)

ABS = 0.02 (Dermal Absorption Efficiency for D/F in soil)