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TABLES (G-6) - EXPOSURE POINT CONCENTRATIONS

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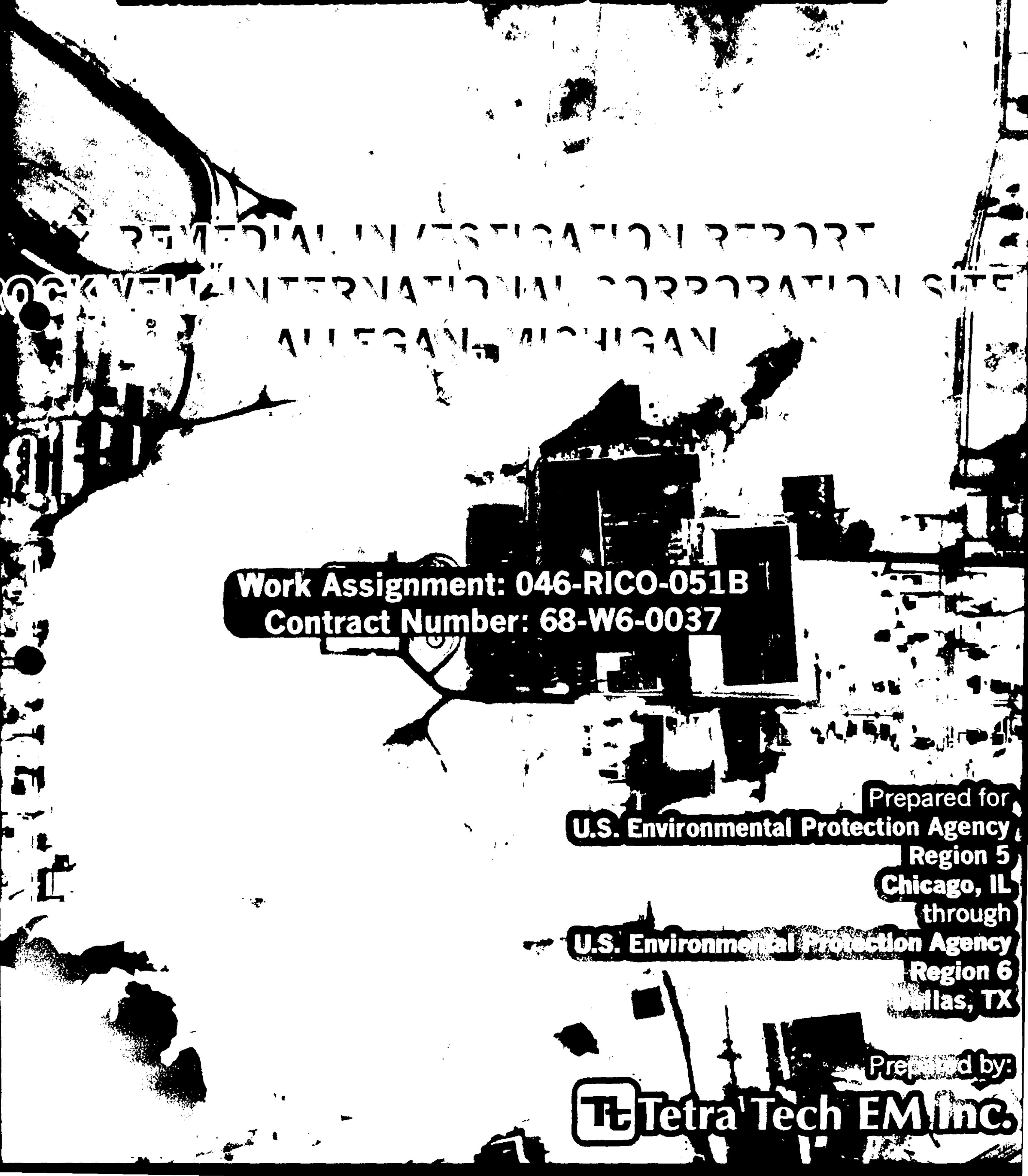
VOLUME 2 of 5

EPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

"...TO PROTECT HUMAN HEALTH AND SAFEGUARD THE NATURAL ENVIRONMENT..."



REMEDIAL INVESTIGATION REPORT
ROCKWELL INTERNATIONAL CORPORATION SITE
ALLEGAN, MICHIGAN

Work Assignment: 046-RICO-051B
Contract Number: 68-W6-0037

Prepared for
U.S. Environmental Protection Agency
Region 5
Chicago, IL
through
U.S. Environmental Protection Agency
Region 6
Dallas, TX

Prepared by:
Tetra Tech EM Inc.

ATTACHMENT

MDEQ COMMENTS ON DRAFT HHRA DATED MAY 9, 2001

(Nine Sheets)

JOHN ENGLER, Governor
DEPARTMENT OF ENVIRONMENTAL QUALITY
"Better Service for a Better Environment"
HOLLISTER BUILDING, PO BOX 30473, LANSING MI 48909-7973
INTERNET www.deq.state.mi.us
RUSSELL J. HARDING, Director

REPLY TO
ENVIRONMENTAL RESPONSE DIVISION
KNAPPS CENTRE
PO BOX 30426
LANSING MI 48909-7926

Received 5/13/01

May 9, 2001

Ms. Terese VanDonsel
United States Environmental Protection Agency
Region V
77 West Jackson Boulevard
Chicago, Illinois 60604

Dear Ms. VanDonsel:

Thank you for the opportunity to review the April 2001 Rockwell International Draft Human Health Risk Assessment by Tetra Tech. In addition to my own comments, I have included comments from Mr. Jeff Crum, one of the Environmental Response Division toxicologists.

If you have any questions regarding these comments, please do not hesitate to contact me.

Sincerely,

Mary B. Schafer

Mary B. Schafer, Project Manager
Superfund Section
Environmental Response Division
517-373-9832

Attachment

cc: Mr. David Kline, MDEQ
Mr. Matt Williams, MDEQ
Rockwell Files

EQP 0100e
(Rev 1/90)

Cover page- The United States Environmental Protection Agency Chicago and Michigan are all part of Region V not Region 6. Please correct the error in the notations on the cover page and anywhere else it may exist.

Page G-2-4 Section 2.2.1 first paragraph
Part 201 includes criteria. Please utilize the applicable Michigan Department of Environmental Quality (MDEQ) criteria where appropriate. Mr. Matt Williams, MDEQ, has provided tables to assist in this activity. The MDEQ may be able to come up with additional criteria if needed; please inquire if it becomes difficult to determine appropriate criteria

Page G-2-4 Section 2.2.1 third paragraph
Detections of contaminants at levels above the health based screening levels (HBSLs) should not be considered outliers without additional sampling to verify the scarcity of the contaminants on site.

Page G-2-5 Section 2.2.2 first paragraph
This paragraph states that the soils screening criteria were used for the LNAPL. This is not acceptable. The LNAPL is on the water table and discharges to the Kalamazoo River. The proper screening criteria would be the groundwater/surface water interface (GSI) criteria.

Page G-2-5 Section 2.2.2 third paragraph
The practice of using specific gravity and density values to get the LNAPL concentrations is not a well-known practice. Please reference the source of this derivation and expand the discussion to include areas in which this is commonly done.

PageG-2-5 Section 2.2.3 first paragraph
If a part 201 criterion is not available, provide the MDEQ with a list often the criteria can be generated for individual cases. Also see the table provided by Matt Williams.

Page G-2-6 Section 2.2.3 second paragraph
Please explain why the polynuclear aromatic hydrocarbons were excluded, even though they were regularly detected in soil.

Page G-2-6 Section 2.2.3 fourth paragraph
Please explain why the mercury blanks were contaminated. Additional samples may be necessary for useable data. If a sample comes back as a non-detect, then one half the detection limit is generally used not one half of the contract required detection list. Please utilize the recently provided screening levels and recalculate the percentage of unacceptable data blanks, then a determination can be made about the usefulness of this data.

Page G-2-7 Section 2.2.4 first paragraph
As discussed in our conference call, please use the GSI criteria where available and residential drinking water after that etc. per our discussion and provided table.

Page G-2-7 Section 2.2.4 second paragraph
Some of the contaminants discussed here are likely breakdown products of polychlorinated biphenyls, or possibly chemicals used on site but not previously identified in samples. The recent sampling events have revealed a lot of contamination that we were not aware of before. It is not acceptable to screen out contaminants at this stage with limited data for decision making. We need to at least wait until all of the Earthtech information is available before making decisions.

Page G-2-7 Section 2.2.5 second paragraph
Utilization of sample quantitation limits above HBSLs is not acceptable. Please utilize MDEQ Part 201 criteria instead.

Page G-2-9 Section 2.3.1 fifth paragraph
Some of the contaminants that were excluded as chemical of potential concerns were previously thought to be site contaminants. The step of screening to more conservative criteria should not be done prior to the completion of a final and approved remedial investigation document and really ought to wait until the feasibility study stage since the purpose of risk assessment (RA) is to scrutinize all the risks and determine hazards.

Page G-2-9 and 10 Section 2.3.1 fifth paragraph
The "background" concentrations referred to here are not all acceptable data points. Please provide acceptable background criteria prior to performing any additional screening and rescreen the data properly. Also, please refer to Part 201 criteria for GSI as discussed previously. Several of the sediment and surface water chemical of potential concerns are inappropriately excluded in this section. Please correct this error.

Page G-2-12 Section 2.3.1 11th and 12th paragraph
It is not acceptable to exclude any contaminants detected above HBSLs. Particularly when they have been detected above HBSLs in more than one media. Please correct this error.

Page G-2-14 Section 2.3.1 Essential nutrients paragraphs
All of the recommended dietary allowances should be scaled to the child exposure to be protective of the children in each exposure scenario. There may be something else to be concerned about that is causing all of the nutrients to be elevated to significantly. This should be looked into. This portion of the human health risk assessment is not very clear. One almost has to do the calculations to make sense of the information in this section. Please present it in a format that is more easily understood.

Page G-3-4 Section 3.2.1 bullets
Please include a bullet to include the significant amount of unknown contamination now understood to extend under a large part of the manufacturing building. Also, please add a bullet to include the green fluids discovered in Earthtech's investigative work.

Page G-3-10 Adult and off-site residents
Please modify the off-site designation when referring to the residents across North Street. The National Priority List defines the site by extent of contamination. A less confusing designation might be "off-property".

Page G-3-11 Recreationalists
Fish data for the river near this site may be easily found in any of the six information repositories for the Kalamazoo River Superfund site. This may be a useful tool to utilize.

Page G-5-5 Section 5.2.1 first paragraph
The C&O railroad tracks are referred to in the second sentence. Please refer to this area as the former C&O railroad bed, since the tracks are no longer there.

Page G-5-14 Section 5.2.2.2
The area under and north of the former West Manufacturing building has not been adequately defined prior to these calculations being performed. Please incorporate all additional data that is available prior to the issuance of the record of decision for this site. Also, the off-site residential area (background soil) is not clear. The residences across North Street from the property are now "on-site" as defined in the NCP. We may want to use a more palatable term for the residents, but referring to it as "off-site" is not acceptable. Also if this section applies to the residences across North Street from the property, then the utilization of these samples for background is not appropriate.

Page G-5-27 Section 5.4 second paragraph
The LNAPL most definitely extends beneath the building. Why is the LNAPL not addressed in the indoor air segment of this document? Please explain this exemption.

Page G-5-28 Section 5.5.1
Scenario of the groundwater for use as a drinking water source must be addressed in the RA. There is not currently any ordinance or deed restriction placed on the aquifer. There is also potential for the nearby municipal well to be contaminated by the narrow gravel layer from which it draws its water one half mile away from the site. The layer also runs under this site and is contaminated. This needs further investigation and also needs to be addressed in the RA.

Page G-6-2 Section 6.1 fifth paragraph
The previous investigative work was not complete enough to justify assumptions of a chemical not being a site-contaminant based on that. There is potential for hexavalent chrome contamination at the site. It is not appropriate to screen out this possibility prior to the completion of the RA. The additional data gap work being performed by the state district staff includes hex chrome. Please withhold making opinion statements about it until the data is back from the lab.

Page G-6-3 Section 6.2 second paragraph
The assessment of only the parking lot attendant for exposure in the parking lot misses the children at the fairgrounds. It is very common for children to run around barefoot, wade in the river, and for people to stay back at tailgating parties after fairground events. This exposure scenario has not been adequately addressed.

Table G-2 Page 1
Please modify this table. These samples are not acceptable for background calculations.

Table G-3
Please perform additional investigation as to what would cause the chemistry to shift in such a way as to make more of the nutrients soluble/mobile in the site groundwater. These are unusually high concentrations of parameters that are not normally considered to be a problem unless the concentrations are extremely elevated. This could be indicative of a chemistry-altering problem associated with the site. Otherwise, these nutrients are still above the Part 201 criteria and need to be addressed.

Table G-4
This table is not very useful without the detection limits or at least number of samples with the parameter detected in it. Please modify this table to incorporate this necessary information.

Table G-A-1
Please revise the screening levels in this table and specify which health-based criteria are used.

Table G-A-2
In the review of this document it has become a problem that there are no maps showing the locations of the samples referenced in the text and tables. Please provide figures or one oversized map to show sample locations.

Table G-A-4
Please revise this table and any other text or tables in the document to properly reference the samples that were taken as background. Only two samples were potentially acceptable as background samples, the others belong with the rest of the samples taken as site data.

Table G-B-1
Please correct the reference to background concentrations as discussed in the screening levels conference call. Whatever background criteria are utilized, the source needs to be properly referenced in each table.

Figure G-C-1
The numbers and key are all wrong. Please correct this figure.

Page G-C-24
Please include an exposure assessment for nearby residents during the construction phase. This area does not seem to be well characterized.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

May 9, 2001

TO: Mary Schafer, Superfund Section, Environmental Response Division (ERD)

FROM: Jeffrey A. Crum, Toxicology Specialist, Toxicology Unit, ERD

SUBJECT: Rockwell International Corporation: Review of Draft Human Health Risk Assessment (HHRA)

I have completed a review of the above document prepared by Tetra Tech EM Inc. (TT). The information and calculations presented in the HHRA are enormous. Given my current priorities and workload I was unable to conduct an in-depth detailed review that this amount of material requires. As a result, it is difficult for me to judge the effect that my comments would have on the reported risk estimates for the numerous exposure scenarios evaluated. On projects of this magnitude, and for all Superfund HHRAs, it is the Environmental Protection Agency's (EPA) recommendation to involve the risk assessors and risk assessment reviewers throughout the process to facilitate development of a scientifically sound report and increase the timeliness of preparation and review of the report. Please consider this for future projects.

Still, TT provided a very organized and comprehensive report. In summary, I have concern with completely ignoring past data that exists for the site, particularly that from the mid 90's; weakness in documenting (i.e., showing) the procedures used to derive exposure point concentrations (EPCs); and use of EPA or Michigan Department of Environmental Quality (MDEQ) guidance interpreted incorrectly or that is outdated (e.g., converting inhalation toxicity values to oral toxicity values). My specific comments are listed below.

<u>Pg. G-2-1 (Section 2.1 Data Collection)</u>
I cannot concur with TT's decision to use only data collected by them for conducting the HHRA. In accordance with EPA risk assessment guidance for Superfund sites (EPA, 1989) the rationale for not evaluating and including past data, which is substantial for this site, must be fully discussed in the HHRA. Justification for elimination of any data sets from the HHRA must be fully described in the report.

<u>Pg. G-2-3 (Section 2.2 Data Evaluation)</u>
It is not appropriate to use subsurface soil moisture content data as a surrogate for surface soil. It is well documented that moisture content varies as a function of depth. This application can have a significant effect on the transport modeling of contaminant volatile hazardous substances (HS) from surface soil to ambient air.

<u>Pg. G-2-4 (Section 2.2.1 Data Evaluation of Soil Sampling Results)</u>
<u>Pg. G-2-7 (Section 2.2.4 Data Evaluation of Surface Water Sampling Results)</u>
In the above sections a statement is made indicating that elevated sample quantitation limits (SQLs) above health-based screening levels (HBSLs) are unlikely to result in underestimation of risk. TT suggests that when SQLs were below HBSLs chemicals were not detected above HBSLs and therefore that for the cases where SQLs were above HBSLs it is unlikely that concentrations would be present above HBSLs. I am not confident of this reasoning given the

uneven distribution of source areas and the lack of spatial correlation in chemical concentrations observed in the current and past data sets.

Pg. G-2-10 (Section 2.3.1 COPC Selection Process)
The use of a concentration-toxicity screen in conjunction with detection frequency for identifying chemicals of potential concern (COPC) cannot be accepted. An HS reported at concentrations above applicable Part 201 generic cleanup criteria for the relevant land use category is generally considered a COPC. Professional judgment in some cases may be used to justify elimination of an HS as a COPC if the immediate surrounding area contains no detections of the HS in question, and the sample location of concern contains a concentration of the HS that is not markedly above criteria.

Pg. G-2-15 (Section 2.3.1 Evaluation of Essential Nutrients)
This comment does not relate to essential nutrients. Rather, it is pertinent to the statement that future residents will likely obtain drinking water from the city of Allegan, not on-site groundwater. Assessment of future risk to residents from use of groundwater for drinking water must be included in the HHRA unless there is an institutional control such as a municipal ordinance that prohibits residents from installing drinking water wells.

Pg. G-3-8 (Section 3.2.2 Potential Receptor and Exposure Pathways)
The statement is made that volatilization of Volatile Organic Compounds (VOCs) from soil was not evaluated as a potential exposure pathway because VOCs were not detected in ***surface*** soil. VOC results reported in Table G-A-1 do not support this statement. In addition, there was detection of VOCs in ***subsurface*** soil. As such, volatilization of VOCs from both surface and subsurface soil should be included as potential exposure pathways in the HHRA.

Pg. G-3-14 (Section 3.3.1 Exposure Point Concentrations)
Automatically assuming that data sets are lognormally distributed is not recommended after a normality test fails. Instead it is recommended that testing be performed for both a normal and lognormal distribution. The distribution that best fits the data set should be selected.

Pg. G-3-14 (Section 3.3.1 Exposure Point Concentrations)
Procedures Used to Calculate EPCs: The first paragraph under this section is confusing since the documentation prior to this section indicated that a lognormal distribution is assumed, yet in this section a lognormal distribution is noted as being possibly rejected.

Please have TT provide references supporting their method for determining a "percent equivalent" to the 95% UCL, or indicate that this is their own derivation. Also request the consultants to describe how non-detects were incorporated into this determination. All calculations used in the HHRA must be shown in the report.

Pg. G-3-20 (Section 3.3.2 Pathway-Specific Intake Equations and Exposure Parameters)
FI – Fraction Ingested: Because soil ingestion values (i.e., rates) are based on studies of individuals conducting activities indoors as well as outdoors, and a high percentage of indoor dust is comprised of outdoor soil, a default value of 1 is appropriate for all receptor scenarios that include this parameter.

Pg. G-3-20 (Section 3.3.2 Pathway-Specific Intake Equations and Exposure Parameters)
EF – Exposure Frequency: The MDEQ does not have guidance for EF values for off-site recreationalists or on-site visitors as indicated by TT. Please have the consultants explain the basis for the EF values of 145 and 73 days/year reported in this section. It is also confusing to

use different names for the same receptor population - off-site recreationalists and on-site visitor. I recommend that there may be on-site and off-site recreationalists.

Pg. G-3-21 (Section 3.3.2 Pathway-Specific Intake Equations and Exposure Parameters)
ED – Exposure Duration: TT states that the ED "for the reasonable maximum exposure value is the 90th percentile of this distribution (30 years for noncarcinogenic risk and 24 years for carcinogenic risk) (EPA 1991a)." The EPA guidance cited does not contain this recommendation. There is no basis for using a different ED for carcinogens and noncarcinogens, since this parameter is simply based on the time spent at one residence.

Pg. G-3-23 (Section 3.3.2 Pathway-Specific Intake Equations and Exposure Parameters)
ET – Exposure Time: Because intake rates, such as soil ingestion and adherence factor, are daily (24-hour) and event-specific measurements, it is not appropriate to include the parameter ET in the risk calculations.

Pg. G-3-23 (Section 3.3.2 Pathway-Specific Intake Equations and Exposure Parameters)
IW – Ingestion Rate for Drinking Water: A value of four ounces (0.125L/day) for this parameter is not a representative estimate for an on-site visitor who is characterized as partaking in activities such as ball playing or other likely sporting activities. Sixteen ounces seems more reasonable for these activities.

Pg. G-4-2 (Section 4.1 Toxicity Values for Noncarcinogenic COPC)
EPA no longer recommends conversion of inhalation toxicity values to oral-based toxicity values as shown in equations (G-15) and (G-16). Please direct TT to the appropriate equations presented in EPA's 1996 "Soil Screening Guidance: Technical Background Document", which supersedes the equations presented in EPA's 1991 document titled "Risk Assessment Guidance for Superfund (RAGS), Volume I. Human Health Evaluation Manual (HHEM), Part B."

Pg. G-5-15 (Section 5.2 Risk and Hazard Estimates)
Please have the consultants explain why the risk estimates for inhalation of indoor air are not included in the table for the on-site worker.

Pg. G-5-15 (Section 5.2 Risk and Hazard Estimates)
Again, please have the consultants explain why the risk estimates for inhalation of indoor air are not included in the table for the adult on-site resident.

Appendix G-C (Calculation of Particulate Emissions and Air Concentrations

Pg. G-C-2 (Section 1.0 Land-Use and Source-Area Assumptions)
Assuming that off-site residential property is completely vegetated is not appropriate, nor is assuming that future disturbances such as vehicle traffic will not occur. Is it also accurate that vehicle traffic does not occur on-site under current use?

Pg. G-C-5 Future Recreational Scenario
The listed "grass-covered" recreational uses such as ball fields and walking trails are very likely to have areas that are not grass-covered. Please have the consultants address this issue.

Park maintenance workers should be the receptor population to assess risk for particulate emission given the mowing and landscaping activities that will result in the greatest emission of contaminants and the fact that the workers will frequent the area to a greater extent than other subpopulations.

Pg. G-C-5 Future Residential Scenario
I do not agree that fugitive emissions are assumed to be solely due to wind erosion for this scenario. It is easily probable that two round trips in an unpaved driveway at a residence occur daily. It is not appropriate to eliminate the particulate emission exposure pathway under this scenario since unvegetated areas and unpaved driveways are common to many residential settings.

Pg. G-C-24 (Section 3.0 On-Site Particulate Emissions and Air Concentrations Resulting From Construction Activities)
It seems unlikely for a 30-acre residential development that workers will park their vehicles off-site. I recommend that particulate emission modeling and risk estimates be derived based on likely vehicle traffic for this scenario.

Pg. G-C-28 (Section 4.0 Off-Site Air Concentration Modeling)
I do not have the expertise to review EPA's SCREEN3 air dispersion model. I recommend that Craig Fitzner of the Air Quality Division be contacted for this review.

Appendix G-D (Indoor Air Concentrations of VOCs from Groundwater and Light Non Aqueous Phase Liquids)

Pg. G-D-8 (Section 2.1 Site-Specific Parameter Values)
The value of 10 feet assumed as an average groundwater depth is not consistent with many other places in the report which state values of 8 feet and a water table being encountered 1 to 7 feet below ground surface (bgs). Please have the consultants address these discrepancies.

Table G-D-3
Why is vinyl chloride (VC) not included in this table when chemical-specific parameter values were listed for VC in Table G-D-1?

This concludes my comments. Please feel free to contact me at 335-3092 with any questions.

cc: George Carpenter, ERD
Christine Flaga, ERD
Toxicology Unit, ERD

Jeffrey A. Crum

REFERENCES

EPA (U.S. Environmental Protection Agency). 1989. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. (Part A). Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002.

Attachment

TABLE G-15

SUMMARY OF GASTROINTESTINAL ABSORPTION EFFICIENCY VALUES (ABS_{GI}) AND RECOMMENDATIONS FOR ADJUSTMENT OF ORAL TOXICITY VALUES FOR SPECIFIC COMPOUNDS[a]

Compound	ABS_{GI} (%)	Reference[b]	Adjustment Required?
Inorganics			
Arsenic	95	Bettley and O'Shea 1975	No
Barium	7 (aqueous)	Taylor and others 1962; Cuddihy and Griffith 1972	Yes
Cadmium	3-5 (food)	Ellis and others 1979 Morgan and Sherlock 1984	Yes
	5 (water)	McLellan and others 1978	Yes
Chromium (III)	1.3 (feed/aqueous)	Donaldson and Barreras 1996 Keim and others 1987	Yes
Copper	57	Strickland and others 1972	No
Cyanide	>47	Farooqui and Ahmed 1982	No
Manganese	6	Ruoff 1995	Yes
Insoluble or metallic mercury	<7	EPA 1997f	Yes
Nickel	4	Elakhovskaya 1972	Yes
Selenium	30 to 80	Young and others 1982	No
Silver	4	EPA 1997f	Yes
Thallium	100	Lie and others 1960	No
Vanadium	2.6	Conklin and others 1982	Yes
Zinc	Highly variable	Multiple references	No

Note:

a All gastrointestinal absorption efficiency values and associated recommendations and references were obtained from U.S. Environmental Protection Agency (EPA) Region 5 Dermal Workgroup Staff (Tetra Tech 1998c).

b The full citations for each reference are provided in the reference section of this report.

TABLE G-1

DATA GROUPINGS

Area of Interest	Area Description	Matrix	Sample Number
Background locations	Area east of River Street	Soil	RW-BG04-0507
		Sediment - school pond	RW-SD13-0000
		Sediment - Kalamazoo River	RW-SD11-0000
			RW-SD12-0000
			RW-SD28-0000
			RW-SD31-0000
		Surface water - school pond	RW-SW13-0000
		Surface water - Kalamazoo River	RW-SW11-0000 RW-SW12-0000
Former SOS pond area	Former SOS pond	Soil	RW-SB25-0002 RW-SB57-0002 RW-SB57-1416 RW-SB58-0002 RW-SB58-0204 RW-SB70-0002 RW-SB70-1012 RW-MB-011416
Former Rockwell WWTP area	Former interim pond; holding ponds 1, 2, and 3; and equalization and former waste oil tanks	Sediment	RW-SD14-0000 RW-SD15-0000 RW-SD16-0000 RW-SD17-0000
		Surface water	RW-SW14-0000 RW-SW15-0000
		Soil	RW-SB03-0406 RW-SB05-0002 RW-SB10-0002 RW-SB59-0002 RW-SB59-0810 RW-SB61-0002 RW-SB61-1315 RW-SB62-0002 RW-SB62-1012 RW-SB64-0002 RW-SB64-0204 RW-SB65-0002 RW-SB66-0002 RW-SB66-1214 RW-SB67-0002 RW-SB67-0406

TABLE G-1 (Continued)

DATA GROUPINGS

Area of Interest	Area Description	Matrix	Sample Number
Former railroad right-of-way (on-site)	Former oil flotation house; substation and quench oil tank area; pumphouse and former 10,000-gallon oil tanks; former fuel tank; chip and oil recovery system; and chip loading facility	Soil	RW-SB29-0002 RW-SB31-0002 RW-SB35-0406 RW-SB54-0002 RW-SB54-0810 RW-SB55-0002 RW-SB55-0406 RW-SB56-0002 RW-SB56-0406 RW-SB74-0002 RW-SB74-0406
Grassy area	Area east of former railroad right-of-way	Soil	RW-SB45-0608 RW-SB47-0002 RW-SB50-0002 RW-SB72-0002 RW-SB72-0204 RW-SB73-0002 RW-SB73-0204
Area under and north of the former west manufacturing building	Machinery pits, floor drains, former backwater area under and north of building; and other areas of known or suspected liquid waste deposition	Soil	RW-SB60-0002 RW-SB60-1315 RW-SB68-0002 RW-SB68-0406 RW-SB69-0002 RW-SB69-0406 RW-SB71-0002 RW-SB71-0406 RW-MB-120406 RW-MB-18C

TABLE G-1 (Continued)

DATA GROUPINGS

Area of Interest	Area Description	Matrix	Sample Number
On-site groundwater	Not applicable	Groundwater	RW-GW-MW1 RW-GW-MW2B RW-GW-MW4C RW-GW-MW4B RW-GW-MW5B RW-GW-MW5A RW-GW-MW7 RW-GW-MW11 RW-GW-MW13 RW-GW-MW18 RW-GW-MW19I RW-GW-MW19D RW-GW-MW20 RW-GW-MW21 RW-GW-MW22 RW-GW-MW23S RW-GW-MW23I RW-GW-MW23D RW-GW-MW26 RW-GW-MW27S RW-GW-MW27I RW-GW-MW27D RW-GW-MW28S RW-GW-MW29S
		LNAPL	RW-GW-MW1 RW-GW-MW4A RW-GW-MW-10 RW-GW-MW19S RW-GW-MW30S
Saturated zone beneath former City of Allegan landfill	Saturated zone beneath former City of Allegan landfill	Groundwater	RW-GW-MW15 RW-GW-MW16
Former railroad right of way (off-site)	Includes the area south of the Rockwell property line	Soil	RW-SB40-0406 RW-SB43-0002 RW-SB53-0002 RW-SB53-0406 RW-SB53-0810
		Groundwater	RW-GW-MW14 RW-GW-MW24I RW-GW-MW24D RW-GW-MW25S RW-GW-MW25I RW-GW-MW25D
		LNAPL	RW-GW-MW-24S

TABLE G-1 (Continued)

DATA GROUPINGS

Area of Interest	Area Description	Matrix	Sample Number
Off-site soil	Area east of River Street, excluding background locations	Soil	RW-BG01-0002 RW-BG01-0608 RW-BG03-0002 RW-BG03-0406 RW-BG04-0002
Kalamazoo River	Downstream along shoreline	Sediment	RW-SD01-0000 RW-SD02-0000 RW-SD03-0000 RW-SD04-0000 RW-SD05-0000 RW-SD06-0000 RW-SD07-0000 RW-SD08-0000 RW-SD09-0000 RW-SD10-0000 RW-SD18-0000 RW-SD25-0000 RW-SD26-0000 RW-SD27-0000 RW-SD29-0000 RW-SD30-0000
		Surface water	RW-SW01-0000 RW-SW02-0000 RW-SW03-0000 RW-SW04-0000 RW-SW05-0000 RW-SW06-0000 RW-SW07-0000 RW-SW08-0000 RW-SW09-0000 RW-SW10-0000

Notes:

LNAPL = Light nonaqueous-phase liquid
Rockwell = Rockwell International Corporation
SOS = Soluble oil separation
WWTP = Wastewater treatment plant

TABLE G-2

CHEMICALS DETECTED IN AT LEAST ONE MEDIUM-SPECIFIC SAMPLE

Soil				
VOCs	**SVOCs**	**Metals**	**PCBs and Pesticides**	**Dioxins and Furans**
Acetone	Acenaphthene	Aluminum	Aldrin	1,2,3,6,7,8-HxCDD
Bromoform	Acenaphthylene	Antimony	beta-BHC	1,2,3,7,8,9-HxCDD
Bromomethane	Benzaldehyde	Arsenic	delta-BHC	1,2,3,4,6,7,8,-HpCDD
2-Butanone	Benzo(a)anthracene	Barium	gamma-BHC	OCDD
Carbon disulfide	Benzo(a)pyrene	Beryllium	alpha-Chlordane	2,3,7,8-TCDF
Chlorobenzene	Benzo(b)fluoranthene	Cadmium	gamma-Chlordane	1,2,3,7,8-PeCDF
cis-1,2-Dichloroethene	Benzo(g,h,i)perylene	Calcium	4,4'-DDD	2,3,4,7,8-PeCDF
Cyclohexane	Benzo(k)fluoranthene	Chromium	4,4'-DDE	1,2,3,4,7,8-HxCDF
1,2-Dichlorobenzene	1,1'-Biphenyl	Cobalt	4,4'-DDT	1,2,3,6,7,8-HxCDF
1,4-Dichlorobenzene	bis(2-Ethylhexyl)phthalate	Copper	Dieldrin	2,3,4,6,7,8-HxCDF
Ethylbenzene	Carbazole	Iron	Endosulfan I	1,2,3,4,6,7,8-HpCDF
2-Hexanone	Chrysene	Lead	Endosulfan II	1,2,3,4,7,8,9-HpCDF
Methyl acetate	Dibenzo(a,h)anthracene	Magnesium	Endosulfan sulfate	OCDF
Methylcyclohexane	Dibenzofuran	Manganese	Endrin	
4-Methyl-2-pentanone	Diethylphthalate	Mercury	Endrin aldehyde	
Tetrachloroethene	Dimethylphthalate	Nickel	Endrin ketone	
Toluene	Di-n-butylphthalate	Potassium	Heptachlor	
Trichloroethene	Fluoranthene	Selenium	Heptachlor epoxide	
Xylenes (total)	Fluorene	Silver	Methoxychlor	
	2-Methylnaphthalene	Sodium	Toxaphene	
	2-Methylphenol	Thallium	Aroclor 1248	
	4-Methylphenol	Vanadium	Aroclor 1254	
	Naphthalene	Zinc	Aroclor 1260	
	Phenanthrene	Cyanide		
	Pyrene			

Light Nonaqueous-Phase Liquid			
VOCs	**SVOCs**	**Metals**	**PCBs and Pesticides**
Acetone	Acenaphthene	Aluminum	4,4'-DDD
Benzene	Benzo(a)pyrene	Antimony	4,4'-DDE
2-Butanone	Benzo(g,h,i)perylene	Arsenic	Endosulfan II
Chlorobenzene	Benzo(k)fluoranthene	Barium	Endrin
Chloromethane	bis(2-Ethylhexyl)phthalate	Calcium	Endrin aldehyde
1,2-Dichloroethene	Chrysene	Chromium	Heptachlor epoxide
Ethylbenzene	Dibenzo(a,h)anthracene	Copper	Methoxychlor
2-Hexanone	Dibenzofuran	Iron	Aroclor 1254
Methylene chloride	1,2-Dichlorobenzene	Lead	
4-Methyl-2-pentanone	1,3-Dichlorobenzene	Magnesium	
Tetrachloroethene	1,4-Dichlorobenzene	Manganese	
Toluene	Fluoranthene	Nickel	
Trichloroethene	Fluorene	Sodium	
Xylenes (total)	2-Methylnaphthalene	Vanadium	
	Naphthalene	Zinc	
	Phenanthrene		

TABLE G-2 (Continued)

CHEMICALS DETECTED IN AT LEAST ONE MEDIUM-SPECIFIC SAMPLE

Groundwater				
VOCs	**SVOCs**	**Metals**	**PCBs and Pesticides**	**Dioxins and Furans**
Acetone	No detections	Aluminum	gamma-Chlordane	OCDD
Benzene		Antimony	4,4'-DDD	
2-Butanone		Arsenic	4,4'-DDE	
Chlorobenzene		Barium	Dieldrin	
Chloroethane		Beryllium	Endosulfan II	
Chloroform		Cadmium	Endrin	
cis-1, 2- Dichloroethene		Calcium	Endrin ketone	
1,2-Dichlorobenzene		Chromium	Heptachlor	
1,4-Dichlorobenzene		Cobalt	Heptachlor epoxide	
1,1-Dichoroethane		Copper	Methoxychlor	
1,2-Dichloroethene		Iron	Aroclor 1248	
Ethylbenzene		Lead	Aroclor 1254	
Styrene		Magnesium		
Tetrachloroethene		Manganese		
Toluene		Mercury		
trans-1, 2-Dichloroethene		Nickel		
Trichloroethene		Potassium		
1,1,1-Trichloroethane		Selenium		
Vinyl chloride		Silver		
Xylenes (total)		Sodium		
		Thallium		
		Vanadium		
		Zinc		
		Cyanide		

Sediment				
VOCs	**SVOCs**	**Metals**	**PCBs and Pesticides**	**Dioxins and Furans**
Acetone	Acenaphthene	Aluminum	delta-BHC	2,3,7,8-TCDD
Benzene	Acenaphthylene	Arsenic	Heptachlor	1,2,3,6,7,8-HxCDD
Carbon disulfide	Acetophenone	Barium	Dieldrin	1,2,3,7,8,9-HxCDD
Chlorobenzene	Anthracene	Cadmium	4,4'-DDE	1,2,3,4,6,7,8,-HpCDD
Cyclohexane	Benzaldehyde	Calcium	4,4'-DDD	OCDD
1,2-Dichlorobenzene	Benzo(a)anthracene	Chromium	Aroclor 1242	2,3,7,8-TCDF
Ethylbenzene	Benzo(a)pyrene	Cobalt	Aroclor 1248	1,2,3,4,7,8-HxCDF
2-Hexanone	Benzo(b)fluoranthene	Copper	Aroclor 1254	1,2,3,6,7,8-HxCDF
Isopropylbenzene	Benzo(g,h,i)perylene	Iron		2,3,4,6,7,8-HxCDF
Methylcyclohexane	Benzo(k)fluoranthene	Lead		1,2,3,4,6,7,8-HpCDF
Methylene chloride	1,1'-Biphenyl	Magnesium		OCDF
Toluene	Carbazole	Manganese		
Xylenes (total)	Chrysene	Mercury		
	Dibenzo(a,h)anthracene	Nickel		
	Dibenzofuran	Potassium		
	Fluoranthene	Selenium		
	Pyrene			

TABLE G-2 (Continued)

CHEMICALS DETECTED IN AT LEAST ONE MEDIUM-SPECIFIC SAMPLE

Surface Water				
VOCs	**SVOCs**	**Metals**	**PCBs and Pesticides**	**Dioxins and Furans**
Acetone Benzene Bromodichloromethane Carbon disulfide Chlorobenzene Chloroform Cyclohexane 1,1-Dichloroethene Ethylbenzene Methylcyclohexane Methylene chloride Tetrachloroethane Toluene Trichloroethene Vinyl chloride Xylenes (total)	No detections	Aluminum Arsenic Barium Calcium Chromium Cobalt Copper Iron Lead Magnesium Manganese Nickel Potassium Selenium Silver Sodium Vanadium Zinc Cyanide	Heptachlor	Not analyzed

Notes:

HpCDD = Heptachlorodibenzo-p-dioxin
HpCDF = Heptachlorodibenzofuran
HxCDD = Hexachlorodibenzo-p-dioxin
HxCDF = Hexachlorodibenzofuran
OCDD = Octachlorodibenzo-p-dioxin
OCDF = Octachlorodibenzofuran
PCB = Polychlorinated biphenyl
PeCDF = Pentachlorodibenzofuran
SVOC = Semivolatile organic compound
TCDD = Tetrachlorodibenzodioxin
TCDF = Tetrachlorodibenzofuran
VOC = Volatile organic compound

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TABLE G-3

COMPARISON OF ESTIMATED ON-SITE TOTAL DAILY INTAKES AND REFERENCE INTAKES FOR CALCIUM, MAGNESIUM, AND SODIUM

Chemical	Maximum Detected Concentration (mg/kg or mg/L)	ADI[a] (mg/kg-day)		On-Site TDI[b] (mg/day)		Reference Intake (mg/day)	On-Site TDI_c/ Reference Intake (%)	On-Site TDI_a/ Reference Intake (%)
		Child Resident	Adult Resident	Child Resident (TDI_c)	Adult Resident (TDI_a)			
Soil								
Calcium	158,800	2.03	0.063	30.45	4.42	800[c] 800 to 1,200[c] **500 to 1,000[d]**	6	0.88
Magnesium	35,000	0.45	0.014	6.71	0.97	30[e] (infant only) **320 to 420[e]**	2	0.26
Groundwater								
Calcium	2,000,000	159,817	65,753	2,397,260	4,602,740	800[c] 800 to 1,200[c] **500 to 1,000[d]**	4,795	9,205
Magnesium	600,000	47,945	19,720	719,178	1,380,822	30[e] (infant only) **320 to 420[e]**	1,943	3,732
Sodium	2,980,000	200,000	100,000	4E+06	7E+06	**500[f]** 2,400[f] 4,000 to 6,000[g] 2,000 to 4,000[g] 1,100 to 3,300[h] 1,150 to 5,750[i]	8,000	14,000

Notes:

ADI = Average daily intake
mg/day = Milligram per day
mg/kg = Milligram per kilogram
mg/kg-day = Milligram per kilogram per day

TABLE G-3 (Continued)

COMPARISON OF ESTIMATED ON-SITE TOTAL DAILY INTAKES AND REFERENCE INTAKES FOR CALCIUM, MAGNESIUM, AND SODIUM

Notes: (Continued)

mg/L	=	Milligram per liter
TDI	=	Total daily intake

[a] ADIs were calculated based on incidental ingestion of soil. Appendix G-F presents the equation and input parameter values used.

[b] TDIs were calculated as ADI x body weight.

[c] Source: NAS 1998

[d] Source: NAS 1997

[e] Source: NAL 2001

[f] Source: USDA 1995

[g] Source: Healthtouch 1997

[h] Source: DCES 1998

[i] Source: Salt Institute 1998

TABLE G-4

SITEWIDE (ON-SITE)
MEDIUM-SPECIFIC COPCs

Soil		
SVOCs Naphthalene Phenanthrene	Pesticides and PCBs Dieldrin Endosulfan sulfate Endrin aldehyde Endrin ketone Aroclor 1254 Aroclor 1260	Metals Aluminum Arsenic Barium Cadmium Chromium Cobalt Copper Iron Lead Manganese Mercury Nickel Selenium Silver Zinc Cyanide

LNAPL		
VOCs Benzene Chlorobenzene 1,2-Dichloroethene Ethylbenzene Methylene chloride Tetrachloroethene Trichloroethene Xylenes	Pesticides and PCBs 4,4'-DDD 4,4'-DDE Endosulfan II Endrin Endrin aldehyde Heptaclor epoxide Aroclor 1254 SVOCs Acenaphthene Benzo(a)pyrene Dibenzo(a,h)anthracene Dibenzofuran 1,2-Dichlorobenzene 1,4-Dichlorobenzene Fluoranthene Fluorene Naphthalene Phenanthrene	Metals Aluminum Arsenic Barium Chromium Iron Lead Manganese Vanadium Zinc

TABLE G-4 (Continued)

SITEWIDE (ON-SITE) MEDIUM-SPECIFIC COPCs

Groundwater		
VOCs cis-1,2-Dichloroethene 1,1-Dichloroethane 1,2-Dichloroethene Tetrachloroethene Trichloroethene Vinyl chloride	Pesticides and PCBs 4,4'-DDD 4,4'-DDE Dieldrin Endosulfan II Endrin Aroclor 1254	Metals Aluminum Arsenic Barium Cadmium Chromium Cobalt Copper Iron Lead Manganese Mercury Nickel Selenium Silver Vanadium Zinc Cyanide

Sediment (On-Site Ponds)		
SVOCs Benzo(b)fluoranthene Note: Many SVOC detection limits for on-site pond sediment samples were above project-required quantitation limits.	Pesticides and PCBs Endosulfan sulfate Aroclor 1242 Aroclor 1254 Dioxins and Furans Total dioxins and furans	Metals Aluminum Arsenic Barium Cadmium Chromium Cobalt Copper Iron Lead Manganese Mercury Nickel Selenium Zinc

TABLE G-4 (Continued)

SITEWIDE (ON-SITE)
MEDIUM-SPECIFIC COPCs

Sediment (Off-Site)		
<u>SVOCs</u> Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene	<u>Pesticides and PCBs</u> Dieldrin Aroclor 1242 Aroclor 1248 Aroclor 1254 <u>Dioxins and Furans</u> Total dioxins and furans	<u>Metals</u> Aluminum Arsenic Barium Cadmium Chromium Cobalt Copper Iron Lead Manganese Mercury Nickel Selenium Silver Vanadium Zinc Cyanide

Surface Water (On-Site Ponds)	
<u>Metals</u>	
Aluminum	Lead
Arsenic	Manganese
Barium	Mercury
Chromium	Nickel
Copper	Zinc
Iron	

Surface Water (Off-Site)	
<u>VOCs</u> Benzene Trichloroethene	<u>Metals</u> Aluminum Barium Iron Lead Manganese Mercury Zinc Cyanide

Notes:

COPC = Chemical of potential concern
LNAPL = Light nonaqueous-phase liquid
PCB = Polychlorinated biphenyl
SVOC = Semivolatile organic compound
VOC = Volatile organic compound

TABLE G-5

AREA- AND MEDIUM-SPECIFIC COPCs

Former SOS Pond Area - Soil	
Metals	
Aluminum	Lead
Arsenic	Manganese
Barium	Mercury
Cadmium	Nickel
Chromium	Selenium
Cobalt	Zinc
Copper	Cyanide
Iron	

Former Rockwell WWTP Area - Soil		
Pesticides and PCBs	Metals	
Endosulfan sulfate	Aluminum	Iron
Endrin aldehyde	Arsenic	Lead
Aroclor 1254	Barium	Manganese
Aroclor 1260	Cadmium	Mercury
	Chromium	Nickel
	Cobalt	Selenium
	Copper	Zinc

Former Rockwell WWTP Area - Sediment (On-Site Ponds)		
SVOCs	Pesticides and PCBs	Metals
Benzo(b)fluoranthene	Endosulfan sulfate	Aluminum
	Aroclor -1242	Arsenic
	Aroclor -1254	Barium
Note:		Cadmium
Many SVOC detection limits for on-site pond sediment samples were above project-required quantitation limits.	Dioxins and Furans	Chromium
	Total dioxins and furans	Cobalt
		Copper
		Iron
		Lead
		Manganese
		Mercury
		Nickel
		Selenium
		Zinc

TABLE G-5 (Continued)

AREA- AND MEDIUM-SPECIFIC COPCs

Former Rockwell WWTP Area - Surface Water (On-Site Ponds)	
Metals	
Aluminum	Lead
Arsenic	Manganese
Barium	Mercury
Chromium	Nickel
Copper	Zinc
Iron	Cyanide

Former On-Site Railroad Right-of-Way - Soil	
Metals	
Aluminum	Iron
Arsenic	Lead
Barium	Manganese
Cadmium	Nickel
Chromium	Selenium
Cobalt	Zinc
Copper	Cyanide

Grassy Area - Soil		
SVOC	Pesticides and PCBs	Metals
Phenanthrene	Endosulfan sulfate	Aluminum
	Endrin aldehyde	Barium
	Endrin ketone	Chromium
	Aroclor 1254	Cobalt
		Copper
		Iron
		Lead
		Manganese
		Mercury
		Nickel
		Selenium
		Zinc

TABLE G-5 (Continued)

AREA- AND MEDIUM-SPECIFIC COPCs

Area Under And North of The Former West Manufacturing Building - Soil	
Pesticides	Metals
Endosulfan sulfate	Aluminum
Endrin aldehyde	Arsenic
	Barium
	Chromium
	Cobalt
	Copper
	Iron
	Lead
	Manganese
	Mercury
	Nickel
	Selenium
	Zinc
	Cyanide

Saturated Zone Beneath The Former City of Allegan Landfill - Groundwater
Metals
Cobalt
Iron
Lead
Mercury
Nickel
Silver
Vanadium

Former Off-Site Railroad Right-of-Way - Soil		
SVOC	Pesticides and PCBs	Metals
Naphthalene	Dieldrin	Aluminum
Phenanthrene	Endosulfan sulfate	Arsenic
	Endrin aldehyde	Barium
	Aroclor 1254	Cadmium
		Chromium
		Cobalt
		Copper
		Iron
		Lead
		Manganese
		Mercury
		Nickel
		Selenium
		Zinc
		Cyanide

TABLE G-5 (Continued)

AREA- AND MEDIUM-SPECIFIC COPCs

Former Off-Site Railroad Right-of-Way - LNAPL	
VOCs Ethylbenzene Tetrachloroethene Trichloroethene Xylenes	SVOCs Acenaphthene Benzo(a)pyrene Dibenzo(a,h)anthracene Dibenzofuran 1,2-Dichlorobenzene 1,4-Dichlorobenzene Fluoranthene Fluorene Naphthalene Phenanthrene

Former Off-Site Railroad Right-of -Way - Groundwater	
Pesticides Dieldrin Aroclor 1254	Metals Cobalt Iron Lead Mercury Nickel Selenium Vanadium Cyanide

Off-Site Residential Area (Background Soil) - Soil
Metals Aluminum Arsenic Barium Chromium Cobalt Copper Iron Lead Manganese Mercury Nickel Zinc Cyanide

TABLE G-5 (Continued)

AREA- AND MEDIUM-SPECIFIC COPCs

Kalamazoo River - Sediment (Shoreline Only)		
<u>SVOC</u> Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene	<u>Pesticides and PCBs</u> Dieldrin Aroclor 1242 Aroclor 1248 Aroclor 1254 <u>Dioxins and Furans</u> Total dioxins and furans	<u>Metals</u> Aluminum Arsenic Barium Cadmium Chromium Cobalt Copper Iron Lead Manganese Mercury Nickel Selenium Silver Vanadium Zinc Cyanide

Kalamazoo River - Surface Water	
<u>VOC</u> Benzene	<u>Metals</u> Aluminum Barium Iron Lead Manganese Zinc

Notes:

COPC = Chemical of potential concern
LNAPL = Light nonaqueous-phase liquid
PCB = Polychlorinated biphenyl
SOS = Soluble oil separation
SVOC = Semivolatile organic compound
VOC = Volatile organic compound
WWTP = Wastewater treatment plant

TABLE G-6

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Sitewide (on-site)	Surface Soil	Phenanthrene	4.30e+02	2.50e+03
		Dieldrin	1.86e+01	1.10e+01
		Endosulfan sulfate	1.87e+01	1.00e+01
		Endrin aldehyde	2.61e+01	8.90e+01
		Endrin ketone	2.02e+01	1.00e+01
		Aroclor 1254	[redacted]	6.90e+04
		Aroclor 1260	[redacted]	2.30e+03
		Aluminum	[redacted]	6.01e+03
		Arsenic	[redacted]	2.26e+01
		Barium	[redacted]	3.43e+03
		Cadmium	[redacted]	5.20e+00
		Chromium	[redacted]	1.87e+02
		Cobalt	[redacted]	1.88e+01
		Copper	[redacted]	3.77e+03
		Iron	[redacted]	1.24e+05
		Lead	[redacted]	1.41e+02
		Magnesium	[redacted]	2.10e+04
		Manganese	[redacted]	1.86e+03
		Mercury	[redacted]	6.30e-01
		Nickel	[redacted]	2.86e+02
		Selenium	[redacted]	3.50e+00
		Silver	[redacted]	7.70e-01
		Zinc	[redacted]	3.02e+02
		Cyanide	[redacted]	1.70e+00
	Surface and Subsurface Soil	Naphthalene	[redacted]	7.00e+03
		Phenanthrene	[redacted]	3.30e+03
		Dieldrin	[redacted]	1.60e+03
		Endosulfan sulfate	2.05e+01	[redacted]
		Endrin aldehyde	[redacted]	5.10e+02
		Endrin ketone	2.40e+01	[redacted]
		Aroclor 1254	[redacted]	6.90e+04
		Aroclor 1260	[redacted]	2.30e+03
		Aluminum	[redacted]	6.01e+03
		Arsenic	[redacted]	4.20e+01
		Barium	[redacted]	3.43e+03
		Cadmium	[redacted]	1.10e+01
		Chromium	[redacted]	5.79e+02
		Cobalt	[redacted]	4.46e+01
		Copper	[redacted]	3.77e+03
		Iron	[redacted]	1.24e+05

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Sitewide (on-site) (continued)	Surface and Subsurface Soil (Continued)	Lead	[redacted]	2.27e+02
		Magnesium	[redacted]	3.50e+04
		Manganese	[redacted]	3.84e+03
		Mercury	[redacted]	6.30e-01
		Nickel	[redacted]	4.82e+02
		Selenium	[redacted]	4.20e+00
		Silver	[redacted]	7.70e-01
		Zinc	[redacted]	3.02e+02
		Cyanide	[redacted]	1.70e+00
	LNAPL	Benzene	3.08e+02	[redacted]
		Chlorobenzene	3.16e+04	[redacted]
		cis-1,2-Dichloroethene	3.41e+03	[redacted]
		Ethylbenzene	[redacted]	5.19e+02
		Methylene chloride	5.38e+03	[redacted]
		Tetrachloroethene	2.75e+03	[redacted]
		Trichloroethene	[redacted]	3.89e+02
		Xylenes	1.53e+03	[redacted]
		4,4'-DDD	[redacted]	1.02e+03
		4,4'-DDE	5.44e+04	[redacted]
		Endosulfan II	[redacted]	2.69e+03
		Endrin	1.06e+04	[redacted]
		Endrin aldehyde	[redacted]	1.21e+03
		Heptaclor epoxide	3.60e+03	[redacted]
		Aroclor 1254	1.746e+10	[redacted]
		Benzo(a)pyrene	1.22e+06	[redacted]
		1,2-Dichlorobenzene	4.50e+05	[redacted]
		1,4-Dichlorobenzene	2.58e+06	[redacted]
		Fluorene	8.46e+04	[redacted]
		Naphthalene	1.74e+05	[redacted]
		Phenanthrene	2.09e+05	[redacted]
		Aluminum	1.22e+08	[redacted]
		Arsenic	5.146e+09	[redacted]
		Barium	5.78e+05	[redacted]
		Chromium	5.53e+05	[redacted]
		Iron	1.72e+12	[redacted]
		Lead	4.93e+02	[redacted]
		Magnesium	5.86e+03	[redacted]
		Manganese	6.17e+04	[redacted]
		Vanadium	3.86e+06	[redacted]
		Zinc	1.34e+05	[redacted]

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL$_{95}$	Maximum Detected Concentration[a]
Sitewide (on-site) (continued)	Groundwater	cis-1,2-Dichloroethene	[redacted]	5.00e+02
		1,1-Dichloroethane	[redacted]	1.40e+01
		1,2-Dichloroethene	[redacted]	5.80e+01
		Tetrachloroethene	[redacted]	1.40e+01
		Trichloroethene	[redacted]	5.90e+01
		Vinyl chloride	[redacted]	3.10e+01
		4,4'-DDD	[redacted]	1.10e+03
		4,4'-DDE	[redacted]	8.00e+02
		Dieldrin	[redacted]	1.60e+00
		Endosulfan II	[redacted]	4.70e+02
		Endrin	[redacted]	1.90e+02
		Aroclor 1254	[redacted]	3.40e+01
		Aluminum	8.08e+04	[redacted]
		Arsenic	[redacted]	2.08e+02
		Barium	[redacted]	6.32e+03
		Cadmium	[redacted]	2.60e+00
		Chromium	[redacted]	1.61e+02
		Cobalt	[redacted]	6.99e+01
		Copper	[redacted]	2.42e+02
		Iron	[redacted]	2.66e+05
		Lead	2.06e+02	[redacted]
		Magnesium	[redacted]	6.29e+05
		Manganese	[redacted]	1.09e+04
		Mercury	[redacted]	7.40e-01
		Nickel	[redacted]	2.61e+02
		Selenium	[redacted]	5.30e+00
		Silver	[redacted]	1.15e+01
		Vanadium	3.82e+02	[redacted]
		Zinc	[redacted]	9.17e+02
		Cyanide	[redacted]	2.03e+01
	Sediment (On-Site Ponds)	Benzo(b)fluoranthene	4.44e+03	[redacted]
		Endosulfan sulfate	1.37e+20	[redacted]
		Aroclor 1242	4.40e+10	[redacted]
		Aroclor 1254	1.61e+06	[redacted]
		Total dioxins and furans	NC	[redacted]
		Aluminum	1.53e+04	[redacted]
		Arsenic	1.52e+01	[redacted]
		Barium	3.18e+02	[redacted]
		Cadmium	1.62e+01	[redacted]
		Chromium	2.41e+02	[redacted]

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Sitewide (on-site) (Continued)	Sediment (On-Site Ponds) (Continued)	Cobalt	2.37e+02	[redacted]
		Copper	3.59e+03	[redacted]
		Iron	5.09e+04	[redacted]
		Lead	8.35e+04	[redacted]
		Magnesium	1.62e+04	7.03e+03
		Manganese	1.20e+03	5.10e+02
		Mercury	5.30e-01	3.90e-01
		Nickel	7.66e+03	7.67e+01
		Selenium	1.56e+01	2.50e+00
		Zinc	2.88e+05	[redacted]
	Surface Water (On-Site Ponds)	Aluminum	NC	[redacted]
		Arsenic	NC	
		Barium	NC	
		Chromium	NC	
		Copper	NC	
		Iron	NC	
		Lead	NC	
		Magnesium	NC	
		Manganese	NC	
		Mercury	NC	
		Nickel	NC	
		Zinc	NC	
		Cyanide	NC	
Former SOS Pond Area	Surface and Subsurface Soil	Aluminum	[redacted]	2.76e+03
		Arsenic	4.38e+01	[redacted]
		Barium	[redacted]	2.69e+01
		Cadmium	1.05e+02	[redacted]
		Chromium	5.19e+04	
		Cobalt	8.44e+01	
		Copper	6.07e+03	
		Iron	2.55e+04	
		Lead	1.03e+03	
		Magnesium	2.49e+04	
		Manganese	6.97e+03	
		Mercury	[redacted]	1.80e-01
		Nickel	1.16e+04	[redacted]
		Selenium	1.84e+01	
		Silver	[redacted]	3.90e-01
		Zinc	7.64e+01	[redacted]
		Cyanide	1.76e+00	

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Former SOS Pond Area (Continued)	Surface Soil	Aluminum	3.54e+03	[redacted]
		Arsenic	7.22e+00	[redacted]
		Barium	3.49e+01	[redacted]
		Cadmium	1.56e+01	[redacted]
		Chromium	2.40e+04	[redacted]
		Cobalt	4.88e+00	[redacted]
		Copper	1.10e+02	[redacted]
		Iron	3.19e+05	[redacted]
		Lead	1.81e+01	[redacted]
		Magnesium	9.16e+04	[redacted]
		Manganese	1.03e+03	[redacted]
		Mercury	3.00e-02	[redacted]
		Nickel	1.24e+02	[redacted]
		Selenium	1.83e+02	[redacted]
		Silver	[redacted]	3.30e-01
		Zinc	1.02e+03	[redacted]
		Cyanide	3.17e+00	[redacted]
Former Rockwell WWTP Area	Surface and Subsurface Soil	Endosulfan sulfate	2.42e+01	[redacted]
		Endrin aldehyde	[redacted]	3.00e+02
		Aroclor 1254	[redacted]	3.70e+04
		Aroclor 1260	[redacted]	2.30e+03
		Aluminum	[redacted]	4.26e+03
		Arsenic	[redacted]	2.76e+01
		Barium	[redacted]	1.20e+02
		Cadmium	[redacted]	1.90e+00
		Chromium	[redacted]	6.33e+01
		Cobalt	[redacted]	1.13e+01
		Copper	[redacted]	1.62e+02
		Iron	[redacted]	4.48e+04
		Lead	[redacted]	9.52e+01
		Magnesium	[redacted]	1.67e+04
		Manganese	[redacted]	1.01e+03
		Mercury	[redacted]	6.30e-01
		Nickel	[redacted]	6.14e+01
		Selenium	[redacted]	1.50e+00
		Cyanide	[redacted]	2.90e-01

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Former Rockwell WWTP Area (Continued)	Surface Soil	Endrin aldehyde	2.15e+01	4.60e+01
		Aroclor 1254	8.17e+03	2.60e+03
		Aroclor 1260	2.04e+03	2.30e+03
		Aluminum	4.92e+03	4.21e+03
		Arsenic	[redacted]	7.60e+00
		Barium	[redacted]	1.05e+02
		Cadmium	[redacted]	1.30e+00
		Chromium	5.95e+01	4.29e+01
		Cobalt	[redacted]	5.45e+00
		Copper	9.60e+01	[redacted]
		Iron	2.26e+04	[redacted]
		Lead	1.73e+02	[redacted]
		Magnesium	1.17e+04	[redacted]
		Manganese	6.24e+02	[redacted]
		Mercury	7.00e-01	[redacted]
		Nickel	2.49e+01	[redacted]
		Selenium	1.45e+00	[redacted]
		Zinc	1.76e+02	[redacted]
		Cyanide	[redacted]	1.28e-01
	Sediment (On-Site Ponds)	Benzo(b)fluoranthene	5.46e+03	[redacted]
		Endosulfan sulfate	1.37e+07	[redacted]
		Aroclor 1242	2.21e+05	[redacted]
		Aroclor 1254	7.74e+03	[redacted]
		Total dioxins and furans	3.87e+03	[redacted]
		Aluminum	6.01e+03	[redacted]
		Arsenic	1.33e+01	[redacted]
		Barium	3.02e+02	[redacted]
		Cadmium	5.67e+00	[redacted]
		Chromium	1.97e+02	[redacted]
		Cobalt	2.07e+01	[redacted]
		Copper	7.96e+02	[redacted]
		Iron	3.44e+04	[redacted]
		Lead	2.64e+03	[redacted]
		Magnesium	1.09e+04	[redacted]
		Manganese	6.27e+02	[redacted]
		Mercury	[redacted]	3.90e-01
		Nickel	2.34e+02	[redacted]
		Selenium	3.56e+00	[redacted]
		Zinc	4.02e+03	[redacted]

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Former Rockwell WWTP Area (Continued)	Surface Water	Aluminum	NC	7.95e+02
		Arsenic	NC	[redacted]
		Barium	NC	[redacted]
		Chromium	NC	[redacted]
		Copper	NC	5.80e+01
		Iron	NC	2.90e+04
		Lead	NC	3.28e+01
		Magnesium	NC	9.31e+03
		Manganese	NC	6.13e+02
		Mercury	NC	[redacted]
		Nickel	NC	[redacted]
		Zinc	NC	[redacted]
		Cyanide	NC	[redacted]
Former On-Site Railroad Right-of-Way	Surface and Subsurface Soil	Aluminum	[redacted]	5.09e+03
		Arsenic	[redacted]	2.26e+01
		Barium	1.28e+04	[redacted]
		Cadmium	1.54e+01	[redacted]
		Chromium	4.51e+02	[redacted]
		Cobalt	4.59e+01	[redacted]
		Copper	9.90e+05	[redacted]
		Iron	1.83e+05	[redacted]
		Lead	1.99e+02	[redacted]
		Magnesium	1.83e+04	[redacted]
		Manganese	[redacted]	1.86e+03
		Nickel	1.09e+03	[redacted]
		Selenium	4.59e+00	[redacted]
		Zinc	[redacted]	3.02e+02
		Cyanide	4.17e+00	[redacted]
	Surface Soil	Aluminum	4.37e+03	[redacted]
		Arsenic	8.76e+01	[redacted]
		Barium	4.10e+08	[redacted]
		Cadmium	3.76e+04	[redacted]
		Chromium	9.20e+04	[redacted]
		Cobalt	8.91e+01	[redacted]
		Copper	8.40e+15	[redacted]
		Iron	6.65e+06	[redacted]
		Lead	7.24e+03	[redacted]
		Magnesium	3.02e+04	[redacted]
		Manganese	7.92e+03	[redacted]
		Nickel	1.59e+06	[redacted]

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Former On-Site Railroad Right-of-Way (Continued)	Surface Soil (Continued)	Selenium	1.64e+01	**3.50e+00**
		Zinc	8.10e+03	**3.02e+02**
		Cyanide	1.94e+01	**1.70e+00**
Grassy Area	Surface and Subsurface Soil	Phenanthrene	**1.70e+03**	2.30e+03
		Endosulfan sulfate	4.51e+01	**1.00e+01**
		Endrin aldehyde	1.34e+02	**6.10e+00**
		Endrin ketone	4.51e+01	**1.00e+01**
		Aroclor 1254	**6.98e+01**	8.90e+01
		Aluminum	3.56e+03	**3.15e+03**
		Barium	2.89e+01	[redacted]
		Chromium	5.57e+00	[redacted]
		Cobalt	2.75e+00	[redacted]
		Copper	8.26e+00	[redacted]
		Iron	7.18e+03	[redacted]
		Lead	5.42e+01	[redacted]
		Magnesium	5.32e+04	[redacted]
		Manganese	3.00e+02	[redacted]
		Mercury	9.71e+00	[redacted]
		Nickel	7.29e+00	[redacted]
		Selenium	9.00e-01	[redacted]
		Zinc	4.19e+01	[redacted]
	Surface Soil	Phenanthrene	4.15e+05	[redacted]
		Endosulfan sulfate	1.91e+01	[redacted]
		Endrin aldehyde	8.89e+01	[redacted]
		Endrin ketone	1.91e+01	[redacted]
		Aluminum	NC	[redacted]
		Barium	NC	[redacted]
		Chromium	NC	[redacted]
		Cobalt	NC	[redacted]
		Copper	NC	[redacted]
		Iron	NC	[redacted]
		Lead	NC	[redacted]
		Magnesium	NC	[redacted]
		Manganese	NC	[redacted]
		Mercury	NC	[redacted]
		Nickel	NC	[redacted]
		Selenium	NC	[redacted]
		Zinc	NC	[redacted]

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Area Under and North of the Former West Manufacturing Building	Surface and Subsurface Soil	Endosulfan sulfate	2.80e+01	4.40e+00
		Endrin aldehyde	3.08e+01	1.30e+01
		Aluminum	[redacted]	5.11e+03
		Arsenic	[redacted]	7.50e+00
		Barium	[redacted]	3.32e+01
		Chromium	[redacted]	2.89e+01
		Cobalt	[redacted]	9.80e+00
		Copper	[redacted]	2.03e+01
		Iron	[redacted]	1.39e+04
		Lead	[redacted]	1.55e+01
		Magnesium	5.83e+04	[redacted]
		Manganese	[redacted]	5.91e+02
		Mercury	[redacted]	2.50e-01
		Nickel	[redacted]	1.23e+01
		Selenium	[redacted]	5.40e-01
		Zinc	[redacted]	4.17e+01
		Cyanide	8.70e-01	[redacted]
	Surface Soil	Endrin aldehyde	1.34e+01	[redacted]
		Aluminum	2.30e+04	[redacted]
		Arsenic	2.82e+01	[redacted]
		Barium	6.64e+01	[redacted]
		Chromium	1.08e+04	[redacted]
		Cobalt	1.53e+01	[redacted]
		Copper	1.65e+02	[redacted]
		Iron	2.12e+04	[redacted]
		Lead	1.23e+02	[redacted]
		Magnesium	2.75e+04	[redacted]
		Manganese	4.22e+03	[redacted]
		Mercury	1.38e+01	[redacted]
		Nickel	7.08e+01	[redacted]
		Selenium	1.40e+00	[redacted]
		Zinc	7.75e+01	[redacted]
		Cyanide	1.04e+01	[redacted]

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Saturated Zone Beneath the Former City of Allegan Landfill	Groundwater	Cobalt	NC	4.97e+01
		Iron	NC	1.64e+05
		Lead	NC	5.89e+02
		Mercury	NC	1.10e+00
		Nickel	NC	1.31e+02
		Silver	NC	3.70e+00
		Vanadium	NC	1.31e+02
Former Off-Site Railroad Right-of-Way	Surface and Subsurface Soil	Naphthalene	8.03e+05	9.90e+02
		Phenanthrene	2.30e+15	3.30e+03
		Dieldrin	4.50e+15	1.60e+03
		Endosulfan sulfate	1.59e+06	[illegible]
		Endrin aldehyde	1.80e+16	[illegible]
		Aroclor 1254	1.04e+34	[illegible]
		Aluminum	2.73e+04	[illegible]
		Arsenic	6.35e+02	[illegible]
		Barium	7.03e+04	[illegible]
		Cadmium	6.35e+03	[illegible]
		Chromium	1.73e+02	[illegible]
		Cobalt	1.79e+01	[illegible]
		Copper	6.19e+06	[illegible]
		Iron	4.91e+05	2.10e+04
		Lead	1.02e+16	1.17e+02
		Magnesium	2.10e+07	7.04e+03
		Manganese	1.42e+04	3.05e+02
		Mercury	1.16e+02	[illegible]
		Nickel	3.40e+02	[illegible]
		Selenium	3.05e+03	[illegible]
		Zinc	2.10e+07	[illegible]
		Cyanide	3.45e+01	[illegible]
	Surface Soil	Dieldrin	NC	[illegible]
		Endosulfan sulfate	NC	[illegible]
		Endrin aldehyde	NC	[illegible]
		Aroclor 1254	NC	[illegible]
		Aluminum	NC	[illegible]
		Arsenic	NC	[illegible]
		Barium	NC	[illegible]
		Cadmium	NC	[illegible]
		Chromium	NC	1.37e+01
		Cobalt	NC	6.70e+00
		Copper	NC	4.90e+01

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Former Off-Site Railroad Right-of-Way (Continued)	Surface Soil (Continued)	Iron	NC	2.10e+04
		Lead	NC	1.17e+02
		Magnesium	NC	7.04e+03
		Manganese	NC	3.05e+02
		Mercury	NC	1.50e-01
		Nickel	NC	1.58e+01
		Selenium	NC	2.00e+00
		Zinc	NC	2.74e+02
		Cyanide	NC	[illegible]
	LNAPL	Benzene	NC	[redacted]
		Ethylbenzene	NC	[redacted]
		Tetrachloroethene	NC	[redacted]
		Trichloroethene	NC	[redacted]
		Xylenes	NC	[redacted]
		Acenaphthene	NC	[redacted]
		Benzo(a)pyrene	NC	[redacted]
		Dibenzo(a,h)anthracene	NC	[redacted]
		Dibenzofuran	NC	[redacted]
		1,2-Dichlorobenzene	NC	[redacted]
		1,4-Dichlorobenzene	NC	[redacted]
		Fluoranthene	NC	[redacted]
		Fluorene	NC	[redacted]
		Naphthalene	NC	[redacted]
		Phenanthrene	NC	[redacted]
	Groundwater	Dieldrin	[redacted]	1.60e+01
		Aroclor 1254	4.85e+00	[redacted]
		Cobalt	1.10e+03	[redacted]
		Iron	3.46e+05	[redacted]
		Lead	4.87e+03	[redacted]
		Magnesium	1.77e+06	[redacted]
		Mercury	2.96e+00	[redacted]
		Nickel	3.76e+02	[redacted]
		Selenium	3.01e+04	[redacted]
		Vanadium	1.35e+04	[redacted]
		Cyanide	[redacted]	4.61e+01

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Off-Site Residential Area (Background Soil)	Surface and Subsurface Soil	Aluminum	6.70e+03	4.00e+03
		Arsenic	5.55e+00	5.60e+00
		Barium	5.31e+01	4.57e+01
		Chromium	1.27e+01	1.01e+01
		Cobalt	4.46e+00	3.80e+00
		Copper	[redacted]	7.30e+00
		Iron	1.23e+04	1.20e+04
		Lead	[redacted]	1.73e+01
		Magnesium	2.30e+05	1.40e+04
		Manganese	5.71e+02	[redacted]
		Mercury	1.83e+00	[redacted]
		Nickel	9.32e+00	[redacted]
		Zinc	4.27e+01	[redacted]
		Cyanide	[redacted]	2.60e-01
	Surface Soil	Aluminum	4.11e+03	[redacted]
		Arsenic	5.99e+00	[redacted]
		Barium	4.66e+01	[redacted]
		Chromium	1.12e+01	[redacted]
		Cobalt	3.21e+00	[redacted]
		Copper	[redacted]	2.50e+00
		Iron	1.00e+04	[redacted]
		Lead	3.30e+01	[redacted]
		Magnesium	1.20e+07	[redacted]
		Manganese	7.18e+02	[redacted]
		Mercury	2.90e+05	[redacted]
		Nickel	8.67e+00	[redacted]
		Zinc	3.16e+01	[redacted]
		Cyanide	3.00e-01	[redacted]
Kalamazoo River Downstream Shoreline Only	Sediment	Benzo(a)anthracene	[redacted]	1.50e+03
		Benzo(a)pyrene	[redacted]	1.30e+03
		Benzo(b)fluoranthene	[redacted]	1.50e+03
		Benzo(k)fluoranthene	[redacted]	1.10e+03
		Dibenzo(a,h)anthracene	[redacted]	5.10e+02
		Indeno(1,2,3-cd)pyrene	[redacted]	1.00e+03
		Dieldrin	[redacted]	3.70e+01
		Aroclor 1242	2.76e+05	[redacted]
		Aroclor 1248	[redacted]	3.60e+02
		Aroclor 1254	3.04e+03	1.40e+03
		Aroclor 1260	[redacted]	1.40e+03
		Total dioxins and furans	6.84e+01	8.64e+00

TABLE G-6 (Continued)

EXPOSURE POINT CONCENTRATIONS

Area	Medium	COPC	UCL_{95}	Maximum Detected Concentration[a]
Kalamazoo River Downstream Shoreline Only (Continued)	Sediment (Continued)	Aluminum	**5.64e+03**	8.57e+03
		Arsenic	**1.13e+01**	1.75e+01
		Barium	**2.49e+02**	3.30e+02
		Cadmium	1.16e+01	**4.40e+00**
		Chromium	2.98e+02	**2.45e+02**
		Cobalt	**5.72e+00**	7.40e+00
		Copper	2.03e+02	**2.02e+02**
		Iron	**1.42e+04**	1.65e+04
		Lead	3.70e+02	**3.45e+02**
		Manganese	**5.37e+02**	7.71e+02
		Mercury	1.73e+00	**1.10e+00**
		Nickel	**5.36e+01**	6.50e+01
		Selenium	**1.21e+00**	1.90e+00
		Silver	**2.46e+00**	3.80e+00
		Vanadium	**1.06e+01**	1.42e+01
		Zinc	**4.21e+02**	5.46e+02
		Cyanide	**5.30e-01**	9.60e-01
Kalamazoo River Total Downstream Area	Surface Water	Benzene	[illegible]	6.10e+01
		Aluminum	[illegible]	3.59e+02
		Barium	**8.55e+01**	8.78e+01
		Iron	**5.47e+02**	6.83e+02
		Lead	**2.40e+00**	4.60e+00
		Magnesium	**2.51e+04**	2.55e+04
		Manganese	**7.28e+01**	7.64e+01
		Zinc	**4.05e+02**	5.50e+02

Notes:

Denotes EPC

COPC = Chemical of potential concern
EPC = Exposure point concentration
LNAPL = Light nonaqueous-phase liquid
NC = Not calculated because sample size consisted of three or less samples; therefore, UCL_{95} could not be calculated
SOS = Soluble oil separation
UCL_{95} = 95 Percent upper confidence limit on the arithmetic mean

[a] Soil and sediment concentrations of VOCs, SVOCs, and pesticides and PCBs are in micrograms per kilogram. For metals, the concentrations are in milligrams per kilogram. Groundwater and surface water concentrations are in micrograms per liter. LNAPL concentrations are in milligrams per liter.

TABLE G-7

CHEMICAL-SPECIFIC PLANT-SOIL BIOCONCENTRATION FACTORS

COPC	Br_{ag}	$Br_{rootveg}$
Naphthalene	0.435	8.23
Phenanthrene	0.0908	1.49
Dieldrin	0.0349	10.4
Endosulfan sulfate	0.377	5.75
Endrin aldehyde	0.0576	12.6
Endrin ketone	0.0576	12.6
Aroclor 1254	0.01	14.2
Aroclor 1260	0.01	14.2
Aluminum	NA	NA
Arsenic	0.00633	0.008
Barium	0.0322	0.015
Cadmium	0.125	0.064
Chromium	0.00488	0.0045
Cobalt	NA	NA
Copper	NA	NA
Iron	NA	NA
Lead	0.0136	0.009
Magnesium	NA	NA
Manganese	NA	NA
Mercury	NA	NA
Nickel	0.00931	0.008
Selenium	0.0195	0.022
Silver	0.138	0.1
Zinc	0.046	0.044
Cyanide	NA	NA

Notes:

Br_{ag} = Plant-soil bioconcentration factor for aboveground produce (unitless); source: Appendix A-3 of EPA 1998

$Br_{rootveg}$ = Plant-soil bioconcentration factor for belowground produce (unitless); source: Appendix A-3 of EPA 1998

COPC = Chemical of potential concern

NA = Not available

TABLE G-8

ABSORPTION FACTORS

Compound	Value	Reference
Aluminum	0.01	b
Arsenic	0.03	b,c
Barium	0.01	b
Cadmium	0.01	b,d
Chromium	0.01	b
Cobalt	0.01	b
Copper	0.01	b
Cyanide	0.01	a
Iron	0.01	b
Lead	0.01	b
Magnesium	0.01	a
Manganese	0.01	b
Mercury	0.01	b
Nickel	0.01	b
Selenium	0.01	b
Silver	0.01	b
Thallium	0.01	b
Vanadium	0.01	b
Zinc	0.01	b
1,1-Dichloroethane	0.1	a
1,2-Dichloroethene	0.1	a
Benzene	0.1	a
Chlorobenzene	0.1	a
cis-1,2-Dichloroethene	0.1	a
Ethyl benzene	0.1	a
Methylene chloride	0.1	a

Compound	Value	Reference
Tetrachloroethene	0.1	a
Trichloroethene	0.1	a
Vinyl chloride	0.1	a
Xylenes	0.1	a
4,4'-DDD	0.03	a
4,4'-DDE	0.03	f
Aroclor 1254	0.14	g
Aroclor 1260	0.14	g
Dieldrin	0.1	e
Endosulfan II	0.1	a
Endosulfan sulfate	0.1	a
Endrin	0.1	e
Endrin aldehyde	0.1	e
Endrin ketone	0.1	a
Heptachlor epoxide	0.1	e
1,2-Dichlorobenzene	0.13	a
1,4-Dichlorobenzene	0.13	a
Acenaphthene	0.13	f
Benzo(a)pyrene	0.13	f
Dibenzo(a,h)anthracene	0.13	f
Dibenzofuran	0.03	f
Fluorene	0.13	f
Fluoranthene	0.13	f
Naphthalene	0.1	e
Phenanthrene	0.13	f

Notes:

[a] EPA Region 5 Dermal Workgroup staff (Tetra Tech 1998c)
[b] EPA 1998
[c] Wester and others 1993a
[d] Wester and others 1992a
[e] EPA 1992a
[f] Wester and others 1990
[g] Wester and others 1993b

TABLE G-9

DA_{event} CHEMICAL-SPECIFIC CONSTANTS

Compound	DA_{event} if ET=1	PC	Tau	t*	B	t_{event} (hr)	DA_{event} if ET=2	t_{event} (hr)	DA_{event} if ET=1.25	t_{event} (hr)	DA_{event} if ET=2.5	t_{event} (hr)	DA_{event} if ET=0.01	t_{event} (hr)	DA_{event} if ET=0.12	t_{event} (hr)	DA_{event} if ET=0.2	t_{event} (hr)	DA_{event} if ET=0.27	t_{event} (hr)
DA_{event} Values for Organic COPCs																				
1,1 Dichloroethane	0.015151936	0.0089	0.35	0.84	0.0062	1	0.023997096	2	0.017363226	1.25	0.028419676	2.5	0.001454519	0.01	0.005038601	0.12	0.006504806	0.2	0.007558	0.27
1,2 Dichloroethene	0.009016341	0.0053	0.35	0.84	0.003	1	0.014300489	2	0.010337378	1.25	0.016942562	2.5	0.000866174	0.01	0.003000515	0.12	0.003873648	0.2	0.004500773	0.27
Benzene	0.15371767	0.11	0.2	0.63	0.013	1	0.262306022	2	0.180864758	1.25	0.316600197	2.5	0.013589484	0.01	0.047075355	0.12	0.060774022	0.2	0.070613032	0.27
Chlorobenzene	0.076462292	0.041	0.43	1	0.0069	1	0.117181331	2	0.086642052	1.25	0.13754085	2.5	0.007426999	0.01	0.02572788	0.12	0.03321455	0.2	0.03859182	0.27
cis 1,2 Dichloroethene	0.009016341	0.0053	0.35	0.84	0.003	1	0.014300489	2	0.010337378	1.25	0.016942562	2.5	0.0009	0.01	0.0030005	0.12	0.00387365	0.2	0.004501	0.27
Ethyl Benzene	1.726113671	1	0.39	1.3	0.14	1	2.725964912	2	1.928779609	1.25	3.164561404	2.5	0.172515293	0.01	0.597610504	0.12	0.771511843	0.2	0.89641575	0.27
Methylene Chloride	0.007111294	0.0045	0.29	0.69	0.0018	1	0.011603208	2	0.008234272	1.25	0.013849166	2.5	0.000669433	0.01	0.002318982	0.12	0.002993793	0.2	0.003478473	0.27
Tetrachloroethene	0.970197313	3.70E-01	9.00E-01	4.3	2.5	1	1.371302515	2	1.084109827	1.25	1.533162821	2.5	0.096965731	0.01	0.335899145	0.12	0.433643931	0.2	0.503848717	0.27
Trichloroethene	0.471461539	2.30E-01	5.50E-01	1.3	2.60E-02	1	0.714165692	2	0.526816639	1.25	0.826251462	2.5	0.047119913	0.01	0.163228166	0.12	0.210726656	0.2	0.244842248	0.27
Vinyl Chloride	0.01036332	0.0073	0.21	0.51	0.0023	1	0.017646568	2	0.012184132	1.25	0.021288193	2.5	0.000924119	0.01	0.003201241	0.12	0.004132785	0.2	0.004801862	0.27
Xylenes	0.013808909	0.008	0.39	1.4	0.16	1	0.021754483	2	0.015430237	1.25	0.025202759	2.5	0.001380122	0.01	0.004780884	0.12	0.006172095	0.2	0.007171326	0.27
4,4'-DDD	2.161436204	0.28	7.8	37	63	1	3.055031035	2	2.415214098	1.25	3.415628534	2.5	0.216023316	0.01	0.748326718	0.12	0.966085639	0.2	1.122490078	0.27
4,4'-DDE	1.828753316	0.24	7.6	36	49	1	2.584808253	2	2.043470348	1.25	2.889903481	2.5	0.182773544	0.01	0.63314613	0.12	0.817388139	0.2	0.949719195	0.27
Aroclor-1254	7.342762062	0.71	14	66	520	1	10.37845389	2	8.204888225	1.25	11.60346421	2.5	0.733867513	0.01	2.542191636	0.12	3.28195529	0.2	3.813287454	0.27
Aroclor-1260	7.342762062	0.71	14	66	520	1	10.37845389	2	8.204888225	1.25	11.60346421	2.5	0.733867513	0.01	2.542191636	0.12	3.28195529	0.2	3.813287454	0.27
Dieldrin	0.187626131	0.016	18	94	3.6	1	0.265195731	2	0.209655634	1.25	0.296497841	2.5	0.01875217	0.01	0.064959422	0.12	0.083862254	0.2	0.097439134	0.27
Endosulfan II	0					1	0	2	0	1.25	0	2.5	0	0.01	0	0.12	0	0.2	0	0.27
Endosulfan sulfate	0					1	0	2	0	1.25	0	2.5	0	0.01	0	0.12	0	0.2	0	0.27
Endrin	0.187626131	0.016	18	94	3.6	1	0.265195731	2	0.209655634	1.25	0.296497841	2.5	0.01875217	0.01	0.064959422	0.12	0.083862254	0.2	0.097439134	0.27
Endrin aldehyde	0.187626131	0.016	18	94	3.6	1	0.265195731	2	0.209655634	1.25	0.296497841	2.5	0.01875217	0.01	0.064959422	0.12	0.083862254	0.2	0.097439134	0.27
Endrin ketone	0.187626131	0.016	18	94	3.6	1	0.265195731	2	0.209655634	1.25	0.296497841	2.5	0.01875217	0.01	0.064959422	0.12	0.083862254	0.2	0.097439134	0.27
Heptachlor epoxide	0.358952477	0.02852	20.73484	100.186	10	1	0.507352914	2	0.401097697	1.25	0.567237802	2.5	0.035875269	0.01	0.124275576	0.12	0.160439079	0.2	0.186413364	0.27
1,2 Dichlorobenzene	0.140052695	0.061	0.69	3.2	0.24	1	0.197954179	2	0.156496519	1.25	0.2213195	2.5	0.013997474	0.01	0.048488673	0.12	0.062598608	0.2	0.07273301	0.27
1,4-Dichlorobenzene	0.14234864	0.062	0.69	3.3	0.25	1	0.201199329	2	0.159062036	1.25	0.224947689	2.5	0.014226941	0.01	0.049283569	0.12	0.063624814	0.2	0.073925354	0.27
Acenapthene	3.320729101	0.81	2.2	10	46	1	4.693606245	2	3.710621544	1.25	5.247611312	2.5	0.33188808	0.01	1.149694035	0.12	1.484248618	0.2	1.724541053	0.27
Benzo(a)pyrene	5.648294516	1.2	2.9	14	130	1	7.983448697	2	6.311470367	1.25	8.925766991	2.5	0.564515071	0.01	1.95553757	0.12	2.524588147	0.2	2.933306354	0.27
Dibenzo(a,h)anthracene	3.320729101	0.81	2.2	10	46	1	4.693606245	2	3.710621544	1.25	5.247611312	2.5	0.33188808	0.01	1.149694035	0.12	1.484248618	0.2	1.724541053	0.27
Dibenzofuran	0.458650233	0.172203	0.928555	5.588925	1.584893	1	0.648268357	2	0.512501136	1.25	0.724786057	2.5	0.045839495	0.01	0.158792669	0.12	0.205000454	0.2	0.238189004	0.27
Fluorene	1.218667471	0.36	1.5	7.3	8.9	1	1.722496801	2	1.361753289	1.25	1.925809969	2.5	0.121798917	0.01	0.421923825	0.12	0.544701315	0.2	0.632885737	0.27
Fluroanthene	1.218667471	0.36	1.5	7.3	8.9	1	1.722496801	2	1.361753289	1.25	1.925809969	2.5	0.121798917	0.01	0.421923825	0.12	0.544701315	0.2	0.632885737	0.27
Napthalene	0.13884304	0.069	0.53	2.2	0.2	1	0.196244421	2	0.155144837	1.25	0.24127	2.5	0.013876576	0.01	0.04806987	0.12	0.062057935	0.2	0.072104804	0.27
Phenantherene	0.666747303	0.23	1.1	5.6	2.9	1	0.942398253	2	0.745031236	1.25	1.053633278	2.5	0.06663762	0.01	0.230839485	0.12	0.298012494	0.2	0.346259228	0.27

TABLE G-9 (Continued)

DA_{event} CHEMICAL-SPECIFIC CONSTANTS

Compound	DA_{event}	PC	t_{event} (hr)	DA_{event}	t_{event} (hr)	DA_{event}	t_{event} (hr)	DA_{event}	t_{event} (hr)	DA_{event}	t_{event} (hr)	DA_{event}	t_{event} (hr)	DA_{event}	t_{event} (hr)	DA_{event}	t_{event} (hr)
DA_{event} Values for Inorganic COPCs																	
Aluminum	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Arsenic	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Barium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Cadmium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Chromium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Cobalt	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Copper	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Cyanide	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Iron	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Lead	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Magnesium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Manganese	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Mercury	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Nickel	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Selenium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Silver	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Thallium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Vanadium	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27
Zinc	0.001	0.001	1	0.002	2	0.00125	1.25	0.0025	2.5	0.00001	0.01	0.00012	0.12	0.0002	0.2	0.00027	0.27

Notes:

B	=	Bunge constant reflecting the partitioning properties of a compound (dimensionless)
COPC	=	Chemical of potential concern
DA_{event}	=	Dermally absorbed dose per event (in milligrams per square centimeter per event)
ET	=	Exposure time (hours)
PC	=	Dermal permeability coefficient (centimeters per hour)
t*	=	Time to steady state conditions (hours)
Tau	=	Lag time (hours)

TABLE G-10

SURROGATE CHEMICALS FOR COPCs WITHOUT REFERENCE DOSES

Compound Without RfD	Structure	Surrogate with RfD	OralRfD[a] (mg/kg-day)	Structure
Benzo(a)pyrene	Five 6-carbon ring cluster	Pyrene	3.0E-02	Four 6-carbon ring cluster
Dibenzo(ah)anthracene	Five 6-carbon ring chain	Anthracene	3.0E-01	Three 6-carbon ring chain
Acenaphthene	One 5- & two 6- carbon ring cluster	Acenaphthylene	6.0E-02	One 5- & two 6-carbon ring cluster
Endosulfan II	Multiple overlapping non-aromatic rings	Endosulfan	6.0E-3	Multiple overlapping non-aromatic rings
Endosulfan sulfate	Multiple overlapping non-aromatic rings	Endosulfan	6.0E-3	Multiple overlapping non-aromatic rings
Endrin aldehyde	Multiple overlapping non-aromatic rings	Endrin	3.0E-4	Multiple overlapping non-aromatic rings
Endrin ketone	Multiple overlapping non-aromatic rings	Endrin	3.0E-4	Multiple overlapping non-aromatic rings
Aroclor-1260	Two phenyl rings with assorted chlorines	Aroclor-1254	2.0E-05	Two phenyl rings with assorted chlorines
Phenanthrene	Three 6-carbon ring chain	Anthracene	3.0E-01	Three 6-carbon ring chain
Benzo(a)anthracene	Four 6-carbon ring chain	Anthracene	3.0E-01	Three 6-carbon ring chain
Benzo(b)fluoranthene	One 5- & four 6- carbon ring cluster	Fluoranthene	4.0E-02	One 5- & two 6-carbon ring cluster
Benzo(k)fluoranthene	One 5- & four 6- carbon ring cluster	Fluoranthene	4.0E-02	One 5- & two 6-carbon ring cluster
Indeno(1,2,3-cd)pyrene	One 5- & four 6- carbon ring cluster	Fluoranthene	4.0E-02	One 5- & two 6-carbon ring cluster
Aroclor-1242	Two phenyl rings with assorted chlorines	Aroclor-1254	2.0E-05	Two phenyl rings with assorted chlorines
Aroclor-1248	Two phenyl rings with assorted chlorines	Aroclor-1254	2.0E-05	Two phenyl rings with assorted chlorines

Notes:

COPC	=	Chemical of potential concern
RfD	=	Reference dose

[a] U.S. Environmental Protection Agency's Integrated Risk Information System (IRIS). On-Line Address: www.epa.gov/ngispgm3/iris/index.html

[b] Most or all of the rings joined by 3 carbons.

[c] Most or all of the rings joined by 2 carbons forming a chain or branched chain.

TABLE G-11

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
ORAL REFERENCE DOSES

Chemical of Potential Concern	Oral RfD (mg/kg-day)	Source (date accessed)	Confidence Level	Critical Effect or Site of Critical Effect	UF	MF
Aluminum	1.00E+00	Region 9 (N)	Low	Gastrointestinal disturbances	--	--
Arsenic	3.00E-04	IRIS (2/6/01)	Medium	Hyper pigmentation, ketosis, and possible vascular complications	3	1
Barium	7.00E-02	IRIS (2/6/01)	Medium	No adverse effect	3	1
Cadmium (water)	5.0E-04	IRIS (2/6/01)	High	Significant proteinuria	10	1
Cadmium (food)	1.0E-03	IRIS (2/6/01)	High	Significant proteinuria	10	1
Chromium (III)	1.5E+00	IRIS (2/6/01)	Low	No effects observed	100	10
Cobalt	6.0E-02	Region 9	Low	Respiratory dysfunction and skin sensitization	--	--
Copper	3.7E-02	Region 9	Low	Gastrointestinal irritation, vomiting, low blood pressure	--	--
Cyanide (free)	2.0E-02	IRIS (2/6/01)	Medium	Respiratory arrest, death, liver effects	100	5
Iron	3.0E-01	Region 9	Medium	Acute toxicity causes gastrointestinal distress	--	--
Lead	NA	--	--	--	--	--
Magnesium	NA	--	--	--	--	--
Manganese	1.4E-01	IRIS (2/6/01)	Medium	CNS effects	1	1
Mercury	NA	--	--	--	--	--
Nickel (soluble salts)	2.0E-02	IRIS (2/6/01)	Medium	Decreased body and organ weights	300	1
Selenium	5.0E-03	IRIS (2/6/01)	High	Clinical selenosis	3	1
Silver	5.0E-03	IRIS (2/6/01)	Low	Argyria	3	1
Thallium	6.6E-05	Region 9 (I)	Low	Gastrointestinal irritation and CNS depression	--	--
Vanadium	7.0E-03	HEAST	Medium	Respiratory irritation	100	1
Zinc	3.0E-01	IRIS (2/6/01)	Medium	Decrease in erythrocyte superoxide distribution (ESOD)	3	1
1,1-Dichloroethane	1.0E-01	HEAST	Low	No effects observed	1000	1
1,2-Dichloroethene	9.0E-03	HEAST	Low	Lesions	1000	1
Benzene	3.0E-03	Region 9 (N)	Medium	Leukemia, tumors, CNS depression	--	--
Chlorobenzene	2.0E-02	IRIS (2/6/01)	Medium	Histopathological changes in liver	1000	1
cis-1,2-Dichloroethene	1.0E-02	HEAST	Low	Decrease hemoglobin	3000	1
Ethylbenzene	1.00E-01	IRIS (2/6/01)	Low	Liver and kidney damage	1000	1
Methylene chloride	6.0E-02	IRIS (2/6/01)	Medium	Liver toxicity	100	1
Tetrachloroethene	1.0E-02	IRIS (2/6/01)	Medium	Hepatoxicity in mice and weight gain in rats	1000	1
Trichloroethene	6.0E-3	Region 9 (X)	Low	CNS depression, liver and kidney effects	--	--
Vinyl chloride	3.0E-03	IRIS (2/6/01)	Medium	Liver cell polymorphism	30	1
Xylenes	2.00E+00	IRIS (2/6/01)	Medium	Hyperactivity, decreased body weight and increased mortality	100	1
4,4'-DDD	NA	--	--	--	--	--
4,4'-DDE	NA	--	--	--	--	--
Aroclor-1254	2.0E-05	IRIS (2/6/01)	Medium	Ocular exudate, inflamed and prominent meibamian glands	300	1
Aroclor-1260*	2.0E-05	IRIS (2/6/01)	Medium	Ocular exudate, inflamed and prominent meibamian glands	300	1

TABLE G-11 (Continued)

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
ORAL REFERENCE DOSES

Chemical of Potential Concern	Oral RfD (mg/kg-day)	Source (date accessed)	Confidence Level	Critical Effect or Site of Critical Effect	UF	MF
Dieldrin	5.0E-05	IRIS (2/6/01)	Medium	Salivation, convulsions, and CNS effects	100	1
Endosulfan II[a]	6.0E-03	IRIS (2/6/01)	Medium	Reduced body weight gain in males and females and progressive glomerulonephrosis	100	1
Endosulfan sulfate[a]	6.0E-03	IRIS (2/6/01)	Medium	Reduced body weight gain in males and females and progressive glomerulonephrosis	100	1
Endrin	3.0E-04	IRIS (2/6/01)	Medium	Mild histological lesions in liver, occasional convulsions	100	1
Endrin aldehyde[b]	3.0E-04	IRIS (2/6/01)	Medium	Mild histological lesions in liver, occasional convulsions	100	1
Endrin ketone[b]	3.0E-04	IRIS (2/6/01)	Medium	Mild histological lesions in liver, occasional convulsions	100	1
Heptachlor epoxide	1.3E-05	IRIS (2/6/01)	Low	Increased liver-to-body weight ratio	1000	1
1,2-Dichlorobenzene	9.0E-02	IRIS (2/6/01)	Low	No adverse effects observed	1000	1
1,4-Dichlorobenzene	NA	--		--	--	--
Acenaphthene	6.0E-02	IRIS (2/6/01)	Low	Hepatotoxicity	3,000	1
Benzo(a)pyrene[d]	3.0E-02	IRIS (2/6/01)	Low	Kidney Effects	3,000	1
Dibenz(a,h)anthracene[c]	3.00E-01	IRIS (2/6/01)	Low	No observed effects	3,000	1
Dibenzofuran[c]	3.00E-01	IRIS (2/6/01)	Low	No observed effects	3,000	1
Fluoranthene	4.00E-02	IRIS (2/6/01)	Low	Nephropathy, increased liver weights, hematological alterations	3,000	1
Fluorene	4.00E-02	IRIS (2/6/01)	Low	Decreased red blood cell, packed cell volume, and hemoglobin	3,000	1
Naphthalene	2.0E-02	IRIS (2/6/01)	Low	Decreased mean terminal body weight in males (rats) and nausea, headache, and malaise in humans	3,000	1
Phenanthrene[c]	3.00E-01	IRIS (2/6/01)	Low	No observed effects	3000	1
Benzo(a)anthracene [c]	3.00E-01	IRIS (2/6/01)	Low	No observed effects	3000	1
Benzo(b)fluoranthene [f]	4.00E-02	IRIS (2/6/01)	Low	Nepropathy, increased liver weights, hematological alterations, and clinical effects	3000	1
Benzo(k)anthracene [f]	4.00E-02	IRIS (2/6/01)	Low	Nepropathy, increased liver weights, hematological alterations, and clinical effects	30001	
Indeno(1,2,3-cd)pyrene [f]	3.00E-02	IRIS (2/6/01)	Low	Nepropathy, increased liver weights, hematological alterations, and clinical effects	3000	1
Aroclor-1242 [e]	2.0E-05	IRIS (2/6/01)	Medium	Ocular exudate, inflamed and prominent meibamian glands	300	1
Aroclor-1248 [e]	2.0E-05	IRIS (2/6/01)	Medium	Ocular exudate, inflamed and prominent meibamian glands	300	1
Total dioxins and furans	NA	--	--	--	--	--

TABLE G-11 (Continued)

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
ORAL REFERENCE DOSES

Notes:

CNS	=	Central nervous system
HEAST	=	U.S. Environmental Protection Agency's (EPA) "Health Effects Assessment Summary Tables. FY 1997 Update." Office of Solid Waste and Emergency Response (OSWER). EPA-540-R-97-036. July.
IRIS	=	EPA's Integrated Risk Information System. On-Line Address: http://www.epa.gov/ngispgm3/iris/index.html
Region 9	=	Region 9 Preliminary Remediation Goals (PRGs). 2000 Edition. November 22. Accessed on March 20, 2001. On-line address: http://www.epa.gov/region09/waste/sfund/prg/index.htm
mg/kg-day	=	Milligram per kilogram-day
NA	=	Not available in HEAST, IRIS, or in Region 9 tables
MF	=	Modifying factor
RfD	=	Reference dose
UF	=	Uncertainty factor
N	=	Region 9 values referenced rom NCEA values
I	=	Region 9 values referenced from IRIS values
X	=	Region 9 values withdrawn
–	=	Not available

[a] Based on the RfD for Endosulfan. See table G-10 for surrogate details.

[b] Based on the RfD for Endrin. See table G-10 for surrogate details.

[c] Based on the RfD for Anthracene. See table G-10 for surrogate details.

[d] Based on the RfD for Pyrene. See table G-10 for surrogate details.

[e] Based on the RfD for Aroclor-1254. See table G-10 for surrogate details.

[f] Based on the RfD for Fluoranthene. See table G-10 for surrogate details.

TABLE G-12

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
INHALATION REFERENCE DOSES

Chemical of Potential Concern	Inhalation RfD (mg/kg-day)	Source (date accessed)	Confidence Level	Critical Effect or Site of Critical Effect	UF	MF
Aluminum	1.4E-03	Region 9 (N)	Low	Gastrointestinal disturbances	--	--
Arsenic	NA	--	--	--	--	--
Barium	NA	--	--	--	--	--
Cadmium	NA	--	--	--	--	--
Chromium (III)	NA	--	--	--	--	--
Cobalt	NA	--	--	--	--	--
Copper	NA	--	--	--	--	--
Cyanide	NA	--	--	--	--	--
Iron	NA	--	--	--	--	--
Lead	NA	--	--	--	--	--
Magnesium	NA	--	--	--	--	--
Manganese	1.4E-05	IRIS (2/6/01)	Medium	Impairment of neurobehavioral function	1000	1
Mercury	8.6E-05	IRIS (2/6/01)	Medium	Hand tremor, increases in memory disturbances, autonomic dysfunction	30	1
Nickel	NA	--	--	--	--	--
Selenium	NA	--	--	--	--	--
Silver	NA	--	--	--	--	--
Thallium	NA	--	--	--	--	--
Vanadium	NA	--	--	--	--	--
Zinc	NA	--	--	--	--	--
1,1-Dichloroethane	1.0E-01	HEAST	Low	No effects observed	1000	1
1,2-Dichloroethene	NA	--	--	--	--	--
Benzene	1.7E-03	Region 9 (N)	Medium	--	--	--
Chlorobenzene	NA	--	--	--	--	--
cis-1,2-Dichloroethene[a]	1.0E-02	Region 9 (R)	Low	--	--	--
Ethylbenzene	2.9E-01	IRIS (2/6/01)	Low	Developmental toxicity	300	1
Methylene chloride	8.6E-02	HEAST	Medium	Liver toxicity	100	1
Tetrachloroethene	1.1E-01	Region 9 (N)	Medium	--	--	--
Trichloroethene	6.0E-3	Region 9 (R)	Low	--	--	--
Vinyl chloride	2.9E-02	IRIS (2/6/01)	Medium	Liver cell polymorphism	30	1
Xylenes	2.0E-01	Region 9 (X)	Medium	--	--	--
4,4'-DDD	NA	--	--	--	--	--
4,4'-DDE	NA	--	--	--	--	--
Aroclor-1254	NA	--	--	--	--	--
Aroclor-1260	NA	--	--	--	--	--
Dieldrin	5.0E-05	Region 9 (R)	Medium	--	--	--
Endosulfan II[b]	6.0E-03	Region 9 (R)	Medium	--	--	--
Endosulfan sulfate[b]	6.0E-03	Region 9 (R)	Medium	--	--	--
Endrin	3.0E-04	Region 9 (R)	Medium	--	--	--
Endrin aldehyde[c]	3.0E-04	Region 9 (R)	Medium	--	--	--
Endrin ketone[c]	3.0E-04	Region 9 (R)	Medium	--	--	--
Heptachlor epoxide	1.3E-05	Region 9 (R)	Low	--	--	--
1,2-Dichlorobenzene	5.7E-02	Region 9 (H)	Low	--	--	--
1,4-Dichlorobenzene	2.3E-01	IRIS (2/6/01)	Medium	Increased liver weights	100	1

TABLE G-12 (Continued)

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
INHALATION REFERENCE DOSES

Chemical of Potential Concern	Inhalation RfD (mg/kg-day)	Source (date accessed)	Confidence Level	Critical Effect or Site of Critical Effect	UF	MF
Acenaphthene	NA	--	--	--	--	--
Benzo(a)pyrene	NA	--	--	--	--	--
Dibenz(a,h)anthracene	NA	--	--	--	--	--
Dibenzofuran	NA	--	--	--	--	--
Fluoranthene	NA	--	--	--	--	--
Fluorene	NA	--	--	--	--	--
Naphthalene	8.6E-04	IRIS (2/6/01)	Low	Nasal effects	3,000	1
Phenanthrene	NA	--	--	--	--	--
Benzo(a)anthracene	NA	--	--	--	--	--
Benzo(b)fluoranthene	NA	--	--	--	--	--
Benzo(k)anthracene	NA	--	--	--	--	--
Indeno(1,2,3-cd)pyrene	NA	--	--	--	--	--
Aroclor-1242	NA	--	--	--	--	--
Aroclor-1248	NA	--	--	--	--	--
Total dioxins and furans	NA	--	--	--	--	--

Notes:

CNS = Central nervous system

HEAST = U.S. Environmental Protection Agency's (EPA) "Health Effects Assessment Summary Tables, FY 1997 Update." Office of Solid Waste and Emergency Response (OSWER). EPA-540-R-97-036. July.

IRIS = EPA's Integrated Risk Information System. On-Line Address: http://www.epa.gov/ngispgm3/iris/index.html

Region 9 = Region 9 Preliminary Remediation Goals (PRGs). 2000 Edition. November 22. Accessed on March 20, 2001. On-line address: http://www.epa.gov/region09/waste/sfund/prg/index.htm

mg/kg-day = Milligram per kilogram-day

NA = Not applicable

MF = Modifying factor

RfD = Reference dose

UF = Uncertainty factor

H = Region 9 values referenced from HEAST values

R = Region 9 values obtained by route extrapolation

X = Region 9 values withdrawn

N = Region 9 values referenced from NCEA values

[a] Based on the RfD for cis-1,2-Dichloroethylene

[b] Based on the RfD for Endosulfan

[c] Based on the RfD for Endrin

[d] The inhalation RfD values were calculated from the IRIS values by multiplying the chemical specific RfC values by 20 m^3/day and divided by 70 kg for the adult. Region 9 values were obtained by this same calculation method.

TABLE G-13

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
ORAL SLOPE FACTORS

Chemical of Potential Concern	Oral SF (mg/kg-day)$^{-1}$	Source (date accessed)	Weight of Evidence[a]
Aluminum	NA	--	--
Arsenic	1.5E+00	IRIS (3/20/01)	A
Barium	NA	--	--
Cadmium	NA	--	--
Chromium	NA	--	--
Cobalt	NA	--	--
Copper	NA	--	--
Cyanide	NA	--	--
Iron	NA	--	--
Lead	NA	--	--
Magnesium	NA	--	--
Manganese	NA	--	--
Mercury	NA	--	--
Nickel	NA	--	--
Selenium	NA	--	--
Silver	NA	--	--
Thalllium	NA	--	--
Vanadium	NA	--	--
Zinc	NA	--	--
1,1-Dichloroethane	NA	--	--
1,2-Dichloroethene	NA	--	--
Benzene	3.5E-02	IRIS (3/20/01)	A
Chlorobenzene	NA	--	--
cis-1,2-Dichloroethene	NA	--	--
Ethyl benzene	NA	--	--
Methylene chloride	7.5E-03	IRIS (3/20/01)	B2
Tetrachloroethene	5.2E-02	Region 9 (N)	C
Trichloroethene	1.1E-02	Region 9 (N)	C/B2
Vinyl chloride	1.4E+00	IRIS (3/20/01)	A
Xylenes	NA	--	--
4,4'-DDD	2.4E-01	IRIS (3/20/01)	B2
4,4'-DDE	3.4E-01	IRIS (3/20/01)	B2
Aroclor-1254	2.0E+00	IRIS (3/20/01)	B2
Aroclor-1260	2.0E+00	IRIS (3/20/01)	B2
Dieldrin	1.6E+01	IRIS (3/20/01)	B2
Endosulfan II	NA	--	--
Endosulfan sulfate	NA	--	--
Endrin	NA	--	--
Endrin aldehyde	NA	--	--

TABLE G-13 (Continued)

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
ORAL SLOPE FACTORS

Chemical of Potential Concern	Oral SF (mg/kg-day)$^{-1}$	Source (date accessed)	Weight of Evidence[a]
Endrin ketone	NA	--	--
Heptachlor epoxide	9.1E+00	IRIS (3/20/01)	B2
1,2-Dichlorobenzene	NA	--	--
1,4-Dichlorobenzene	2.4E-02	HEAST	B2
Acenapthene	NA	--	--
Benzo(a)pyrene	7.3E+00	IRIS (3/20/01)	B2
Dibenzo(a,h)anthracene	7.3E+00	IRIS (3/20/01)	B2
Dibenzofuran	NA	--	--
Fluorene	NA	--	--
Fluroanthene	NA	--	--
Napthalene	NA	--	--
Phenantherene	NA	--	--
Benzo(a)anthracene	7.3E-01	IRIS (3/20/01)	B2
Benzo(b)fluoranthene	7.3E-01	IRIS (3/20/01)	B2
Benzo(k)anthracene	7.3E-02	IRIS (3/20/01)	B2
Indeno(1,2,3-cd)pyrene	7.3E-01	IRIS (3/20/01)	B2
Aroclor-1242	2.0E+00	IRIS (3/20/01)	B2
Aroclor-1248	2.0E+00	IRIS (3/20/01)	B2
Total dioxins and furans	7.3E-01	Region 9 (H)	B2

Notes:

HEAST	=	U.S. Environmental Protection Agency's (EPA) "Health Effects Assessment Summary Tables, FY 1997 Update." Office of Solid Waste and Emergency Response (OSWER). EPA-540-R-97-036. July.
IRIS	=	EPA's Integrated Risk Information System. On-Line Address: http://www.epa.gov/ngispgm3/iris/index.html
Region 9	=	Region 9 Preliminary Remediation Goals (PRGs). 2000 Edition. November 22. Accessed on March 20, 2001. On-line address: http://www.epa.gov/region09/waste/sfund/prg/index.htm
(mg/kg-day)$^{-1}$	=	(milligram per kilogram-day)$^{-1}$
NA	=	Not applicable
SF	=	Slope factor
N	=	Region 9 value obtained from NCEA

[a] The EPA's weight of evidence designation indicates the likelihood that a chemical is carcinogenic to humans (see Section 4.2 of the main text for further explanation).

[b] Oral SFs for PAHs other than benzo(a)pyrene were calculated using EPA-derived toxicity equivalent factors (TEF) (see Appendix G-H).

TABLE G-14

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS INHALATION SLOPE FACTORS

Chemical of Potential Concern	Inhalation SF[c] (mg/kg-day)$^{-1}$	Source (date accessed)	Weight of Evidence[a]
Aluminum	NA	--	--
Arsenic	1.5E+00	IRIS (3/20/01)	A
Barium	NA	--	--
Cadmium	6.3	IRIS (3/20/01)	B1
Chromium	NA	--	--
Cobalt	NA	--	--
Copper	NA	--	--
Cyanide	NA	--	--
Iron	NA	--	--
Lead	NA	--	--
Magnesium	NA	--	--
Manganese	NA	--	--
Mercury	NA	--	--
Nickel	NA	--	--
Selenium	NA	--	--
Silver	NA	--	--
Thallium	NA	--	--
Vanadium	NA	--	--
Zinc	NA	--	--
1,1-Dichloroethane	NA	--	--
1,2-Dichloroethene	NA	--	--
Benzene	1.8E-02	IRIS (3/20/01)	A
Chlorobenzene	NA	--	--
cis-1,2-Dichloroethene	NA	--	--
Ethylbenzene	NA	--	--
Methylene chloride	1.6E-03	IRIS (3/20/01)	B2
Tetrachloroethene	5.2E-02	Region 9 (N)	C
Trichloroethene	1.1E-02	Region 9 (N)	C/B2
Vinyl chloride	3.1E-02	IRIS (3/20/01)	A
Xylenes	NA	--	--
4,4'-DDD	--	--	--
4,4'-DDE	--	--	--
Aroclor-1254	--	--	--
Aroclor-1260	--	--	--
Dieldrin	1.6E+01	IRIS (3/20/01)	B2
Endosulfan II	NA	--	--
Endosulfan sulfate	NA	--	--
Endrin	NA	--	--
Endrin aldehyde	NA	--	--

TABLE G-14 (Continued)

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
INHALATION SLOPE FACTORS

Chemical of Potential Concern	Inhalation SF[c] (mg/kg-day)$^{-1}$	Source (date accessed)	Weight of Evidence[a]
Endrin ketone	NA	--	--
Heptachlor epoxide	9.1E+00	IRIS (3/20/01)	B2
1,2-Dichlorobenzene	NA	--	--
1,4-Dichlorobenzene	2.4E-02	Region 9 (H)	B2
Acenapthene[b]	3.1E+00	Region 9	D
Benzo(a)pyrene[b]	3.1E+00	Region 9	B2
Dibenzo(a,h)anthracene[b]	3.1E+00	Region 9	B2
Dibenzofuran[b]	3.1E+00	Region 9	D
Fluorene[b]	3.1E+00	Region 9	D
Fluroanthene[b]	3.1E+00	Region 9	D
Napthalene[b]	3.1E+00	Region 9	D
Phenantherene[b]	3.1E+00	Region 9	D
Benzo(a)anthracene	3.1E+00	Region 9	D
Benzo(b)fluoranthene	3.1E+00	Region 9	D
Benzo(k)anthracene	3.1E+00	Region 9	D
Indeno(1,2,3-cd)pyrene	3.1E+00	Region 9	D
Aroclor-1242	--	--	--
Aroclor-1248	--	--	--
Total dioxins and furans	1.5E+05	Region 9	B2

Notes:

HEAST	=	U.S. Environmental Protection Agency's (EPA) "Health Effects Assessment Summary Tables, FY 1997 Update." Office of Solid Waste and Emergency Response (OSWER). EPA-540-R-97-036. July.
IRIS	=	EPA's Integrated Risk Information System. On-Line Address: http://www.epa.gov/ngispgm3/iris/index.html
Region 9	=	Region 9 Preliminary Remediation Goals (PRGs). 2000 Edition. November 22. Accessed on March 20, 2001. On-line address: http://www.epa.gov/region09/waste/sfund/prg/index.htm
(mg/kg-day)$^{-1}$	=	(milligram per kilogram-day)$^{-1}$
NA	=	Not available from HEAST, IRIS, or Region 9 tables
--	=	Not available
SF	=	Slope factor
N	=	Region 9 values obtained from NCEA tables.

[a] The EPA's weight of evidence designation indicates the likelihood that a chemical is carcinogenic to humans (see Section 4.2 of the main text for further explanation).

TABLE G-14 (Continued)

RECEPTOR-SPECIFIC EXPOSURE AND RISK RESULTS
INHALATION SLOPE FACTORS

[b] Oral SFs for PAHs other than benzo(a)pyrene were calculated using EPA-derived toxicity equivalent factors (TEF) (see Appendix G-H).

[c] The inhalation SFs were obtained by multiplying the unit risk factor (URF) by 70 kg and dividing by 20 m^3/kg. Region 9 inhalation SFs were obtained using this formula.

APPENDIX G

HUMAN HEALTH RISK ASSESSMENT
ROCKWELL INTERNATIONAL CORPORATION
ALLEGAN, MICHIGAN

(942 Pages)

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

FIGURES

CONTENTS (Continued)

TABLES

Volume III

Appendix

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ADA	American Dietetic Association
ADD	Average daily dose
AF	Adherence factor
AI	Adequate intake
AOI	Area of interest
ARAR	Applicable or relevant and appropriate requirement
Aware	Aware, Inc.
bgs	Below ground surface
CLP	Contract Laboratory Program
cm^2	Square centimeter
COPC	Chemical of potential concern
CRDL	Contract-required detection limit
CSM	Conceptual site model
CT	Central tendency
DCES	Delaware Cooperative Extension Service
DRI	Dietary reference intake
E&E	Ecology and Environment, Inc.
EAR	Estimated average requirement
ECAO	Environmental Criteria and Assessment Office
ELCR	Excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERD	Environmental Response Division
ESC	Environmental Strategies Corporation
FR	*Federal Register*
FS	Feasibility study
FSP	Field sampling plan
G.I.	Gastrointestinal
HBSL	Health-based screening level
HCV	Human cancer value
Healthtouch	Healthtouch Online
HEAST	Health Effects Assessment Summary Tables
HHRA	Human health risk assessment
HNV	Human noncancer value
HQ_i	Initial hazard quotient
hr/day	Hour per day
IEUBK	"Integrated Exposure Uptake Biokinetic Model for Lead in Children"
IRIS	Integrated Risk Information System

kg	Kilogram
LADD	Lifetime average daily dose
L/day	Liter per day
LNAPL	Light nonaqueous-phase liquid
LOAEL	Lowest observed adverse effect level
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
mg/cm^2	Milligram per square centimeter
mg/day	Milligram per day
mg/kg	Milligram per kilogram
mg/kg-day	Milligram per kilogram of body weight per day
mg/L	Milligram per liter
mg/m^3	Milligram per cubic meter
m^3/hr	Cubic meter per hour
NAS	National Academy of Sciences
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	No observed adverse effect level
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear aromatic hydrocarbon
PbB	Blood lead concentration
PCB	Polychlorinated biphenyl
PEF	Particulate emission factor
POTW	Publicly owned treatment works
ppm	Part per million
PRG	Preliminary remediation goal
QAPP	Quality assurance project plan
RAGS	"Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)"
RBRG	Risk-based remediation goal
RDA	Recommended dietary allowance
RfC	Reference concentration
RfD	Reference dose
RI	Remedial investigation
RME	Reasonable maximum exposure
RMT	Residual Management Technology, Inc.
Rockwell	Rockwell International Corporation
SF	Slope factor

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (Continued)

SOP	Standard operating procedure
SOS	Soluble oil separation
SQL	Sample quantitation limit
SVOC	Semivolatile organic compounds
TCAPCOA	Toxic Committee of the California Air Control Officers Association
TDI	Total daily intake
Tetra Tech	Tetra Tech EM Inc.
UCL_{95}	95th percentile upper confidence limit
UIL	Upper intake level
URF	Unit risk factor
USDA	U.S. Department of Agriculture
VOC	Volatile organic compound
WSDE	Washington State Department of Ecology
WWTP	Wastewater treatment plant
μg/L	Microgram per liter
μg/kg	Microgram per kilogram

1.0 INTRODUCTION

Tetra Tech EM Inc. (Tetra Tech) prepared this human health risk assessment (HHRA) for the Rockwell International Corporation (Rockwell) site. This assessment is based on data obtained during the site characterization and sampling activities discussed in the remedial investigation (RI) report prepared by Tetra Tech.

As described in U.S. Environmental Protection Agency (EPA) guidance, an HHRA is typically conducted in the following four basic steps: (1) data evaluation and identification of chemicals of potential concern (COPC), (2) exposure assessment, (3) toxicity assessment, and (4) risk and hazard characterization (EPA 1989). These four steps and a risk assessment summary step are discussed as detailed below in *Sections 2.0 through 6.0 of this HHRA.*

- **Section 2.0, Data Evaluation and Identification of COPCs**: This section summarizes data collection and evaluation activities, discusses modeling issues, and identifies COPCs.

- **Section 3.0, Exposure Assessment**: This section characterizes the exposure setting, identifies potential human exposure pathways, estimates environmental concentrations of COPCs at points of potential exposure (exposure point concentrations [EPC]) and human intake or dose, and discusses exposure assessment uncertainties.

- **Section 4.0, Toxicity Assessment**: This section summarizes relevant toxicological information, including regulatory toxicity criteria for the COPCs.

- **Section 5.0, Risk and Hazard Characterization**: This section discusses numerical estimates of carcinogenic risks and noncarcinogenic hazards, general conclusions regarding potential risks and hazards associated with exposure to COPCs under both current and potential future land-use scenarios, the COPCs and exposure pathways that contribute most significantly to the overall risks and hazards, and major uncertainties associated with these estimates.

- **Section 6.0, HHRA Summary**: This section summarizes the HHRA process, major assumptions, and significant conclusions and uncertainties related to the HHRA.

References, figures, and tables cited in this report are presented after Section 6.0. In addition, the report also includes eight appendixes that document data and methods used to perform the HHRA. These appendixes are identified below.

- **Appendix G-A**: HHRA data tables, including sitewide and area-specific tables

- **Appendix G-B**: Summary of statistics for soil, light nonaqueous-phase liquid (LNAPL), groundwater, surface water, and sediment COPCs

- **Appendix G-C**: Discussion of the algorithms, assumptions, and input parameter values used to estimate source area- and land-use scenario-specific estimates of particulate emissions and COPC-specific on-site and off-property air concentrations associated with particulate emissions

- **Appendix G-D**: Discussion of the algorithms, assumptions, and input parameter values used to estimate indoor air concentrations and volatilization of contaminants from groundwater to air in trenches

- **Appendix G-E**: Discussion of the algorithms, assumptions, and input parameter values used to estimate receptor- and land-use scenario-specific risks associated with potential exposure to lead in on-site soil

- **Appendix G-F**: Exposure Factor Tables: Tables showing the equations and parameter values used for each exposure pathway

- **Appendix G-G**: Sitewide and area-specific exposure, risk, and hazard results under reasonable maximum exposure and central tendency conditions

- **Appendix G-H**: Toxicological profiles for COPCs

The HHRA objective and technical approach are discussed below. This final HHRA addresses Michigan Department of Environmental Quality (MDEQ) comments, as appropriate, on the draft HHRA dated May 9, 2001 (see attachment).

1.1 HHRA OBJECTIVE

The objective of this HHRA is to evaluate potential risks and hazards associated with human exposure to COPCs associated with the Rockwell site under both current and potential future land-use scenarios. Specifically, the HHRA evaluates exposures, hazards, and risks to human health under the current abandoned and industrial land-use scenarios and future residential, recreational, and industrial land-use scenarios at the site. The HHRA also evaluates site-related exposures, hazards, and risks to human health for off-property areas potentially impacted by releases from the site such as residences in the vicinity of the site and recreational uses of the adjacent Kalamazoo River. However, it should be noted that site-specific remediation goals will not be based on this HHRA. Applicable or relevant and appropriate requirements (ARAR) providing the basis for site-specific remediation goals include MDEQ Part 201 cleanup criteria and EPA Region IX preliminary remediation goals (PRG). Hazards and risks are calculated for sitewide exposures to on-site soil and groundwater as well as for area-specific exposures in the following areas:

- Former soluble oil separation (SOS) pond area
- Former Rockwell wastewater treatment plant (WWTP) area
- Former on-site railroad right-of-way
- Grassy area
- Area under and north of the former west manufacturing building
- Saturated zone beneath the former City of Allegan landfill
- Former off-property railroad right-of-way
- Off-property residential area (background soil)
- Kalamazoo River downstream shoreline only

Area-specific hazards and risks were not evaluated for on-site groundwater because groundwater moves readily between areas. The HHRA areas are identified in Figure G-1. These areas include all areas of interest (AOI) identified in the Rockwell RI report. In addition, several unique areas are included in the HHRA because exposure scenarios differed throughout portions of AOIs (such as the former railroad right-of-way, which is split into off-property and on-site areas, and the Kalamazoo River, downstream shoreline only). An additional HHRA area was also created for residential areas where soil background samples were collected for the RI. These locations, except for RW-BG04-0507, were determined to be affected by the site. The sampling area is identified as the HHRA off-property residential area (background soil).

1.2 HHRA TECHNICAL APPROACH

The HHRA was prepared in accordance with EPA and MDEQ guidance. Some of the key guidance documents used to prepare the HHRA are listed below. This list is not comprehensive, and other EPA and MDEQ guidance documents as well as other documents are cited in the text as appropriate.

EPA Guidance Documents

- 1988. "Superfund Exposure Assessment Manual." Office of Emergency and Remedial Response (OERR). Washington, DC. EPA/540/1-88/001. April.

- 1989. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)" (RAGS). OERR. Washington, DC. EPA/540/1-89/002. Interim Final. December.
- 1991. "RAGS, Volume I: Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors." Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03. Interim Final. March 25.
- 1991. "RAGS, Volume 1: Human Health Evaluation Manual (Part B), Development of Risk-Based Preliminary Remediation Goals." Interim. Publication 9285.7-01B. December.
- 1992. "Dermal Exposure Assessment: Principles and Applications." Office of Health and Environmental Assessment. Interim Report. EPA/600/8-91/011B. January.
- 1996. "Proposed Guidelines for Carcinogenic Risk Assessment." *Federal Register* (FR). 61 FR 7960. Volume 61. Number 79. April 23.
- 1996. "Soil Screening Guidance: Technical Background Document." OSWER. EPA/540/R-95/128. May.
- 1997. "Exposure Factors Handbook." Volumes 1 through 3. Office of Research and Development. EPA/600/P-95/002Fa, -Fb, and -Fc. August.

MDEQ Guidance Documents

- 1998. "Part 201 Generic Soil Direct Contact Criteria: Technical Support Document." Environmental Response Division (ERD). August 31.
- 1998. "Part 201 Generic Drinking Water Criteria: Technical Support Document." ERD. August 31.
- 1998. "Part 201 Generic Soil Inhalation Criteria for Ambient Air: Technical Support Document." ERD. August 31.
- 1998. "Part 201 Generic Soil/Water Partitioning Criteria: Technical Support Document." ERD. August 31.
- 2000. "Part 201 Cleanup Criteria Changes for June 7, 2000." ERD Accessed on January 18, 2001. On-Line Address: http://www.deq.state.mi.us/erd/critguide

The HHRA was conducted in accordance with the four basic steps discussed in Section 1.0. The technical approach for each step is discussed in detail in Sections 2.0 through 6.0 of the HHRA.

2.0 DATA EVALUATION AND IDENTIFICATION OF COPCs

The primary purpose of this section is to discuss methods used to identify COPCs associated with the Rockwell site. COPCs represent chemicals that may be site-related, are carried through the remainder of the HHRA and for which carcinogenic risks and noncarcinogenic hazards are estimated. The section is organized as:

- Section 2.1, data collection
- Section 2.2, data evaluation
- Section 2.3, COPC identification process
- Section 2.4, modeling activities conducted to fill data gaps
- Section 2.5, uncertainties related to the identification of COPCs

2.1 DATA COLLECTION

Historical investigations that have been conducted at the Rockwell site include the following:

- Shilts & Graves oil seepage investigation (1975)
- Residual Management Technology, Inc. (RMT), surface and well evaluation (1984)
- Ecology and Environment, Inc. (E&E), preliminary site assessment (1994)
- Aware, Inc. (Aware), resampling and analysis (1985)
- Remcor; Environmental Strategies Corporation; McLaren/Hart, Inc.; and PTI Environmental Services RI/feasibility study (FS) (1990, 1992, 1993, and 1996)

Tetra Tech has identified data gaps in previous investigations, and differences in the investigations make using and combining data from them difficult and, in some cases, inappropriate (EPA 1992b). The objectives of Tetra Tech's RI/FS include filling data gaps identified by Tetra Tech's conceptual site model (CSM) and conducting an HHRA for soil, LNAPL, groundwater, sediment, and surface water matrices associated with the site. Therefore, this HHRA is based solely on data collected by Tetra Tech as part of the RI because these data represent the most complete and consistent set of data for the Rockwell site. Also, the Tetra Tech RI provides adequate data to evaluate potential risks and hazards to human health at the Rockwell site. The RI report provides additional details on data collection methodologies.

MDEQ conducted several investigations at the Rockwell site after the Tetra Tech RI. These investigations are documented in the following reports:

- Earth Tech, Inc. (Earth Tech). 2001. "Technical Memorandum, Former Manufacturing Building Investigation."
- Earth Tech. 2001. "Technical Memorandum No. 2 - Addendum, Southern Outfall Investigation."

These and other recent MDEQ investigations provide additional detail regarding the nature and extent of contamination at the site. However, the data collected during these investigations are not included in this HHRA. The additional data does not alter the conclusion of this HHRA, which documents that significant risk to human health exists at the Rockwell site.

2.2 DATA EVALUATION

EPA's "Guidance for Data Useability in Risk Assessment (Part A) Final" identifies five primary criteria that ideally should be satisfied before data are used in a quantitative risk assessment (EPA 1992b). These criteria are summarized below.

- Reports should be available to risk assessors that include site descriptions and present the sampling program design, sampling locations, analytical methods, detection limits, sampling results, and sample quantitation limits (SQL).
- Documentation should be available for review of sampling results as they relate to geographic locations (that is chain-of-custody documentation, standard operating procedures [SOP], and field and analytical records).
- Sampling results should be available for each medium within an exposure area generated using a broad spectrum of analytical techniques as well as documentation of any field measurements needed to support fate and transport modeling.
- Acceptable analytical methods should have been used with SQLs capable of detecting concentrations of significant health concern.
- Data validation review should have been performed including consideration of data completeness, comparability, representativeness, precision, and accuracy.

Data collected by Tetra Tech as part of the RI meet all five of these primary criteria as summarized below.

Samples were collected and analyzed in accordance with the EPA-approved site-specific plans (Tetra Tech 2000a). As described in the RI quality assurance project plan (QAPP) and field sampling plan (FSP), samples were generally analyzed in accordance with EPA Contract Laboratory Program (CLP) procedures and protocols for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides and polychlorinated biphenyls (PCB), and metals. The analytical methods were selected in part to ensure to the degree possible that the method detection limits used were capable of detecting concentrations of significant health concern (Tetra Tech 2000a). However, many "screening" samples were collected during the RI that do not meet the level of data quality required for quantitative risk assessment; therefore, only samples analyzed by approved CLP laboratories were included in the HHRA. RI analytical results analyzed by approved CLP laboratories include those analyzed by the EPA Region 5 CLP laboratory and Southwest Laboratories of Oklahoma. Documentation of all sampling procedures, records, and results was available to the risk assessment team.

Documentation regarding data needed to support fate and transport modeling in the HHRA was also available to the risk assessment team except for silt and moisture content of surficial soil needed for particulate emissions modeling. However, subsurface soil silt and moisture content data were collected during RI field activities and used as a surrogate for surface soil silt and moisture content data. Appendix G-C provides methods for the evaluation and results of particulate emission modeling calculations.

RI data were all subject to a data validation review. Analytical results produced by the EPA CLP laboratory were validated by EPA. EPA's validation reports were provided to Tetra Tech with each data package. Analytical results produced by all other laboratories were validated by Tetra Tech. Appendix D of the RI report presents Tetra Tech's data validation report. Only data determined by the data validation procedures to be acceptable for use were considered in the quantitative HHRA. All data were acceptable for use; however, several samples had concentrations less than five times the maximum blank-related concentrations. The concentrations in the samples associated with contaminated blanks were treated as nondetect, and the detection limits were adjusted to equal one half of the contract-required detection limit (CRDL) in accordance with EPA guidance (EPA 1989).

Tables G-A-1 through G-A-23 in Appendix G-A compare sitewide sample analytical results to health-based screening levels (HBSL) (or CRDLs when HBSLs were not available) and are color-coded according to specific data evaluation parameters and the results of these comparisons. Red indicates a sample concentration that exceeds the HBSL for that analyte, yellow indicates a sample-specific detection limit that exceeds the HBSL, green indicates a sample-specific detection limit significantly higher than that of other samples for the same analyte, and dark blue indicates a sample in a specific data set with contamination in a blank used for that data set. Only samples with a concentration less than five times the maximum blank-related concentration are presented in dark blue. Light blue indicates an analyte that was not detected in any sample for a given medium. Pink indicates that a HBSL was modified to equal a soil background concentration (only applicable to metals). Tables G-A-24 through G-A-84 in Appendix G-A compare area-specific analytical results to HBSLs. These data sets are subsets of the sitewide analytical results.

As indicated in MDEQ's May 9, 2001, comments on the HHRA, MDEQ provided EPA with alternate HBSLs for several contaminants. These alternate HBSLs are listed in Tables 7 through 11 of the RI report. The alternate HBSLs differ from the HBSLs included in the HHRA as discussed below.

- State-wide background values presented in MDEQ's Part 201 criteria for soil were used instead of the site-specific background concentrations included in the HHRA for aluminum, chromium, cobalt, iron, manganese, and silver.
- For lead, the HBSL proposed by MDEQ is based on direct contact with soil instead of the site-specific background concentration included in the HHRA.
- For LNAPL, the HBSL proposed by MDEQ is based on groundwater screening criteria instead of the soil-based criteria included in the HHRA.

With the exception of the alternate LNAPL criteria, all criteria proposed by MDEQ are higher than HBSLs used in the HHRA. Higher HBSLs may result in the exclusion of several COPCs now included in the HHRA. For LNAPL, alternate HBSLs are both higher and lower than HHRA HBSLs. However, risks and hazards significantly exceeding appropriate thresholds for LNAPL are identified in this HHRA. Therefore, use of the alternate HBSLs does not alter the conclusions of the HHRA and no alternate HBSLs are included in the final HHRA.

As discussed above, the first, second, third, and fifth of EPA's data evaluation criteria were all met for data included in the HHRA. The remainder of Section 2.2, specifically Sections 2.2.1 through 2.2.5, focuses on the fourth of EPA's criteria - whether acceptable analytical methods were used with SQLs capable of detecting concentrations of potential health concern (HBSLs, as described above). Section 2.2.6 summarizes medium-specific data sets used as the foundation of the HHRA.

2.2.1 Data Evaluation of Soil Sampling Results

Tables G-A-1 through G-A-5 in Appendix G-A compare sitewide soil sample analytical results to HBSLs for VOCs, SVOCs, pestcides and PCBs, metals, and dioxins, respectively. For the purposes of the HHRA, HBSLs for soil are defined as the lowest MDEQ Part 201 Residential and Commercial I soil criterion (MDEQ 2000). If a Part 201 criterion was not available for a given chemical, the EPA Region IX PRG for residential soil was selected as the HBSL (EPA 2000). If a criterion was not available from MDEQ or EPA Region IX, the EPA CLP CRDL was used for that analyte. In accordance with MDEQ criteria for certain metals, the highest background metal concentration was chosen as the HBSL only when the background sample concentration exceeded the MDEQ criterion.

In most cases, SQLs were below HBSLs; however, several SQLs exceeded HBSLs in some or all soil samples for a specific chemical. Chemicals for which all SQLs exceeded HBSLs include atrazine with an HBSL of 60 micrograms per kilogram (μg/kg) and a minimum SQL of 330 μg/kg and pentachlorophenol with an HBSL of 22 μg/kg and a minimum SQL of 830 μg/kg. Neither atrazine nor pentachlorophenol were detected in any soil samples, and these chemicals are not known to be site-related. Also, several chemicals have some SQLs that exceed HBSLs; however, these chemicals were not detected above HBSLs in the samples with SQLs below HBSLs. Therefore, although elevated SQLs exist, they are unlikely to result in an underestimation of risk for these contaminants.

Table G-A-1 and G-A-2 in Appendix G-A indicate that one sample concentration for cis-1,3-dichloropropene and one sample concentration for 1,1'-biphenyl exceeded HBSLs. However, because these analytes were detected only once at concentrations not significantly above the HBSLs, the concentrations were considered outliers and were not used in the HHRA.

Also, significantly elevated (in other words, at least an order of magnitude higher than other SQLs) SQLs were noted for SVOCs for the following samples: RW-SB40-0406, RW-SB47-0002, RW-SB58-0204, RW-SB68-0002, and RW-SB68-0406, and for pesticides and PCBs for sample RW-SB40-0406. Significantly elevated detection limits may result in the over- or underestimation of risks in the HHRA. Risks may be overestimated because one-half of each sample detection limit for non-detect samples is used in 95th percentile upper confidence limit (UCL_{95}) calculations and in some cases one-half the detection limit is higher than the highest detected concentration of a contaminant. Risks may be underestimated because an undetected contaminant may be present at a concentration greater than an HBSL but less than the elevated detection limit.

2.2.2 Data Evaluation of LNAPL Sampling Results

LNAPL was detected in five on-site groundwater monitoring wells and one off-property groundwater monitoring well located in the former off-property railroad right-of-way area. Tables G-A-6 through G-A-9 in Appendix G-A compare LNAPL sample analytical results with their HBSLs for VOCs, SVOCs, pestcides and PCBs, and metals, respectively. For the purposes of the HHRA, HBSLs for LNAPL are defined as the lowest MDEQ Part 201 Residential and Commercial I soil criterion (MDEQ 2000). If a Part 201 criterion was not available for a given chemical, the EPA Region IX PRG for residential soil was selected as the HBSL (EPA 2000).

Because of the complex nature of the LNAPL matrix, most SQLs were significantly elevated compared to soil SQLs. In many cases, these elevated SQLs exceeded HBSLs. Because elevated SQLs are associated with site-related chemicals such as polynuclear aromatic hydrocarbons (PAH) and PCBs, risk associated with exposure to LNAPL may be underestimated in the HHRA.

LNAPL concentrations were reported by the laboratory in μg/kg because the density of the source material was unknown. These concentrations were converted to micrograms per liter (μg/L) using an average specific gravity of 0.927. This average was calculated based on a range of cutting oil formulations (Cornell University 2000).

2.2.3 Data Evaluation of Groundwater Sampling Results

Tables G-A-10 through G-A-14 in Appendix G-A compare groundwater sample analytical results to HBSLs for VOCs, SVOCs, pestcides and PCBs, metals, and dioxins, respectively. For the purposes of the HHRA, HBSLs for groundwater are defined as the lowest MDEQ Part 201 Residential and Industrial-Commercial Groundwater criterion (MDEQ 2000). If a Part 201 criterion was not available for a given chemical, the EPA CLP CRDL for drinking water or groundwater was selected as the HBSL.

In most cases, SQLs were below HBSLs; however, several SQLs exceeded HBSLs in some or all groundwater samples for a specific chemical. Chemicals for which all SQLs exceeded HBSLs include benzo(a)anthracene with an HBSL of 2.1 μg/L and a minimum SQL of 5 μg/L; benzo(b)fluoranthene and bis(2-chloroethyl)ether both with HBSLs of 2 μg/L and minimum SQLs of 5 μg/L; dibenzofuran with an HBSL of 4 μg/L and a minimum SQL of 5 μg/L; fluoranthene with an HBSL of 1.6 and a minimum SQL of 5 μg/L; hexachlorobutadiene with an HBSL of 0.053 μg/L and a minimum SQL of 5 μg/L;

nitrobenzene with an HBSL of 3.4 µg/L and a minimum SQL of 5 µg/L; pentachlorophenol with an HBSL of 1 µg/L and a minimum SQL of 20 µg/L; toxaphene with an HBSL of 1 µg/L and a minimum SQL of 2.5 µg/L; 4,4'-DDT and endrin aldehyde both with HBSLs of 0.02 µg/L and minimum SQLs of 0.08 µg/L; and PCBs with HBSLs of 0.2 or 0.4 µg/L and a minimum SQL of 1 µg/L. None of these analytes except Aroclor 1254 was detected in any groundwater samples. Also, with the exception of hexachlorobutadiene and pentachlorophenol, SQLs were not significantly greater than HBSLs. Furthermore, hexachlorobutadiene and pentachlorophenol are not known to be site-related. Therefore, although elevated SQLs exist, they are unlikely to result in an underestimation of risk for these contaminants. However, underestimation of risk may result from the exclusion of PAHs, which were regularly detected in soil.

The cis-1,2-dichloroethene concentrations in samples RW-GW-MW27S and RW-GW-MW22 and vinyl chloride in sample RW-GW-MW22 exceeded instrument calibration ranges. Therefore, concentrations for these analytes may be underestimated.

Also, it is important to note that contaminated laboratory blanks were associated with several mercury analyses. The mercury sample concentrations were less than five times the blank concentrations. Therefore, these samples were treated as nondetect and their detection limits were changed to the CLP CRDL, which, in accordance with EPA HHRA guidance, were then each multiplied by one half (EPA 1989).

2.2.4 Data Evaluation of Surface Water Sampling Results

Tables G-A-15 through G-A-18 in Appendix G-A compare the surface water sample analytical results to HBSLs for VOCs, SVOCs, pestcides and PCBs, and metals, respectively. For the purposes of the HHRA, surface water HBSLs are defined as the most conservative MDEQ Rule 57 water quality criterion (MDEQ 2000b). Only human cancer values (HCV) and human noncancer values (HNV) were used. If a Rule 57 Water Quality criterion was not available for a given a chemical, the EPA CLP CRDL for water was selected as the HBSL.

In most cases, SQLs were below HBSLs; however, several SQLs exceeded HBSLs in some or all surface water samples for a specific chemical. Chemicals for which all SQLs exceeded HBSLs include atrazine with an HBSL of 4.3 µg/L and a minimum SQL of 10 µg/L; hexachlorobenzene with an HBSL of 0.00045 µg/L and a minimum SQL of 5 µg/L; gamma-BHC with an HBSL of 0.025 µg/L and a minimum

SQL of 0.04 μg/L; 4,4'-DDT with an HBSL of 0.00015 μg/L and a minimum SQL of 0.08 μg/L; dieldrin with an HBSL of 0.0000065 μg/L and a minimum SQL of 0.08 μg/L; toxaphene with an HBSL of 0.000068 μg/L and a minimum SQL of 2.5 μg/L; and PCBs with an HBSL of 0.000026 μg/L and a minimum SQL of 1 μg/L. None of these analytes was detected in any surface water samples and, with the exception of PCBs and dieldrin, are not known to be site-related. Because SQLs are significantly above HBSLs, risks from PCBs and dieldrin may be underestimated in the HHRA. Also, several chemicals have some SQLs above HBSLs; however, these chemicals were not detected above HBSLs in the samples with SQLs below HBSLs. Therefore, although elevated SQLs exist, they are unlikely to result in an underestimation of risks for these contaminants.

Also, it should be noted that copper, lead, zinc, and cyanide all had samples associated with contaminated blanks, and their sample concentrations were less than five times the blank-related concentrations. For the purposes of the HHRA, these samples, presented in dark blue in Table G-A-18, were assigned a value either equal to the highest sample-specific detection limit of another sample result for the same analyte or the corresponding CLP CRDL for that analyte. In accordance with EPA guidance, these samples were treated as nondetect and their detection limits were changed to the CRDL each multiplied by one half.

2.2.5 Data Evaluation of Sediment Sampling Results

Tables G-A-19 through G-A-23 in Appendix G-A compare sediment sample analytical results to HBSLs for VOCs, SVOCs, pesticides and PCBs, metals, and dioxins, respectively. For the purposes of the HHRA, HBSLs for sediment are defined as the EPA Region IX PRG for residential soil criteria. If a PRG was not available for a given chemical, the EPA CLP CRDL for soil was selected as the HBSL.

Similar to LNAPL, because of the complex nature of the sediment matrix, many SQLs were significantly elevated compared to soil SQLs. In many cases, these elevated SQLs were above HBSLs. Because elevated SQLs are associated with site-related chemicals such as PAHs and PCBs, risks associated with exposure to sediment may be underestimated in the HHRA. However, elevated detection limits may also result in the overestimation of risk because one-half of each sample detection limit for non-detect samples is used in UCL_{95} calculations; therefore, elevated detection limits may result in elevated EPCs.

2.2.6 Medium-Specific Data Sets

Sediment, soil, and surface water samples were collected during Rockwell RI field activities in August 2000, and groundwater and LNAPL samples were collected in September 2000. Sample analytical results retained for use in the HHRA were grouped and evaluated according to area of concern as well as for the site as a whole (for soil and groundwater) (see Table G-1). Analytical results for the soil samples are presented in Appendix G-A.

For the purposes of the HHRA, hazards and risks were calculated for sitewide exposure to on-site soil and groundwater as well as for area-specific exposures in the following nine areas:

- Former SOS pond area
- Former Rockwell WWTP area
- Former on-site railroad right-of-way
- Grassy area
- Area under and north of the former west manufacturing building
- Saturated zone beneath the former City of Allegan landfill
- Former off-property railroad right-of-way
- Off-property residential area (background soil)
- Kalamazoo River downstream shoreline only

For the purposes of this HHRA, background samples are defined as samples collected from the location east of River Street (soil), adjacent to Ammerman Street immediately east of the site (groundwater), and upstream of the railroad bridge in the Kalamazoo River (sediment and surface water) (see Figure G-1). Analytical results for sediment and surface water samples indicate that the background locations have not been influenced by site-related contamination. However, all but one soil and all groundwater samples that were originally collected to provide background information appear to have been influenced by the Rockwell site and were not used in the HHRA for background data. Soil samples determined to be influenced by site-related contamination were later grouped in the off-property residential area and include samples RW-BG01-0002, RW-BG01-0608, RW-BG03-0002, RW-BG03-0406, and RW-BG04-0002. Analytical results from the remaining soil background sample (RW-BG04-0507) compare favorably to statewide background concentrations for southwest Michigan (MDNR 1991). Also, all background groundwater sampling locations were determined to be influenced by site-related contamination; therefore, these samples were grouped with sitewide groundwater data because their sampling locations are located immediately adjacent to the eastern boundary of the site. As a result, no background groundwater concentrations were available for comparison with on-site inorganic contaminants. Therefore, inorganic COPCs identified in soil were assumed to be COPCs for groundwater. Appendix G-A presents analytical results for the sitewide and area-specific data groups.

2.3 IDENTIFICATION OF COPCs

This section describes the COPC selection process and medium-specific COPCs in soil, LNAPL, groundwater, surface water, and sediment for the Rockwell site.

2.3.1 COPC Selection Process

In accordance with EPA guidance, COPCs were identified following a four-step process (EPA 1989). The first step in the COPC identification process is to identify all chemicals that were positively detected in at least one sample, including chemicals with no qualifiers and chemicals with data qualifiers that indicate known identities but unknown concentrations (for example, J-qualified data). Chemicals detected at concentrations insignificantly elevated above their concentrations in associated blank samples were not considered to be positively detected.

Table G-2 presents a medium-specific list of all the chemicals positively detected in at least one sample. As discussed in RAGS, this initial list of chemicals may be further reduced based on a limited number of factors, including the following:

- Comparison with appropriate background concentrations
- Evaluation of detection frequency
- Evaluation of essential nutrients
- Use of a concentration-toxicity screen

A concentration-toxicity screen was used to select sitewide COPCs for this HHRA only in conjunction with an evaluation of detection frequency. Consideration of each of the first three factors listed above is discussed below. For area-specific COPCs, the sitewide COPC list was used a starting point and sitewide COPCs were eliminated if they were not detected at concentrations at or above HBSLs in a particular area.

Comparison with Appropriate Background Concentrations

Comparison of on-site concentrations to background concentrations is generally appropriate only for inorganic chemicals. The majority of organic chemicals are not naturally occurring and are likely present as a result of human activity (EPA 1989). Therefore, for the purposes of this HHRA, background comparisons were conducted only for inorganic chemicals. As discussed in Section 2.2.6, background samples are defined as samples collected from the location east of River Street (soil), upstream of the railroad bridge in the Kalamazoo River (sediment and surface water), and sediment collected in the school pond. No background groundwater concentrations were available. Therefore, inorganic COPCs identified in soil were assumed to be COPCs for groundwater.

All but one background soil sample (RW-BG04-0507) appeared to be influenced by site-related contamination. Because only one background sample was available, statistical comparisons could not be conducted. Therefore, the lower of the UCL_{95} or the maximum concentrations of inorganic contaminants in sitewide and area-specific soil samples were compared to the inorganic concentrations in background soil sample RW-BG04-0507. Calculation of the UCL_{95} values is discussed in greater detail in Section 3.3.1.

If the site-related inorganic concentrations exceeded background concentrations, the inorganic contaminants were compared to HBSLs. This conservative approach resulted in the inclusion of most inorganic contaminants as soil COPCs; only antimony, beryllium, thallium, and vanadium were excluded as COPCs.

For Kalamazoo River sediment and surface water, the maximum concentrations of inorganic contaminants in background sediment and surface water samples were compared to the lower of the UCL_{95} or the maximum concentrations of downstream inorganic contaminants. If site-related inorganic concentrations exceeded background concentrations, the inorganic contaminants were compared to HBSLs. If the lower of the UCL_{95} or the maximum concentration of downstream contaminants exceeded the HBSL, the contaminant was considered a COPC. For sediment, only antimony, beryllium, and thallium were excluded as COPCs based on this approach. For surface water, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, mercury, nickel, selenium, silver, thallium, vanadium, and cyanide were excluded as COPCs based on this approach.

For sediment in on-site ponds, the maximum concentration of inorganic contaminants in the school pond located across River Street was compared to the lower of the UCL_{95} or the maximum concentration of inorganic contaminants detected in on-site pond sediment. If the site-related inorganic concentrations exceeded background concentrations, the inorganic contaminants were compared to HBSLs. If the lower of the UCL_{95} or the maximum concentration of downstream contaminants exceeded HBSLs the contaminant was considered a COPC for the site. Only antimony, beryllium, silver, thallium, vanadium, and cyanide were not included as on-site pond sediment COPCs based on this screening approach. For surface water in on-site ponds, inorganic contaminants were screened against HBSLs. Only contaminant concentrations that exceeded HBSLs were retained as COPCs. Based on this approach, antimony, beryllium, cadmium, cobalt, selenium, and silver were excluded as COPCs for on-site pond surface water.

Evaluation of Detection Frequency

EPA's RAGS states the following:

> "Chemicals that are infrequently detected may be artifacts in the data due to sampling, analytical, or other problems, and therefore may not be related to site operations or disposal practices." (EPA 1989)

However, RAGS also cautions that evaluation of a chemical's detection frequency in one medium must be made considering the following other factors:

- A chemical's potential relation to site operations
- A chemical's detection in other media
- The concentration at which a chemical was detected in each medium

The data set representing soil, sediment, surface water, groundwater, and LNAPL COPC concentrations associated with the Rockwell site contains a total of 147 samples, which have the following matrix distribution:

- 63 soil samples
- 29 sediment samples
- 17 surface water samples
- 32 groundwater samples
- 6 LNAPL samples

These data sets were further broken down into smaller area-specific data sets (see Table G-1). Contaminants that were detected at least once above the HBSL at the site but infrequently (less than 5 percent detection frequency) were eliminated as COPCs as discussed below.

For soil samples, one sample concentration for cis-1,3-dichloropropene; one concentration for 1,1'-biphenyl; two concentrations for antimony; and one concentration for thallium exceeded the HBSL. However, because these analytes were detected only once or twice (less than 5 percent detection frequency) and at concentrations not significantly higher than their respective HBSLs or detection limits, they were not included as a COPCs.

For LNAPL, one sample concentration for antimony exceeded the HBSL. However, because this analyte was detected only once and at a concentration not significantly higher than its HBSL, it was not included as a COPC.

No contaminants were eliminated as COPCs based on detection frequency for groundwater, surface water, and sediment samples.

Evaluation of Essential Nutrients

As discussed in EPA guidance, chemicals that are (1) essential human nutrients, (2) present at low concentrations, and (3) toxic only at very high doses may be eliminated as COPCs in a quantitative HHRA. Such chemicals generally include iron, magnesium, calcium, potassium, and sodium (EPA 1989).

As shown in Table G-4, iron was retained as a COPC in all media. A toxicity factor for iron was obtained from the EPA Region IX PRG tables, and hazard and risk calculations for iron exposure are included in the HHRA (EPA 2000). Calcium, magnesium, and potassium were detected in soil at the site at elevated concentrations based on comparison to background concentrations. Also, calcium, magnesium, potassium, and sodium were detected in groundwater at the site at elevated concentrations. Therefore, dietary intake values were researched and identified only for calcium, magnesium, and sodium. No recommended dietary intake values were found for potassium. Potassium was therefore eliminated as a COPC. Calcium, magnesium, and sodium were evaluated further based on the identified dietary intake values.

In order to determine whether these three inorganic chemicals are present at concentrations that could cause health risks, the potential intake of these three chemicals was compared to recommended, average, or minimal required daily intakes (referred to as "reference intakes") for these chemicals. If the estimated intake resulting from on-site exposure exceeded one-tenth the reference intake, the essential nutrient was retained as a COPC.

Because calcium, magnesium, and sodium are inorganic, exposure through dermal contact with soil is expected to be minimal. Likewise, review of preliminary exposure calculations revealed that potential exposure through inhalation of airborne particulates is minimal compared to exposure through incidental ingestion of soil and ingestion of groundwater. Again, based on preliminary exposure calculations for the potential receptors considered in this HHRA (see Section 3.0 for a more detailed discussion), the greatest potential exposures are expected for child and adult residents.

Estimated daily on-site intakes of calcium and magnesium and calcium, magnesium, and sodium through incidental ingestion of soil and ingestion of groundwater, respectively, were calculated for these receptors using a two-step process. First, average daily doses (ADD) were calculated using Equation G-7 (see Section 3.3.2), the exposure parameter values identified in Appendix G-F (assuming reasonable maximum exposure [RME] conditions), and total soil column and groundwater maximum detected concentrations for those essential nutrients. Second, the ADDs in units of milligrams per kilogram-day [mg/kg-day] were multiplied by child and adult body weights (15 and 70 kilograms [kg], respectively) for conversion to on-site total daily intakes (TDI) in units of milligrams per day (mg/day). Soil and groundwater ADDs and on-site TDIs are summarized in Table G-3.

The estimated on-site TDIs were then compared with reference intakes for calcium, magnesium, and sodium. These reference intakes are recommended or cited by a variety of dietetic, scientific, and industrial sources as briefly summarized below. Reference intakes are summarized first for calcium and then for magnesium and sodium, respectively.

Historically, the Committee on Dietary Allowances of the National Academy of Sciences (NAS) established recommended dietary allowances (RDA) for a variety of nutrients including calcium but not sodium or magnesium (NAS 1998). The calcium RDA for children 1 to 10 years of age was established as 800 mg/day. The RDAs for older individuals (11 to 51 or more years of age) range from 800 to 1,200 mg/day (NAS 1998); a time-weighted average of 894 mg/day was used for this HHRA based on this information.

More recently, the Food and Nutrition Board of the American Dietetic Association has begun establishing dietary reference intakes (DRI) that represent a new approach to providing "quantitative estimates of nutritional intakes" and that are intended to expand on and replace historical RDAs (Yates and others 1998). The DRIs consist of four reference intakes: (1) the RDA, (2) the tolerable upper intake level (UIL), (3) the estimated average requirement (EAR), and (4) the adequate intake (AI). No RDA, UIL, or EAR value is available for calcium. The AI represents a level judged by the experts establishing the DRIs "to meet the needs of all individuals in a group, but which is based on much less data and substantially more judgment than used in establishing an EAR or subsequently the RDA" (Yates and others 1998). The AI for calcium ranges from 500 mg/kg for children 1 to 3 years of age to 1,000 mg/kg for adults 19 to 50 years of age (NAS 1997). In order to be conservative, a reference intake of 500 mg/day (the AI for children 1 to 3 years of age) was selected to evaluate exposure of the child resident and a reference intake of 1,000 mg/day (the AI for adults 19 to 50 years of age) was selected to evaluate exposure of the adult resident.

The DRIs for magnesium recommended by NAS are 30 mg/day for infants, 410 mg/day for male teenagers, 360 mg/day for female teenagers, 420 mg/day for men over 30, and 320 mg/day for women over 30 (NAL 2001). For the purposes of this HHRA, a reference intake of 370 mg/day (the average of the DRI for men and women) was selected to evaluate exposure of the child and adult residents.

DRIs have not been established for sodium. However, several minimal necessary or average sodium intake values or ranges of values were identified from a variety of sources. As part of its "Nutrition and Your Health: Dietary Guidelines for Americans," the U.S. Department of Agriculture (USDA) states that "the human body only needs about 500 milligrams of sodium per day." USDA also identifies a daily value of 2,400 mg/day (USDA 1995). The American Dietetic Association (ADA) states that the "average adult" consumes 4,000 to 6,000 mg/day of sodium (Healthtouch 1997). The ADA also cites the National Research Council as recommending a daily sodium intake of 2,000 to 4,000 mg/day "for people who do not have high blood pressure" (Healthtouch 1997).

The Delaware Cooperative Extension Service (DCES) "Food and Nutrition Facts" cites the NAS as indicating that "the safe and adequate level for adults is approximately 1,100 to 3,300 mg of sodium daily" (DCES 1998). Finally, the Salt Institute cites NAS as stating that "Americans consume a minimum of 500 mg/day of sodium." The Salt Institute also refers to a "hygienic safety range" for sodium of 1,150 to 5,750 mg/day based on the work of a hypertension expert (Salt Institute 1998). As a conservative measure, a reference intake of 500 mg/day was selected to evaluate exposure of both child and adult residents.

As can be seen in Table G-3, the calcium and magnesium on-site TDIs calculated for child and adult residents are less than 10 percent of the reference intakes for these same inorganic chemicals in soil. Therefore, calcium and magnesium were eliminated as soil COPCs. For groundwater, the TDIs for calcium, magnesium, and sodium were significantly greater than the reference intakes. This indicates that consumption of groundwater at the site may pose a risk to human receptors. This is consistent with hazards and risks identified in Section 5 of the HHRA related to other COPCs as a result of groundwater consumption. However, it should be noted that residents in the vicinity of the site do not use groundwater as drinking water. Drinking water is obtained from the City of Allegan. Furthermore, it is likely that future residents will also obtain drinking water from the City of Allegan and not on-site groundwater. Therefore, calcium, magnesium, and sodium were not retained as COPCs for groundwater.

2.3.2 Medium-Specific COPCs

As indicated in Section 2.3.1, medium-specific COPCs were identified following a four-step process (EPA 1989). COPCs remaining at the conclusion of this process were compared to the HBSLs identified in Section 2.2. Contaminants with any detections above HBSLs were retained as final sitewide (on-site) and area-specific COPCs. Sitewide (on-site) and area-specific COPCs are listed in Tables G-4 and G-5, respectively.

2.4 MODELING ACTIVITIES

Several types of modeling were conducted in support of the HHRA to supplement available medium-specific data sets. These modeling activities include the following:

- Particulate emission modeling for both on- and off-property locations to estimate the concentrations of COPCs associated with particulate emissions (see Appendix G-C)
- Indoor air concentration modeling to estimate potential risks to on- and off-property residents and on-site workers from the migration of soil, LNAPL, and groundwater COPCs to indoor air (see Appendix G-D)
- Modeling of volatilization of contaminants from groundwater to air in trenches for the construction and utility workers (see Appendix G-D)

- Blood lead modeling to estimate concentrations resulting from receptor-specific exposure to lead (see Appendix G-E)

2.5 UNCERTAINTIES RELATED TO IDENTIFICATION OF COPCS

Uncertainties associated with the selection of COPCs result from a variety of sources. This section briefly discusses some of the more significant sources of uncertainty, including the assumption of steady-state conditions, the number and type of samples collected, the lack of air samples collected, and elevated detection limits. These uncertainties may result in over- or underestimation of risks and hazards as discussed below.

2.5.1 Assumption of Steady-State Conditions

COPC identification is based on the assumption of steady-state conditions in site soil, sediment, surface water, LNAPL, and groundwater. This assumption ignores the potential degradation of chemicals. For example, chemicals previously detected may have degraded. In general, the assumption of steady-state conditions usually contributes to an overestimation of chemical concentrations and of resulting doses, risks, and hazard if no additional contamination enters a system. However, the assumption of steady-state conditions may also result in an underestimation of hazard and risk when degradation products (such as, vinyl chloride) are more toxic than source COPCs.

2.5.2 Number and Type of Samples Collected

The soil background samples were collected only from an area east of River Street thought to be uninfluenced by the Rockwell site. Only one sample's results were comparable to normal, published background data for the region; the remaining background samples appeared to have been influenced by the Rockwell site and were excluded from the background data group for the purposes of the HHRA. To reduce potential uncertainty, a conservative approach was employed which compared background concentrations to the UCL_{95} or maximum detected on-site concentrations. This resulted in the inclusion of many inorganic COPCs, which may overestimate site-related hazards and risks. No background groundwater concentrations were available. Therefore, inorganic COPCs identified in soil were assumed to be COPCs for groundwater. Also, because most inorganic contaminants remained soil COPCs, the use of inorganic soil COPCs may overestimate site-related hazards and risks.

Also, speciation of chromium analytical results into trivalent and hexavalent forms was not conducted. According to MDEQ and EPA, no methods exist for calculating concentrations of trivalent and hexavalent chromium from total chromium. Because hexavalent chromium is not stable in the environment and is not known to be a site-related contaminant, total chromium concentrations were assumed to consist exclusively of trivalent chromium. This assumption may result in a significant underestimation of risk because the toxicity of hexavalent chromium, if present at the site, is significantly greater than trivalent chromium toxicity.

Only data collected during the Tetra Tech RI were evaluated in the HHRA. This data set provides sufficient basis for evaluation of risk to human health and the environment. As indicated in Section 5, significant risk has been documented at the Rockwell site based on RI data. However, it should be noted that additional historic and more recent data have been collected at the Rockwell site as listed in Section 2.1. Additional risks maybe identified based on the additional data.

2.5.3 Lack of Air Samples Collected

No air samples were collected during the RI field investigation because air sample collection was not in the scope of work for this work assignment. Therefore, COPCs were not identified specifically for the air medium. However, on- and off-property air concentrations were estimated based on COPC-specific concentrations in on-site soil. Soil COPCs were assumed to represent air COPCs. Therefore, the lack of air samples is expected to have limited impact on uncertainty associated with selection of air COPCs.

2.5.4 Elevated Detection Limits

As discussed in Sections 2.2.1 through 2.2.5, the detection limits associated with the analytical methods used to measure contaminant concentrations in soil, LNAPL, groundwater, sediment, and surface water samples in some cases exceeded the medium-specific HBSLs. Therefore, it is possible that contaminants may be present that were not detected because of the elevated, medium-specific detection limits. Elevated detection limits may also introduce uncertainty into EPCs because one-half of the detection limit is included in the EPC calculation for contaminants not detected. However, in terms of the selection of medium-specific COPCs, elevated detection limits are not expected to contribute significantly to uncertainty.

3.0 EXPOSURE ASSESSMENT

This section discusses methods used to estimate the types and magnitude of potential human exposure to COPCs present at or migrating from the Rockwell site. Exposure is defined as human contact with a chemical or physical agent (EPA 1989). This exposure assessment consists of three fundamental steps: (1) exposure setting characterization, (2) exposure pathway identification, and (3) exposure quantification. These steps are discussed below. Specifically, Section 3.1 characterizes the exposure setting with respect to the general physical characteristics of the site and surrounding areas and the characteristics of human receptors at or near the site. Section 3.2 discusses the conceptual site model (CSM) used to identify contaminant sources, mechanisms for release, potential receptors, and exposure pathways. Section 3.3 discusses the methods used to quantify exposure associated with each complete exposure pathway. Finally, Section 3.4 identifies and discusses uncertainties associated with the exposure assessment process as it applies to the site.

3.1 EXPOSURE SETTING CHARACTERIZATION

The exposure setting consists of the physical setting of the site and the characteristics of populations living near the site area. Section 3.1.1 describes the physical setting of the site and the surrounding area, including the climate, soil and geology, and groundwater. Section 3.1.2 discusses demographics in the site area. These sections focus on the specific aspects of the site's current physical setting and demographics considered relevant to the evaluation of exposures at or near the site currently and in the future.

3.1.1 Physical Setting

The Rockwell site is located at Glass Street in Allegan, Michigan (see Figure 1 of the Rockwell RI report). The City of Allegan is located approximately 28 miles northwest of Kalamazoo, Michigan. The Rockwell site covers 30.4 acres in the northwestern section of the City of Allegan. The site is bordered on the east by River Street, on the south by North Street, on the west by the City of Allegan publicly owned treatment works (POTW), and on the northwest and north by the Kalamazoo River. Land use in the vicinity of the site is residential and industrial. The undeveloped area southwest of the facility is largely owned by Consumers Power. The nearest residential areas are located adjacent to the site along River Street and across North Street. The North Ward Elementary School is located immediately east of River Street from the site.

The Rockwell site is currently divided into an eastern section owned by the Allegan Metal Finishing Company and a western section owned by the City of Allegan. C&O Railroad tracks roughly run along the dividing line between the east and west sections of the site. The eastern section includes a former drive-line assembly building and former heat-treat building. The western section includes a former manufacturing building, former WWTP, and three former holding ponds.

Additional site features include an unused grassy area in the northeast corner, an aboveground storage tank and a shed in the northern area of the former heat-treat building, a pumphouse near the northeast corner of the former manufacturing building, a parking lot near the southwest corner of the former manufacturing building, parts storage areas, a backwater area, and a storm water drainage system. The backwater area borders the Kalamazoo River along the western and northern portions of the site. The western portion was used by the City of Allegan for landfilling, and the northern portion was used for wastewater discharge. Wastewater effluent is discharged through three storm water drains (north, west, and east). The north drain runs from the northeast corner of the manufacturing building to holding pond 2, the west drain runs from the storm water catch basin inside the former manufacturing building through the backwater area to the Kalamazoo River, and the east drain runs from the center of the site south along the former C&O Railroad. Figure 2 of the Rockwell RI report and Figure G-1 show the site layout.

Climate

Climate in the site area is continental and controlled largely by the movement of pressure systems across the nation and by the proximity to Lake Michigan. The Great Lakes influence local climate by increasing cloudiness and windiness. The average daily high temperature is 58.8 °F, and the average daily low temperature is 37.7 °F. Precipitation is well distributed throughout the year and averages 38.33 inches per year. The average snowfall is 85.4 inches per year. The non-snow season lasts from about May to October (MRCC 2001).

Soil and Geology

On-site surface soil consists of sand or sand and gravel to approximately 2 feet below ground surface (bgs). The surface soil is sparsely vegetated, with distressed vegetation and surface staining. The subsurface consists of four layers: fill, alluvial and glaciofluvial sediments, till, and bedrock. The fill material underlying surface soil consists mainly of sand and gravel at the site. Below the fill are alluvial and glaciofluvial sediments of clayey till to fine gravel characteristic of recent deposition by a mature river system and an outwash depositional environment. The till layer below the alluvial and glaciofluvial sediments consists of dark gray and clayey silt with a trace of fine gravel and fine- to coarse-grained sand. The bedrock underlying the till is a light blue-gray shale of the Coldwater Formation. Bedrock was encountered at approximately 85 to 151 feet bgs at the site (ESC 1997).

Groundwater

The Rockwell site is situated over an area of coarse sand and gravel outwash deposits. Soil borings drilled during the RI indicate that the sand and gravel fill under the site area is approximately 8 to 34 feet thick. The alluvial and glaciofluvial sediment layer is approximately 20 to 63 feet thick. The till is approximately 113 feet thick. The water table in the sand and gravel aquifer is located at approximately 1 to 7 feet bgs. The City of Allegan provides residents with an average of approximately 1.5 million to 2 million gallons of water per day from two of four municipal wells located in the city. The city wellfield includes three wells located on Park Street approximately 0.5 mile upstream of the site and within the flood plain of the Kalamazoo River. A fourth (emergency) well is located in town behind the Allegan library at Hubbard and Chestnut. All of the wells are screened in recent alluvium deposits at depths of approximately 80 feet bgs. Only two of the production wells are in service at any time, producing a combined average production rate of approximately 1,700 gallons per minute. A well survey indicates that there are no potable private water wells within 0.5 mile of the site (ESC 1997; Tetra Tech 2001).

3.1.2 Demographics

The total population of Allegan was 4,547 in 1990. The average household income is $31,219. An average of 20 percent of the population has an income below the poverty level. Approximately 65.1 percent of the housing units are owner-occupied, and 34.9 percent are renter-occupied (State of Michigan 2001). The top three principal economic base employers include Perrigo; Thermotron Industries; and Robertshaw Controls (MultiMag 2000).

The western portion of the Rockwell site is currently governmental-zoned land. The eastern portion of the site is zoned for industrial use. A City of Allegan health services facility located south of the site is also zoned for government use. Residential zoning areas are present northeast, east, and southeast of the site (City of Allegan 2000).

3.2 CONCEPTUAL SITE MODEL

The HHRA evaluates potential exposures to COPCs associated with the Rockwell site. As discussed in Section 2.0, in addition to evaluation of sitewide hazards and risks, hazards and risks to potential on- and off-property receptors were evaluated for nine areas (see Section 1.1). Also, as described in Section 2.0, site-related COPCs include PCBs, metals, SVOCs, dioxins, and VOCs.

Figure G-2 presents the CSM for the Rockwell site. The CSM links potential and actual releases to potential human exposures. Specifically, the CSM identifies (1) contaminant sources and mechanisms of release, (2) potential receptors and exposure pathways, and (3) exposure scenarios. These three elements are discussed below.

3.2.1 Contaminant Sources and Mechanisms of Release

As shown in Figure G-2, various contaminant sources related to former Rockwell site and former City of Allegan landfill operations are present at the site and in the vicinity of the site. On-site source areas related to former Rockwell operations include the following:

- WWTP ponds
- Tanks, structures, discharge pipes, and chip loading and coolant unloading facility associated with the railroad right-of-way
- The electric meter pad in the Grassy Area
- Former SOS pond
- Floor drains, sumps, machinery pits, and other areas of known or suspected previous waste disposal under and north of the former west manufacturing building
- Other underground sources, including former waste oil storage tanks and sewers
- Other aboveground sources, including the WWTP building, equalization tanks, areas of known or suspected liquid waste deposition in the backwater areas along the west and north site boundaries, and an area of free product beneath the western portion of the former west manufacturing building discovered by MDEQ in 2001

Off-property sources of contamination include the former City of Allegan landfill. EPA requested that Tetra Tech only evaluate the saturated zone beneath the landfill as part of the RI.

Key mechanisms involved in the migration of chemicals from source areas into environmental media include the following:

- Fugitive emissions
- Deposition
- Volatilization
- Surface water releases/overflow
- Leaching by percolation
- Uptake through food webs
- Groundwater seep or discharge

The release and transport mechanisms determined to be both significant and part of a complete exposure pathway are incorporated into the quantitative exposure assessment. Each mechanism is briefly discussed below.

Fugitive Emissions

Fugitive emissions of soil particulates can result when physical forces (for example, wind erosion, construction activities, vehicular traffic, and so on) act on exposed and dry surface soil. Vegetation minimizes the potential for fugitive emissions. Currently, vegetation exists over many areas at the Rockwell site. However, the vegetation is sparse in some areas and therefore does not effectively inhibit particulate migration. Based on visual observations, 15 to 30 percent of the site is estimated to be currently effectively covered by vegetation. For the future on-site resident exposure scenario, it was assumed that 50 percent of the Rockwell site would be effectively covered with vegetation. For the future on-site parking lot and park scenario, it was assumed that 5 percent of the site would be effectively covered with vegetation. Also, particulates may be generated by construction and utility installation activities during future on-site development.

Deposition

Deposition of particulates is a secondary release mechanism that results from fugitive emissions of on-site soil. Deposition of particulates to on- or off-property soil and surface water and off-property homegrown produce may occur under current or future exposure scenarios (see "Fugitive Emissions" description above for additional detail).

Deposition of waste directly into the groundwater table is a primary release mechanism for the WWTP ponds. Historic deposition of waste occurred during Rockwell operations.

Volatilization

Volatilization represents a potential release mechanism for chemicals detected in LNAPL, groundwater, and on-site surface water. This potential release mechanism is typically evaluated for chemicals considered to be volatile as defined by a Henry's Law constant greater than 10^{-5} and a molecular weight less than 200 grams per mole. However, no volatile COPCs have been identified in soil, sediment, or off-property surface water; therefore, this release mechanism was not evaluated for these media.

Surface Water Releases/Overflow

Overflow of WWTP ponds to the Kalamazoo River has been documented. Also, contaminants may be released to underlying soil, LNAPL, and groundwater by precipitation (such as rain or melting snow). About 38.33 inches per year of precipitation is expected at the Rockwell site. Also, contaminants may migrate laterally between HHRA areas or from surface soil to surface water.

Leaching by Percolation

Chemicals may migrate by leaching from soil to underlying LNAPL and groundwater. The potential for this process to act as a release and transport mechanism was determined by evaluating (1) the characteristics of the soil column and (2) the physiochemical properties of the COPCs. Surface and subsurface soil at the Rockwell site consists primarily of sand, and contaminants include VOCs and SVOCs. Therefore, COPCs may readily migrate through soil to underlying groundwater and the LNAPL layer.

Uptake through Food Webs

Contaminants present in surface water and sediment may be taken up by fish and other organisms in the Kalamazoo River. Once contaminants such as PCBs enter the food web, bioconcentration occurs as organisms higher on the foodchain ingest smaller organisms (such as human ingestion of fish). Also, contaminants in soil may enter the foodchain through uptake of plants such as homegrown produce.

Groundwater Seep or Discharge

Chemicals that have leached from soil may potentially impact groundwater. The potential for groundwater to act as a transport medium was determined based on (1) the direction of groundwater flow, (2) use of the affected aquifer, and (3) physiochemical properties. Contaminants in groundwater would be transported in a downgradient direction. At the Rockwell site, groundwater typically flows west toward the Kalamazoo River; however, groundwater in the upper aquifer is affected by the Kalamazoo River and may flow east during times of high river water levels.

3.2.2 Potential Receptors and Exposure Pathways

Identification and evaluation of current and future potential receptors and exposure routes for the Rockwell site are based on the following:

- Physical site setting
- Demographics, including zoning and land use
- Presence of contaminant sources

Potential receptors and exposure pathways identified based on these factors are discussed below.

Potential Receptors

Under current conditions, exposure scenarios are expected to consist of child and teenaged trespassers; on-site workers; construction or utility workers; child and adult off-property residents; construction or utility workers; child and adult off-property residents; and child, teenaged, and adult off-property recreationalists. Under expected future conditions, exposure scenarios are expected to consist of on-site workers; construction or utility workers; child and adult off-property residents; construction or utility workers; child and adult off-property residents; child, teenaged, and adult off-property recreationalists; child and adult on-site residents, child and adult on-site visitors to a park; and an adult on-site parking attendant.

Exposure Pathways

Points of contact between potential receptors and site-related contaminants present in environmental media represent potential exposure pathways at the Rockwell site. Exposure pathways include inhalation, ingestion, and dermal contact (also referred to in text as direct contact). Media available for potential contact include soil, subsurface soil, LNAPL, groundwater, on-site surface water and sediment, off-property surface water and sediment, and homegrown produce.

Migration of on-site soil particulates to on- and off-property air was modeled to determine potential EPCs (see Appendix G-C). Volatilization of contaminants to air was evaluated for LNAPL, groundwater; and on-site surface water; however, volatilization was not evaluated for soil because VOCs were not detected above HBSLs in surface soil, subsurface soil, sediment, or off-property surface water. VOCs are present in on-site surface water; however, volatilization was not evaluated because contribution of this pathway to receptor exposure is likely to be insignificant.

3.2.3 Exposure Scenarios

Complete exposure pathways and scenarios exist when a point of contact exists between an affected medium and a receptor. For the Rockwell site, several complete exposure scenarios exist for the following receptors:

- Child and teenaged trespassers (current only)
- On-site workers (current and future)
- Construction or utility worker (current and future)
- Adult and child off-property residents (current and future)
- Adult, teenaged, and child off-property recreationalist (current and future)
- Adult and child on-site residents (future only)
- Adult and child on-site visitor (future only)
- Adult on-site parking attendant (future only)

Exposure scenarios for these receptors are discussed below.

Child and Teenaged Trespassers

Currently, the site is surrounded by a fence topped with barbed wire and access is restricted by a locked gate along the southern border of the site. Because the site borders residential areas, it is assumed that children and teenagers may periodically trespass on the site. During RI activities, children were noted trespassing on the site. Trespassers may be exposed to surficial soil through ingestion, direct contact, and inhalation of particulates. Trespassers may also be exposed to on-site surface water and sediment in the former Rockwell WWTP area through ingestion and dermal contact. Potential exposure of trespassers to off-property surface water and sediment in the Kalamazoo River is evaluated as part of the off-property recreationalist scenario.

On-Site Workers

Current on-site workers include those at the Allegan Metal Finishing Company and City of Allegan POTW. The Allegan Metal Finishing Company is located in the eastern portion of the site in the former Rockwell drive-line assembly building. Operations are primarily conducted indoors; however, it is assumed that an individual may work outdoors or on a loading dock for up to 4 hours out of an 8-hour work day. A portion of the City of Allegan POTW is located in the western portion of the site near the Kalamazoo River. Again, it is assumed that POTW workers may spend up to half of an 8-hour work day outdoors. Under future conditions, it is assumed that current on-site industrial operations would remain unchanged and that industrial operations similar to current operations may occur in the area west of the former on-site railroad right-of-way; therefore, on-site workers may be exposed to sitewide contaminants.

On-site workers will likely be exposed to contaminants in surficial soil through ingestion, dermal contact, and particulate inhalation. Workers may also be exposed through inhalation to contaminants migrating from LNAPL and groundwater to indoor air.

Construction or Utility Workers

Under current and future conditions, it is expected that construction activities will occur, including demolition of the west manufacturing building, construction of a residential area including 30 homes, and construction of park features (for example, picnic areas, shelters, and grills) and site preparation activities (such as earth moving and compaction). It is also likely that inspections or repairs to existing or newly installed underground utilities may require infrequent subsurface excavation. Construction and utility workers may be exposed to surface and subsurface soil and on-site surface water and sediment through ingestion, dermal contact, and inhalation of particulates. Inhalation of contaminants from surface water was not evaluated because surface water COPCs do not include VOCs. These workers may also be exposed to LNAPL and groundwater during excavation activities, primarily through dermal contact and inhalation. Ingestion of LNAPL and groundwater may also occur but is likely to be insignificant and is not quantitatively evaluated in the HHRA.

Adult and Child Off-Property Residents

The nearest residential areas are located adjacent to the site's eastern boundary along River Street and south across North Street. LNAPL has been detected in the residential area south of the site and subsurface contaminants have migrated to an aboveground, low-lying area in a resident's backyard at [redacted] North Street. At this residence, a portion of the basement, which may be impacted by migration of volatile contaminants from LNAPL and groundwater to indoor air, is used as a bedroom. It is assumed that adult and child residents may be exposed to fugitive dust generated on site and volatile contaminants migrating to indoor air. Residents may also be exposed to contaminated soil located in the low-lying area through ingestion and dermal contact. Residents may be exposed in site-related soil and particulate contaminants taken up in and deposited on homegrown produce. Currently, groundwater is not used as a source of drinking water; however, these residences are located hydrogeologically downgradient of the site, and it was assumed that the residents may be exposed to groundwater used as a drinking water source in the future. In the future, it was also assumed that residents would be exposed to groundwater through showering. LNAPL detected on the groundwater table off the property was not evaluated as a drinking water source or under the showering scenario because it was assumed that if LNAPL was detected in a residential well, use of that well would be discontinued. Also, exposure to Kalamazoo River surface water and sediments is evaluated under the off-property recreationalist scenario. However, it is assumed that residents may also be recreationalists.

Adult, Teen, and Child Off-Property Recreationalists

Under current and future conditions, off-property recreationalists consisting of children, teenagers, and adults are expected to be exposed to Kalamazoo River sediment and surface water while walking or wading along the shore or swimming. It is assumed that exposure would be the result of walking or wading along the shore 75 percent of the time and swimming 25 percent of the time. Children are known to play along the river shore near the former off-property railroad right-of-way. Also, a park with a pier is located across the Kalamazoo River from the former off-property railroad right-of-way (see Figure G-1). Children, teenagers, and adults visiting the river are assumed to be exposed through ingestion and dermal contact of surface water and sediment. Inhalation of volatile contaminants from sediment and surface water is expected to be insignificant. Off-property recreationalists may also be exposed to fish caught in the river; however, this exposure scenario was not evaluated because (1) a fishing advisory already exists for this stretch of the Kalamazoo River for all fish based on PCBs, (2) no fish tissue data were available, and (3) RI data for semi-permeable membrane devices are only usable for qualitative evaluation of human health and ecological risks.

Adult and Child On-Site Residents

Based on discussions with EPA and MDEQ, it is assumed that a residential area may be built on the site in the future. This is consistent with surrounding land use. Based on the site size of approximately 30 acres, it is assumed that current structures would be demolished and a residential area would be constructed consisting of 30 residences. Exposure pathways for future adult and child on-site residents are the same as those for off-property residents and include inhalation of fugitive dust generated on site, inhalation of volatile contaminants migrating from LNAPL and groundwater to indoor air, ingestion and dermal contact with soil, ingestion and dermal contact with groundwater, and ingestion of homegrown produce.

On-Site Visitor

Based on discussions with MDEQ and the City of Allegan, under future conditions, it is assumed that a park may be constructed across the entire site consisting of open fields covered by grass. It is also likely picnic areas containing shelters, tables, and grilling areas will be present at the park. Activities that may occur at the park include ball playing, picnicking, walking, and other recreational activities. Adult and child on-site visitors may be exposed to surface soil through ingestion, dermal contact, and inhalation of particulates. These on-site visitors may also be exposed to groundwater during ingestion of groundwater from an on-site drinking water fountain. Exposure to groundwater through dermal contact is expected to be insignificant because the only available groundwater point of contact would be a water fountain. On-site visitors may also come into contact with surface water and sediment in the adjacent Kalamazoo River, but these scenarios were not evaluated for this receptor because it was assumed that the exposure frequency of the off-property recreationalist would be greater.

On-Site Parking Attendant

Based on discussions with MDEQ and the City of Allegan, in the future, the western portion of the site may be used as a parking lot for the Allegan County fairgrounds located across the Kalamazoo River. Under this scenario, a foot bridge would be built from the site across the river to the fairgrounds. An adult attendant working at the parking lot is assumed to be exposed more than visitors using the parking lot. Therefore, only the parking attendant was quantitatively evaluated under this scenario. An adult parking attendant may be exposed to surface soil through ingestion, dermal contact, and inhalation of particulates for the duration of the county fair (14 days), plus an additional 14 days under the RME scenario assuming that the parking lot will be used for other miscellaneous civic events.

3.3 EXPOSURE QUANTIFICATION

Exposure is defined as the contact of an organism with a chemical or physical agent. The magnitude of potential chemical exposure, which is the amount of chemical available at human exchange boundaries (skin, lungs, and gut) during a specified time period, are quantitatively assessed for the human receptors discussed in Section 3.2.3 above.

Exposure dose equations consider contact rate, receptor body weight, and frequency and duration of exposure to estimate the intake or dose of each COPC for the receptor. Exposure doses were calculated for the RME case, which is the highest level of exposure reasonably expected to occur, and for the central tendency (CT) case, which is the most likely level of exposure expected to occur.

Exposure can occur over a period of time. The total exposure can be divided by the time period to calculate an average exposure per unit of time. An average exposure can be expressed in terms of body weight. All exposures quantified in this HHRA are normalized for time and body weight, presented in units of milligrams of chemical per kilogram of body weight per day (mg/kg-day), and termed "intakes." Equation G-1 is a generic equation for calculating chemical intake (EPA 1989).

$$I = \frac{C \times CR \times EF \times ED}{BW \times AT} \qquad \text{(G-1)}$$

where

I = Intake: the amount of chemical at the exchange boundary (mg/kg-day); to evaluate exposure to noncarcinogenic chemicals, the intake is referred to as average daily dose (ADD); to evaluate exposure to carcinogenic chemicals, the intake is referred to as lifetime average daily dose (LADD)

C = Chemical concentration: the average concentration (referred to as the EPC) contacted over the exposure period (for example, milligrams per kilogram [mg/kg] for soil and milligrams per liter [mg/L] for groundwater)

CR = Contact rate: the amount of contaminated medium contacted per unit of time or event (for example, milligrams per day [mg/day] for soil and liters per day [L/day] for groundwater)

EF = Exposure frequency: how often the exposure occurs (days/year)

ED = Exposure duration: how long the exposure occurs (years)

BW = Body weight: the average body weight of the receptor over the exposure period (kilograms [kg])

AT = Averaging time: the period over which exposure is averaged (days); for carcinogens, the averaging time is 25,550 days based on a lifetime exposure of 70 years; for noncarcinogens, the averaging time is calculated as ED (years) x 365 days/year

Variations of Equation G-1 were used to calculate pathway-specific exposures to COPCs. The equations and parameter values used for each exposure pathway are presented in Tables G-F-1 through G-F-61 in Appendix G-F.

Calculation of EPCs and pathway-specific intake equations and exposure parameters are discussed below.

3.3.1 Exposure Point Concentrations

The EPC is defined as the concentration of a COPC that a human receptor is exposed to at an exposure point. This section summarizes how EPCs were derived for soil, air, groundwater, LNAPL, surface water, and sediment samples collected during the field investigation. Medium-specific EPCs for each area, medium, and COPC are presented in Table G-6.

Data used in the HHRA were obtained from samples collected by Tetra Tech as part of the field investigation for the RI. The procedures used to identify data outliers and compare on-site data sets to the background soil data are discussed in Section 2.2.1. Prior to calculation of EPCs, data were first evaluated to determine their distribution. The data sets were tested for normal and lognormal distributions. Specifically, the data were evaluated using normal probability plots and the W-test (appropriate for sample lots less than 50). For parameter-specific data sets with nondetect values (censored data), the W-test requires the substitution of one-half the detection limit for the censored data. The distribution of data sets with more than 50 percent censored data was not determined and assumed to be lognormal.

The 95^{th} percentile upper confidence limit (UCL_{95}) on the mean was determined for data sets with normal or lognormal distributions using the distribution-specific methods in EPA's "Supplemental Guidance to RAGS: Calculating the Concentration Term" (EPA 1992c). Procedures used to estimate EPCs are discussed below.

Procedures Used to Calculate EPCs

For normal or lognormal distributions, the UCL_{95} was calculated as described in EPA's "Supplemental Guidance to RAGS: Calculating the Concentration Term" (EPA 1992c). If the normal and lognormal distributions were rejected and a nonparametric distribution was assumed, a percentile equivalent to the UCL_{95} was calculated as the EPC (WSDE 1992 and 1993). This equivalent was calculated using the "Z factor" as described below. An equivalent percentile was determined for each data set based on the number of samples associated with the data set. With an exactly normal distribution, the UCL_{95} is a percentile above the 50th percentile of the distribution as shown in Equation 2.

$$UCL = x + \left(t/\sqrt{n}\right)s \qquad \text{(G-2)}$$

where

x	=	Mean of sample chemical concentrations
t	=	Student t-value (alpha = 0.05)
n	=	Number of samples
s	=	Standard deviation of sample chemical concentrations

Equation G-2 becomes the exact parameter calculated in Equation G-3 below.

$$UCL = \mu + \left(t/\sqrt{n}\right)\sigma \qquad \text{(G-3)}$$

where

μ	=	Mean of sample chemical concentration distribution
t	=	Student t-value

n	=	Number of samples
σ	=	Standard deviation of sample chemical concentration distribution

How much the percentile exceeds the 50th percentile is an inverse function of the number of samples. The percentile can be calculated by calculating the factor $\left[t_{(n-a,95\%)}\sqrt{n}\right]$. This factor, normally called "Z" or the "standard normal variable," is entered into a table of the cumulative normal distribution to determine an equivalent percentile. This equivalent or ideal percentile can be used as the RME point concentration for non-normal distributions when applied in nonparametric style (that is, with no assumptions regarding the type and shape of the distribution). The equivalent percentile for each chemical set is calculated using the following nonparametric procedure (Gilbert 1987):

1. Order the sample data from minimum to maximum: $x_1 \leq x_2 \leq \ldots x_k \leq \ldots x_n$.
2. Calculate the kth value that corresponds to the quantile using k = q (n+1), where q = percentile equivalent to UCL_{95} and n = number of samples.
3. If k is an integer, use the required concentration term x_k.
4. If k is not an integer (for example, for a set of 10 samples, k = 7.92), select the conservative value, which is the next largest integer (in this example, k = 8). If there is a large difference in the data values above and below a noninteger, use the more precise value of linear interpolation. For a k of 7.92, EPC = $x_7 + 0.92\ (x_8 - x_7)$.

Alternate EPC calculation methods are required for air and homegrown produce exposures because contaminant fate and transport mechanisms must be estimated to determine EPCs for these exposure pathways. EPC calculation methods for air and homegrown produce exposure are presented below.

Air EPCs

On-site and off-property air contaminant concentrations were also determined using particulate emission factors (PEF) and the SCREEN3 model. PEFs were used to estimate on-site particulate contaminant air concentrations under both current and future land-use scenarios. PEFs were calculated using dispersion factors; emission rates for wind, vehicle activity, and site preparation activities; and percentages of vegetative cover. Separate PEFs were also calculated for each HHRA area. On-site contaminant concentrations were calculated by dividing soil EPCs by the appropriate PEFs. The SCREEN3 model was used to estimate off-property air contaminant concentrations. Appendix G-C summarizes the algorithms and assumptions used to (1) estimate particulate emissions under a variety of scenarios and (2) estimate on-site and downwind (off-property) airborne particulate contaminant concentrations.

EPCs were calculated for resident and worker exposure to indoor air concentrations using the Johnson and Ettinger (1991) model. This model is recommended for use by EPA and MDEQ. The model estimates diffusive and convective transport of contaminant vapors emanating from soil and groundwater into indoor spaces. Appendix G-D discusses the algorithms, assumptions, and input parameter values used to estimate indoor air concentrations.

EPCs were also calculated for construction or utility worker exposure to VOCs migrating from contaminated groundwater to air present in trenches. These EPCs were calculated by estimating the (1) flow rate of contaminated groundwater into a trench excavated by construction or utility workers, (2) amount of VOCs that will volatilize into air present within the trench and, (3) air flow rate within the trench. Appendix G-D discusses the algorithms, assumptions, and input parameter values used to estimate air EPCs in construction or utility trenches.

Homegrown Produce EPCs

Concentrations of COPCs in residential homegrown produce were also calculated using EPA Region 6 methodologies (EPA 1998). The total concentration of COPCs in the leafy, fruit, and tuber portions of the plant were calculated. Aboveground and below ground produce concentrations resulting from root uptake (see Equations G-4 and G-5) were included in the calculations. Concentrations of COPCs in aboveground produce were calculated as follows:

$$Pr_{ag} = Cs \times Br_{ag} \qquad \text{(G-4)}$$

where

Pr_{ag}	=	Concentration of COPC in aboveground produce resulting from root uptake (mg COPC/kg dry weight)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil) (see Table G-6)
Br_{ag}	=	Plant-soil bioconcentration factor for aboveground produce (unitless) (see Table G-7)

Concentrations of COPCs in below ground produce resulting from root uptake were calculated as follows:

$$Pr_{bg} = Cs \times Br_{rootveg} \times VG_{rootveg} \qquad \text{(G-5)}$$

where

Pr_{bg}	=	Concentration of COPC in below ground produce resulting from root uptake (mg COPC/kg dry weight)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil) (see Table G-6)
$Br_{rootveg}$	=	Plant-soil bioconcentration factor for below ground produce (unitless) (see Table G-7)
$VG_{rootveg}$	=	Empirical correction factor for below ground product (unitless) (conservatively assumed to be 1)

Daily intakes of COPCs for child and adult residents from aboveground and below ground produce were calculated as follows:

$$I_{ag} = [(Pr_{ag} \times CR_{ag}) + (Pr_{ag} \times CR_{pp}) + (Pr_{bg} \times CR_{bg})] \times F_{ag} \qquad \text{(G-6)}$$

where

I_{ag}	=	Daily intake of COPC from produce (mg/kg-day dry weight)
Pr_{ag}	=	Aboveground exposed and protected produce concentration due to root uptake (mg/kg) (calculated using Equation G-4)
CR_{ag}	=	Consumption rate of exposed aboveground produce (kg/kg-day dry weight) (0.00042 for the child resident and 0.0003 for the adult resident) (EPA 1998)
CR_{pp}	=	Consumption rate of protected aboveground produce (kg/kg-day dry weight) (0.00077 for the child resident and 0.00057 for the adult resident) (EPA 1998)
Pr_{bg}	=	Below ground produce concentration resulting from root uptake (mg/kg) (calculated using Equation G-5) (EPA 1998)
CR_{bg}	=	Consumption rate of below ground produce (kg/kg-day dry weight) (0.00022 for the child resident and 0.00014 for the adult resident) (EPA 1998)
F_{ag}	=	Fraction of produce that is contaminated (unitless) (0.25 for child and adult residents) (EPA 1998)

Concentrations of COPCs in homegrown produce from air-to-plant migration of COPCs was not evaluated because VOCs are not COPCs in surface soil. Also, homegrown produce COPC concentrations from particulate deposition were not evaluated because this migration pathway is expected to be insignificant; PCBs and metals, the primary soil particulate COPCs, are unlikely to be desorbed from soil particulates and migrate through plant membranes.

3.3.2 Pathway-Specific Intake Equations and Exposure Parameters

The equations and parameter values used to estimate exposures under RME and CT exposure conditions for each exposure pathway are summarized in Tables G-F-1 through G-F-61 in Appendix G-F. This section discusses the calculation algorithms that were used to quantify intake (or dose) for each COPC. A description of the value used for each exposure parameter is also provided. For both the RME and CT evaluations, estimates of the LADDs and ADDs are quantified. The LADD defines a dose level that is distributed (averaged) over an entire lifetime rather than a specific incremental exposure period. Unlike the LADD, the ADD is not averaged over an entire lifetime. The RME LADDs and ADDs will be used to calculate upper-bound estimates of the increased potential carcinogenic risks and noncarcinogenic hazards, respectively, and the CT LADDs and ADDs will be used to estimate the average carcinogenic risks and noncarcinogenic hazards, respectively.

The equations used for quantifying exposure to COPCs in site media and the rationale for each point estimate value to be used for both the RME and CT evaluations are discussed below. In general, exposure values were taken from established EPA guidance documents, including RAGS (EPA 1989), "Exposure Factors Handbook" (EPA 1997a), "Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors" (EPA 1991a), and "Dermal Exposure Assessment: Principles and Applications" (EPA 1992a). These documents were used along with site-specific information and information from peer-reviewed scientific literature to identify appropriate RME and CT exposure parameters.

Potentially exposed populations associated with the site and surrounding area include trespassers, residents, recreationalists, on-site workers, construction or utility workers, and on-site parking attendants. Tables G-F-1 through G-F-61 in Appendix G-F present the proposed exposure parameter values for these populations. Exposure parameters are presented for the potential exposure routes (for example, ingestion, inhalation, and dermal contact) and points of contact (for example, soil and groundwater).

Equations used to calculate the LADD and ADD are presented below.

Exposure Through Soil and Sediment Ingestion:

$$LADD\ /\ ADD = \frac{C \times IS \times FI \times CF \times EF \times ED}{BW \times AT} \qquad \text{(G-7)}$$

Exposure Through Dermal Contact with Soil and Sediment:

$$LADD\ /\ ADD = \frac{C \times AF \times ABS \times SA \times CF \times EF \times ED}{BW \times AT} \qquad \text{(G-8)}$$

Exposure Through Inhalation of Particulates:

$$LADD\ /\ ADD = \frac{C \times INR \times EF \times ED \times ET \times CF}{BW \times AT} \qquad \text{(G-9)}$$

Exposure Through Ingestion of Groundwater and Surface Water:

$$LADD\ /\ ADD = \frac{C \times IW \times EF \times ED}{BW \times AT} \qquad \text{(G-10)}$$

Exposure Through Dermal Contact with Groundwater and Surface Water:

$$LADD\ /\ ADD = \frac{C \times DA_{event} \times SA \times CF \times EF \times ED}{BW \times AT} \qquad \text{(G-11)}$$

Exposure parameters and values for these equations are discussed below.

LADD-Lifetime Average Daily Dose (mg/kg-day): This term represents the dose averaged over a 70-year lifetime used to evaluate potential carcinogenic effects.

ADD-Average Daily Dose (mg/kg-day): This term represents the dose averaged over the exposure duration used to evaluate potential noncarcinogenic effects.

C-Concentration of Chemical in Medium (in medium-specific units): Concentrations are represented by the lower of the UCL_{95} or maximum concentrations for RME and CT evaluations. For soil (see Equations G-7 and G-8), the concentration term is expressed as mg/kg. For air (see Equation G-9), it is milligrams per cubic meter (mg/m^3). For water (see Equations G-10 and G-11), it is mg/L.

IS-Ingestion Rate for Soil and Sediment (mg/day): EPA recommends a soil ingestion rate of 100 mg/day for adults based primarily on Hawley's 1985 published estimate of 65 mg/day. This ingestion rate was also used as the RME value for teenagers. Activity patterns of children and construction or utility workers result in increased ingestion rates. A 200-mg/day ingestion rate will be used for the RME value for these receptors. CT values are one-half of the RME ingestion rates for all of the receptors discussed (EPA 1991a). For the on-site worker, a 50-mg/day soil ingestion rate was used for RME and CT evaluations (EPA 1991a). All soil ingestion rates were also applied to sediment ingestion rates.

FI-Fraction Ingested (unitless): This term accounts for the fraction of soil (including sediment) or dust ingested that is presumed to be contaminated. National studies indicate that children, teenagers, and adults spend an average of 4, 5, and 1.5 hours per day, respectively, at outdoor recreation (EPA 1997b). Therefore, for the teenage trespasser RME value, the fraction ingested is calculated as 2 hours on site out of 5 hours spent in outdoor activity. For child recreationalists and on-site visitors, the RME value is calculated as 2 hours on site out of 4 hours spent in outdoor activity. For adult recreationalists and on-site visitors, the RME value is 1 because the adult is also assumed to spend 2 hours on site. CT values are assumed to be one-half of the RME values. All workers are conservatively assumed to spend the entire day at the site, and 100 percent of the fraction of soil ingested is assumed to be contaminated. Therefore, the fraction ingested is 1 for all workers.

CF-Conversion Factor (in route- and medium-specific units): Conversion factors are used in some of the dose equations when the parameter units are not directly comparable. For example, in Equations G-7 and G-8, a conversion factor of 10^{-6} kg/mg was used. In Equation G-11, a conversion factor of 1 liter per 1,000 cubic centimeters was used.

EF-Exposure Frequency (days/year): This term represents the amount of time an individual may spend potentially exposed to site-related chemicals. For the trespasser, an RME value for an exposure frequency of 54 days/year was obtained from discussions with EPA (Tetra Tech 1998a and 1999). The CT value was assumed to be one-half of the RME value. For the on-site worker, the exposure frequency of 128 days/year was based on the value of 112 days/year recommended by MDEQ for dermal contact with soil (MDEQ 1998b). However, on-site workers were assumed to be exposed to particulates an additional 16 days/year, which includes every non-winter and non-rain day that the worker is present on site. For the construction or utility worker, an exposure frequency of 20 days/year was used for CT and RME evaluation of soil ingestion and dermal contact, and 200 days/year was used for the CT evaluations of particulate inhalation and exposure to groundwater. For the off-property recreationalist and on-site visitors, exposure frequency values of 145 (RME) and 73 (CT) days/year were based on the assumption that individuals will be involved in recreational activities two days per week, except for 120 days of

Michigan winter (MDEQ 1998b), one rainy day per non-winter week (MDEQ 1998b), and one week of non-winter vacation. The EPA default value of 350 days/year was used for the RME residential evaluation, and 206 days/year will be used for the CT residential evaluation. This value accounts for time spent at home and allows for an absence of 2 weeks per year (EPA 1991a). For on-site parking attendants, exposure frequency values of 28 and 14 days per year are based on the duration of the county fair (14 days for the CT evaluation) plus 14 additional days for miscellaneous civic events (28 days for the RME evaluation).

ED-Exposure Duration (years): The exposure duration is the amount of time an individual may be exposed to site-related chemicals. Typically, this term describes the number of years spanning the receptor group (for example, children and teenagers), occupational tenure or length of construction activity for industrial scenarios, or residency time for residential scenarios. For on-site workers, this parameter describes the number of years that an individual will spend performing work-related activities at the site. Available data indicate that average occupational tenure is 6.6 years, which was used for the CT value, and an appropriate upper-bound estimate of 25 years was used for the RME value (EPA 1991a). Construction or utility workers were assumed to spend 1 year on the site performing construction activities.

For residential scenarios, the exposure duration parameter is the fraction of a lifetime an individual spends at his or her home. National data were used for both the RME and CT evaluations. The exposure duration for the CT will be the 50th percentile of the residential tenure distributions of owner-occupied housing in the United States (9 years for noncarcinogenic risk). The exposure duration for the RME value is the 90th percentile of this distribution (30 years for noncarcinogenic risk) (EPA 1991a). For the adult off-property recreationalist, on-site visitors, and on-site parking attendant, resident exposure durations were used to represent these receptors because nearby residents were assumed to be engaged in these activities.

BW-Body Weight (kg): Standard EPA and MDEQ default body weights were used for exposure scenarios for both the RME and CT evaluations. A body weight of 70 kg were used for adults (EPA 1991a; MDEQ 1998b). Child and teenager body weights of 15 and 58.1 kilograms, respectively, were taken from recent EPA guidance (EPA 1997b). An older child body weight of 33 kilograms was also taken from recent EPA guidance (EPA 1997b).

AT-Averaging Time (days): The average lifetime for humans is assumed to be 70 years (EPA 1989) for the LADD calculations. For the ADD calculations. the averaging time was set equal to the exposure duration.

AF-Soil Adherence Factor (milligrams per square centimeter [mg/cm²]): EPA has determined that a range of values from 0.2 to 1.5 mg/cm² appears to be plausible for this term (EPA 1992a). EPA believes that the lower end of the range may be the best value to represent an average overall soil adherence factor (EPA 1992a). Therefore, the value of 0.2 mg/cm² was used for the RME estimates for trespassers, construction or utility workers, and child residents. These estimates are consistent with the current values presented in revisions to the dermal exposure assessment and MDEQ guidance (Tetra Tech 1998d). This is also the soil adherence factor presented by EPA Region IX (EPA 2000). For the construction or utility worker, 0.2 mg/cm² was also used for CT estimates. For other the CT estimates, soil adherence factors were calculated from EPA guidance (EPA 1997). For the trespasser, child on-site visitor, and child resident, a CT adherence factor of 0.03 mg/cm² was calculated from EPA guidance (EPA 1997b) based on loadings to hands, arms, and legs for outdoor soccer activities (EPA 1997b). For the adult resident, adult on-site visitor, on-site parking attendant, and on-site worker, RME and CT estimates were calculated from EPA guidance based on "landscape and rockery" activities (EPA 1997b).

ABS - Dermal Absorption Factor (unitless): This term is used to determine the amount of a chemical absorbed through the skin from soil. ABS terms have been experimentally determined for only a few chemicals (EPA 1992a; Tetra Tech 1998b). In addition to available guidance, EPA Region 5 staff from the dermal work group provided absorption factors that are to be included in the revised dermal exposure assessment guidance currently being prepared by EPA (Tetra Tech 1998b). In the absence of experimental data, ABS values of 0.25, 0.1, and 0.01 are proposed for VOCs, SVOCs, and inorganics, respectively. Chemical-specific ABS values are summarized in Table G-8 for all COPCs.

SA-Skin Surface Area (square centimeter [cm²] or cm²/day): EPA guidance states that 10 to 25 percent of the total skin surface area is available for contact with soil throughout the year (EPA 1992a). Therefore, a value of 25 percent of the average total skin surface area was used for most RME and CT evaluations. However, exposed skin surface area for workers is likely less than for other receptors; therefore, 10 percent of the total skin surface area was used for the CT value for this receptor.

The average total skin surface area for the teenager (ages 12 through 17) is 15,800 cm² (EPA 1997b). The upper-bound total skin surface area for adult men and women, 20,000 cm², was obtained from

MDEQ and is in agreement with available EPA guidance (MDEQ 1998b; EPA 1992a; Tetra Tech 1998d). The average adult skin surface area, 18,000 cm^2, was obtained from EPA (EPA 1997b). The average total skin surface area for the child is 7,213 cm^2 (ages 0 to 6) or 11,336 cm^2 (ages 7 to 12) (EPA 1997b). Skin surface area exposed to groundwater will be evaluated on a scenario-by-scenario basis.

INR-Inhalation Rate (cubic meters per hour [m^3/hr]): Inhalation rates are based on national studies and represent average rates for resident receptors. For the child and adult, inhalation rates of 0.31 and 0.55 m^3/hr, respectively, were used for both the RME and CT evaluations. For all other receptors, inhalation rates were calculated on a scenario-by-scenario basis from EPA guidance based on the types of activities conducted by each receptor (EPA 1997b).

ET-Exposure Time (hours per day [hr/day] or hr/event): The exposure time is the amount of time an individual may be exposed to site-related chemicals each day. Trespassers, on-site visitors, and off-property recreationalists were assumed to spend 2 hr/day (RME) or 1 hr/day (CT) engaged in scenario-specific activities. For on-site and construction or utility worker exposure to groundwater, exposure times were assumed to be 0.25 (RME) and 0.17 (CT) hr/event and 2 (RME) and 1 (CT) hr/event, respectively (EPA 1997). A standard worker exposure time for all other scenarios is 8 hr/day and is applicable to both the RME and CT scenarios. However, on-site workers were estimated to spend an average of 4 hours outdoors and construction or utility workers are assumed to spend 8 hr/day outdoors. Residential exposure times are conservatively assumed to be 24 hr/day. On-site parking attendant exposure times were assumed to be 12 (RME) and 8 (CT) hr/day based on the likely duration of a typical work day.

IW-Ingestion Rate for Drinking Water (L/day): Future on-site visitors may ingest groundwater from an on-site drinking water fountain. Based on professional judgment, the child was conservatively assumed to ingest approximately 4 ounces of groundwater (about 0.125 L/day) and the adult was assumed to ingest 8 ounces of groundwater (about 0.25 L/day) for the RME evaluation. CT values are assumed to be one-half of the RME values. EPA-recommended ingestion rates will be used for the on-site worker (1 L/day for RME and CT evaluations) and residents (2.4 and 1.5 L/day for the RME and CT estimates, respectively) (EPA 1991a and 1997c).

DA_{event}-Dermally Absorbed Dose per Event (in mg/cm^2 per event): For organics, a nonsteady-state approach was used for estimating the dermally absorbed dose from water. EPA recommends this approach because the method more accurately reflects normal human exposure conditions and accounts for the dose that can occur after the actual exposure event resulting from absorption of contaminants stored in skin lipids. However, this nonsteady-state approach was developed for application to organics that exhibit octanol-water partitioning. Thus, it is not applicable to inorganics (EPA 1992a). The following equations were used to calculate DA_{event}:

Organics:

$$\text{If } ET < t^*, \text{ then } DA_{event} = 2PC \times EPC \times CF \times (6\,Tau \times ET/\pi)^{0.5} \quad \text{(G-12)}$$

$$\text{If } ET > t^*, \text{ then } DA_{event} = PC \times EPC \times CF \times \{[ET/(1+B)] + 2\,Tau[(1+3B/(1+B)]\} \quad \text{(G-13)}$$

Inorganics:

$$DA_{event} = PC \times EPC \times CF \times ET \quad \text{(G-14)}$$

where

PC	=	Permeability coefficient (centimeters per hour); used to determine the dose of an inorganic chemical absorbed through the skin from water; chemical-specific values for PC available in EPA's "Dermal Exposure Assessment: Principles and Applications" (EPA 1992a)
t*	=	Time to steady state conditions (hr)
Tau	=	Lag time (hours)
B	=	Bunge constant reflecting the partitioning properties of a compound (dimensionless)

Chemical-specific constants, including PC, B, *Tau*, and t* values, are summarized in Table G-9.

3.4 EXPOSURE ASSESSMENT UNCERTAINTIES

Uncertainty and variability are associated with all aspects of the exposure assessment process. Often, these two terms are used interchangeably; however, the two terms are not equivalent. Variability refers to the natural variation associated with specific processes or terms that are measured or represented with estimated values. Variability cannot be reduced by further measurements or more data collection. However, additional data or greater data analysis may allow the variability to be better characterized.

Uncertainties, on the other hand, generally refer to gaps in knowledge. Defined this way, further measurements or more data collection may reduce uncertainty.

For the purposes of this HHRA, the term "uncertainties" is used to refer to both variability and uncertainty as defined above. For the most part, the results of the exposure assessment are impacted more by uncertainties, or gaps in knowledge, than by variability. For the specific uncertainties discussed below, the discussion addresses both gaps in knowledge and natural variability. The following discussion is not intended to be all-inclusive. The intention is to identify and discuss the uncertainties that most significantly impact the results of the exposure assessment so that the exposure assessment results and the overall HHRA results can be interpreted in the proper context.

The major areas of uncertainty discussed below involve (1) environmental chemical concentrations, including modeling and calculation of EPCs; (2) exposure pathway identification; (3) exposure parameters and assumptions; and (4) assumption of steady-state conditions.

3.4.1 Environmental Chemical Concentrations

Significant uncertainties are associated with the modeled concentrations as well as with the use of medium-specific analytical results that are often limited. The medium- and chemical-specific air concentrations and EPCs used in the HHRA were based on fate and transport modeling rather than on analytical results. Uncertainties are also associated with soil, LNAPL, groundwater, surface water, and sediment analytical results used in the HHRA. Uncertainties associated with medium-specific concentrations are discussed below.

Air Concentrations

Estimates of air concentrations are based entirely on modeling. Significant uncertainty is associated with the modeling itself. The model used to estimate particulate emissions and on-site and off-property air concentrations requires values for a large number of input parameters, as well as knowledge regarding the nature, frequency, and duration of fugitive dust-generating activities that may occur on site under both current and potential future land-use scenarios. In reality, measured values are available for only a handful of the necessary input parameters, and activities that may occur on-site in the future cannot be known with certainty. Therefore, both the required input parameter values and the nature of site activities must be assumed. Each of these assumptions introduces uncertainty into the estimates of on-and off-property COPC-specific air concentrations. Unless air testing is conducted, it is impossible to determine whether the emissions estimates, including the particle size distributions, are accurate. Specific sources of uncertainty include the (1) use of default dispersion factors; (2) uncertainties associated with estimating respirable particulate (particles with diameters less than or equal to 10 microns) emissions from wind erosion, vehicle traffic, and site preparation; (3) use of soil EPCs; and (4) the use of the SCREEN3 model to estimate off-property air concentrations. A more detailed discussion of uncertainties associated with estimating air concentrations is presented in Appendix G-D.

Semi-Permeable Membrane Device Concentrations

In general, contaminant data obtained from the use of semi-permeable membrane devices (SPMD) are typically used for qualitative evaluation purposes such as (1) detecting contaminants that are present at such low levels that they are undetectable in grab samples of surface water, (2) determining pollutant sources, and (3) evaluating relative contaminant levels at different locations. Although semi-permeable membrane devices may mimic the bioconcentration of lipophilic contaminants, such as PCBs, PAHs, and dioxins and furans, in fatty tissues of organisms such as fish, the data was not included in the HHRA because semi-permeable membrane devices are stationary and do not reflect activity patterns of fish. Also, numerous chromatograms of semi-permeable membrane device extracts show greater quantities of nonpolar low K_{ow} chemicals (such as PCBs) sequestered in semi-permeable membrane devices relative to caged fish because biota more readily metabolize or depurate most low K_{ow} chemicals (USGS 1999). Furthermore, fish ingestion was not evaluated in the HHRA because (1) a fishing advisory already exists for the stretch of the Kalamazoo River adjacent to the site for all fish based on PCBs, (2) no fish tissue data were available, and (3) RI data for semi-permeable membrane devices are only usable for qualitative evaluation purposes as noted above. The use and results of the SPMDs deployed at the Rockwell site are discussed in the Ecological Risk Assessment (see Appendix H of the RI).

Soil, LNAPL, Groundwater, Surface Water, and Sediment Concentrations

Based on the available information, the uncertainty associated with chemical concentrations in soil, LNAPL, groundwater, surface water, and sediment is limited. Systematic or random errors in the chemical analyses may yield erroneous data and result in over- or underestimated risks.

3.4.2 Exposure Pathway Identification

Exposure pathways for this HHRA were identified based on observed and assumed activity patterns of current and future receptors at or near the site. The magnitude of uncertainty associated with current exposure pathways is low; however, for future exposure scenarios the magnitude of uncertainty is high. For example, future residents at the site are assumed to use groundwater for drinking water; however, current residents in the area obtain drinking water from the City of Allegan. It is likely that any future residents will also obtain drinking water from the City of Allegan and not from the aquifer beneath the site. Therefore, the assumption that groundwater at and in the vicinity of the site will be used for drinking water introduces significant uncertainty to the HHRA. To the extent that assumed activity patterns are inaccurate, uncertainty is introduced into the identification of exposure pathways.

3.4.3 Exposure Parameters and Assumptions

Standard exposure parameter assumptions made for population characteristics, such as body weight, body surface area, life expectancy, and period of exposure, as well as assumptions made for exposure characteristics, such as exposure frequency, exposure duration, contact rate, and degree of absorption or soil adherence, may not represent actual exposure conditions.

The impact of population characteristic differences is probably insignificant when the entire potentially exposed population is considered because population characteristics used in the HHRA are based on national averages of large sample populations. However, the characteristics used may not accurately represent individuals who may be exposed at or near the site; therefore, actual exposures may be over- or underestimated. Use of upper-bound contaminant concentrations to represent EPCs may also result in an overestimation of risk.

The drinking water ingestion rate for the on-site visitor was assumed to be 4 ounces based on professional judgment. Actual drinking water ingestion rates may be higher during strenuous physical activity (such as ball playing). Therefore, risks may be underestimated. However, risks and hazards for ingestion of drinking water by on-site visitors significantly exceed acceptable ranges based on an intake rate of 4 ounces.

For recreationalists and on-site visitors, the fraction of soil and sediment ingested was based on national studies on time spent in outdoor recreation (EPA 1997b). This does not account for indoor dust comprised of outdoor soil and sediment. Therefore, actual amounts of outdoor soil and sediment may be slightly higher. Higher fractions of contaminated soil and sediment ingested by receptors may result in some additional risk.

3.4.4 Assumption of Steady-State Conditions

Analytical data collected in 2000 during the field investigations were used to estimate EPCs for exposures assumed to take place 30 or more years in the future. The inherent assumption is that future on- and off-property chemical concentrations will not change. This assumption ignores the effects of various fate and transport mechanisms that will alter the composition and distribution of chemicals in the various media over time.

The concentrations of metals and PCBs in soil are not expected to be significantly impacted by fate and transport mechanisms. In general, assumption of steady-state conditions usually results in overestimation of chemical concentrations and of resulting exposure doses and risks.

4.0 TOXICITY ASSESSMENT

This section identifies the toxicity values for quantifying potential adverse effects on human health associated with exposure to COPCs at the Rockwell site. These toxicity values include reference doses (RfD) for noncarcinogenic COPCs and slope factors (SF) for carcinogenic COPCs. The toxicity values for assessing the effects of noncarcinogenic COPCs are discussed in Section 4.1. The toxicity values for assessing the effects of carcinogenic COPCs are discussed in Section 4.2. Section 4.3 discusses the approach used to estimate toxicity values for evaluating dermal exposure. Section 4.4 discusses the toxicity profiles for COPCs at the site. Section 4.5 discusses uncertainties related to the identification of toxicity values.

4.1 TOXICITY VALUES FOR NONCARCINOGENIC COPCs

Standard risk assessment models assume that noncarcinogenic effects, unlike carcinogenic effects, exhibit a threshold; that is, a level of exposure exists below which no adverse effects are observed. The potential for noncarcinogenic health effects resulting from potential exposure to a COPC is assessed by comparing an estimated intake to an RfD. The RfD represents an estimated daily intake rate for a noncarcinogenic COPC that is believed to pose no appreciable risk of deleterious effects on human health, including the health of sensitive populations, during a lifetime. Similarly, a reference concentration (RfC) is a chemical-specific air concentration that is believed to pose no appreciable risk of deleterious effects on human health, including the health of sensitive populations, during a lifetime.

An RfD is specific to a chemical and a route of exposure, such as ingestion or inhalation. In addition, chronic and subchronic RfDs are developed for different periods of exposure. Chronic RfDs are used to evaluate exposures occurring over periods of more than 7 years, and subchronic RfDs are used to evaluate exposures occurring over periods of 2 weeks to 7 years. For this HHRA, chronic RfDs for the oral and inhalation routes of exposure were used; these RfDs were obtained from the Integrated Risk Information System (IRIS) (EPA 2000 and 2001a) and Health Effects Assessment Summary Tables (HEAST) (EPA 1997b). In some cases, for COPCs without RfDs, surrogate chemicals with similar chemical structures were identified and the surrogate RfDs were included for those COPCs. Table G-10 presents these surrogate chemicals and RfDs.

To derive an RfD, EPA work groups review all human and animal studies relevant to a chemical and select the study or studies pertinent to the derivation of the RfD. RfDs are often derived from a measured or estimated no observed adverse effect level (NOAEL). The NOAEL corresponds to the dose, in mg/kg-day, that can be administered over the exposure period without inducing observable adverse effects. If a NOAEL cannot be determined, the lowest observed adverse effect level (LOAEL) is used. The LOAEL corresponds to the lowest daily dose administered over the exposure period that induces an observable adverse effect. The toxic effect characterized by the LOAEL is referred to as the "critical effect."

To derive an RfD, the NOAEL or LOAEL is divided by an uncertainty factor to ensure that the RfD will be protective of human health. Uncertainty factors usually occur in multiples of 10, and each factor represents a specific area of uncertainty inherent in the extrapolation from available data. Uncertainty factors account for (1) variations in the general population to protect sensitive human populations such as child and elderly receptors, (2) extrapolation of data from animals to humans (interspecies extrapolation), (3) derivation of a chronic RfD based on a subchronic rather than a chronic study, and (4) derivation of an RfD based on a LOAEL instead of a NOAEL. Modifying factors may be applied to the data to reflect additional uncertainties associated with the data. Modifying factors range from 0 to 10. Tables G-11 and G-12 present the oral and inhalation RfDs used in this HHRA and summarize the source, route of administration (basis), critical effect, uncertainty factor, and modifying factor for each COPC identified at the site. Inhalation RfDs were calculated from RfCs using an average adult inhalation rate and body weight as shown in the following equation:

$$\text{Inhalation RfD} = \text{RfC} \times \frac{20 \text{ m}^3/\text{day}}{70 \text{ kg}} \qquad \text{(G-15)}$$

Inhalation RfDs are used in the HHRA to calculate hazards to receptors exposed to air contaminants through inhalation of particulates and VOCs in indoor and outdoor air.

Toxicity factors are not available for lead. The potential for human health effects as a result of exposure to lead is typically estimated on the basis of blood-lead concentrations. EPA guidance recommends the use of separate models for assessing risks associated with exposure to lead by children and adults. Specifically, EPA recommends using the "Integrated Exposure Uptake Biokinetic Model for Lead in Children" (IEUBK) model, Version 0.99d, to assess lead exposure of children 0 to 7 years (84 months) of age (EPA 1994a and 1994b). To assess the risks associated with lead exposure of adults, EPA recommends using the "Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead" (EPA 1996c). Both models are run to assess risks associated with exposure to lead (that is, the probability of receptor-specific blood-lead concentrations exceeding 10 micrograms per deciliter). Appendix G-E provides the risk methodologies used to evaluate lead exposures for child and adult receptors.

4.2 TOXICITY VALUES FOR CARCINOGENIC COPCs

The potential for exposure to a given chemical to result in carcinogenic effects is evaluated differently than for noncarcinogenic effects. The upper-bound excess lifetime cancer risk (ELCR) associated with a given dose is calculated by multiplying the dose from a given route of exposure by an SF. An SF is an upper-bound estimate of the probability of a carcinogenic response per unit dose of a chemical over a lifetime. SFs are derived through use of mathematical models based on a high-to-low dose extrapolation and assume that no threshold exists for initiation of cancer. Because of the use of the nonthreshold assumption and the UCL_{95} of the slope of the dose-response curve, use of SFs provides a conservative, upper-bound estimate of potential cancer risks. The actual response to a given dose of a chemical is therefore probably less than the predicted response (EPA 1989).

EPA assigns weight-of-evidence designations to indicate the likelihood that a chemical agent is a carcinogen in humans. These designations are defined below (EPA 1989).

- "A" indicates that a chemical is considered to be a proven carcinogen in humans.
- "B" indicates that a chemical is considered to be a probable human carcinogen. "B1" indicates that suggestive but inconclusive evidence of carcinogenicity in humans is associated with the chemical, and "B2" indicates that conclusive evidence of a chemical's carcinogenicity is documented in repeated animal studies but that evidence of carcinogenicity in humans is inconclusive.
- "C" indicates that a chemical is a possible human carcinogen either because a single, high-quality animal study demonstrates carcinogenicity or because several low-quality animal studies indicate carcinogenicity.
- "D" indicates that evidence of a chemical's carcinogenicity in animals or humans is inconclusive.
- "E" indicates that no evidence of a chemical's carcinogenicity is available from adequate human or animal studies.

SFs are specific to a chemical and route of exposure and are generally available for both the oral (ingestion or gavage) and inhalation routes. Sources of SFs include, in order of preference, IRIS, HEAST, and the National Center for Environmental Assessment (NCEA). Tables G-13 and G-14 summarize the oral (ingestion or gavage) and inhalation SFs used in this HHRA and summarize the source, route of administration (basis), target organ, and weight-of-evidence for each COPC identified at the site.

Inhalation SFs were calculated from unit risk factors (URF) using an average adult inhalation rate and body weight as shown in the following equation:

$$\text{Inhalation SF(mg/kg-day)}^{-1} = \text{URF}\left(\frac{\mu g}{m^3}\right)^{-1} \times \frac{1 \text{ day}}{20 \text{ m}^3} \times 70 \text{ kg} \times \text{Conversion Factor } (1{,}000\ \mu g/mg) \qquad \text{(G-16)}$$

Inhalation SFs are used in the HHRA to calculate risks to receptors exposed to air contaminants through inhalation of particulates and VOCs in indoor and outdoor air.

4.3 ESTIMATION OF TOXICITY VALUES FOR DERMAL EXPOSURE

RfDs and SFs are not available for the dermal exposure pathway. In many cases, noncarcinogenic and carcinogenic risks associated with the dermal exposure pathway can be evaluated using an oral RfD or SF (EPA 1989). Most oral RfDs and SFs are expressed as the amount of substance administered per unit time and unit body weight, or the administered dose. However, exposure estimates developed for dermal exposure to COPCs in soil or water are expressed as the amount of substance absorbed or the absorbed dose. Adjustments are sometimes required to ensure that the exposure estimate and the toxicity value are both expressed as absorbed doses or are both expressed as administered doses.

To ensure that the exposure estimate and toxicity value are comparable, the toxicity value (RfD or SF), which is generally based on an administered dose, is adjusted to reflect an absorbed dose. Specifically, the oral RfD or SF for a COPC is adjusted using the gastrointestinal (G.I.) absorption efficiency for that COPC (EPA 1989). For noncarcinogens, the absorbed dose RfD is the product of the oral administered dose RfD and the G.I. absorption efficiency. For carcinogens, the absorbed dose SF is the quotient of the oral administered dose SF and the G.I. absorption efficiency. However, if the toxicity value derived by EPA is expressed as an absorbed dose, no adjustment is required.

G.I. absorption efficiencies and associated references are summarized in Table G-15. Values for G.I. absorption efficiency and adjustment recommendations were obtained from EPA Region 5 Dermal Workshop staff (Tetra Tech 1998a). When no adjustment is recommended, absorption was assumed to be complete and 100 percent was used as the G.I. absorption efficiency.

4.4 TOXICITY PROFILES

A brief description of the toxic effects of each COPC is presented in the toxicological profiles in Appendix G-H of this report. The profiles focus on the effects most likely to be observed at the environmental exposure levels that form the basis for the toxicity values. Toxic effects other than the carcinogenic and noncarcinogenic effects quantitatively assessed include reproductive, teratogenic, and mutagenic effects. One of the contaminants known to cause reproductive effects is lead, and these effects are discussed in its toxicity profile. The toxicity values, critical effects, and any uncertainty factors used in calculation of toxicity values are also summarized in the toxicological profiles and below in Section 4.5.

4.5 UNCERTAINTIES RELATED TO TOXICITY VALUES

Uncertainties exist in the toxicity assessment as a result of difficulties encountered in identifying the toxicological effects of COPCs and in the methodologies used to derive toxicity values (SFs and RfDs) associated with the toxicological effects. In some instances, these uncertainties may result in overestimation of risks and hazards, and in others, risks and hazards may be underestimated. Sources of uncertainty include (1) extrapolation of animal data to humans, (2) limited availability of chemical-specific data, (3) toxicity value extrapolation, (4) modeling of SFs, and (5) estimation of toxicity values for dermal exposure. Each of these sources of uncertainty are discussed below.

4.5.1 Extrapolation of Animal Data to Humans

To develop a toxicity value, EPA makes several assumptions that may overestimate the actual hazard or risk to human health resulting from exposure to a COPC. One assumption involves use of animal study data to extrapolate high doses administered to laboratory animals to much lower doses expected to be experienced by humans. The dose-response relationship may not be the same at these lower doses, and their extrapolation may therefore result in overestimation of risk. EPA acknowledges the limitations associated with current evaluation procedures and proposes to revise the procedures for determining the carcinogenic effects of chemicals. EPA proposes to evaluate a broader range of health effects than is addressed by the current procedures, which are based on observance of tumors in animals exposed to large doses of chemicals in laboratory experiments. The additional health effects to be evaluated are those on human cells and genetic material.

4.5.2 Limited Availability of Chemical-Specific Data

Overestimation of risks and hazards may also result from the use of safety factors to derive RfDs when results from animal studies are used to predict adverse health effects in humans. The limited availability of toxicity information on some chemicals affects the use of uncertainty and modifying factors in development of the RfDs. In some cases, only limited data are available; in others, a greater volume of data is available but is to some degree contradictory.

4.5.3 Toxicity Value Extrapolation

In some cases, data from a study of adverse health effects resulting from exposure through a particular route (ingestion, inhalation, or dermal contact) are used to predict adverse health effects resulting from exposure through a different route. This extrapolation introduces uncertainty that may result in under- or overestimation of adverse health effects.

As discussed in Sections 4.1 and 4.2, some RfCs and URFs are based on extrapolation from oral RfDs and SFs, respectively. Because these RfCs and URFs were artificially derived in the first place and do not allow receptor-specific exposures to be accounted for, the HHRA simply reversed the initial derivation to restore the original oral RfDs and SFs and used these toxicity factors in conjunction with intakes calculated using standard exposure equations. Uncertainty results from the fact that the oral toxicity values are based on a different route of exposure. However, this same uncertainty would have resulted if the oral-based RfCs and URFs had been used. No additional uncertainty is created, and the methodology used allows receptor-specific exposures to be evaluated.

4.5.4 Modeling of SFs

To develop an SF, an upper confidence limit on the dose-response relationship is calculated and used as the final toxicity value. Use of this mathematical model results in a conservative estimate of the potential carcinogenic response and may overestimate the true health effects associated with exposure to a given chemical.

4.5.5 Estimation of Toxicity Values for Dermal Exposure

Toxicity values based on oral exposure were adjusted based on chemical-specific estimates of G.I. absorption efficiency. To the extent that the absorption efficiency estimates are incorrect, uncertainty is introduced. However, the degree of uncertainty associated with estimates of G.I. absorption efficiency and the resulting dermal toxicity values is assumed to be less than the uncertainty introduced by using oral exposure-based toxicity factors to characterize risks and hazards associated with dermal intakes calculated as absorbed doses. Specifically, the risks and hazards estimated using the dermal toxicity values are higher and therefore more conservative than the risks and hazards that would be estimated using oral exposure-based toxicity factors.

5.0 RISK AND HAZARD CHARACTERIZATION

This section characterizes the carcinogenic risks and noncarcinogenic hazards associated with the exposure pathways identified in Section 3.0. Risks and hazards are characterized for individual COPCs, for multiple COPCs within each exposure pathway, and for exposures attributable to multiple exposure pathways, as appropriate. Carcinogenic risk estimates are derived based on LADDs, and noncarcinogenic hazard estimates are derived based on ADDs.

Section 5.1 discusses the methodology used to characterize carcinogenic risks and noncarcinogenic hazards. Section 5.2 characterizes significant risks and hazards. Section 5.3 summarizes the risk and hazard estimates associated with exposure to lead. Section 5.4 discusses the risk estimates associated with exposure to VOCs in indoor air from groundwater. Finally, Section 5.5 discusses uncertainties associated with the risk and hazard characterization process.

5.1 RISK AND HAZARD CHARACTERIZATION METHODOLOGY

The methodologies used to quantify carcinogenic risks and noncarcinogenic hazards are discussed below.

5.1.1 Carcinogenic Risks

For carcinogenic COPCs, a risk estimate represents the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to the COPCs (EPA 1989). These ELCRs are calculated as follows:

$$\text{Upper-Bound ELCR (Risk)} = \text{LADD} \times \text{SF} \qquad \text{(G-17)}$$

where

LADD = Lifetime average daily intake (mg/kg-day)

SF = Slope factor $(\text{mg/kg-day})^{-1}$

Risk is expressed as a probability. For example, a risk of 1×10^{-6} translates to one additional case of cancer in an exposed population of 1 million. The SF in almost all cases represents a UCL_{95} of the probability of a carcinogenic response based on experimental data used in a multistage model. The resulting risk estimate therefore represents an upper-bound estimate of the carcinogenic risk. The actual risk will probably not exceed the estimate and is likely to be less.

According to the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990), EPA has established an "acceptable" range for carcinogenic risk from exposure at a Superfund site of 1×10^{-6} to 1×10^{-4} (one case of cancer in an exposed population of 10,000). In general, a potential upper-bound risk of 1×10^{-6} is used by EPA as a point of departure for determining remediation goals.

Within a given exposure pathway, a receptor may be exposed to more than one chemical. The total upper-bound risk associated with exposure to all chemicals through a single exposure pathway is estimated as follows:

$$Risk_{(EP)} = Risk_1 + Risk_2 + \ldots + Risk_i \quad \text{(G-18)}$$

where

$Risk_{(EP)}$ = Total risk for a given exposure pathway

$Risk_i$ = Risk estimate for the ith COPC

At particular exposure points, receptors may be exposed through a number of exposure pathways. At each exposure point, the total exposure for a receptor equals the sum of the exposures through the various exposure pathways to which the receptor is exposed. Under each exposure case, exposure pathway combinations were developed for each receptor. The total risk posed to a receptor through a combination of exposure pathways was calculated as follows:

$$\text{Total Risk} = \text{Risk}(EP_1) + \text{Risk}(EP_2) + \ldots + \text{Risk}(EP_j) \quad \text{(G-19)}$$

where

Total Risk = Risk resulting from multiple exposure pathways

Risk (EP_j) = Risk resulting from the jth exposure pathway

This approach is consistent with the widely held belief that the total carcinogenic risk from exposure to multiple carcinogenic COPCs can be estimated as the sum of the carcinogenic risks posed by individual COPCs (EPA 1986).

5.1.2 Noncarcinogenic Hazards

For noncarcinogenic COPCs, the potential for receptors to develop noncancerous health effects is characterized by comparing an intake for a specific exposure period (the ADD) to an RfD developed for a similar exposure period. When performed for a single chemical, this comparison yields a ratio known as the HQ, which is calculated as follows:

$$HQ = ADD/RfD \quad \text{(G-20)}$$

where

ADD = Average daily intake (mg/kg-day)

RfD = Reference dose (mg/kg-day)

Generally, an HQ of less than or equal to 1 is considered to be health-protective. An HQ exceeding 1 indicates a potential for adverse noncarcinogenic health effects (EPA 1989). For the purposes of this HHRA, chronic RfDs are used to characterize noncarcinogenic hazards for all receptor-exposure pathway combinations.

As with carcinogenic COPCs within a given exposure pathway, a receptor may be exposed to multiple substances associated with noncarcinogenic health effects. To estimate the total noncarcinogenic hazards for each exposure pathway, this HHRA uses the procedures outlined in "Guidelines for the Health Risk Assessment of Chemical Mixtures" (EPA 1986) and RAGS (EPA 1989). The total noncarcinogenic hazard attributable to exposure to all COPCs through a single pathway is calculated as follows:

$$HI_{(EP)} = HQ_1 + HQ_2 + \ldots + HQ_i \quad \text{(G-21)}$$

where

$HI_{(EP)}$ = Total HI for a given exposure pathway

HQ_i = Hazard quotient for the ith COPC

This summation methodology assumes that the effects of the various COPCs to which a receptor is exposed are additive.

As discussed above for carcinogenic COPCs, exposure pathway combinations are developed for receptors under both RME and CT conditions. The total noncarcinogenic hazards posed to a receptor through a combination of exposure pathways is calculated as follows:

$$\text{Total HI} = \text{HI}(EP_1) + \text{HI}(EP_2) + \ldots + \text{HI}(EP_j) \qquad \text{(G-22)}$$

where

$\text{HI}(EP_j)$ = HI resulting from the jth exposure pathway

In accordance with EPA guidance, all total HIs equal to or exceeding 1 were further evaluated (EPA 1989). The total HI for an exposure pathway can exceed 1 as a result of the presence of either (1) a single COPC with an HQ exceeding 1, (2) several COPCs whose HQ sum exceeds 1, or (3) several pathway-specific HIs whose sum exceeds 1. In the second and third cases, a detailed analysis is required to determine whether the potential for noncarcinogenic health effects is accurately estimated by the total HI because the toxicological effects associated with exposure to multiple COPCs may not be additive; therefore, the HI may overestimate the potential for noncarcinogenic health effects. To address this issue, the primary contributors to the total HI were grouped according to target organ or effect, and the total segregated HI for each group was derived. This process is referred to as the segregation of the HI.

Typically, target organs and systems affected by each COPCs are identified from (1) effects (termed "critical effects" by EPA) that occur at levels of exposure corresponding to LOAEL or (2) effects at dose levels slightly exceeding LOAELs, as appropriate. References that identify target organs and systems include EPA (1997c), EPA (1998c), EPA (1998d), Amdur and others (1991), and TCAPCOA (1993).

5.2 RISK AND HAZARD ESTIMATES

Appendix G-G presents receptor-specific exposure and risk results for sitewide (onsite) and area-specific exposures, including EPCs, ADDs, LADDs, RfDs, SFs, HIs, and risks for each COPC within each exposure scenario. Appendix G-E presents methodologies used to characterize risks to child and adult receptors associated with exposure to lead. Section 5.3 summarizes risk and hazard estimates for exposure to lead. Section 5.4 summarizes risk and hazard estimates for exposure to VOCs in indoor air from groundwater. Figures G-3 and G-4 summarize sitewide and offsite risk and hazard estimates for RME and CT exposure, respectively, by receptor and exposure pathway and also present total risk and hazard estimates.

The remainder of this section discusses significant risks and hazards only. For the purposes of this HHRA, risks equal to or greater than 1×10^{-6} are considered significant because this approach is consistent with EPA policy that identifies a risk level of 1×10^{-6} as the low end of EPA's "acceptable" risk range (EPA 1990). Risks less than 1×10^{-6} are considered insignificant. Similarly, HIs equal to or greater than 1 are also considered significant because such HIs indicate a potential for adverse health effects as a result of exposure. HIs less than 1 are considered insignificant. Insignificant exposure pathways for sitewide or area-specific risks and hazards that are not discussed elsewhere in Section 5.2 include:

- All complete exposure pathways for the teenaged trespassers (except total ELCR for all pathways)
- All complete exposure pathways for the on-site parking attendant

Results are presented below separately for sitewide (on-site) (Section 5.2.1) and area-specific (Section 5.2.2) exposure scenarios. For the sitewide and area-specific exposure scenarios, results are presented for the current land-use scenario (Sections 5.2.1.1 and 5.2.2.1), the current and future land-use scenarios (Section 5.2.1.2 and 5.2.2.2), and the future land-use scenario (Section 5.2.1.3 and 5.2.2.3). Within each section, the land-use scenario(s) is briefly summarized and the receptors evaluated are identified. For each receptor, risks for the RME and CT exposure scenarios are discussed first, followed by discussion of hazards. The COPCs contributing significantly to potentially significant risks and hazards are also identified.

5.2.1 Sitewide (On-Site) Risk and Hazard Estimates

The Rockwell site is currently divided into an eastern section owned by the Allegan Metal Finishing Company and a western section owned by the City of Allegan (see Figure G-1). The C&O Railroad bed roughly runs along the dividing line between the eastern and western sections of the site. The eastern section includes the current Allegan Metal Finishing Company operation, former heat-treat building, and an open grassy area. The western section includes an abandoned former Rockwell manufacturing building, former WWTP, and three former holding ponds. Sitewide (on-site) receptors include child and teenaged trespassers expected to be present only under current conditions (see Section 5.2.1.1); adult on-site workers and adult construction or utility workers expected to be present under current and future conditions (see Section 5.2.1.2); and child and adult on-site residents, child and adult on-site visitors, and adult on-site parking attendants expected to be present only under future conditions (see Section 5.2.1.3).

5.2.1.1 Current Land-Use Scenario

It is assumed that the child and teenaged trespassers are present only under the current land-use scenario. Tables G-G-1 through G-G-7 and G-G-23 through G-G-29 provide exposure and risk results under RME and CT conditions, respectively. Significant risks or hazards result from child and teenaged trespasser exposure to contaminants through the following:

- Ingestion of sediment in on-site ponds under RME conditions (child trespasser only)

Child Trespasser

The pathway-specific ELCR for ingestion of sediment in on-site ponds under RME (1.3×10^{-6}) exceeds 1×10^{-6}. The RME ingestion ELCR is driven by arsenic (7.3×10^{-7}), Aroclor 1242 (3.5×10^{-7}), and Aroclor 1254 (2.3×10^{-7})

The total RME ELCR for all pathways (2.8×10^{-6} is the only significant total ELCR or HI for the child trespasser receptor.

5.2.1.2 Current and Future Land-Use Scenarios

Adult on-site workers and adult construction or utility workers are expected to be present during current and future conditions. Tables G-G-8 through G-G-14 and G-G-30 through G-G-36 present exposure and risk results under RME and CT conditions, respectively. Significant risks or hazards result from on-site worker or construction or utility workers exposure to contaminants through the following:

<u>On-Site Worker</u>

- Inhalation of indoor air (LNAPL only)
- Direct contact with surface soil (ELCR only)
- Ingestion of surface soil (ELCR only)

<u>Construction or Utility Worker</u>

- Direct contact with groundwater
- Direct contact with LNAPL
- Direct contact with surface and subsurface soil (ELCR and HI under RME conditions)

On-Site Worker

The pathway-specific total ELCR for inhalation of indoor air for LNAPL under RME and CT conditions (2.3×10^{-5} and 4.7×10^{-6}, respectively). The RME and CT indoor air ELCRs are driven by trichloroethene (1.1×10^{-5} and 2.2×10^{-6}, respectively).

The pathway-specific total ELCR for direct contact with surface soil under RME conditions (8.9×10^{-6}) exceeds 1×10^{-6}. The RME direct contact ELCR is driven by arsenic (7.4×10^{-6}).

The pathway-specific total ELCR for ingestion of surface soil under RME conditions (1.2×10^{-6}) exceed 1×10^{-6}. The RME direct contact ELCR is driven by arsenic (1.0×10^{-6}).

The total on-site worker RME and CT ELCRs for all pathways (3.3×10^{-5} and 5.4×10^{-6}, respectively) exceeds 1×10^{-6}. The total RME HI for all pathways (1.5) exceeds 1.

Construction or Utility Worker

The pathway-specific total ELCRs for direct contact with groundwater under RME and CT conditions (1.0×10^{-5} and 2.6×10^{-6}, respectively) exceed 1×10^{-6}. The RME direct contact ELCR is driven by Aroclor 1254 (6.9×10^{-6}) and arsenic (2.9×10^{-6}). The CT direct contact ELCR is driven by Aroclor 1254 (1.5×10^{-6}). The pathway-specific total HIs for direct contact with groundwater under RME and CT conditions (18 and 3.6, respectively) exceed 1. The RME and CT direct contact HIs are driven by Aroclor 1254 (15 and 3.2, respectively).

The pathway-specific total ELCRs for direct contact with LNAPL under RME and CT conditions (1.9 and 5.8×10^{-1}, respectively) exceed 1×10^{-6}. The RME and CT direct contact ELCRs are driven by Aroclor 1254 (1.9 and 5.7×10^{-1}, respectively). The pathway-specific total HIs for direct contact with groundwater under RME and CT conditions ($4.1 \times 10^{+6}$ and $1.2 \times 10^{+6}$, respectively) exceed 1. The RME and CT direct contact HIs are driven by Aroclor 1254 ($4.1 \times 10^{+6}$ and $1.2 \times 10^{+6}$, respectively). However, the immediate health and safety danger related to potential explosivity of LNAPL significantly decreases the likelihood of exposure to LNAPL.

The pathway-specific total ELCR for direct contact with surface and subsurface soil under RME conditions (1.1×10^{-6}) exceeds 1×10^{-6}. The RME direct contact ELCR is driven by arsenic (1.1×10^{-6}). The pathway-specific total HI for direct contact with surface and subsurface soil under RME conditions (2.5) exceeds 1. The direct contact HI is driven by iron (0.48), Aroclor 1254 (0.49), and arsenic (0.22).

The total RME and CT ELCRs and HIs significantly exceed 1×10^{-6} or 1, respectively; based on construction or utility worker direct contact with LNAPL.

5.2.1.3 Future Land-Use Scenario

Child and adult on-site residents, child and adult on-site visitors, and adult on-site parking attendants are expected to be present only during future conditions. Tables G-G-15 through G-G-22 and G-G-37 through G-G-44 present exposure and risk results under RME and CT conditions, respectively. Significant risks or hazards result from on-site resident, on-site visitor, and on-site parking attendant exposure to contaminants through the following:

Child and Adult On-Site Residents

- Direct contact with groundwater
- Ingestion of groundwater
- Direct contact with soil (ELCR under RME conditions only)
- Ingestion of soil (ELCR under RME conditions only)
- Ingestion of homegrown produce
- Inhalation of indoor air

Child and Adult On-Site Visitors

- Ingestion of groundwater
- Ingestion of soil

Child On-Site Residents

The pathway-specific total ELCRs for direct contact with groundwater under RME and CT conditions (1.5×10^{-3} and 3.6×10^{-5}, respectively) exceed 1×10^{-6}. The RME and CT direct contact ELCRs are driven by arsenic (3.8×10^{-4} and 1.1×10^{-5}, respectively) and Aroclor 1254 (1×10^{-3} and 2.3×10^{-5}, respectively). The pathway-specific total HIs for direct contact with groundwater under RME and CT conditions (130 and 29, respectively) exceed 1. The RME direct contact HI is driven by Aroclor 1254 (76), manganese (12), and vanadium (15). The CT direct contact HI is driven by Aroclor 1254 (20).

The pathway-specific total ELCRs for ingestion of groundwater under RME and CT conditions (6.2×10^{-1} and 3.9×10^{-3}, respectively) exceed 1×10^{-6}. The RME and CT ingestion ELCRs are driven by arsenic (6.2×10^{-1} and 3.9×10^{-3}, respectively). The pathway-specific total HIs for ingestion of groundwater under RME and CT conditions (4.9×10^{4} and 4.9×10^{2}, respectively) exceed 1. The RME and CT ingestion HIs are driven by arsenic (1.6×10^{4} and 1×10^{2}, respectively) and iron (2.2×10^{4} and 1.4×10^{2}, respectively).

The pathway-specific total ELCR for direct contact with soil under RME conditions (4.6×10^{-6}) exceeds 1×10^{-6}. The direct contact ELCR is driven by arsenic (2.1×10^{-6}) and Aroclor 1254 (2×10^{-6}).

The pathway-specific total ELCR for ingestion of soil under RME conditions (4.9×10^{-6}) exceeds 1×10^{-6}. The ingestion ELCR is driven by arsenic (3.8×10^{-6}).

The pathway-specific total RME and CT ELCRs for ingestion of homegrown produce (8.9×10^{-5} and 3.0×10^{-5}, respectively) exceed 1×10^{-6}. The RME and CT ingestion ELCRs are driven by Aroclor 1254 (7.0×10^{-5} and 2.3×10^{-5}, respectively). The pathway -specific total RME and CT HIs for ingestion of produce (22) exceed 1. The RME and CT ingestion HIs are driven by Aroclor 1254 (20).

The pathway-specific total RME and CT ELCRs for inhalation of indoor air (8.8×10^{-5} and 1.7×10^{-5}, respectively) exceed 1×10^{-6}. The RME and CT inhalation ELCRs are driven by tetrachloroethene (3.8×10^{-5} and 7.4×10^{-6}, respectively) and methylene chloride (3.5×10^{-5} and 6.9×10^{-6}, respectively). The pathway -specific total RME and CT HIs for inhalation of indoor air (9.4 and 5.5, respectively) exceed 1. The RME and CT inhalation HIs are driven by methylene chloride (3 and 1.8, respectively), benzene (3 and 1.8, respectively), and cis-1,2-dichloroethene (2 and 1.2, respectively).

Adult On-Site Residents

The pathway-specific total ELCRs for direct contact with groundwater under RME and CT conditions (1.6×10^{-3} and 1.1×10^{-4}, respectively) exceed 1×10^{-6}. The RME and CT direct contact ELCRs are driven by arsenic (6.2×10^{-4} and 3.2×10^{-6}, respectively) and Aroclor 1254 (8.6×10^{-4} and 6.7×10^{-5}, respectively). The pathway-specific total HIs for direct contact with groundwater under RME and CT conditions (110 and 25, respectively) exceed 1. The RME direct contact HI is driven by Aroclor 1254 (62), manganese (10), and vanadium (13). The CT direct contact HI is driven by Aroclor 1254 (17).

The pathway-specific total ELCRs for ingestion of groundwater under RME and CT conditions (1 and 1.8×10^{-1}, respectively) exceed 1×10^{-6}. The RME and CT ingestion ELCRs are driven by arsenic (1 and 1.8×10^{-1}, respectively). The pathway-specific total HIs for ingestion of groundwater under RME and CT conditions (2×10^{4} and 1.2×10^{2}, respectively) exceed 1. The RME and CT ingestion HIs are driven by arsenic (6.6×10^{3} and 4.1×10^{3}, respectively) and iron (9.2×10^{3} and 5.7×10^{3}, respectively).

The pathway-specific total ELCR for direct contact with soil under RME conditions (1.4×10^{-5}) exceeds 1×10^{-6}. The direct contact ELCR is driven by arsenic (6.2×10^{-6}) and Aroclor 1254 (5.9×10^{-6}).

The pathway-specific total ELCR for ingestion of soil under RME conditions (1.2×10^{-5}) exceeds 1×10^{-6}. The ingestion ELCR is driven by arsenic (9.6×10^{-6}).

The pathway-specific total RME and CT ELCRs for ingestion of homegrown produce (2.2×10^{-4} and 6.6×10^{-5}, respectively) exceed 1×10^{-6}. The RME and CT ingestion ELCRs are driven by Aroclor 1254 (1.7×10^{-4} and 5.2×10^{-5}, respectively). The pathway -specific total RME and CT HIs for ingestion of produce (11) exceed 1. The RME and CT ingestion HIs are driven by Aroclor 1254 (10).

The pathway-specific total RME and CT ELCRs for inhalation of indoor air (1.3×10^{-4} and 2.3×10^{-5}, respectively) exceed 1×10^{-6}. The RME and CT inhalation ELCRs are driven by tetrachloroethene (5.7×10^{-5} and 9.9×10^{-6}, respectively) and methylene chloride (5.3×10^{-5} and 9.2×10^{-6}, respectively). The pathway-specific total RME and CT HIs for inhalation of indoor air (3.6 and 2.1, respectively) exceed 1. The RME and CT inhalation HIs are driven by methylene chloride (1.1 and 0.67, respectively) and benzene (1.1 and 0.68, respectively).

Child and Adult On-Site Residents

RME ELCRs are based on an exposure duration of 30 years, which was divided as 6 child years and 24 adult years in one residence. Therefore, it is appropriate to sum the child and adult RME ELCRs to obtain total RME ELCRs for on-site residents as listed below.

Total RME ELCRs

- Direct contact with groundwater = 3.1×10^{-3}
- Ingestion of groundwater = 8.0×10^{-1}
- Direct contact with soil = 1.9×10^{-5}
- Ingestion of soil = 1.7×10^{-5}
- Ingestion of homegrown produce = 3.1×10^{-4}
- Inhalation of indoor air = 2.2×10^{-4}

Child On-Site Visitor

The pathway-specific total ELCRs for ingestion of groundwater under RME and CT conditions (2.6×10^{-2} and 2.1×10^{-3}, respectively) exceed 1×10^{-6}. The RME and CT ingestion ELCRs are driven by arsenic (2.6×10^{-2} and 2.1×10^{-3}, respectively). The pathway-specific total HIs for ingestion of groundwater under RME and CT conditions (2×10^{3} and 5.1×10^{2}, respectively) exceed 1. The RME and CT ingestion HIs are driven by arsenic (6.6×10^{2} and 1.7×10^{2}, respectively) and iron (9.2×10^{2} and 2.3×10^{2}, respectively).

The pathway-specific total ELCR for ingestion of soil under RME conditions (3.5×10^{-6}) exceeds 1×10^{-6}. The ingestion ELCR is driven by arsenic (2.9×10^{-6}).

Adult On-Site Visitor

The pathway-specific total ELCRs for ingestion of groundwater under RME and CT conditions (4.4×10^{-2} and 3.2×10^{-3}, respectively) exceed 1×10^{-6}. The RME and CT ingestion ELCRs are driven by arsenic (4.4×10^{-2} and 3.2×10^{-3}, respectively). The pathway-specific total HIs for ingestion of groundwater under RME and CT conditions (8.6×10^{2} and 2.2×10^{2}, respectively) exceed 1. The RME and CT ingestion HIs are driven by arsenic (2.8×10^{2} and 7.1×10^{1}, respectively) and iron (3.9×10^{2} and 9.9×10^{1}, respectively).

The pathway-specific total ELCR for ingestion of soil under RME conditions (1.5×10^{-6}) exceeds 1×10^{-6}. The ingestion ELCR is driven by arsenic (1.2×10^{-6}).

5.2.2 Area-Specific Risk and Hazard Estimates

Hazards and risks were calculated for area-specific exposures in the following areas:

- Former SOS pond area
- Former Rockwell WWTP area
- Former on-site railroad right-of-way
- Grassy area
- Area under and north of the former west manufacturing building
- Saturated zone beneath the former City of Allegan landfill
- Former off-property railroad right-of-way
- Off-property residential area (background soil)
- Kalamazoo River (downstream shoreline only)

Area-specific hazards and risks were not evaluated for groundwater because groundwater moves readily between areas. Hazards and risks for groundwater were evaluated for sitewide scenarios (see Section 5.2.1). It should be noted that all on-site area-specific receptors may also be exposed to contaminants in groundwater and LNAPL in each area. The HHRA areas are identified in Figure G-1. Receptors for the on-site areas are identical to the sitewide (on-site) receptors identified in Section 5.2.1. Off-property receptors include child and adult off-property residents; off-property construction or utility workers; and child, teenaged, and adult off-property recreationalists expected to be present during current and future conditions (see Section 5.2.2.2). Section 5.2.2.1 summarizes significant area-specific risks and hazards for receptors expected to be present under the current land-use scenario only. Section 5.2.2.2 summarizes area-specific significant risks and hazards for receptors expected to be present during the current and future land-use scenarios. Section 5.2.2.3 summarizes area-specific significant risks and hazards for receptors expected to be present during the future land-use scenario only.

5.2.2.1 Current Land-Use Scenario

As stated in Section 5.2.1.1, it is assumed that the on-site child and teenaged trespassers are expected to be present only under the current land-use scenario. Area-specific significant risks or hazards result from child and teenaged trespasser exposure to on-site contaminants through the following:

<u>Former WWTP Area</u>

- Ingestion of sediment in on-site ponds

Former On-Site Railroad Right-of-Way

- Ingestion of surface soil (child trespasser only)

The significant risks and hazards listed above are summarized below by receptor to facilitate identification of appropriate remediation goals by risk managers because remediation goals are typically based on receptor-specific exposure pathways. Area-specific significant risks and hazards are identified for each receptor and are summarized in tabular format. The risk and hazard summary tables below identify risk and hazard result tables presented in Appendix G-G, significant RME and CT risks and hazards, and risk and hazard drivers for each exposure pathway.

Child Trespasser

Significant area-specific risks for the on-site child trespasser are summarized below.

Child Trespasser			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former WWTP Area			
G-G-73, G-G-87	Ingestion of sediment in on-site ponds	**RME:** 1.3×10^{-6} **CT:** Insignificant	Aroclor 1242 (3.5×10^{-7})
Former On-Site Railroad Right-of-Way			
G-G-99 G-G-110	Ingestion of surface soil	**RME:** 1.3×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.

5.2.2.2 Current and Future Land-Use Scenarios

Adult on-site workers; adult on- and off-property construction or utility workers; child and adult off-property residents; and child, teenaged, and adult off-property recreationalists are expected to be present under current and future land-use conditions. Area-specific significant risks or hazards result from receptor exposure to contaminants through the following:

Former SOS Pond Area

- On-site worker inhalation of indoor air - LNAPL
- On-site worker direct contact with surface soil

- On-site construction or utility worker direct contact with surface soil
- On-site construction or utility worker ingestion of surface soil

Former WWTP Area

- On-site worker inhalation of indoor air - LNAPL
- On-site worker direct contact with soil
- On-site worker ingestion of soil
- On-site construction or utility worker direct contact with soil
- On-site construction or utility worker ingestion of soil

Former On-Site Railroad Right-of-Way

- On-site worker inhalation of indoor air - LNAPL
- On-site worker direct contact with soil
- On-site worker ingestion of soil
- On-site construction or utility worker direct contact with soil

Grassy Area

- On-site worker inhalation of indoor air

Area Under and North of the Former West Manufacturing Building

- On-site worker inhalation of indoor air - LNAPL
- On-site worker direct contact with soil

Former Off-Property Railroad Right-of-Way

- Off-property resident inhalation of indoor air - LNAPL
- Off-property resident direct contact with groundwater while showering
- Off-property resident ingestion of groundwater
- Off-property resident direct contact with soil
- Off-property resident ingestion of soil
- Off-property resident ingestion of homegrown produce
- Off-property construction or utility worker direct contact with groundwater
- Off-property construction or utility worker direct contact with LNAPL
- Off-property construction or utility worker direct contact with soil
- Off-property construction or utility worker ingestion of soil

Off-Property Residential Area (Background Soil)

- Off-property resident ingestion of soil

Kalamazoo River Downstream Shoreline Only

- Off-property recreationalist direct contact with sediment
- Off-property recreationalist ingestion of sediment

The significant risks and hazards listed above are summarized below by receptor to facilitate identification of appropriate remediation goals by risk managers because remediation goals are typically based on receptor-specific exposure pathways. Area-specific significant risks and hazards are identified for each receptor and are summarized in tabular format. The risk and hazard summary tables below identify risk and hazard result tables presented in Appendix G-G, significant RME and CT risks and hazards, and risk and hazard drivers for each exposure pathway.

On-Site Worker

Significant area-specific risks for the on-site worker are summarized below.

On-Site Worker			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former SOS Pond Area			
G-G-50, G-G-61	Direct contact with surface soil	**RME:** 5.3×10^{-6} **CT:** Insignificant	Arsenic is the only COPC with an SF.
Former WWTP Area			
G-G-76, G-G-91	Direct contact with soil	**RME:** 1.1×10^{-5} **CT:** 1.3×10^{-6}	**RME:** Arsenic (5.7×10^{-6}) and Aroclor 1254 (2.8×10^{-6}) **CT:** Aroclor 1254 (9.8×10^{-7}) and Arsenic (2.6×10^{-7})
G-G-77, G-G-92	Ingestion of soil	**RME:** 3.9×10^{-6} **CT:** insignificant	Arsenic (7.7×10^{-7}) and Aroclor 1254 (3.0×10^{-6})
Former On-Site Railroad Right-of-Way			
G-G-102, G-G-113	Direct contact with soil	**RME:** 2.0×10^{-5} **CT:** Insignificant	Arsenic is the only COPC with an SF.
G-G-103, G-G-114	Ingestion of soil	**RME:** 2.7×10^{-6} **CT:** Insignificant	Arsenic is the only COPC with an SF.
Area Under and North of the Former West Manufacturing Building			
G-G-146, G-G-157	Direct contact with soil	**RME:** 6.5×10^{-6} **CT:** Insignificant	Arsenic is the only COPC with an SF.

Significant area-specific hazards for the on-site worker are summarized below.

On-Site Worker			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former On-Site Railroad Right-of-Way			
G-G-102, G-G-113	Direct contact with soil	**RME:** 3.2 **CT:** insignificant	Barium (1.1)

Construction or Utility Worker

Significant area-specific risks for the construction or utility worker are summarized below.

Construction or Utility Worker			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former SOS Pond Area			
G-G-50 G-G-61	Direct contact with soil	**RME:** 5.9×10^{-6} **CT:** 2.1×10^{-6}	Arsenic is the only COPC with an SF.
G-G-51 G-G-62	Ingestion of soil	**RME:** 1.1×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
Former WWTP Area			
G-G-76 G-G-91	Direct contact with soil	**RME:** 5.4×10^{-6} **CT:** 1.9×10^{-6}	**RME:** Aroclor 1254 (3.5×10^{-6}) and Arsenic (1.8×10^{-6}) **CT:** Aroclor 1254 (1.2×10^{-6})
G-G-77 G-G-92	Ingestion of soil	**RME:** 1.1×10^{-6} **CT:** insignificant	Aroclor 1254 (6.9×10^{-7}) and Arsenic (3.5×10^{-7})
Former On-Site Railroad Right-of-Way			
G-G-102 G-G-113	Direct contact with soil	**RME:** 2.6×10^{-6} **CT:** Insignificant	Arsenic is the only COPC with an SF.
Former Off-Property Railroad Right-of-Way			
G-G-177 G-G-187	Direct contact with groundwater	**RME:** 5.3×10^{-5} **CT:** Insignificant	**RME:** Aroclor 1254 (1.1×10^{-3})
G-G-179 G-G-189	Direct contact with LNAPL	**RME:** 35 **CT:** 11	**RME:** Benzo(a)pyrene (21) and dibenzo(a,h)anthracene (14) **CT:** Benzo(a)pyrene (6.3) and dibenzo(a,h)anthracene (4.3)
G-G-182 G-G-192	Direct contact with soil	**RME:** 2.0×10^{-6} **CT:** Insignificant	Aroclor 1254 (1.7×10^{-6})
G-G-183 G-G-193	Ingestion of soil	**RME:** 3.4×10^{-6} **CT:** 1.7×10^{-6}	**RME:** Aroclor 1254 (2.5×10^{-6}) **CT:** Aroclor 1254 (1.2×10^{-6})

Significant area-specific hazards for the construction or utility worker are summarized below.

Construction or Utility Worker			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former SOS Pond Area			
G-G-50 G-G-61	Direct contact with surface soil	**RME:** 14 **CT:** 5	**RME:** Nickel (4.7), Manganese (3.6), Cadmium (3.4), and Arsenic (1.2) **CT:** Nickel (1.7), Manganese (1.3), and Cadmium (1.2)
Former WWTP Area			
G-G-76 G-G-91	Direct contact with soil	**RME:** 11 **CT:** 3.9	**RME:** Aroclor 1254 (7.6) **CT:** Aroclor 1254 (2.7)
Former On-Site Railroad Right-of-Way			
G-G-102 G-G-113	Direct contact with soil	**RME:** 16 **CT:** 5.9	**RME:** Barium (5.5), Iron (3.2), Nickel (2.8) **CT:** Barium (2.0), Iron (1.2)
Former Off-Property Railroad Right-of-Way			
G-G-177 G-G-187	Direct contact with groundwater	**RME:** 110 **CT:** 34	**RME:** Aroclor 1254 (110) **CT:** Aroclor 1254 (34)
G-G-179 G-G-189	Direct contact with LNAPL	**RME:** $1 \times 10^{+5}$ **CT:** $3 \times 10^{+4}$	**RME:** Naphthalene ($1.9 \times 10^{+4}$), Fluoranthene ($1.7 \times 10^{+4}$), fluorene ($1.7 \times 10^{+4}$) **CT:** Naphthalene ($5.6 \times 10^{+3}$), Fluoranthene ($5.2 \times 10^{+3}$), fluorene ($5.2 \times 10^{+3}$)
G-G-182 G-G-192	Direct contact with soil	**RME:** 3.8 **CT:** 1.4	**RME:** Aroclor 1254 (3.8) **CT:** Aroclor 1254 (1.4)
G-G-183 G-G-193	Ingestion of soil	**RME:** 5.7 **CT:** 2.8	**RME:** Aroclor 1254 (5.4) **CT:** Aroclor 1254 (2.7)

Adult Off-Property Resident

Significant area-specific risks for the adult off-property resident are summarized below.

Adult Off-Property Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former Off-Property Railroad Right-of-Way			
G-G-175 G-G-185	Inhalation of indoor air	**RME:** 1.0×10^{-4} **CT:** 1.7×10^{-5}	**RME:** Tetrachloroethene (6.8×10^{-5}) **CT:** Tetrachloroethene (1.2×10^{-5})
G-G-177 G-G-187	Direct contact with groundwater while showering	**RME:** 1.8×10^{-1} **CT:**	**RME:** Aroclor 1254 (1.7×10^{-1}) **CT:**
G-G-178 G-G-188	Ingestion of groundwater	**RME:** 2.0×10^{-4} **CT:** 2.2×10^{-5}	**RME:** Aroclor 1254 (1.0×10^{-4}) **CT:** Aroclor 1254 (1.1×10^{-5})

Adult Off-Property Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
G-G-182 G-G-192	Direct contact with soil	**RME:** 1.9 x 10^{-5} **CT:** Insignificant	**RME:** Aroclor 1254 (1.8 x 10^{-5})
G-G-183 G-G-193	Ingestion of soil	**RME:** 2.2 x 10^{-5} **CT:** 1.6 x 10^{-6}	**RME:** Aroclor 1254 (1.9 x 10^{-5}) **CT:** Aroclor 1254 (1.4 x 10^{-6})
G-G-184 G-G-194	Ingestion of homegrown produce	**RME:** 2.2 x 10^{-4} **CT:** 6.6 x 10^{-5}	**RME:** Aroclor 1254 (1.7 x 10^{-4}) **CT:** Aroclor 1254 (5.2 x 10^{-5})
Off-Property Residential Area (Background Soil)			
G-G-198 G-G-202	Ingestion of soil	**RME:** 1.1 x 10^{-6} **CT:** Insignificant	Arsenic is the only COPC with a SF.

Significant area-specific hazards for the adult off-property resident are summarized below.

Adult Off-Property Resident			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former Off-Property Railroad Right-of-Way			
G-G-175 G-G-185	Inhalation of indoor air	**RME:** 2.4 **CT:** 1.4	**RME:** Benzene (1.5) **CT:** Benzene (0.91)
G-G-177 G-G-187	Direct contact with groundwater while showering	**RME:** 1.3 x 10^{-4} **CT:** 3	**RME:** Aroclor 1254 (1.3 x 10^{-4}) **CT:** Aroclor (3)
G-G-178 G-G-188	Ingestion of groundwater	**RME:** 36 **CT:** 13	**RME:** Iron (18), Selenium (9.2), and Aroclor 1254 (7.6) **CT:** Iron (6.6), Selenium (3.4) and Aroclor 1254 (2.8)
G-G-182 G-G-192	Direct contact with soil	**RME:** 1.4 **CT:** Insignificant	**RME:** Aroclor 1254 (1.3)
G-G-183 G-G-193	Ingestion of soil	**RME:** 1.4 **CT:** Insignificant	**RME:** Aroclor 1254 (1.4)
G-G-184 G-G-194	Ingestion of homegrown produce	**RME:** 11 **CT:** 11	**RME:** Aroclor 1254 (10) **CT:** Aroclor 1254 (10)

Child Off-Property Resident

Significant area-specific risks for the child off-property resident are summarized below.

Child Off-Property Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former Off-Property Railroad Right-of-Way			
G-G-175 G-G-185	Inhalation of indoor air	**RME:** 6.7 x 10^{-5} **CT:** 1.3 x 10^{-5}	**RME:** Tetrachloroethene (4.5 x 10^{-5}) **CT:** Tetrachloroethene (8.8 x 10^{-6})

Child Off-Property Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
G-G-177 G-G-187	Direct contact with groundwater while showering	**RME:** 1.1×10^{-3} **CT:** 2.2×10^{-5}	**RME:** Aroclor 1254 (1.1×10^{-3}) **CT:** Aroclor 1254 (1.1×10^{-5})
G-G-178 G-G-188	Ingestion of groundwater	**RME:** 1.2×10^{-4} **CT:** 1.1×10^{-5}	**RME:** Aroclor 1254 (6.4×10^{-5}) and Dieldrin (5.9×10^{-5}) **CT:** Aroclor 1254 (5.5×10^{-6}) and Dieldrin (5.1×10^{-6})
G-G-182 G-G-192	Direct contact with soil	**RME:** 4.0×10^{-5} **CT:** 1.2×10^{-6}	**RME:** Aroclor 1254 (3.8×10^{-5}) **CT:** Aroclor 1254 (1.1×10^{-6})
G-G-183 G-G-193	Ingestion of soil	**RME:** 1.8×10^{-4} **CT:** 8.7×10^{-6}	**RME:** Aroclor 1254 (1.5×10^{-4}) **CT:** Aroclor 1254 (7.3×10^{-6})
G-G-184 G-G-194	Ingestion of homegrown produce	**RME:** 8.9×10^{-5} **CT:** 3.0×10^{-5}	**RME:** Aroclor 1254 (7.0×10^{-5}) **CT:** Aroclor 1254 (2.3×10^{-5})
Off-Property Residential Area (Background Soil)			
G-G-198 G-G-203	Ingestion of soil	**RME:** 8.5×10^{-6} **CT:** Insignificant	Arsenic is the only COPC with an SF.

Significant area-specific hazards for the child off-property resident are summarized below.

Child Off-Property Residents			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former Off-Property Railroad Right-of-Way			
G-G-175 G-G-185	Inhalation of indoor air	**RME:** 6.3 **CT:** 3.7	**RME:** Benzene (4.1) and trichloroethene (2.0) **CT:** Benzene (2.4)
G-G-177 G-G-187	Direct contact with groundwater while showering	**RME:** 310 **CT:** 16	**RME:** Aroclor 1254 (310) **CT:** Aroclor 1254 (16)
G-G-178 G-G-188	Ingestion of groundwater	**RME:** 88 **CT:** 23	**RME:** Iron (44), Selenium (22), and Aroclor 1254 (19) **CT:** Iron (11), Selenium (5.8) and Aroclor 1254 (4.8)
G-G-182 G-G-192	Direct contact with soil	**RME:** 11 **CT:** Insignificant	**RME:** Aroclor 1254 (11)
G-G-183 G-G-193	Ingestion of soil	**RME:** 46 **CT:** 6.7	**RME:** Aroclor 1254 (44) **CT:** Aroclor 1254 (6.4)
G-G-184 G-G-194	Ingestion of homegrown produce	**RME:** 22 **CT:** 22	**RME:** Aroclor 1254 (20) **CT:** Aroclor 1254 (20)

Child and Adult Off-Property Residents

RME ELCRs were based on an exposure duration of 30 years, which was divided as 6 child years and 24 adult years in one residence. Therefore, it is appropriate to sum the child and adult RME ELCRs to obtain total RME ELCRs for off-property residents as listed below.

Child and Adult Off-Property Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former Off-Property Railroad Right-of-Way			
G-G-175	Inhalation of indoor air	1.7×10^{-4}	Tetrachloroethene
G-G-177	Direct contact with groundwater while showering	1.8×10^{-1}	Aroclor 1254
G-G-178	Ingestion of groundwater	3.2×10^{-4}	Aroclor 1254
G-G-182	Direct contact with soil	5.9×10^{-5}	Aroclor 1254
G-G-183	Ingestion of soil	2.3×10^{-5}	Aroclor 1254
G-G-184	Ingestion of homegrown produce	3.0×10^{-4}	Aroclor 1254
Off-Property Residential Area (Background Soil)			
G-G-198	Ingestion of soil	9.6×10^{-6}	Arsenic is the only COPC with an SF.

Adult Recreationalist

Significant area-specific risks for the adult off-property recreationalist are summarized below.

Adult Recreationalist			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Kalamazoo River (Downstream Shoreline Only)			
G-G-205 G-G-209	Direct contact with sediment	RME: 6.3×10^{-6} CT: Insignificant	Aroclor 1242 (3.3×10^{-6})
G-G-206 G-G-210	Ingestion of sediment	RME: 6.4×10^{-6} CT: Insignificant	Aroclor 1242 (2.5×10^{-6})

Teenaged Recreationalist

Significant area-specific risks for the teenaged recreationalist are summarized below.

Teenaged Recreationalist			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Kalamazoo River (Downstream Shoreline Only)			
G-G-205 G-G-209	Direct contact with sediment	**RME:** 1.2×10^{-6} **CT:** Insignificant	Aroclor 1242 (6.1×10^{-7}), benzo(a)pyrene (1.4×10^{-7}), and arsenic (1.1×10^{-7})

Child Recreationalist

Significant area-specific risks for the child recreationalist are summarized below.

Child Recreationalist			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Kalamazoo River (Downstream Shoreline Only)			
G-G-205 G-G-209	Direct contact with sediment	**RME:** 2.5×10^{-6} **CT:** Insignificant	Aroclor 1242 (1.3×10^{-6})
G-G-206 G-G-210	Ingestion of sediment	**RME:** 5.8×10^{-6} **CT:** Insignificant	Aroclor 1242 (2.3×10^{-6})

5.2.2.3 Future Land-Use Scenario

Adult on-site and child on-site residents, adult and child on-site visitors, and adult on-site parking attendants are expected to be present only during future conditions. Area-specific significant risks or hazards result from on-site resident, on-site visitor, and on-site parking attendant exposure to contaminants through the following:

<u>Former SOS Pond Area</u>

- On-site resident inhalation of indoor air - LNAPL
- On-site resident direct contact with soil
- On-site resident ingestion of soil
- On-site visitor ingestion of soil (child visitor only)

Former WWTP Area

- On-site resident direct contact with soil
- On-site resident ingestion of soil
- On-site visitor ingestion of soil

Former On-Site Railroad Right-of-Way

- On-site resident direct contact with soil
- On-site resident ingestion of soil
- On-site visitor ingestion of soil

Area Under and North of the Former West Manufacturing Building

- On-site resident direct contact with soil
- On-site resident ingestion of soil
- On-site visitor ingestion of soil

The significant risks and hazards listed above are summarized below by receptor to facilitate identification of appropriate remediation goals by risk managers because remediation goals are typically based on receptor-specific exposure pathways. Area-specific significant risks and hazards are identified for each receptor and are summarized in tabular format. The risk and hazard summary tables below identify risk and hazard result tables presented in Appendix G-G, significant RME and CT risks and hazards, and risk and hazard drivers for each exposure pathway.

Adult On-Site Resident

Significant area-specific risks for the adult on-site resident are summarized below.

Adult On-Site Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former SOS Pond Area			
G-G-54, G-G-65	Direct contact with soil	**RME:** 3.4×10^{-5} **CT:** insignificant	Arsenic is the only COPC with an SF.

Adult On-Site Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
G-G-55, G-G-66	Ingestion of soil	**RME:** 5.0×10^{-5} **CT:** insignificant	Arsenic is the only COPC with an SF.
Former WWTP Area			
G-G-80, G-G-95	Direct contact with soil	**RME:** 1.1×10^{-4} **CT:** insignificant	Aroclor 1254 (9.2×10^{-5}) and arsenic (1.0×10^{-5})
G-G-81, G-G-96	Ingestion of soil	**RME:** 4.7×10^{-5} **CT:** insignificant	Aroclor 1254 (3.1×10^{-5}) and arsenic (1.5×10^{-5})
Former On-Site Railroad Right-of-Way			
G-G-106, G-G-117	Direct contact with soil	**RME:** 1.5×10^{-5} **CT:** insignificant	Arsenic is the only COPC with an SF.
G-G-107, G-G-118	Ingestion of soil	**RME:** 2.2×10^{-5} **CT:** insignificant	Arsenic is the only COPC with an SF.
Area Under and North of the Former West Manufacturing Building			
G-G-150, G-G-161	Direct contact with soil	**RME:** 5.1×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
G-G-151, G-G-162	Ingestion of soil	**RME:** 7.5×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.

Significant area-specific hazards for the adult on-site resident are summarized below.

Adult On-Site Resident			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former WWTP Area			
G-G-80, G-G-95	Direct contact with soil	**RME:** 5.7 **CT:** insignificant	Aroclor 1254 (5.4)

Child On-Site Resident

Significant area-specific risks for the child on-site resident are summarized below.

Child On-Site Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former SOS Pond Area			
G-G-54, G-G-65	Direct contact with soil	**RME:** 1.1×10^{-5} **CT:** insignificant	Arsenic is the only COPC with an SF.

Child On-Site Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
G-G-55, G-G-66	Ingestion of soil	**RME:** 2.0 x 10^{-5} **CT:** insignificant	Arsenic is the only COPC with an SF.
Former WWTP Area			
G-G-80, G-G-95	Direct contact with soil	**RME:** 3.5 x 10^{-5} **CT:** 1.2 x 10^{-6}	**RME:** Aroclor 1254 (3.1 x 10^{-5}) and arsenic (3.3 x 10^{-6}) **CT:** Aroclor 1254 (1.0 x 10^{-6})
G-G-81, G-G-96	Ingestion of soil	**RME:** 1.9 x 10^{-5} **CT:** insignificant	Aroclor 1254 (1.2 x 10^{-5}) and arsenic (6.1 x 10^{-6})
Former On-Site Railroad Right-of-Way			
G-G-106, G-G-117	Direct contact with soil	**RME:** 4.9 x 10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
G-G-107, G-G-118	Ingestion of soil	**RME:** 8.7 x 10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
Area Under and North of the Former West Manufacturing Building			
G-G-150, G-G-161	Direct contact with soil	**RME:** 1.7 x 10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
G-G-151, G-G-162	Ingestion of soil	**RME:** 3.0 x 10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.

Significant area-specific hazards for the child on-site resident are summarized below.

Child On-Site Resident			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former SOS Pond Area			
G-G-54, G-G-65	Direct contact with soil	**RME:** 1.4 **CT:** insignificant	Arsenic (0.30), nickel (0.40), and manganese (0.31)
G-G-55, G-G-66	Ingestion of soil	**RME:** 1.1 **CT:** insignificant	Arsenic (0.52) and iron (0.29)
Former WWTP Area			
G-G-80, G-G-95	Direct contact with soil	**RME:** 9.6 **CT:** insignificant	Aroclor 1254 (9.0)
G-G-81, G-G-96	Ingestion of soil	**RME:** 4.3 **CT:** insignificant	Aroclor 1254 (3.6)
Former On-Site Railroad Right-of-Way			
G-G-106, G-G-117	Direct contact with soil	**RME:** 1.5 **CT:** insignificant	Barium (0.47), iron (0.28), nickel (0.24), and manganese (0.15)
G-G-107, G-G-118	Ingestion of soil	**RME:** 2.5 **CT:** insignificant	Iron (1.5)

Child and Adult On-Site Residents

RME ELCRs were based on an exposure duration of 30 years, which was divided as 6 child years and 24 adult years in one residence. Therefore, it is appropriate to sum the child and adult RME ELCRs to obtain total RME ELCRs for on-site residents as listed below.

Child and Adult On-Site Resident			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former SOS Pond Area			
G-G-54	Direct contact with soil	4.5×10^{-5}	Arsenic is the only COPC with an SF.
G-G-55	Ingestion of soil	7.0×10^{-5}	Arsenic is the only COPC with an SF.
Former WWTP Area			
G-G-80	Direct contact with soil	1.5×10^{-4}	Aroclor 1254 and arsenic
G-G-81	Ingestion of soil	6.6×10^{-5}	Aroclor 1254 and arsenic
Former On-Site Railroad Right-of-Way			
G-G-106	Direct contact with soil	2.0×10^{-5}	Arsenic is the only COPC with an SF.
G-G-107	Ingestion of soil	3.0×10^{-5}	Arsenic is the only COPC with an SF.
Area Under and North of the Former West Manufacturing Building			
G-G-150	Direct contact with soil	6.8×10^{-6}	Arsenic is the only COPC with an SF.
G-G-151, G-G-162	Ingestion of soil	1.5×10^{-5}	Arsenic is the only COPC with an SF.

Adult On-Site Visitor

Significant area-specific risks for the adult on-site visitor are summarized below.

Adult On-Site Visitor			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former WWTP Area			
G-G-80, G-G-95	Direct contact with soil	**RME:** 1.1×10^{-6} **CT:** insignificant	Aroclor 1254 (5.0×10^{-7}), Aroclor 1260 (4.4×10^{-7}), and Arsenic (2.1×10^{-7})
G-G-81, G-G-96	Ingestion of soil	**RME:** 1.4×10^{-6} **CT:** insignificant	Arsenic (9.6×10^{-7})

Adult On-Site Visitor			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former On-Site Railroad Right-of-Way			
G-G-107, G-G-118	Ingestion of soil	**RME:** 3.3×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
Area Under and North of the Former West Manufacturing Building			
G-G-151, G-G-162	Ingestion of soil	**RME:** 1.1×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.

No significant area-specific hazards were identified for the adult on-site visitor

Child On-Site Visitor

Significant area-specific risks for the child on-site visitor are summarized below.

Child On-Site Visitor			
Table	**Exposure Pathway**	**Risk**	**Risk Driver**
Former SOS Pond Area			
G-G-55, G-G-66	Ingestion of soil	**RME:** 2.1×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
Former WWTP Area			
G-G-80, G-G-95	Direct contact with soil	**RME:** 1.4×10^{-6} **CT:** insignificant	Aroclor 1254 (5.9×10^{-7}), Aroclor 1260 (5.3×10^{-7}), and Arsenic (2.5×10^{-7})
G-G-81, G-G-96	Ingestion of soil	**RME:** 3.3×10^{-6} **CT:** insignificant	Arsenic (2.2×10^{-6})
Former On-Site Railroad Right-of-Way			
G-G-107, G-G-118	Ingestion of soil	**RME:** 7.7×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.
Area Under and North of the Former West Manufacturing Building			
G-G-151, G-G-162	Ingestion of soil	**RME:** 2.6×10^{-6} **CT:** insignificant	Arsenic is the only COPC with an SF.

Significant area-specific hazards for the child on-site visitor are summarized below.

Child On-Site Visitor			
Table	**Exposure Pathway**	**HI**	**Hazard Driver**
Former On-Site Railroad Right-of-Way			
G-G-107, G-G-118	Ingestion of soil	**RME:** 1.8 **CT:** insignificant	Iron (1.1)

5.3 RISK AND HAZARD ESTIMATES - LEAD

The methodologies used to characterize risks to child and adult residents associated with exposure to lead in soil, groundwater, sediment, and surface water are detailed in Appendix G-E. The methodologies and results are briefly summarized below.

The child resident is the most susceptible and the most highly exposed under the future land-use conditions. The adult resident is expected to be exposed the longest; the construction worker or on-site worker is expected to have a higher level of exposure but for a much shorter period of time. Therefore, the child resident and the adult resident are the only receptors discussed in Appendix G-E. Consistent with EPA guidance, the different methodologies discussed below were used to characterize risks associated with exposure to lead by child and adult residents (EPA 1994a and 1996c). In both cases, as recommended by EPA, risks were characterized as the probability that the receptor-specific blood-lead concentration (PbB) would exceed a critical level of 10 micrograms per deciliter (μg/dL).

5.3.1 Child Methodology and Results

Risks associated with the exposure of child residents were characterized using EPA's IEUBK Model, Version 0.99d (EPA 1994a). The concentrations of lead that the child resident was assumed to be exposed to was assumed to equal the maximum concentrations and EPCs. The IEUBK Model was run for the child resident only because this receptor is the most sensitive and most highly exposed. For soil, sediment, and surface water, modeling results indicate that even assuming exposure to the highest concentrations of lead in soil, sediment, and surface water, child receptor PbB levels are well below 10 μg/dL.

For groundwater, most PbB concentrations based on measured concentrations of lead in groundwater, surface water, and sediment were below the limit of 10 μg/dL. However, the model indicates that any groundwater lead concentration above 130 mg/L would result in a PbB exceeding 10 μg/dL. The maximum on-site groundwater lead concentration was 186 mg/L. The groundwater lead level exceeded 130 mg/L at monitoring wells MW-28S, MW-22, MW-20, and MW-07. MW-07 and MW-28S are located just northeast of the former landfill and west of the former manufacturing building. MW-22 and MW-20 are located along the Kalamazoo River north of the former manufacturing building. Any well used for drinking water in these areas could therefore potentially cause health risks.

The groundwater lead concentration in the former landfill area at MW-15 was 589 mg/L. The PbB level associated with this concentration exceeded the 10-μg/dL limit. Any well used for drinking water in this area could therefore cause health risks. However, future residential use of the former landfill is unlikely because this property is not zoned for residential use and deed restrictions will likely remain associated with the property.

5.3.2 Adult Methodology and Results

EPA's "Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead" was used to characterize risks associated with exposure of adult receptors to lead in on-site soil (EPA 1996c). The adult receptor was assumed to be a woman of child-bearing age. The methodology focuses on estimating the concentration of lead in fetal blood (PbB_{fetal}) in women exposed to lead-contaminated soil. Unlike EPA's IEUBK Model (EPA 1994a), this methodology allows the user to select the typical PbB in an adult woman of child-bearing age in the absence of site-related exposures. The methodology then estimates the extent to which this initial PbB is increased as a result of site-related exposures. Therefore, the concentration of lead in on-site soil is considered directly and not as part of a weighted average. The estimated PbB_{fetal} values range from 2.02 μg/dL for the average surface soil concentration to 2.45 μg/dL for the highest surface soil concentration. The probability that PbB_{fetal} exceeds 10 μg/dL is less than 5 percent, the recommended EPA cut-off value, for the adult resident over the entire site. The EPC surface soil lead concentration yields a 1.54 percent probability and the highest surface soil lead concentration yields a 2.87 percent probability that PbB_{fetal} exceeds 10 μg/dL. These results indicate that potential exposure to lead in on-site soil does not pose significant risks to human health.

5.4 RISK AND HAZARD ESTIMATES - INDOOR AIR VOCS FROM GROUNDWATER

The methodologies used to characterize risks to on-site residents associated with exposure to VOCs in groundwater are detailed in Appendix G-D. The methodologies and results are briefly summarized below.

The JEM was used to estimate risk to on-site residents from inhalation of vinyl chloride in indoor air (EPA 2001b). EPA uses the JEM to estimate the transport of contaminant vapors emanating from on-site groundwater into indoor spaces. No VOCs were detected in off-property groundwater. The JEM was used to estimate risks to on-site residents from VOCs in indoor air. Consistent with the approach outlined in Section 2.0 of the HHRA, on-site groundwater VOC EPCs were compared to HBSLs consisting of MDEQ residential and commercial indoor air criteria for groundwater. Concentrations of all VOCs except vinyl chloride were at least two orders of magnitude below MDEQ criteria. Therefore, the risks to on-site residents from indoor air concentrations of vinyl chloride only were estimated using the JEM. Based on the site-specific parameters of contaminant concentration, groundwater depth, and soil type, the incremental cancer risk associated with exposure of on-site residents to vinyl chloride from groundwater migrating to indoor air is 1.7×10^{-6}, which is within the acceptable risk range of 1×10^{-6} to 1×10^{-4}. This risk value is included in the HHRA evaluation of risks to on-site residents.

5.5 RISK AND HAZARD CHARACTERIZATION UNCERTAINTIES

The risk and hazard estimates in this HHRA are subject to various degrees of uncertainty from a variety of sources. The uncertainties discussed in other sections of this report related to data evaluation, exposure assessment, and toxicity assessment contribute to the overall uncertainty associated with risk and hazard characterization results.

The most significant site-specific uncertainties are related to (1) the assumption that groundwater beneath and downgradient of the Rockwell site will be used as a drinking water source under the future on- and off-property residential and on-site visitor land-use scenarios and (2) the use of dermal adherence values. These areas of uncertainty are discussed below, followed by a discussion of other general but significant sources of uncertainty.

5.5.1 Assumption of Future Groundwater Use

For completeness, risks and hazards associated with the future use of groundwater as a drinking water source by residents and on-site visitors were evaluated in the HHRA. However, current residents in the vicinity of the site do not use groundwater as a source of drinking water. Drinking water for all residents in the vicinity of the site is provided by the City of Allegan from wells located approximately 0.5 mile south of the site and within the flood plain of the Kalamazoo River. Because groundwater is not currently used as a drinking water source and because of the presence of high concentrations of contaminants in groundwater that likely render the groundwater unpalatable, the use of groundwater as a source of drinking water is unlikely based on current conditions. Therefore, resident and on-site visitor risks and hazards calculated in the HHRA are likely to be overestimated.

5.5.2 Use of Dermal Adherence Values

As described in Section 5.2, many of the significant ELCRs identified under the current and future land-use scenarios are associated with dermal contact. The calculation of intakes associated with dermal exposure to COPCs in soil requires the use of an adherence factor (AF). The AF parameter is an estimate of the amount of soil that adheres to a receptor's skin per unit of skin surface area. Based on discussions with an EPA Region 5 member of the Dermal Workgroup (Tetra Tech 1998a), the HHRA uses AF values recommended by EPA's "Dermal Exposure Assessment" (EPA 1992a) and used by MDEQ in developing Part 201 criterion (MDEQ 1998b). It should be noted that EPA's "Exposure Factors Handbook" recommends using body part- and activity-specific AF values that are almost one order of magnitude lower than the RME AF value (1 mg/cm^2) used in the HHRA (EPA 1997b). EPA's update to the 1992 "Dermal Exposure Assessment" document incorporates and recommends values similar to these revised and lower AF values (Tetra Tech 1998c). Dermal exposure to arsenic and Aroclors in soil drives the many of the significant risks identified in the HHRA. Based on the discussion above, as calculated in the HHRA, these dermal risks may overestimate actual dermal risks by as much as one order of magnitude.

5.5.3 Other Potential Sources of Uncertainty

Other general but potentially significant sources of uncertainty are associated with the exposure and toxicity assessments (see Sections 3 and 4, respectively). These uncertainties were addressed by selecting conservative values for these assessments. For example, EPA guidance states that the concentration term in exposure equations should be the arithmetic average concentration based on sampling results; however, because of uncertainties associated with estimating the true average concentration, the UCL_{95} of the arithmetic average or the maximum detected concentration, whichever was lower, was used to estimate the concentration (EPA 1992b). By definition, only a 5 percent chance exists that the UCL_{95} of the arithmetic average underestimates the true arithmetic average. Similarly, several other variables in the exposure intake equations are set at values at or near the 95th percentile of the distribution of potential values. Examples of these variables include on-site worker exposure frequency and exposure duration values.

Both RfDs and SFs were developed to be as conservative as possible. RfDs were developed by incorporating several order-of-magnitude uncertainty factors as well as additional, smaller modifying factors. SFs were calculated as the UCL_{95} on the dose response relationship estimated using the linearized multistage model for cancer development. Again, only a 5 percent chance exists that an estimated SF underestimates a chemical's true SF.

Multiplying exposure and toxicity variables, many of which are set at conservative values, results in an ELCR or HI estimate that is even more conservative. One study demonstrates that when values for two or more exposure variables based on the 95th percentile are multiplied, the estimated exposures overestimate the true 95th percentile. In fact, the estimated exposures are located at about the 99th percentile (Cullen 1994). When overestimated exposure results are multiplied again by conservative RfDs and SFs, the resulting ELCR and HI estimates are overestimated to an even greater extent.

The RME ELCR and HI estimates calculated may also significantly overestimate true 95th percentile results. It is important to consider the CT results as well; however, even a CT result may overestimate the true 95th percentile of the distribution of potential values because most CT results incorporate at least two variables, the EPC and the RfD or SF, which are set at the 95th percentile or greater. Even so, CT ELCR and HI characterization results overestimate the true 95th percentile to a lesser extent than RME results. Therefore, CT ELCR and HI characterization results more accurately represent true risks and hazards than results calculated under the RME case.

Additional ELCR and HI characterization uncertainties largely depend on the assumption of additivity. ELCRs and noncarcinogenic HIs for individual COPCs were added together to determine exposure pathway-specific ELCRs and HIs. Exposure pathway-specific ELCRs and HIs were in turn added to determine cumulative total ELCRs and HIs. Uncertainties associated with both types of additivity assumptions are discussed below.

Adding ELCRs and noncarcinogenic HIs for individual COPCs assumes that the COPCs all have the same toxic endpoints and mechanisms of action; however, this may not be the case. For example, although different COPCs cause a variety of noncarcinogenic adverse health effects that impact a variety of target organs or systems, it is assumed that COPC-specific HIs can be added to estimate hazard. Furthermore, chemicals in a mixture may act synergistically or antagonistically once they enter the human body and interactions between chemicals in a mixture may result in new toxic components or change the bioavailability of existing chemicals. Summing individual chemical ELCRs and HIs may result in overestimation or underestimation of cumulative total ELCRs and HIs, depending on the actual chemical interactions involved and the degree to which different COPCs affect similar target organs or systems. However, in all cases in this HHRA where a cumulative total HI greater than 1 is reported, at least one COPC- and exposure pathway-specific HI also exceeds 1.

Summing exposure pathway-specific cumulative total ELCRs and HIs almost certainly overestimates actual cumulative total risks and hazards. Exposure factors were selected for each exposure pathway to estimate RME results for each exposure pathway. It is unlikely that an individual receptor would be exposed under the RME case to multiple exposure pathways. Summing cumulative total ELCRs and HIs for multiple exposure pathways when each exposure pathway is assumed to be under RME conditions therefore likely results in cumulative total ELCR and HI estimates based on all potential exposure pathways that are well above the 95th percentile of possible ELCRs and HIs. These ELCR and HI estimates therefore likely significantly overestimate actual cumulative total risks and hazards for individual receptors.

6.0 HHRA SUMMARY

The primary objective of the HHRA for the Rockwell site was to evaluate potential exposures to site-related contamination and to characterize risks and hazards associated with these exposures. Exposures were evaluated and risks and hazards were characterized for a variety of human receptors under both RME and CT exposure conditions and under the current, current and future, and future land-use scenarios. This section summarizes the HHRA process, major assumptions, and significant conclusions and uncertainties related to the HHRA. Specifically, Section 6.1 summarizes the data evaluation and COPC selection processes. Section 6.2 summarizes the exposure assessment. Section 6.3 summarizes the toxicity assessment. Finally, Section 6.4 summarizes the risk and hazard characterization.

6.1 DATA EVALUATION AND COPC SELECTION

Several historic sampling investigations have been conducted at the Rockwell site. However, Tetra Tech has identified data gaps in the previous investigations, and differences in the investigations that make using and combining data from them difficult and, in some cases, inappropriate. The objectives of Tetra Tech's RI include filling data gaps identified in Tetra Tech's CSM and conducting an HHRA for soil, LNAPL, groundwater, sediment, and surface water matrices associated with the site. Therefore, this HHRA is based solely on data collected by Tetra Tech as part of the RI because these data represent the most complete and consistent set of data for the Rockwell site.

Soil, LNAPL, groundwater, sediment, and surface water samples were collected as part of Tetra Tech's RI and analyzed for VOCs, SVOCs, pesticides and PCBs, metals, and dioxins. As indicated in Section 2.3.1, medium-specific COPCs were identified following a four-step process (EPA 1989). COPCs remaining at the conclusion of this process were compared to the HBSLs identified in Section 2.2. Contaminants detected at concentrations above HBSLs were retained as final sitewide (on-site) and area-specific COPCs. Sitewide (on-site) and area-specific COPCs are listed in Tables G-4 and G-5, respectively.

As indicated in MDEQ's May 9, 2001, comments on the HHRA, MDEQ provided EPA with alternate HBSLs for several contaminants. These alternate HBSLs are listed in Tables 7 through 11 of the RI report. The alternate HBSLs differ from the HBSLs included in the HHRA as discussed below.

- State-wide background values presented in MDEQ's Part 201 criteria for soil were used instead of the site-specific background concentrations included in the HHRA for aluminum, chromium, cobalt, iron, manganese, and silver.
- For lead, the HBSL proposed by MDEQ is based on direct contact with soil instead of the site-specific background concentration included in the HHRA.
- For LNAPL, the HBSL proposed by MDEQ is based on groundwater screening criteria instead of the soil-based criteria included in the HHRA.

With the exception of the alternate LNAPL criteria, all criteria proposed by MDEQ are higher than HBSLs used in the HHRA. Higher HBSLs may result in the exclusion of several COPCs now included in the HHRA. For LNAPL, alternate HBSLs are both higher and lower than HHRA HBSLs. However, risks and hazards significantly exceeding appropriate thresholds for LNAPL are identified in this HHRA. Therefore, use of the alternate HBSLs does not alter the conclusions of the HHRA and no alternate HBSLs are included in the final HHRA.

For inorganic contaminants, analytical results were also compared to background concentrations. A review of background data collected during the RI indicated that all groundwater samples and all but one soil sample were likely impacted by the site. As a result, statistical comparisons of on-site sample results to background sample results could not be conducted. Therefore, the lower of the UCL_{95} or the maximum concentrations of inorganic contaminants in sitewide and area-specific soil samples were compared to the inorganic concentrations in background soil sample RW-BG04-0507. Groundwater inorganic COPCs were assumed to be the same as the soil COPCs because no background data were available for comparison. The lack of background data creates uncertainty; however, because most inorganics remained as soil COPCs, the use of inorganic soil COPCs for groundwater COPCs may overestimate site-related risks and hazards.

Elevated levels (based on a comparison to background concentrations or other sitewide samples) of essential nutrients, including calcium, magnesium, potassium, and sodium, are present in soil and groundwater. Based on a comparison of site-related concentrations to RDAs, DRIs, and other health-based levels, no health risk is associated with ingestion of soil but ingestion of groundwater may pose a health risk. This is consistent with the hazards and risks identified in Section 5.0 of the HHRA related to other COPCs. However, because groundwater use in the vicinity of the site is unlikely, essential nutrients were not retained as COPCs.

Also, speciation of chromium analytical results into trivalent and hexavalent forms was not conducted. According to MDEQ and EPA, no methods exist for calculating concentrations of trivalent and hexavalent chromium from total chromium results. Because hexavalent chromium is not stable in the environment and is not known to be a site-related contaminant, total chromium concentrations were assumed to consist exclusively of trivalent chromium. This assumption may result in a significant underestimation of risk because the toxicity of hexavalent chromium, if present at the site, is significantly greater than that of trivalent chromium.

Several types of modeling were conducted in support of the HHRA to supplement available medium-specific data sets. These modeling activities include the following:

- Particulate emission modeling for both on- and off-property locations to estimate the concentrations of COPCs associated with particulate emissions (see Appendix G-C)
- Indoor air concentration modeling to estimate potential risks to on- and off-property residents and on-site workers from the migration of LNAPL and groundwater COPCs to indoor air (see Appendix G-D)
- Modeling of the volatilization of contaminants from groundwater to air in trenches for the construction and utility workers (see Appendix G-D)
- Blood lead modeling to estimate concentrations resulting from receptor-specific exposure to lead (see Appendix G-E)

6.2 EXPOSURE ASSESSMENT

The primary objective of the HHRA was to evaluate potential risks and hazards associated with human exposure to COPCs detected at and downgradient of the Rockwell site under both current and future land-use scenarios. Under the current land-use scenario, the western portion of the site is abandoned and the entire site is surrounded by a fence topped with barbed wire. Site access is further restricted by a locked gate along the southern site boundary. Because the site borders residential areas, it is assumed that children and teenagers may periodically trespass on the site. During RI activities, children were noted trespassing on the site. Trespassers are assumed to be present only during the current land-use scenario. Other receptors present under the current land-use scenario but also assumed to be present during future land-use scenarios include on-site workers, on- and off-property construction or utility workers, off-property residents residing south and west of the site, and off-property recreationalists wading or walking along and swimming in the Kalamazoo River.

Receptors expected to be present only under the future land-use scenario include on-site residents, on-site visitors, and on-site parking attendants. On-site visitors are assumed to participate in ball playing, picnicking, walking, and other recreational activities at a park that may be constructed across the entire site consisting of open fields covered by grass. It is also assumed that picnic areas containing shelters, tables, and grilling areas will be present at the park. On-site parking attendants are assumed to work in the western portion of the site, which was assumed to be used as an unpaved parking lot for the Allegan County fairgrounds in the future. An adult attendant working at the parking lot is assumed to be exposed more than visitors using the parking lot because the parking lot attendant receptor is assumed to be exposed for the entire duration of the fair (unlike fair visitors who may be present only for a limited time) and is likely to be in close proximity to activities likely to produce the most dust (such as vehicle traffic). For children present in the parking lot, current parking attendant risk and hazard estimates would be decreased by a lower body weight, lower body surface area (increase of body parts such as bare feet exposed would be offset by greater adult body surface area), and lower exposure duration. Ingestion of soil by children may be greater (100 mg/day vs. 50 for adult); however, the decrease in exposure duration (7 days or less vs. 14 days for the parking attendant) would offset the increase in soil ingestion. Children wading in the river are addressed under the off-property recreationalist scenario. Therefore, only the parking attendant was quantitatively evaluated under this scenario.

Selection and development of the land-use scenarios involved several assumptions and introduced significant uncertainty, especially with regard to future conditions. Current land-use conditions are fairly well defined. However, future site development and use cannot be known with certainty. Potential future land-use scenarios for the Rockwell site were based on discussions with EPA, MDEQ, and officials from the City of Allegan, Michigan. One of the most significant assumptions made is the expectation that groundwater will be used as a drinking water source under the future resident and on-site visitor land-use scenarios. The City of Allegan receives drinking water from a series of public wells located 0.5 mile upstream of the site and within the flood plain of the Kalamazoo River. Therefore, it is unlikely that groundwater on or downgradient of the site will ever be used as a drinking water source.

Under all land-use scenarios, receptor-specific exposures were evaluated using standard exposure equations. Values for individual parameters required by these equations were identified based on EPA and MDEQ guidance and professional judgement. The medium-specific EPCs required in each exposure equation were calculated in accordance with EPA guidance. Appendix G-C presents the methodologies used to estimate COPC-specific on- and off-property air concentrations from particulate emissions.

Appendix G-D presents the methodologies used to calculate indoor air concentrations of VOCs from groundwater and LNAPL and construction or utility trench air concentrations of VOCs from groundwater. Appendix G-E presents the methodologies used to calculate risks associated with exposure to lead.

6.3 TOXICITY ASSESSMENT

Consistent with EPA and MDEQ guidance, the HHRA used COPC-specific toxicity values from EPA's on-line IRIS database and hard copy HEAST report. As discussed in Section 4.0 and documented throughout the literature, these toxicity values were developed in a conservative fashion and are unlikely to underestimate a COPC's potential to cause carcinogenic or noncarcinogenic health effects.

In addition to the uncertainty associated with the use of conservative toxicity factors, uncertainty also results from using oral toxicity factors adjusted for oral absorption to characterize risks and hazards associated with dermal exposure. Although consistent with EPA guidance, the use of adjusted oral toxicity factors introduces significant uncertainty. The uncertainty is greatest for COPCs such as carcinogenic PAHs, which are known to be carcinogenic at the point of exposure and not as a result of contaminant absorption. Because of a lack of viable options, the carcinogenic potential of these contact carcinogens was evaluated in the same manner as other potential carcinogens. However, because of significant differences in carcinogenic mechanisms, this approach introduces significant uncertainty. It is not known whether this approach under- or overestimates the actual carcinogenic potential of COPCs such as PAHs (EPA 1989).

It is important to note that inhalation-based toxicity factors are standardized for an adult exposed on a daily basis. Several of the receptors evaluated in the HHRA are not adults (and therefore have different ventilation rates) and are exposed on a less frequent basis. Toxicity factors standardized to daily adult exposures are, therefore, overly conservative for these receptors.

6.4 RISK AND HAZARD CHARACTERIZATION

Section 6.4.1 summarizes sitewide and off-property risks and hazards and Section 6.4.2 summarizes on-site area-specific risks and hazards. All risks and hazards are presented in more detail in Section 5.0 and Appendix G-G.

6.4.1 Sitewide and Off-Property Risk and Hazard Summary

According to the revised NCP (EPA 1990), EPA has established an "acceptable" range for carcinogenic risk from exposure at a Superfund site of 1 x 10^{-6} to 1 x 10^{-4} (one case of cancer in an exposed population of 10,000). Similarly, an HI of 1 is generally considered by EPA to be health-protective. The following sitewide and off-property exposure pathways are insignificant (less than 1 x 10^{-6} for ELCR or 1 for HI):

- All complete exposure pathways for the teenaged trespassers (except total ELCR for all pathways)
- All complete exposure pathways for the on-site parking attendant

The sitewide and off-property exposure pathways indicated in the table below with ● are within EPA's "acceptable" risk range (between 1 x 10^{-6} and 1 x 10^{-4}) or within an HI range of 1 and 100. The exposure pathways indicated in the table below with ▲ exceed EPA's "acceptable" risk range (greater than 1 x 10^{-4}) or an HI of 100. Blank cells in the table below indicated insignificant risk or hazard. Also, only receptors with significant risks or hazards are presented in the table below. Lastly, if both ELCRs and HIs exceed or are within the acceptable ranges, the higher of the two (typically the ELCR) is presented.

Receptor	Ingestion of Sediment	Direct Contact with Sediment	Inhalation of Indoor Air	Direct Contact with Soil	Ingestion of Soil	Direct Contact with Groundwater	Ingestion of Groundwater	Inhalation of Particulates	Ingestion of Homegrown Produce	Direct Contact with LNAPL	Inhalation of Indoor Air from LNAPL
On-Site Child Trespasser	●										
On-Site Worker			●	●	●						
On-Site Construction or Utility Worker				●		●		●		▲	
On-Site Adult Resident				●	●	▲	▲				
On-Site Child Resident			●	●	●	▲	▲		●		
On-Site Child and Adult Visitor					●		▲				

Receptor	Ingestion of Sediment	Direct Contact with Sediment	Inhalation of Indoor Air	Direct Contact with Soil	Ingestion of Soil	Direct Contact with Groundwater	Ingestion of Groundwater	Inhalation of Particulates	Ingestion of Homegrown Produce	Direct Contact with LNAPL	Inhalation of Indoor Air from LNAPL
Off-Property Construction or Utility Worker				●	●	●					
Off-Property Adult Resident				▲	▲		▲				▲
Off-Property Child Resident	●		●	▲	▲		▲		●		▲
Off-Property Child and Adult Recreationalist	●	●									
Off-Property Teenaged Recreationalist		●									

Sitewide and off-property exposure pathways exceeding or within EPA's "acceptable" risk range (between 1×10^{-6} and 1×10^{-4}) or exceeding or within an HI range of 1 and 100 have the following risk or hazard drivers:

- LNAPL and groundwater - PCBs and arsenic
- Soil - PCBs, arsenic, and iron
- Sediment - PCBs
- Homegrown produce - PCBs
- Indoor air from LNAPL - tetrachloroethene, trichloroethene, methylene chloride, and benzene

Sitewide and area-specific risks and hazards are presented in more detail in Section 5.2.1 and Figures G-3 and G-4.

6.4.2 On-site Area-Specific Risk and Hazard Summary

The following on-site area-specific pathways are insignificant (less than 1×10^{-6} for ELCR or 1 for hazard):

- All complete exposure pathways for the teenaged trespassers (except total ELCR for all pathways)
- All complete exposure pathways for the on-site parking attendant

The sitewide and off-property exposure pathways indicated in the table below with ● are within EPA's "acceptable" risk range (between 1 x 10^{-6} and 1 x 10^{-4}) or within an HI range of 1 and 100. Blank cells in the table below indicated insignificant risk or hazard. Also, only receptors with significant risks or hazards are presented in the table below.

Receptor	Ingestion of Sediment	Direct Contact with Soil	Ingestion of Soil
Former SOS Pond Area			
On-site Worker		●	
On-site Construction or Utility Worker		●	●
On-Site Child and Adult Resident		●	●
On-Site Child Resident		●	●
On-Site Child Visitor			●
Former WWTP Area			
On-Site Child Trespasser	●		
On-Site Worker		●	●
On-Site Construction or Utility Worker		●	●
On-Site Adult Resident		●	●
On-Site Child Resident		●	●
On-Site Child and Adult Visitor		●	●
Former On-Site Railroad Right-of-Way			
On-Site Child Trespasser			●
On-Site Worker		●	●
On-Site Construction or Utility Worker		●	
On-Site Child and Adult Residents		●	●
On-Site Child and Adult Visitor			●

Receptor	Ingestion of Sediment	Direct Contact with Soil	Ingestion of Soil
Area Under and North of the Former West Manufacturing Building			
On-Site Worker		●	

No on-site area-specific exposure pathways exceeded EPA's "acceptable" risk range (greater than 1×10^{-4}) or an HI of 100. However, exposures resulting from ingestion and direct contact with groundwater, direct contact with LNAPL, and inhalation of indoor air are summarized in Section 6.4.1 because on-site area-specific EPCs for groundwater and LNAPL were not calculated. Nonetheless, all area-specific on-site receptors may also be exposed to contaminants in groundwater and LNAPL in each on-site area.

On-site area-specific exposure pathways exceeding or within EPA's "acceptable" risk range (between 1×10^{-6} and 1×10^{-4}) or exceeding or within an HI range of 1 and 100 have the following risk or hazard drivers:

- Soil - PCBs, arsenic, and iron
- Sediment - PCBs

Sitewide and area-specific risks and hazards are presented in more detail in Section 5.2.2.

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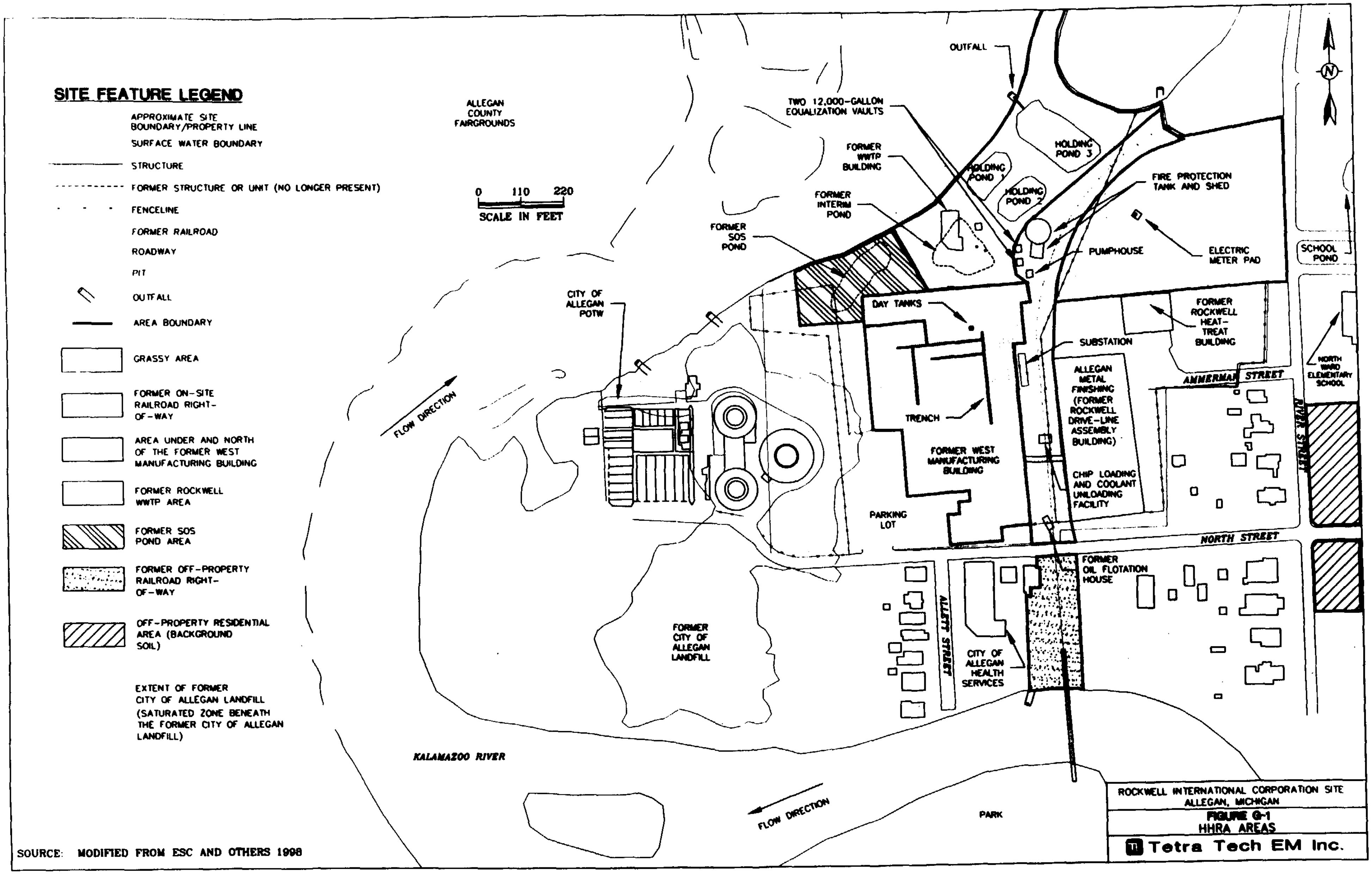
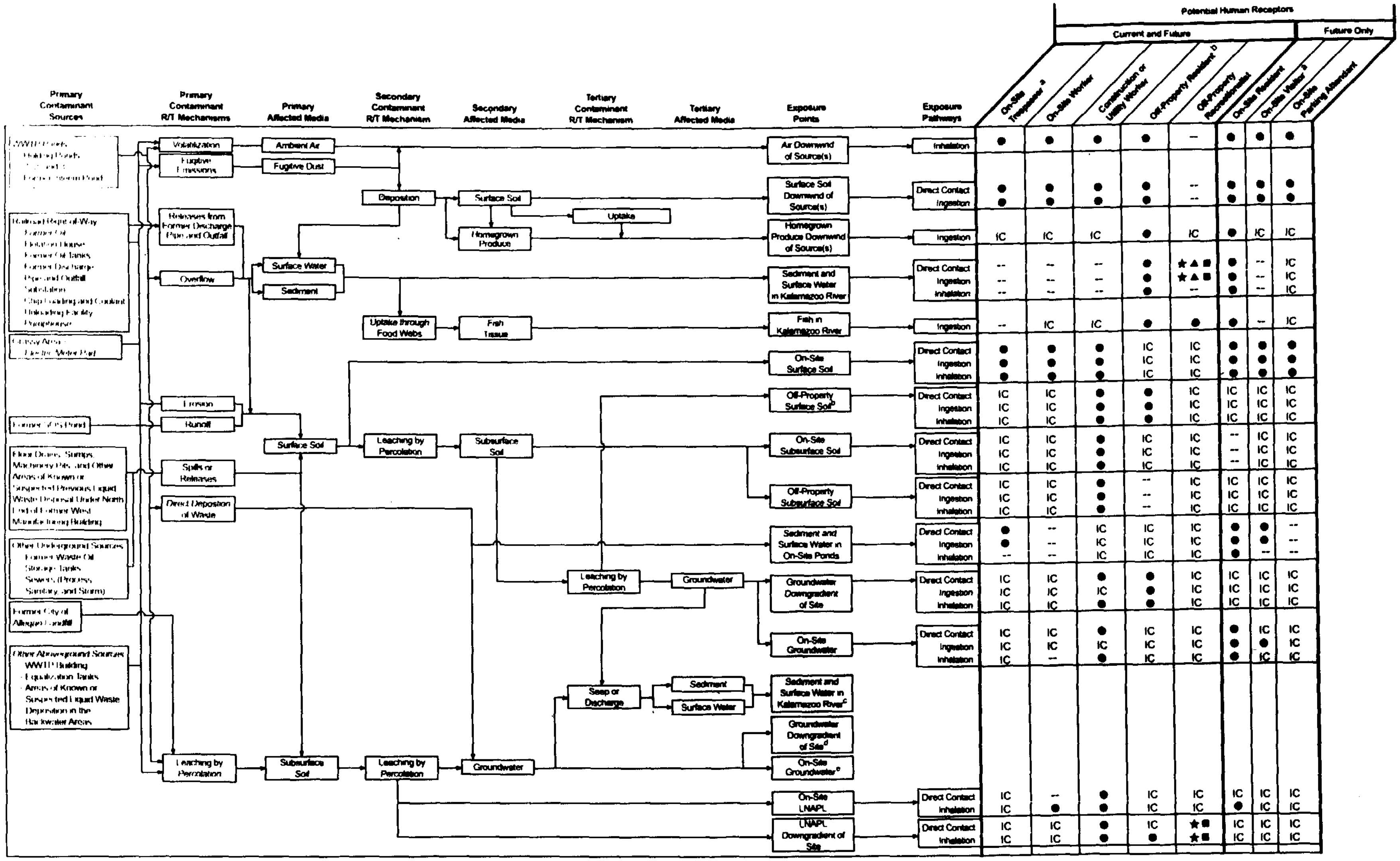

SITE FEATURE LEGEND
APPROXIMATE SITE BOUNDARY/PROPERTY LINE
SURFACE WATER BOUNDARY
STRUCTURE
FORMER STRUCTURE OR UNIT (NO LONGER PRESENT)
FENCELINE
FORMER RAILROAD
ROADWAY
PIT
OUTFALL
AREA BOUNDARY
GRASSY AREA
FORMER ON-SITE RAILROAD RIGHT-OF-WAY
AREA UNDER AND NORTH OF THE FORMER WEST MANUFACTURING BUILDING
FORMER ROCKWELL WWTP AREA
FORMER SOS POND AREA
FORMER OFF-PROPERTY RAILROAD RIGHT-OF-WAY
OFF-PROPERTY RESIDENTIAL AREA (BACKGROUND SOIL)
EXTENT OF FORMER CITY OF ALLEGAN LANDFILL (SATURATED ZONE BENEATH THE FORMER CITY OF ALLEGAN LANDFILL)
0 110 220
SCALE IN FEET
ALLEGAN COUNTY FAIRGROUNDS
OUTFALL
TWO 12,000-GALLON EQUALIZATION VAULTS
FORMER WWTP BUILDING
HOLDING POND 1
HOLDING POND 2
HOLDING POND 3
FIRE PROTECTION TANK AND SHED
FORMER INTERIM POND
FORMER SOS POND
PUMPHOUSE
ELECTRIC METER PAD
SCHOOL POND
CITY OF ALLEGAN POTW
DAY TANKS
SUBSTATION
FORMER ROCKWELL HEAT-TREAT BUILDING
NORTH WARD ELEMENTARY SCHOOL
AMMERMAN STREET
RIVER STREET
ALLEGAN METAL FINISHING (FORMER ROCKWELL DRIVE-LINE ASSEMBLY BUILDING)
TRENCH
FLOW DIRECTION
FORMER WEST MANUFACTURING BUILDING
CHIP LOADING AND COOLANT UNLOADING FACILITY
PARKING LOT
NORTH STREET
FORMER OIL FLOTATION HOUSE
ALLETT STREET
FORMER CITY OF ALLEGAN LANDFILL
CITY OF ALLEGAN HEALTH SERVICES
KALAMAZOO RIVER
FLOW DIRECTION
PARK
ROCKWELL INTERNATIONAL CORPORATION SITE
ALLEGAN, MICHIGAN
FIGURE G-1
HHRA AREAS
Tetra Tech EM Inc.
SOURCE: MODIFIED FROM ESC AND OTHERS 1998



Notes:

- R/T - Release or transport
- ▲,■,● - Potentially complete exposure pathway - retained for quantitative analysis
- ★ - Swimming
- ▲ - Fishing
- ■ - Walking or wading along river's edge
- IC - Incomplete exposure pathway
- -- - *De Minimis* exposure pathway

a = *The current on-site trespasser exposure scenario includes children and teenagers who may occasionally trespass on the site.* The future on-site visitor exposure scenario includes children and adults who may visit a future park.

b = Site-related contaminants have migrated through subsurface soil and groundwater to a low-lying area in an off-property resident's backyard.

c = The exposure routes and scenarios are the same as those listed above under the "Sediment and Surface Water in Kalamazoo River" exposure points.

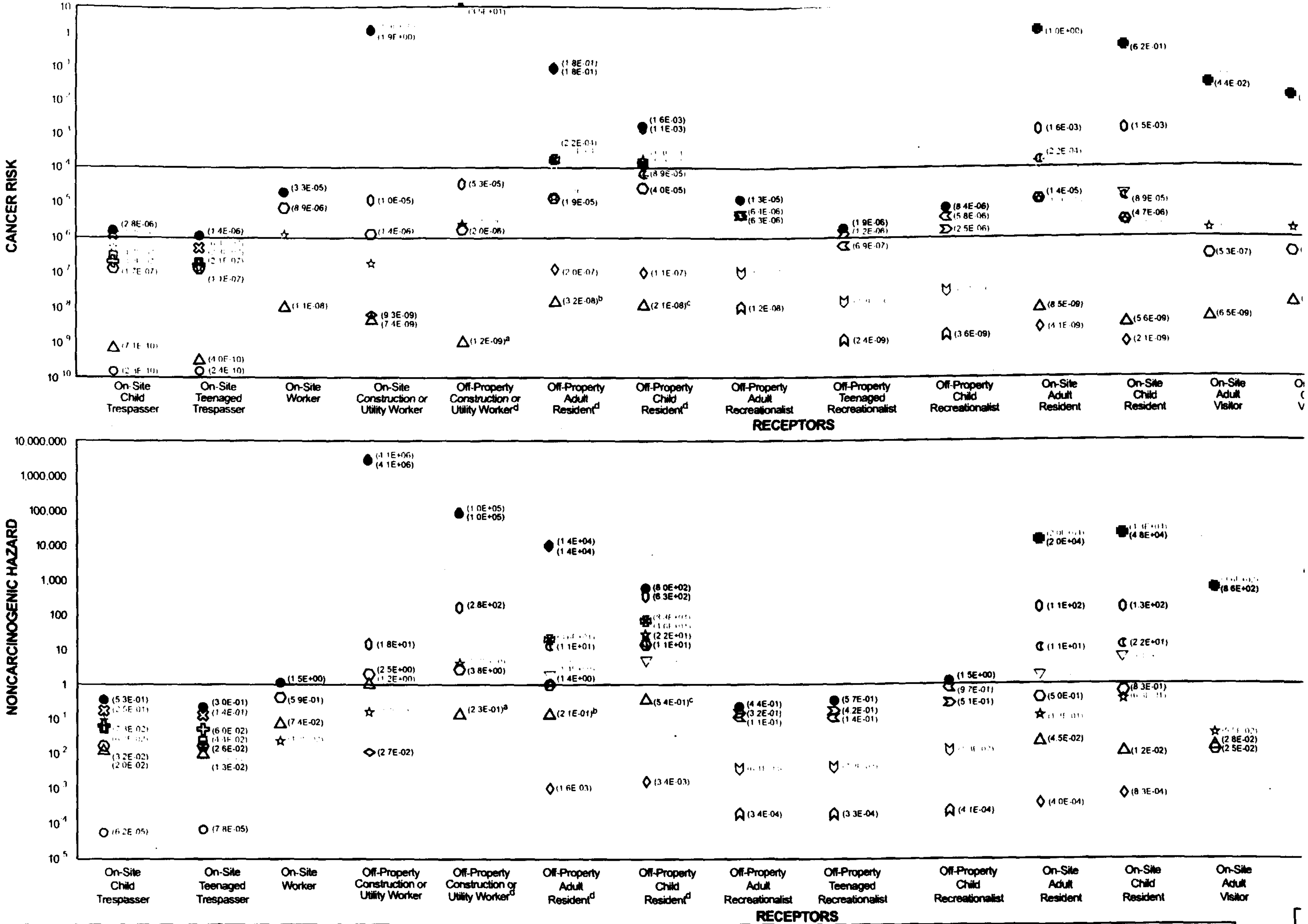
d = The exposure routes and scenarios are the same as those listed above under the "Groundwater Downgradient of Site" exposure points.

e = The exposure routes and scenarios are the same as those listed above under the "On-site Groundwater" exposure points.

ROCKWELL INTERNATIONAL
CORPORATION SITE
ALLEGAN, MICHIGAN

FIGURE G-2
CONCEPTUAL SITE MODEL

Tetra Tech EM Inc.



Key:

- △ INHALATION OF PARTICULATES
- ⬡ DIRECT CONTACT WITH SOIL
- INGESTION OF SOIL
- INGESTION OF HOMEGROWN PRODUCE
- ○ DIRECT CONTACT WITH SURFACE WATER IN ON-SITE PONDS
- □ INGESTION OF SURFACE WATER IN ON-SITE PONDS
- INGESTION OF SEDIMENT IN ON-SITE PONDS
- ▽ INHALATION OF INDOOR AIR
- INGESTION OF GROUNDWATER
- ◊ INHALATION OF GROUNDWATER FROM SHOWERING
- DIRECT CONTACT WITH GROUNDWATER
- ✚ DIRECT CONTACT WITH SEDIMENT IN ON-SITE PONDS
- DIRECT CONTACT WITH LIGHT NONAQUEOUS-PHASE LIQUID
- INGESTION OF KALAMAZOO RIVER SURFACE WATER
- INGESTION OF KALAMAZOO RIVER SEDIMENT
- DIRECT CONTACT WITH KALAMAZOO RIVER SURFACE WATER
- DIRECT CONTACT WITH KALAMAZOO RIVER SEDIMENT
- ◇ INHALATION OF GROUNDWATER
- ● TOTAL RISK OR HAZARD

Notes:

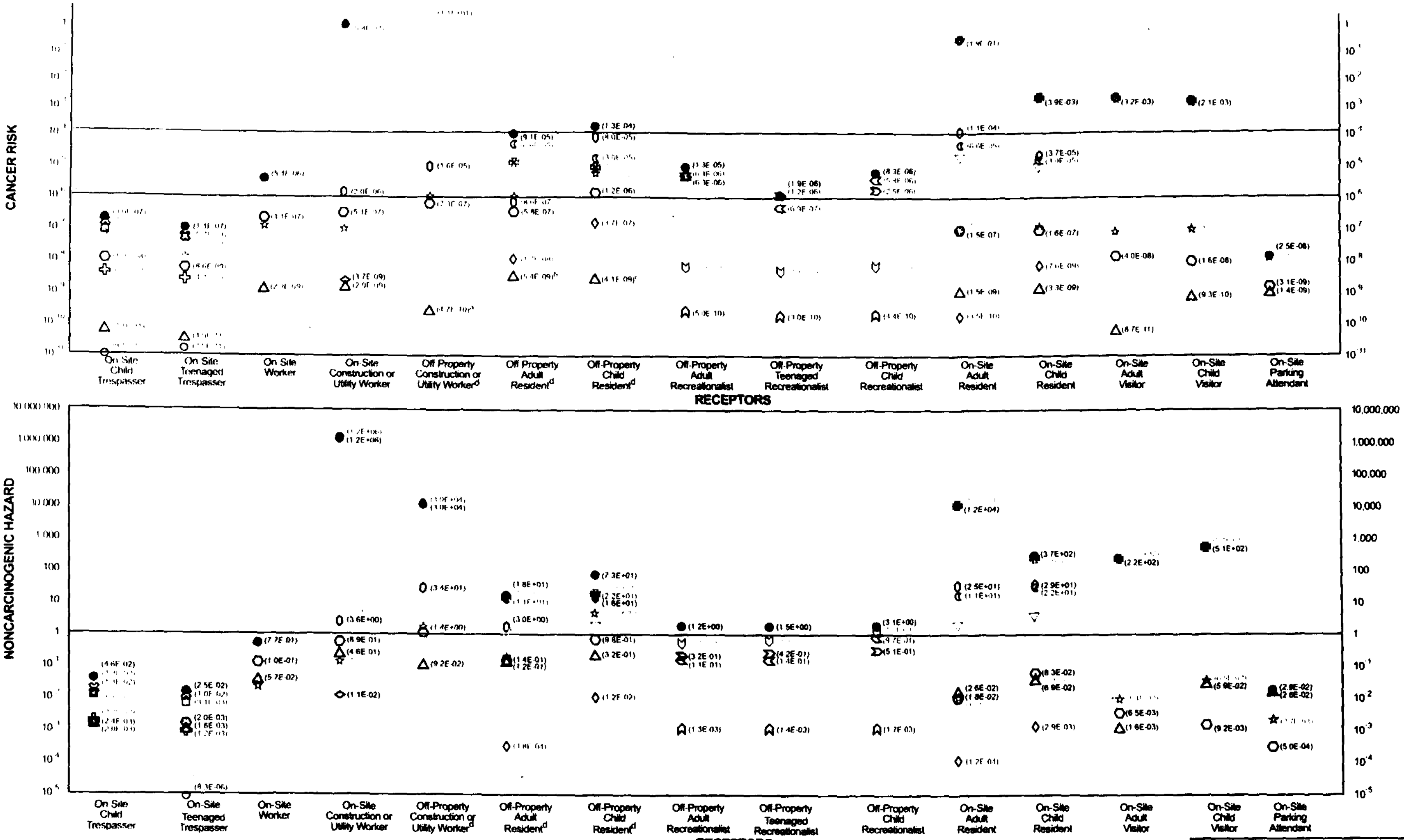
Exposure pathways and contaminants not evaluated in the HHRA m[illegible] present at the Rockwell site

a = Under future conditions, the cancer risk is 1.2E-09 and the noncarc[illegible]nic hazard is 2.3E-01

b = Under future conditions, the cancer risk is 3.2E-08 and the noncarcinogenic hazard is 2.1E-01

c = Under f[illegible]re conditions, the cancer risk is 2.1E-08 and the noncarcinogenic hazard is 5.4E-01

d = Off-p[illegible]y construction or utility worker and resident receptors shown on this figure are those exposed to co[illegible]inants of potential concern in the former off-property railroad right-of-way area



Key:

- △ INHALATION OF PARTICULATES
- ○ DIRECT CONTACT WITH SOIL
- INGESTION OF SOIL
- ☾ INGESTION OF HOMEGROWN PRODUCE
- ○ DIRECT CONTACT WITH SURFACE WATER IN ON-SITE PONDS
- □ INGESTION OF SURFACE WATER IN ON-SITE PONDS
- INGESTION OF SEDIMENT IN ON-SITE PONDS
- INHALATION OF INDOOR AIR
- INGESTION OF GROUNDWATER
- ◊ INHALATION OF GROUNDWATER FROM SHOWERING
- DIRECT CONTACT WITH GROUNDWATER
- ✚ DIRECT CONTACT WITH SEDIMENT IN ON-SITE PONDS
- DIRECT CONTACT WITH LIGHT NONAQUEOUS-PHASE LIQUID
- INGESTION OF KALAMAZOO RIVER SURFACE WATER
- INGESTION OF KALAMAZOO RIVER SEDIMENT
- DIRECT CONTACT WITH KALAMAZOO RIVER SURFACE WATER
- DIRECT CONTACT WITH KALAMAZOO RIVER SEDIMENT
- ◇ INHALATION OF GROUNDWATER
- ● TOTAL RISK OR HAZARD

Notes:

Exposure pathways and contaminants not evaluated in the HHRA may be present at the Rockwell site

a = Under future conditions, the cancer risk is 4.7E-10 and the noncarcinogenic hazard is 9.2E-02

b = Under future conditions, the cancer risk is 5.4E-09 and the noncarcinogenic hazard is 1.2E-01

c = Under future conditions, the cancer risk is 4.1E-09 and the noncarcinogenic hazard is 3.2E-01

d = Off-property construction or utility worker and resident receptors shown on this figure are those exposed to contaminants of potential concern in the former off-property railroad right-of-way area

ROCKWELL INTERNATIONAL
CORPORATION SITE
ALLEGAN, MICHIGAN

FIGURE G-4
SITEWIDE AND OFF-PROPERTY CT RISK AND HAZARD SUMMARY

Tetra Tech EM Inc.