The Dow Chemical Company
Part I - Remedial Investigation Work Plan

December 2014
Revised May 6, 2016

Prepared by URS Corporation

Tables

Figures

Attachment

Appendices

List of Acronyms and Abbreviations

%	percent
°F	degrees Fahrenheit
AOC	Administrative Settlement Agreement and Order on Consent
bgs	below ground surface
BHC	benzenehexachloride
CMI	Corrective Measures Implementation
COC	contaminant of concern
COI	constituent of interest
COM	Community
CSM	conceptual site model
DCC	direct contact criteria
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DOS	Dow on-site
Dow	Dow Chemical Company
DU	decision unit
EcoSSLs	Ecological Soil Screening Levels
EDA	Exploratory Data Analysis
EE/CA	Engineering Evaluation and Cost Analysis
ESL	Ecological Screening Level
ESLB	Ecological Screening Level Benchmark
FAQs	frequently asked questions
FS	Feasibility Study
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
GSI	groundwater surface water interface
HMW	High Molecular Weight
IA	Industrial.
IB	Industrial.
IRA	Interim Response Activity
IRDC	Interim Response Activity Work Plan Designed to Meet Criteria
LANL	Los Alamos National Laboratory
LCMR	Limited Commercial, Manufacturing and Research
License	Part 111 Hazardous Waste Management Facility Operating License
LMW	Low Molecular Weight
LULC	Land Use Land Classification
MAS	Midland Area Soils
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MRA	Midland Resolution Area
MSU	Michigan State University
NOAA	National Oceanic and Atmospheric Administration
PAH	polynuclear aromatic hydrocarbon
Part I	Remedial Investigation Work Plan

Part II	Remedial Investigation Report
Part III	Remedial Action Plan/Corrective Measures Implementation
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
PCOI	potential constituent of interest
ppb	parts per billion
ppt	parts per trillion
QA	Quality Assurance
QC	Quality Control
RA-3	Residential
RA-4	Residential
RAP	Remedial Action Plan
RB	Residential
RC	Regional Commercial or restrictive covenant
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RIWP	Remedial Investigation Work Plan
RL	reporting limit
RSL	Regional Screening Level
SOW	Scope of Work
SSAL	site-specific action level
SVOC	Semivolatile organic compounds
TAL	target analyte list
TCDD	tetrachlorodibenzo-p-dioxin
TEF	toxic equivalency factor
TEQ	toxic equivalent
UMDES	University of Michigan Dioxin Exposure Study
URS	URS Corporation
USDA	U.S. Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	volatile organic compound
WHO	World Health Organization

1.0 Introduction

Pursuant to its Part 111 Hazardous Waste Management Facility Operating License (License), issued September 25, 2015, The Dow Chemical Company (Dow), with oversight from the Michigan Department of Environmental Quality (MDEQ), has investigated the City of Midland area soils. The purpose of this Remedial Investigation Work Plan (RIWP, Part I) for the off-site Midland Area Soils (MAS) is to provide an overview of the site setting, land use, release characterization, and historical investigation activities; identify the potential exposure pathways; and present the methodologies to determine the contaminants of concern for human health and ecological exposure (with the exception of dioxins and furans which were identified as a contaminant of concern for the soil direct contact pathway).

The Remedial Investigation Report (RI Report, Part II) presents and summarizes the results of the human health and ecological risk screening evaluations, any constituents of interest (COIs) identified for relevant exposure pathways, presents the sampling methodology and decision rules for results evaluation, and documents the results of design sampling. The final Remedial Action Plan/Corrective Measures Implementation (RAP/CMI, Part III) describes the types of remedy used to address current and reasonably anticipated future use and documents the completion of remedy for current land use; thereby fulfilling Dow's obligations with respect to the historic airborne releases from the Michigan Operations Facility.

Dow previously submitted a Scope of Work (SOW), as required by Condition XI.B.3.of the 2003 Operating License. The SOW was approved by MDEQ on October 18, 2005. Dow subsequently submitted an RI Work Plan in December of 2006 pursuant to Condition XI.B.5. of the 2003 Operating License. MDEQ approved the 2006 RI Work Plan implementation schedule (with modifications) on July 24, 2007. The remainder of the 2006 RI Work Plan was not approved. A revised RIWP was submitted in October of 2007, but has not been approved or disapproved by the MDEQ. Through ongoing technical meetings between MDEQ, U.S. Environmental Protection Agency (USEPA), Dow and Dow's contractor, the remaining RI Work Plan issues were resolved with the approval of the May 25, 2012 *Interim Response Activity Work Plan Designed to Meet Criteria* (IRDC)(Appendix A). The IRDC presented a schedule for submittal of a revised SOW and RIWP, which encompasses this report (Part I). Section 1.0 of this report therefore constitutes an amended and revised SOW. Dow also hereby withdraws the RI Work

Plan submitted in October 2007, wholly replacing the proposals made with this current RIWP (Part I).

A number of studies have been completed during the intervening period between the original approval of the SOW and the ultimate design, submittal and approval of the IRDC. The IRDC specifically focused on the nature and extent, site-specific action level (SSAL) and sampling approach and remedy for dioxins and furans for the soil direct contact exposure pathway.

1.1 RI Purpose and Objectives

The MAS RI has been conducted to meet applicable requirements of the License and Part 111 of Act 451, as well as relevant Resource Conservation and Recovery Act (RCRA) regulations.

The scope of the MAS Corrective Action Report (Parts I – III) includes the following elements:

- Identification of the source of the release of contaminants;
- Identification of the potential constituents of interest (PCOIs) subject to corrective action beyond the Facility Boundary for this release;
- Characterization of the nature and extent of contamination that has migrated beyond the Facility Boundary;
- Identification of receptor populations;
- Development of sampling approach;
- Development of action levels and remedial decision rules that will be applied at each decision unit (DU) to determine if remedial action is warranted; and
- Evaluation of selected remedy.

1.2 Planning of Remedial Investigation Work

1.2.1 RI Background Information

A description of current conditions including climate and meteorology, geology, soils, hydrogeology, surrounding land use and property zoning of the area are summarized in Section 2.0 of this report.

1.2.2 RIWP Development

The studies that comprise the RI were developed in stages with MDEQ, each building upon the results of the previous study. The development of the studies summarized below were completed specifically to address the design elements listed in Section 1.1 of this report in accordance with Part 111 of Michigan Act 451 as well as RCRA regulations. The studies include the following efforts:

- Sampling and subsequent screening evaluations to establish PCOIs, including the 2005 and 2006 Dow On-Site (DOS) Sampling, 2006 CH2M Hill samples (City of Midland Blind data), and the 2010 Field Characterization Pilot Study (Dow and MDEQ split sampling);
- Sampling and analysis to characterize the nature and extent of the PCOIs have been completed as elements of a number of studies, including the 2005 and 2006 DOS Sampling, 2006 CH2M Hill Data Set, the 2010 Dow and MDEQ split sampling and design sampling at individual DUs beginning in June 2012 upon approval of the IRDC. The vertical extent of contamination was specifically evaluated during both the 2006 CH2M Hill Data Set Sampling as well as the 2010 Field Characterization Pilot Study; and
- The 2006 CH2M Hill Data Set sampling effort included the sampling and analysis of samples collected from over 130 areas representative of conditions on residential or public areas along 23 transects, extending between 3,000 to 11,000 feet from the Facility Boundary to characterize the distribution of properties reported to influence bioavailability (such as total organic carbon, grain size distribution and specific surface area). These data were considered for the development of a SSAL.

A discussion of each of these previously completed studies is included in Section 4.1 of this report.

1.3 Human Health Risk Screening Evaluation

A human health risk screening evaluation was completed for off-site Midland Area Soils. This report provides the methods used to perform the human health risk screening evaluation. Part II presents the results and findings of the screening evaluation and the information required to evaluate potential risks to human health within the area to be investigated as defined by the License. This report includes identification of the potential exposure pathways that will be addressed in Part II for each relevant land use and media related to the MAS project, as appropriate. The human health risk screening evaluation includes the following elements:

- Exposure pathway identification;
- Evaluation of potential receptors;
- Identification of appropriate screening levels;
- Screening-level evaluation; and
- Identification of exposure data for the Generation of Site-Specific Clean-up Criteria, as needed.

Part 201 has generic clean-up criteria for exposure pathways for ingestion, inhalation, and dermal absorption of contaminated soils and protection of groundwater under various land use scenarios. Land uses for the area to be investigated as defined by the License include residential, residential-like and non-residential.

1.4 Ecological Risk Screening Evaluation

An ecological risk screening evaluation was completed for MAS. This report provides the methods used to perform the ecological risk screening evaluation. Part II presents the results and conclusions of the screening evaluation and the information required to evaluate potential risks to ecological receptors within the area to be investigated as defined by the License. The ecological risk screening evaluation includes the following elements:

- Screen TAL according to generic ecological screening criteria;
- Develop ecological screening categories based on results of generic screen;
- Determine the appropriate site-specific ecological receptors; and
- Calculate site-specific ecological benchmarks, as necessary.

The MAS project area is an urban environment. USEPA Region 5 generic ecological screening level benchmarks (ESLBs) for exposure were used for the initial screening effort.

1.5 Preliminary Feasibility Study Planning

Part II defines the nature and extent of dioxins and furans for the soil direct contact exposure pathway resulting from historic aerial releases from the Midland Plant Facility. A request to waive the requirement to develop and implement a Feasibility Study (FS) was made as part of the submittal of the IRDC, approved by MDEQ on June 1, 2012. No additional FS work is proposed as part of this report.

The combination of both institutional controls and the removal of impacted soil at DUs above the SSAL, will be protective of human health and the environment by achieving the media-specific cleanup standards, as well as satisfy the following criteria:

- Short term effectiveness;
- Long-term reliability;
- Reduction of exposure to contaminants;
- Ease of implementation; and
- Cost.

The complete discussion of the nature and extent for the MAS is presented in Part II.

1.6 Public Participation Plan

Public involvement in the RI process for MAS consists of a formal public process, informal availability as well as public repositories of information. The formal public process includes formal public comment periods for both the IRDC, discussed in Part II, and the RAP (Part III), including public hearings. The formal process includes announcements in the local news media and the MDEQ calendar.

General informal availability provides opportunities for members of the public to obtain in-person one-on-one service, attention and discussion via open house meetings (e.g., availability sessions) and the operation of the Midland Resolution Center at 1007 Jefferson Avenue, established in 2012 to support this project. The Midland Resolution Center is an office available to the public during normal business hours (8 AM to 5 PM), or by appointment. A toll-free telephone hotline was also available 24 hours a day to allow the public to express their concerns or obtain additional information. A number of public availability sessions allowed members of the public to come and express concerns or obtain information from both project staff and MDEQ. A number of informational flyers related to gardening, sampling, remedy as well as a compiled list of frequently asked questions (FAQs) were prepared to provide the public with general information. A publically available website, http://www.midlandresolution.com, was established where the public can obtain both informational flyers and updates, and access relevant documents.

1.7 RI Deliverables and Schedule Milestones

A schedule for providing the RI Deliverables was presented in the IRDC. The schedule provided below reflects several updates in deliverable deadlines based on an approved accelerated sampling and remedy schedule achieved based on Adaptive Management as described in Section 9.0 of the approved IRDC (Appendix A). Details of the RAP Completion Summary Report to address direct contact to surface soils for current land use are provided in Part III of this report. A summary of the elements completed to address potential future changes in land use will be included in the first Annual Report. Key RI deliverables and the schedule are listed below:

RI Deliverable	Timeframe/Duration
Revised SOW and RIWP (Part I)	December 2014
Updated Revised SOW and RIWP (Part I)	January 2016
RI Report (Part II)	December 2014
Revised RI Report (Part II)	January 2016
Implementation of Remedy	2012 - Ongoing
RAP/CMI (Part III)	December 2014
Revised RAP/CMI (Part III)	January 2016
RAP Completion Report for ICs	January 2017

1.8 Interim Response Activities

Condition XI.B.3. (a) of the 2003 Operating License requires Dow to propose Interim Response Activities (IRAs) in the SOW. This SOW condition was satisfied by submittal and subsequent approval by MDEQ of the:

- Midland Area Soils Interim Response Activities Work Plan, February 2004, which was modified and approved by MDEQ in January 2005.
- Interim Response Activity Work Plan: Communications, February 2004; modified and approved by MDEQ, October 2004.

Additional IRAs designed to meet criteria were completed by Dow upon approval of the IRDC, and subsequently also the 2012 and 2013 Adaptive Management Reports and 2013 and 2014 Work Plans. Summaries of all IRAs completed are provided in the relevant Implementation Annual Reports.

2.0 Physical Setting and Land Use

The Dow Michigan Operation began operations in 1897. Expansion in production operations during the past century resulted in growth of Michigan Operations from 25 to approximately 1900 acres. The majority of Michigan Operations is located on the east side of the Tittabawassee River in the southern portion of the City of Midland. The facility location and layout are depicted in Figure 2-1.

2.1 General Site Setting

2.1.1 Land Development

In the early 1900s, the area surrounding Michigan Operations and the City of Midland was primarily composed of land used for agricultural and recreational purposes. Beginning in 1916, a marked increase in land development for residential and industrial purposes occurred. By the 1960s, residential properties were distributed throughout the Midland area and the rate of increase had stabilized; however, industrial and commercial land development continued to occur to the east, southeast, and southwest of Midland over the years. From the late 1800s to 2010, the population of the City of Midland increased from 1,160 to 41,863 (U.S. Department of Agriculture, 1997; U. S. Census Bureau, 2014). The city currently encompasses approximately 34 square miles.

2.1.2 Climate and Meteorology

The area is characterized by a continental climate regime, with winter temperatures cold enough to sustain stable snow cover and relatively warm summer temperatures. The mean annual temperature for the area is 48.4 degrees Fahrenheit (°F). The minimum average temperature is 30.8°F (with the coldest month being January), and the maximum average temperature is 83.33°F (with the warmest month being July). Between 1981 and 2010, the Midland area average monthly precipitation ranged between 1.6 inches (February) and 3.7 inches (September), with a monthly average of 2.7 inches and an annual average of 32 inches (National Oceanic and Atmospheric Administration [NOAA], 2010 and Michigan State University [MSU], 2010).

According to annual measurements recorded in Midland from 1981-2010, the average seasonal snowfall between October and April was 32 inches. During the period of 2005-2009, approximately 90 days had either snow cover (e.g., > 1 inch) or frozen soils (e.g., maximum soil temp < 32°F) (NOAA, 2010 and MSU, 2010). This would result in 275 days when the soil is not frozen or there is less than an inch of snow cover.

Wind direction is predominantly from the west-southwest (that is, toward the east-northeast), regardless of season. Wind velocity peaks during February and March and is lowest during July. A wind rose depicting predominant wind direction and velocity for the area is included as Figure 2-2. The data used to develop the wind rose were obtained for the five years 2007, 2008, 2011, 2012, and 2014 from a meteorological station located at Michigan Operations.

2.1.3 Hydrology and Surface Water

The primary natural surface water feature in the area is the Tittabawassee River, which drains approximately 2,600 square miles of land in the Saginaw River watershed (Michigan Department of Natural Resources [MDNR], 1988). The river begins in Roscommon and Ogemaw counties, which are approximately 26 miles north of the City of Midland and Saginaw County. The Tittabawassee River flows south and southeast for approximately 80 miles to its confluence with the Saginaw River, located approximately 22 miles southeast of Midland. Most of the Tittabawassee River watershed upstream of Midland is forested or agricultural land. The Pine and Chippewa rivers are tributaries to the Tittabawassee River and have similar drainage areas and flow contributions to the Tittabawassee River. Together, the Pine and Chippewa rivers contribute approximately 40 percent (%) of the Tittabawassee River flow at Midland (MDNR, 1988).

Other secondary surface water features include small permanent and intermittent streams flowing into tributaries of the Tittabawassee River, small natural and constructed ponds (less than 5 acres), and constructed ditches used to store and convey storm water from developed properties. The flows from storm water drains enter the Tittabawassee River immediately upstream of Michigan Operations. Two small tributaries, Bullock Creek and Lingle Drain, enter the Tittabawassee River adjacent to and immediately downstream of Michigan Operations, respectively. Figure 2-3 depicts surface water bodies and the general topography in and around the area. The regional topography indicates that surficial drainage patterns in the area are generally toward the Tittabawassee River. However, natural drainage patterns in developed portions of the area have likely been altered and might direct surface water away from the Tittabawassee River, toward drainage basins and other storm water collection units.

2.1.4 Geomorphology and Geology

Michigan Operations lies in the Eastern Lowlands Physiographic Region of Michigan's Lower Peninsula. This region has very flat topography of lacustrine origin and is found along coastal areas in the southeastern part of the state, extending north from the Saginaw Bay area, along Lake Huron to the tip of the Lower Peninsula. Soil types are typically derived from glacial and post-glacial fluvial processes and generally are composed of coarse-grained material deposited in ancient beach and near-shore environments and clay-rich lacustrine deposits (MDNR, 1988).

Because the area near Michigan Operations offsite is urban, the near-surface soil has been disturbed by excavation, filling, and grading activities since land development began in the area. The uppermost stratum is the "surface sand" (0 to 20 feet). The surface sand has often been removed or augmented with fill of similar geologic characteristics, making it difficult to determine the boundary between the surface sand and overlying fill.

The surface sand is underlain by a discontinuous layer of lacustrine (former lakebed) clay with varying thicknesses (approximately 2 to 20 feet), generally at a depth of about 5 to 15 feet. Although thin, discontinuous silt layers are interbedded with the clay, this clay serves as an effective subsurface barrier to the underlying glacial till.

Glacial till typically underlies the lacustrine clay layer. The glacial till consists of an unstratified mixture of rocks, gravel, sands, silts, and clays; however, soil in the glacial till is typically rich in clay. Permeability in the glacial till is typically low because of the silts and clays present and the high degree of compaction resulting from deposition. Fractures are common in the upper regions of the till. Some areas of sand, highly variable in length, thickness, and depth from surface, have been encountered in the glacial till unit. These areas of sand exhibit a significantly higher permeability than the clay and silty areas in the glacial till.

A sand layer underlies much of the area at the base of the glacial till; it consists of well-sorted sands and gravels interlayered with silt and clay seams largely located within bedrock valleys. The regional sand is encountered at approximately 150 to 400 feet below ground surface (bgs).

2.1.5 Hydrogeology

Hydrogeologic units, from deepest to shallowest, are as follows: bedrock, the regional aquifer, glacial till, lakebed clay, and surface sands. Groundwater contained in bedrock occurs primarily in sandstone layers. The potentiometric head in the bedrock aquifer is higher than the head in the regional aquifer, resulting in an upward hydraulic gradient. The regional aquifer overlies bedrock in some areas and consists of well-sorted sands and gravels interlayered with silt and clay seams. The low permeability of the overlying glacial till causes the regional aquifer to behave as a confined aquifer with an artesian head.

Groundwater is present throughout the glacial till at saturation, although the extreme compaction of this unit has reduced effective porosity and permeability. Sand bodies of significant size, generally referred to as glacial till sands, occur in the glacial till. Glacial till sands are highly variable in length, thickness, and vertical location in the glacial till, and are relatively more permeable. Glacial till sands are the sole sources of significant quantities of groundwater in the glacial till. Within Midland County, outside the City of Midland Limits, glacial till sands are utilized as a source of drinking water. Within the area of interest, groundwater is not used as a drinking water source.

The lakebed clay is generally considered an aquitard, although some water is contained in thin, discontinuous silt layers interbedded within the clay. The lakebed clay significantly limits downward movement of groundwater. The surface sands contain an unconfined aquifer that varies in both quantity and quality.

2.2 Midland Land Use

The area of interest for the MAS project was defined as the Midland Resolution Area (MRA). The current land use within the MRA was based on general knowledge of local conditions, evaluated by touring the area and reviewing aerial photographs and Geographic Information Systems (GIS) Land Use Land Classification (LULC) map layers for the Midland area. High-resolution aerial photographs taken in April 2010 were available for review along with the 2009 LULC information. Other sources of information, such as local knowledge and local zoning, were used as needed to help establish and refine the classifications.

The MRA covers a total of approximately 1,700 acres. Land uses within the MRA include residential land use and non-residential land use. Figure 2-4 shows the land use areas within the MRA. The predominant land uses are defined and described further in the following subsections. The MRA and the final boundary are described in further detail in Part II.

2.2.1 Non-Residential Land Use

The area in the MRA that is contiguous to the north and east with Michigan Operations site boundary and downwind of on-site historic waste incineration is primarily industrial and commercial land, some of which is owned by Dow. Properties with industrial or commercial land use within the MRA cover approximately 1,275 acres. The aerial extent of these areas with predominantly industrial and commercial uses is shown on Figure 2-4. This is the area with the highest measured dioxin concentrations, although the concentrations are below the generic non-residential direct contact criteria (DCC).

2.2.2 Residential Land Use

Residential land use is the predominant land use type for the properties located north and east of the industrial/commercial land use areas described above. These areas encompass several residential neighborhoods within the City of Midland.

In addition to residential properties, there are additional property types that have aspects that are similar to residential uses, or are “residential-like,” including daycare centers, schools for children, and parks with playgrounds. To be considered “residential-like,” properties generally need to service sensitive populations (e.g., children or the elderly), a significant amount of time is spent there, and their use results in contact with soil. When considering a property to determine if the use is residential-like, the actual land use will be evaluated against the residential and non-residential exposure assumptions of Part 201. Specifically, the following property uses will be managed as residential-like uses:

- Child or day care centers;
- Nursing homes;
- Schools for children;
- Parks with grassy areas adjacent to residential property or play grounds;
- Outdoor maintained public recreation areas, such as ball fields;
- Campgrounds; and
- Juvenile service facilities.

The following uses, although having some aspects similar to residential uses, do not involve long term residency or exposure to soils that are equivalent with residential uses, instead, exposure is similar to commercial uses:

- Colleges, universities, business, vocational, technical, and trade schools (that do not have housing);
- Places of worship (that do not have day or child care facilities).
- Sports stadiums and arenas;
- Community Centers and Civic Centers;
- Fire stations.
- Day shelters (facilities that provide temporary daytime shelter exclusively for adults, such as homeless shelters, but do not involve overnight stays); and
- Public spaces used primarily for paved bike/walking trails and do not contain children's play grounds.

Of the total 1,700 acres of the MRA, approximately 425 acres is residential land use. The aerial extent of the 2012 proposed MRA is shown on Figure 2-5.

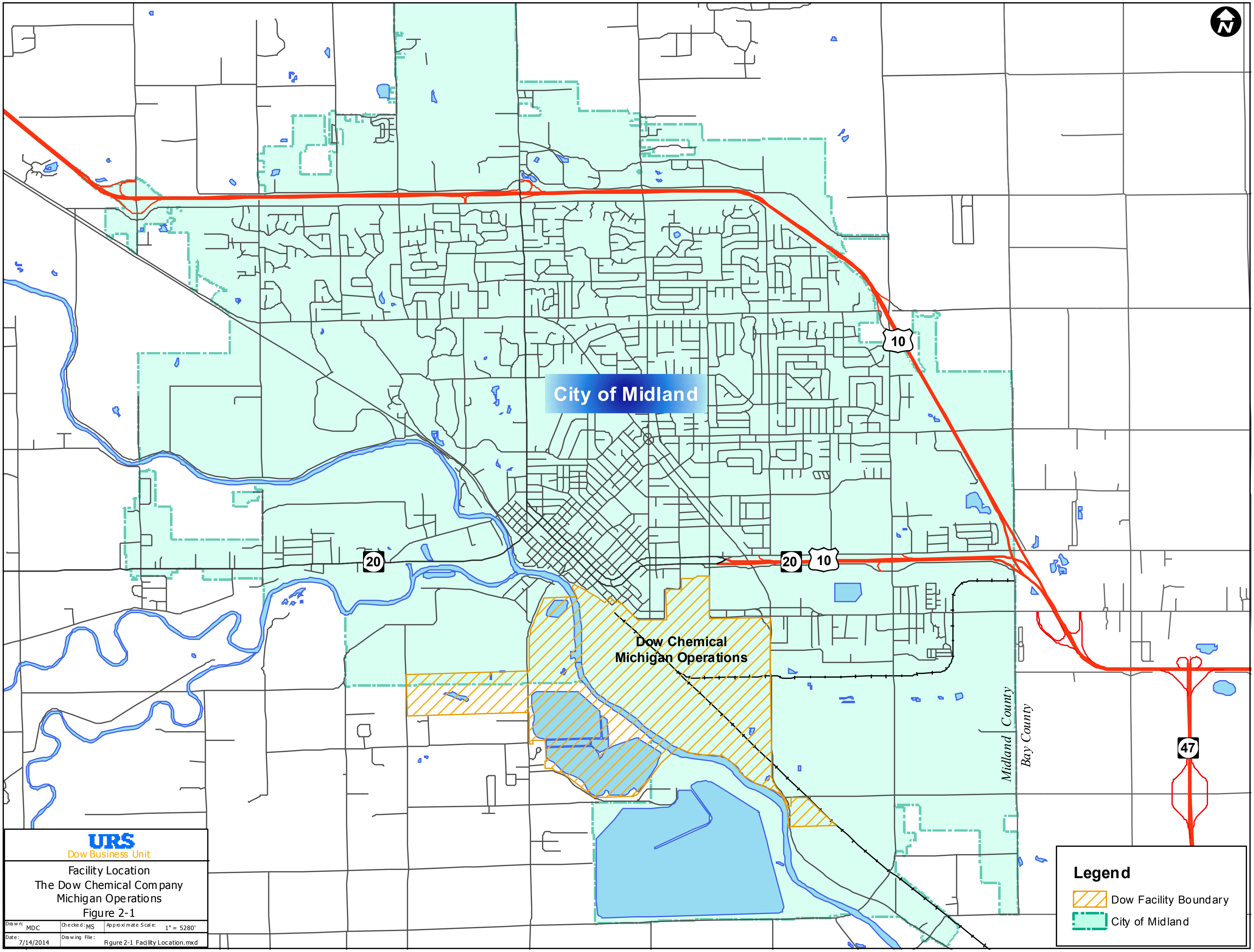
2.2.2.1 Zoning

The MRA contains the following zoning districts as defined in the City of Midland Zoning Ordinance. In each district some uses are permitted as of right, and, therefore, these uses are typically predominant in the district. Other uses are permitted only if permission is granted by the City Council after receiving a recommendation from the Planning Commission (i.e., "conditional land uses").

Zoning District	Summary
RA-3 – Residential.	This district allows single family dwellings, day care centers, schools and similar residential or residential-like uses as of right.
RA-4 – Residential.	Single and double family dwellings and other residential uses are permitted as of right.
RB – Residential.	Multiple family dwellings are permitted with conditions; fire stations, schools, parks and social service agencies are permitted as of right.
RC – Regional Commercial.	The purpose of this district is to offer an area for a diversity of retail, service, entertainment, office, finance and related businesses. Traditional residential uses are not permitted in this district. Aside from traditional commercial uses, the district also allows child care centers, colleges, day shelters, residential treatment facilities, transitional housing, campgrounds, and outdoor recreational facilities.

Zoning District	Summary
OS – Office Services.	The intent of this district is to accommodate administrative and professional offices, personal service businesses, and supporting retail. The only residential uses that are permitted as of right are dwelling units on the upper floors above business establishments. Other uses permitted as of right include schools, parks, child care centers and residential inpatient treatment facilities. Nursing homes are permitted with special conditions. Single and multiple family housing is permitted with the approval of the City Council as a conditional land use.
COM – Community.	This district provides for public and private uses with community significance, such as civic centers, museums, stadiums and parks. Residences are not allowed, however, schools, transitional housing, and residential treatment centers are authorized. Juvenile service facilities and correctional facilities are permitted with the approval of the City Council as conditional land uses.
LCMR – Limited Commercial, Manufacturing and Research.	This district provides for mixed use office and industrial uses in a campus like setting. Although office and industrial uses are the focus, child/day care centers are allowed as of right, and colleges, residential treatment centers, transitional housing and day shelters are permitted with conditions.
IA – Industrial.	Industrial uses with limited off-site impacts. Residential uses are not allowed.
IB – Industrial.	Intensive industrial activities, to be separated from residential and commercial areas. Residential uses are not allowed.
Center City Authority	Corridor Improvement Authority, established pursuant to P.A. 280 to correct and prevent deterioration in business districts, promote economic growth and authorize the use of Tax Increment Financing.

The zoning map for Midland is included as Attachment K of the approved IRDC which is included as Appendix A for this report and current maps can be accessed online at: http://www.midland-mi.org/government/departments/planning/planning/Zoningordinance.htm.



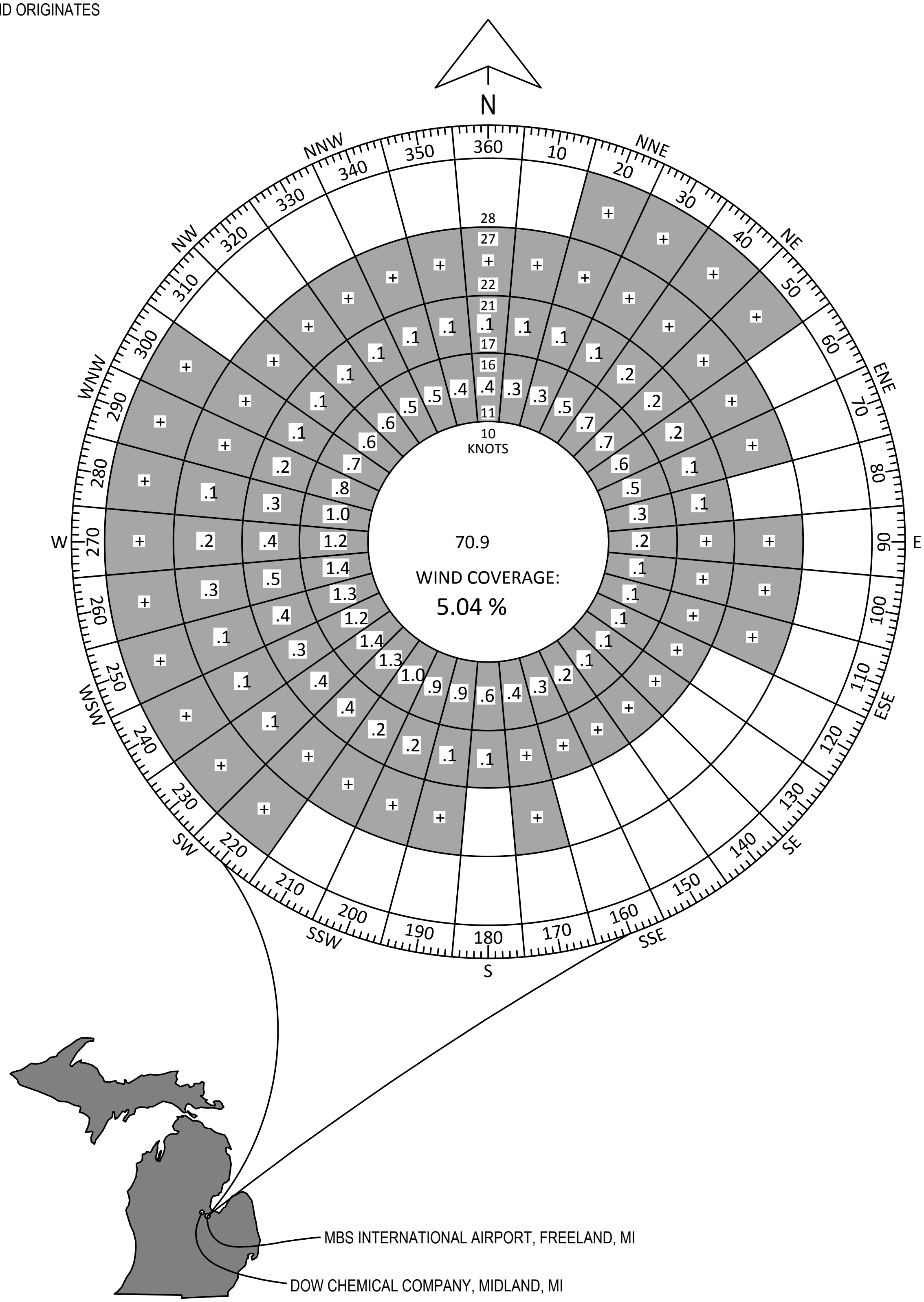
URS
Dow Business Unit

Facility Location
The Dow Chemical Company
Michigan Operations
Figure 2-1

Drawn: MDC | Checked: MS | Approximate Scale: 1" = 5280'
Date: 7/14/2014 | Drawing File: Figure 2-1 Facility Location.mxd

WIND ROSE GENERATED FOR MBS INTERNATIONAL AIRPORT, FREELAND, MI, COMPOSITE FOR 2007, 2008, 2011, 2012 & 2014
SOURCE: FEDERAL AVIATION ADMINISTRATION - FAA.gov
GENERATED: 9-15-2015

NOTE: WIND ROSE INDICATES DIRECTION FROM WHICH WIND ORIGINATES



ISSUED FOR | DATE | IN CHARGE
DA/E
DR JDD
CK TWR
APP

URS
SOUTHFIELD, MI.
27777 FRANKLIN ROAD,
AMERICAN CENTER BLDG.
SUITE 2000
248 204-5900

THE DOW CHEMICAL COMPANY
MICHIGAN OPERATIONS

WIND ROSE DIAGRAM

DOW

DRAWING
FIGURE 2-2

FILE
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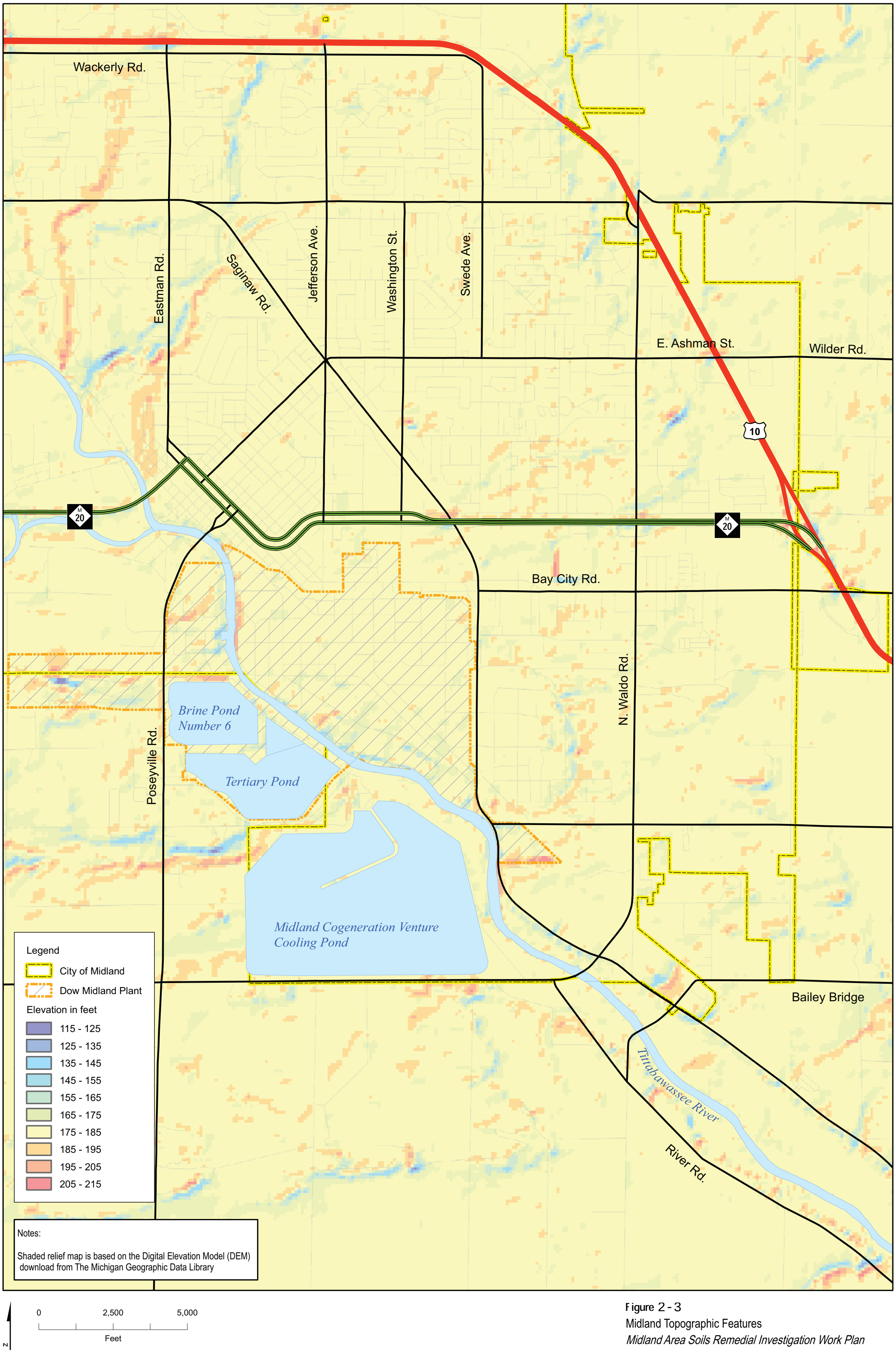
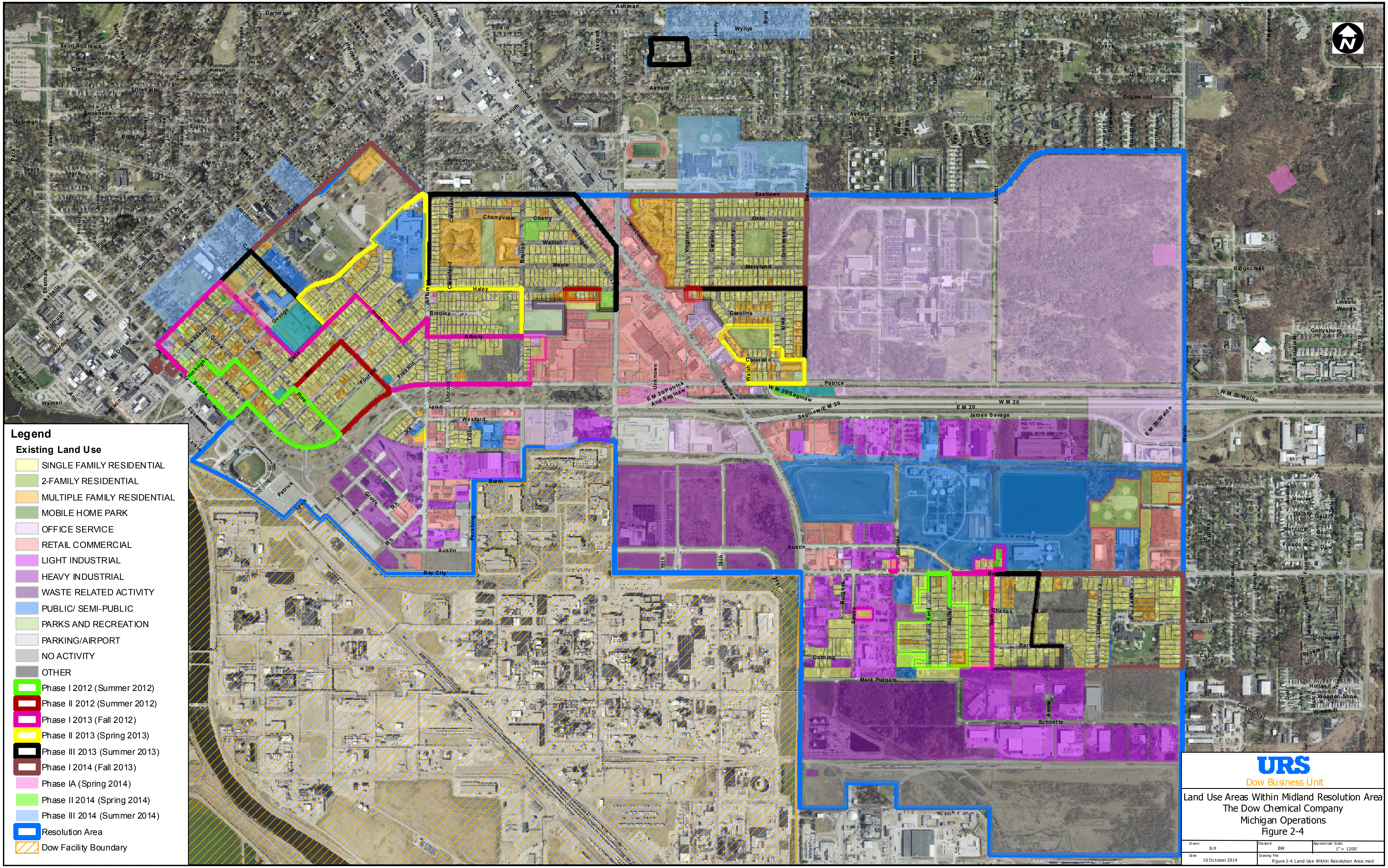
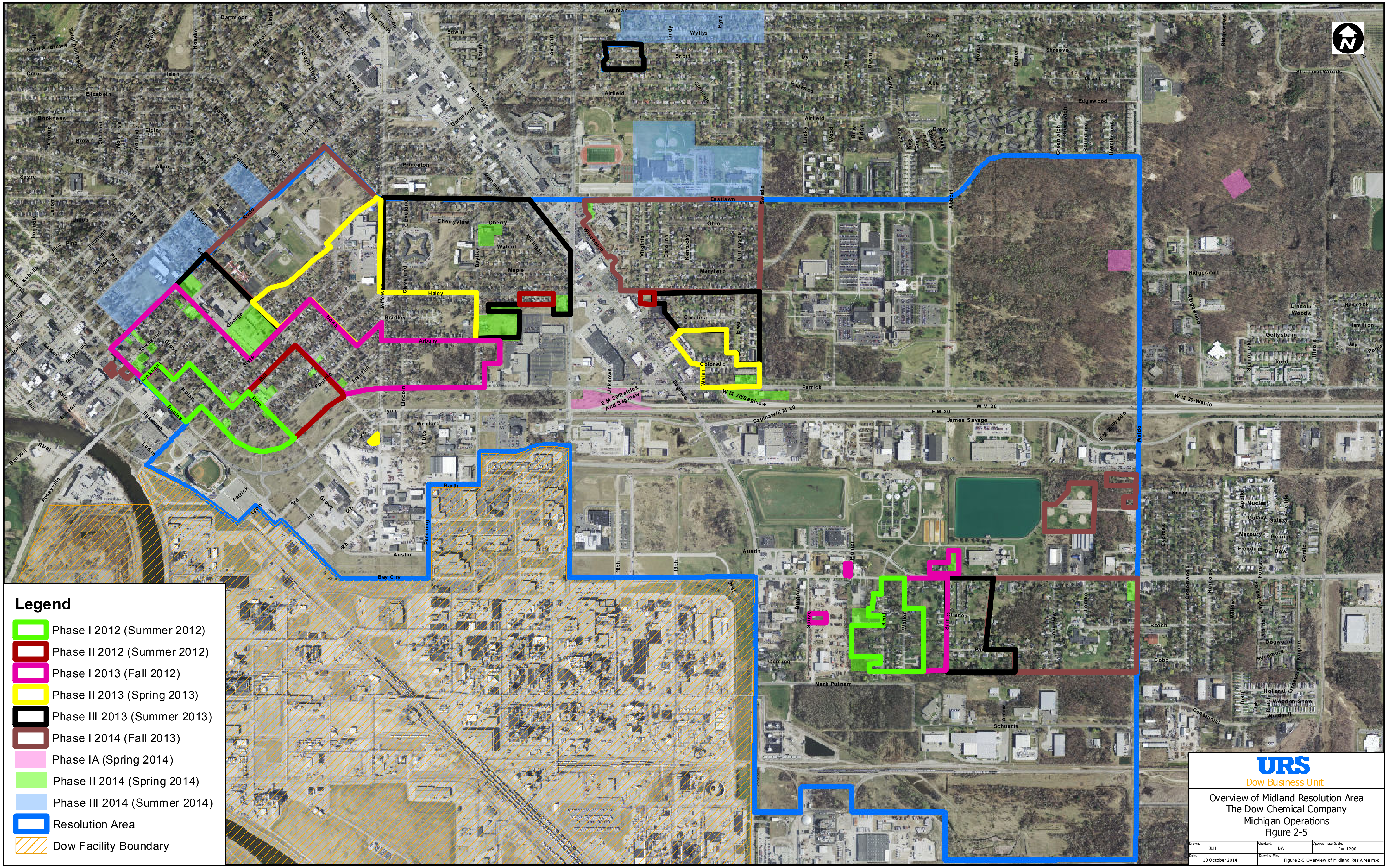


Figure 2-3
Midland Topographic Features
Midland Area Soils Remedial Investigation Work Plan


Legend
Existing Land Use
SINGLE FAMILY RESIDENTIAL
2-FAMILY RESIDENTIAL
MULTIPLE FAMILY RESIDENTIAL
MOBILE HOME PARK
OFFICE SERVICE
RETAIL COMMERCIAL
LIGHT INDUSTRIAL
HEAVY INDUSTRIAL
WASTE RELATED ACTIVITY
PUBLIC/ SEMI-PUBLIC
PARKS AND RECREATION
PARKING/AIRPORT
NO ACTIVITY
OTHER
Phase I 2012 (Summer 2012)
Phase II 2012 (Summer 2012)
Phase I 2013 (Fall 2012)
Phase II 2013 (Spring 2013)
Phase III 2013 (Summer 2013)
Phase I 2014 (Fall 2013)
Phase IA (Spring 2014)
Phase II 2014 (Spring 2014)
Phase III 2014 (Summer 2014)
Resolution Area
Dow Facility Boundary
URS
Dow Business Unit
Land Use Areas Within Midland Resolution Area
The Dow Chemical Company
Michigan Operations
Figure 2-4
Drawn: JLH
Checked: BW
Approximate Scale: 1" = 1200'
Date: 10 October 2014
Drawing File: Figure 2-4 Land Use Within Resolution Area.mxd


Legend
Phase I 2012 (Summer 2012)
Phase II 2012 (Summer 2012)
Phase I 2013 (Fall 2012)
Phase II 2013 (Spring 2013)
Phase III 2013 (Summer 2013)
Phase I 2014 (Fall 2013)
Phase IA (Spring 2014)
Phase II 2014 (Spring 2014)
Phase III 2014 (Summer 2014)
Resolution Area
Dow Facility Boundary
URS
Dow Business Unit
Overview of Midland Resolution Area
The Dow Chemical Company
Michigan Operations
Figure 2-5
Drawn: JLH
Checked: BW
Approximate Scale: 1" = 1200'
Date: 10 October 2014
Drawing File: Figure 2-5 Overview of Midland Res Area.mxd

3.0 Release Characterization

The primary source of hazardous substances from Dow in the nearby MAS is airborne deposition of particulates (USEPA, 1985). The following sections summarize the primary COIs, the potential sources and dioxin and furan distribution, conceptual site model (CSM) and fate and transport mechanisms.

3.1 Primary Constituents of Interest

The approved May 25, 2012 IRDC specifically focused on dioxins and furans and derivation of a site-specific action level for the soil direct contact exposure pathway. Appendix A (the IRDC) presents the location of suspected sources of the historical release of dioxins to off-site soils. Part II discusses the screening evaluation of all non-dioxin analytes for other potentially relevant exposure pathways. The potential exposure pathways relevant to this site are discussed in Section 5.0 of this report and Part II presents the non-dioxin screening process, results and conclusions, and the determination of the COIs for all relevant exposure pathways for the Midland Area Soils.

3.2 Potential Sources and Dioxin and Furan Distribution

The primary source of hazardous substances from Michigan Operations is airborne particulate deposition from historical waste handling and disposal operations. Surface and near-surface soils are the media affected by air emissions and subsequent deposition of dioxins and furans. Elevated dioxin and furan toxic equivalent (TEQ) concentrations are predominantly found to the northeast (downwind) of Michigan Operations.

As part of developing the sampling strategy for the University of Michigan Dioxin Exposure Study (UMDES), geostatistical methods were used to combine existing TEQ concentration data for soils and predictions from a dispersion model for incinerator emissions to estimate the probability of exceeding 90 parts per trillion (ppt) TEQ (Part 201 residential direct contact criteria) in the MAS (Adriaens et al., 2006). This analysis indicated the predominant impact was predicted to be to the north and east, downwind of Michigan Operations. The data from the 2006 bioavailability sampling support this model prediction (CH2M Hill, 2007a). Areas to the north, northeast, and east of the facility, which were predicted by the modeling effort to have higher concentrations and had measured concentrations, have been included in the MRA.

3.3 Fate and Transport Mechanisms

The primary mechanism for transfer of dioxins and furans is historical wind dispersion. Emission sources fall into two categories: fugitive and combustion. The fate (vapor phase and half-life) and transport mechanisms associated with these categories potentially influence the distribution of dioxins and furans.

Fugitive dust emission sources originate from the air suspension of particulates from surface soil, either by wind or mechanical disturbance (driving over surfaces, excavating, or grading). Fugitive dust particle concentrations in air are highest close to the emission source and decrease rapidly with downwind distance, generally within a few hundred feet, because of a combination of vertical mixing in air and particle deposition (USEPA, 1995; Etyemezian et al., 2003; Countess, 2003). Dispersion of emissions from combustion sources is influenced by exhaust gas temperature and plume release height (that is, stack height), in addition to meteorological conditions. Higher exhaust temperatures and higher stacks result in greater plume rise and more, but more dilute, downwind dispersion (USEPA, 1992). Therefore, fugitive dust sources at Michigan Operations (such as landfills or affected surface soil) are associated with deposition relatively close to the Michigan Operations, and deposition from combustion sources is likely to have occurred relatively farther away.

Contaminants are emitted to the air either in vapor or particle form. Generally, most metals, and organic compounds with very low vapor pressures, such as dioxins and furans, adhere to particles that can then be deposited on soil. Compounds with high vapor pressures (such as volatile organic compounds [VOCs]) occur only in the vapor phase; concentrations of VOCs in air typically do not have an effect on surface soil. Semivolatile compounds (SVOCs) partition between vapor and particle phases, depending on their vapor pressure and the particle concentration in the air (USEPA, 2005).

Another chemical-specific property that affects the presence of a chemical in soil after it has been deposited is its half-life in soil. The half-life in soil reflects the persistence of a chemical, taking into account degradation through microbial and abiotic transformations. Abiotic transformation processes include photolysis and hydrolysis. USEPA has defined criteria for persistence, for which chemicals with a half-life in soil greater than 60 days are considered persistent, and chemicals with a half-life in soil greater than 180 days are considered very persistent (USEPA, 1999). Dioxins and furans are considered very persistent.

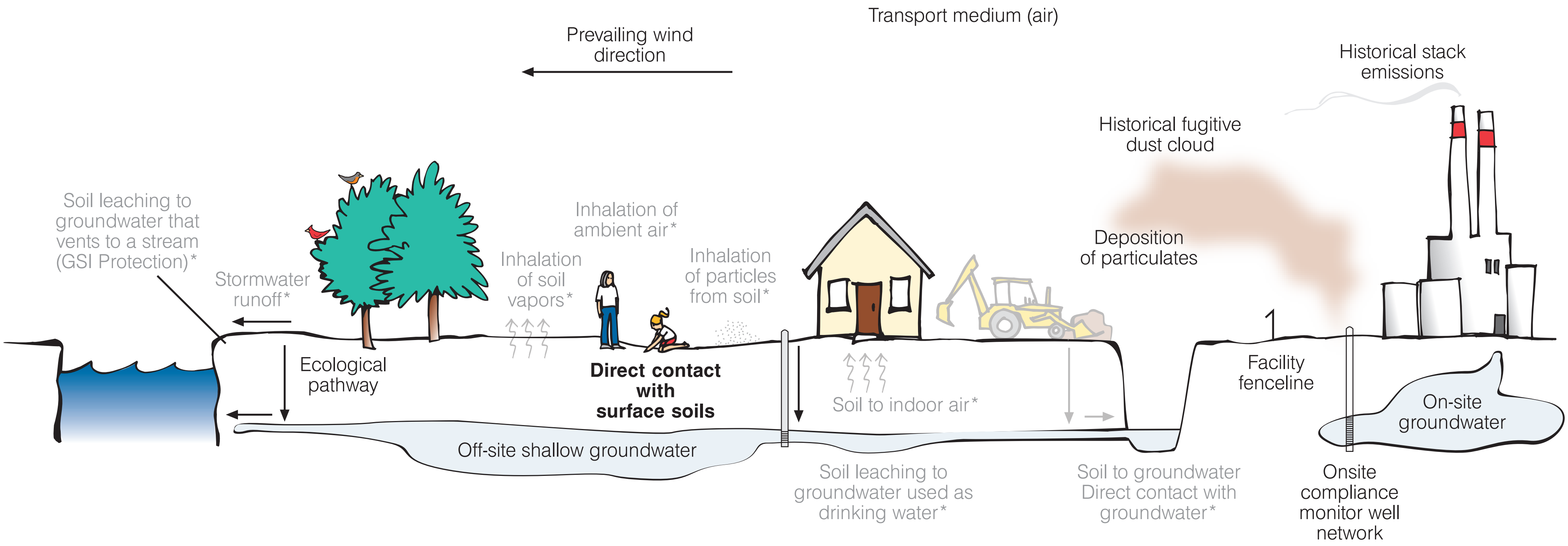
After deposition on soils, particle-bound hazardous substances such as dioxins and furans have the potential to be redistributed through surface water runoff and construction and grading activities (secondary transfer mechanisms). In the case of surface water runoff, the particle-bound substances may be mixed with solids that accumulate in ditches and drainage basins. In the case of construction and grading, particle-bound substances in surface soil may be transferred to and mixed with subsurface soil.

3.4 Conceptual Site Model

A CSM describes the network of relationships between contaminants of concern (COCs) present at a site and the human receptors that may be exposed to those COCs through various pathways leading from the site and ending with exposure through ingestion, inhalation, or dermal contact. The CSM incorporates the range of potential exposure pathways and identifies those that are present and may be material and relevant for human receptors. The CSM helps to identify the main pathways and eliminates those pathways that were evaluated to determine that COC concentrations do not exceed pathway criteria and therefore do not require further evaluation.

Exposure pathways consist of the following four elements: (1) a source of hazardous substances or COCs; (2) a transport mechanism and medium (such as air, water, or soil); (3) a point of human contact with the medium (that is, an exposure point); and (4) a route of exposure at the point of contact (for example, inhalation, ingestion, or dermal contact). Section 5.0 of this report further details the exposure pathways potentially relevant for the MAS project. The pathways relevant for human and ecological exposure are depicted in the conceptual site model (Figure 3-1). The exposure pathway model reflects the outcome of all screening activities performed for the MAS project, which is presented and discussed in Part II.

Figure 3-1 Conceptual Site Model



* A significant effort has been undertaken to identify potential contaminants of concern in relation to Midland Area Soils for the human health and ecological pathways. The analytical results were compared to appropriate screening criteria for each exposure pathway. These exposure pathways were eliminated from further evaluation based on screening results or the outcome of collaborative meetings with MDEQ and other regulatory agencies.

4.0 Remedial Investigation of Media

The understanding of hazardous substances in MAS prior to the current License was based largely on studies conducted by Dow in 1984 (Agin et al., 1984) and 1998 (Dow, 2000), USEPA in 1983-1984 (USEPA, 1985), and MDEQ in 1996 (MDEQ, 1997). Although these studies focused primarily on dioxins and furans, the 1985 USEPA study also analyzed samples for VOCs, SVOCs, and polychlorinated biphenyls (PCBs). Another study conducted by USEPA in 1987 provided limited data on concentrations of dioxins and furans in garden vegetables. More recent soil investigations, which focused on the non-dioxin target analyte list (TAL) development (discussed in Part II), include the 2005/2006 DOS samples, the 2006 CH2M Hill samples and the 2010 Dow and MDEQ split sample results. Also, soil and household dust sampling results were provided by the UMDES. Each of these investigations/studies is summarized below.

4.1 Previous Investigations and Studies

The studies conducted prior to 1996 by Dow, USEPA, and MDEQ focused on sampling and analysis for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) as the main dioxin congener. More recent studies report dioxin and furan data as TEQ concentrations. Dioxin and furan sample results from the laboratory are typically reported on an individual congener basis. TEQ concentrations are calculated according to a toxicity weighting scale. The measured concentration of each TEQ dioxin and furan congener is multiplied by a corresponding toxic equivalency factor (TEF), and the products are summed to determine the TEQ concentration.

TEQ concentrations are typically reported in concentrations of ppt. The mammalian TEFs developed by the World Health Organization (WHO) are provided in Table 4-1. TEFs are developed by the WHO based on the best available information at the time. Some previous investigations utilized TEFs from pre-1998 and 1998. Dow has recalculated these TEQ concentrations using the 2005 WHO TEFs so that prior and more recent TEQs can be directly compared. All TEQs discussed below use the 2005 WHO TEFs (Van den Berg et al, 2006, see Table 4-1).

1984 Dow study—The primary objective of the 1984 Dow study was to identify point sources of dioxins and furans at Michigan Operations (Agin et al., 1984). As part of the study, 11 samples also were collected within the offsite Study Area. At the time this study was published, the Public Health Service Center for Disease Control had indicated that 2,3,7,8-TCDD concentrations below the concern level of 1 part per billion (ppb) were sufficiently low that there was "no medical reason to warrant concern or suggest remedial action" (Agin et al., 1984). Concentrations of 2,3,7,8-TCDD in the offsite samples ranged from 0.6 to 450 ppt. The study concluded that the levels of 2,3,7,8-TCDD were "significantly below the 1 ppb concern level established by the Centers for Disease Control and Prevention for residential areas" (Agin et al., 1984).

1985 USEPA study—The primary objective of the 1985 USEPA study was to determine whether concentrations of dioxins and other substances present in the offsite Study Area might pose an unacceptable public health risk (USEPA, 1985). Approximately 40 samples were collected in the offsite Study Area and analyzed for 2,3,7,8-TCDD. Concentrations of 2,3,7,8-TCDD in the offsite samples ranged from 3 to 310 ppt. Thirteen samples were also analyzed for VOCs, SVOCs, pesticides, and PCBs. Several polynuclear aromatic hydrocarbons (PAHs), chlordane, and PCB-1254 were detected in this sample group. USEPA report concluded in part that "data obtained from this study do not suggest widespread environmental contamination by 2,3,7,8-TCDD, and other PCDDs [polychlorinated dibenzo-p-dioxins] and PCDFs [polychlorinated dibenzofurans] at significant levels with respect to public health or adverse environmental impacts" and that other sampled substances "do not pose an unacceptable health risk" (USEPA, 1985).

1987 USEPA garden vegetable study—In addition to the above studies, in 1987, USEPA Region 5 conducted preliminary screening of homegrown vegetables from two gardens in Midland and a control garden in Eagle, Michigan (USEPA, 1988). Fresh or frozen vegetables (carrots, beets, onions, and lettuce) and garden soil samples were collected and analyzed for dioxins and furans. Although dioxins and furans were present in the soils of both gardens, they were not detected in any vegetable tissue samples (USEPA, 1988).

1988 USEPA risk management recommendations for Dioxin contamination—This study completed evaluation of risk from dioxin sources at Michigan Operations. The report acknowledges actions undertaken by Dow at that time and some of the further actions specifically recommended included:

1. Additional incinerator emissions testing

   Incinerators that existed at the time have been closed. A modern incinerator was constructed and permitted in 2003. The current Hazardous Waste Management Facility Operating License requires testing to demonstrate on-going compliance with the hazardous waste combustor MACT. This testing was completed in 2003, 2009 and again in 2014. Dow will continue to complete emissions testing in accordance with their current permit.

2. Dust suppression program

   Risks for the site were determined to result from soils impacted by historical incineration activities and not due to current incineration emissions. Paving or applying clean cover over contaminated areas on site was recommended and on site areas remaining unpaved or covered should be managed through an updated and ongoing program. Beginning in 2001, significant portions of the greenbelt and facility have had covered with new soil and vegetation. Dow began implementing a fugitive dust suppression control program in 1986. Dow is currently required to control fugitive dust sources and emissions through periodic dust suppression application and to provide an operating program to control fugitive dust sources or emissions that is regularly updated (every six months).

3. Point source and environmental monitoring programs

   A limited ambient air monitoring program was recommended to determine particulate levels and current concentrations of dioxins and furans. Dow's current hazardous waste management facility operating permit requires monitoring for possible releases to ambient air (Condition X.K) and migration via windblown soil (Condition X.L). A study of dioxin and furan concentrations in ambient air was conducted in 1997 and 1998. The results of the study indicated that detected dioxin and furan concentrations were within the range reported for rural rather than urban or industrial areas, and that the incinerators and surface soils were not major contributors to the detected levels. Follow-up soil sampling both on the main plant and in the community was also recommended. This was conducted in 1996 and 1998, as described below. In addition, soil monitoring has been on-going at the plant perimeter since 2002, and the data evaluation plan was formally approved by MDEQ September 23, 2011.

1996 MDEQ study—The objective of the 1996 MDEQ study was to evaluate the distribution of dioxin and furan concentrations in the Midland community and Michigan Operations and to compare these results to those of the 1984 Dow and 1985 USEPA studies (MDEQ, 1997). The study reported results for 17 individual dioxin and furan congeners, as well as calculated TEQs using pre-1998 TEFs. Approximately 35 samples were collected in the offsite Study Area. 2,3,7,8-TCDD concentrations in the sample group ranged from 3 to 288 ppt, and TEQ concentrations ranged from 9 to 602 ppt. The study concluded in part that "the 1996 data suggests a decline in the concentrations of 2,3,7,8-TCDD from the 1984 and 1985 results" (MDEQ, 1997).

1998 Dow study—Approximately 45 soil samples were collected in the offsite Study Area during the 1998 Dow study (Dow, 2000). Most samples were collected from Dow owned property (on and between Michigan Operations and the Dow Corporate Center). The objective of this study was to determine descriptive statistics (mean, median, geometric mean, standard deviation, variance, and normality check) for sample groups from the Dow Corporate Center and Saginaw/Salzburg/Rockwell roads site. One area was identified with a concentration of 2,200 ppt TEQ (I-TEFs). This area was addressed in an interim measure. Range of detected TEQ concentrations (based on I-TEFs) in the data set ranged from 8.0 to 660 ppt TEQ (Dow, 2000).

2006 UMDES—The objective of the UMDES was to evaluate human exposure to the dioxins, furans, and dioxin-like PCBs in Midland and along the Tittabawassee River (University of Michigan, 2006). Soil and household dust samples were collected from 32 locations in the Midland area (referred to as the "Midland Plume" in the study) as well as in other areas. Mean and median TEQ concentrations (based on 2005 TEFs and data for 17 dioxin and furan congeners) were lowest in household dust samples (32 and 27 ppt, respectively), and highest in soil samples collected from the perimeters of houses (approximately 110 and 58 ppt, respectively). TEQ concentrations in the City of Midland Soils data set ranged from 4.5 to 850 ppt.

2005/2006 DOS Data Set—In September 2005 and June 2006, surface (0 to 1 inch bgs) soil samples were collected inside the Dow's plant site from 23 locations for non-dioxin constituents and from 28 locations for dioxin constituents. The location/sample identification for these samples began with "DOS" (such as DOS-1, DOS-2, etc.), and hence, they were sometimes referred as the "DOS" data. These samples were analyzed for metals, PCBs, pesticides, SVOCs, VOCs, and dioxins and furans. Figure 4-1 presents the sample locations.

2006 CH2M Hill samples—In November 2006, Dow's contractor, CH2M Hill, collected surface (0 to 1 inch bgs) soil samples from the City of Midland, and subsequently, in March 2007, CH2M Hill prepared a report titled Data Evaluation Report in Support of Bioavailability Study, Midland Area Soils. In this study, 136 stations were designated and located on 21 radial transects extending from the Michigan Operations site into the surrounding community. Thirty percent of the sampling locations, corresponding to the two samples closest to the Michigan Operations site along each transect, included collection of subsurface (1 to 6 inches bgs) soil samples and testing for additional compounds of concern. There were between one and twelve stations in each transect, and each station was approximately 300 feet by 300 feet and included one or more property parcels. One to five parcels were sampled from each station. Figure 4-2 presents the sample locations.

Surface soil samples were collected at all locations, and subsurface soil samples were collected at selected stations near Dow's plant. At the time the samples were analyzed, sample results for dioxins and furans and other chemicals were "blinded" to maintain the anonymity of the property owners, and hence, the geographic locations of sample results were not known. Thus, this data set was sometimes referred to as the "COM Blind" data. More recently, Dow obtained the location information for samples collected from properties where Dow was the sole owner. In addition, if the sample location was owned by multiple property owners, a "centroid" of the sampling station was established and TEQ concentration results were made available to Dow and MDEQ for decision-making purposes. An updated data package was provided to MDEQ on December 11, 2009 with this location information.

At the time that the 2006 CH2M Hill samples were collected, the City of Midland developed a set of criteria that Dow and MDEQ would have to meet in order to unblind the data. These criteria included:

- Development and approval of a SSAL;
- MDEQ establishes that properties in the MRA are not inferred to be "facilities" unless samples indicate that the property has a soil concentration that exceeds the SSAL;
- Properties will not be designated as "facilities" and landowners will not be subjected to Due Care obligations if soil sampling identifies concentrations that are greater than the Generic Residential Cleanup Criteria but below the SSAL (pursuant to 324.20101(1)(s)(III)); and
- Results could be provided to landowners under certain conditions established by the City of Midland (details of these criteria are provided in the Data Evaluation Report in Support of Bioavailability Study, Midland Area Soils (CH2M Hill, 2007b)).

Upon MDEQ approval of the May 25, 2012 IRDC, Dow and MDEQ met all of the City of Midland obligations to acquire the unblinded sampling stations and coordinated data. The City of Midland provided the unblinded data to Dow and MDEQ in June 2012.

2010 Dow and MDEQ Split samples—In December 2010, eleven parcels, ranging from one to several acres, owned by Dow (near Michigan Operations) were selected to conduct the Field Pilot Characterization study. This data set consists of 588 surface and subsurface soil sample locations for dioxin constituents, and 132 surface and subsurface soil sample locations for non-dioxin constituents. Non-dioxin constituents analyzed for included metals, PCBs, pesticides, herbicides, SVOCs, and VOCs. The laboratory analytical testing effort was split between Dow and MDEQ. Figure 4-3 presents the sample locations.

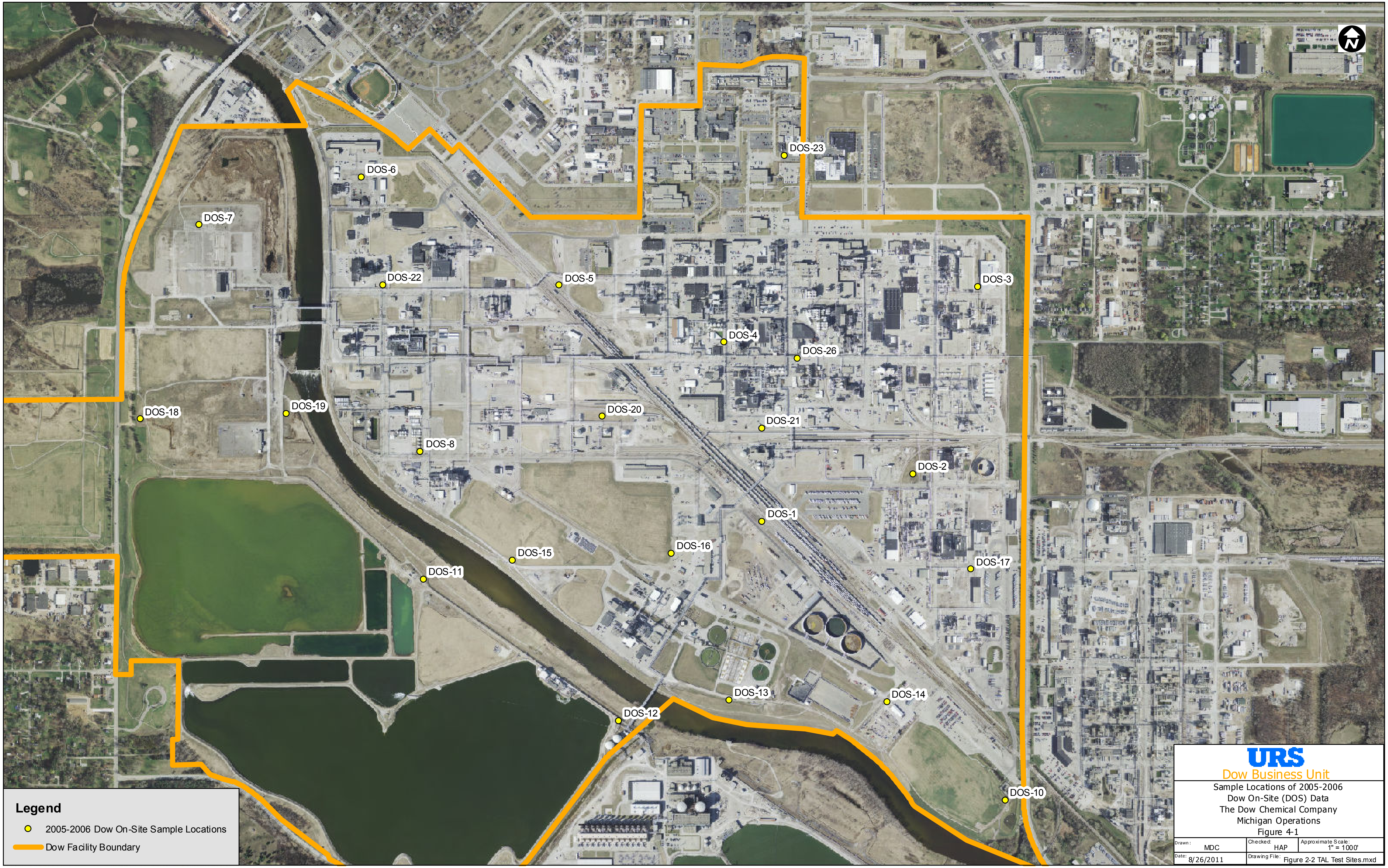
Data from the 2005/2006 DOS, 2006 CH2M Hill, and 2010 Dow and MDEQ split sample data sets were used to inform the approved May 25, 2012 IRDC. The cumulative sampling completed from 2005 through 2010 yielded a thorough investigation of the nature of the release and was used to inform the presumptive remedy.

Table 4-1
World Health Organization Mammalian Toxic Equivalency Factors
Part I - Remedial Investigation Work Plan
The Dow Chemical Company, Michigan Operations

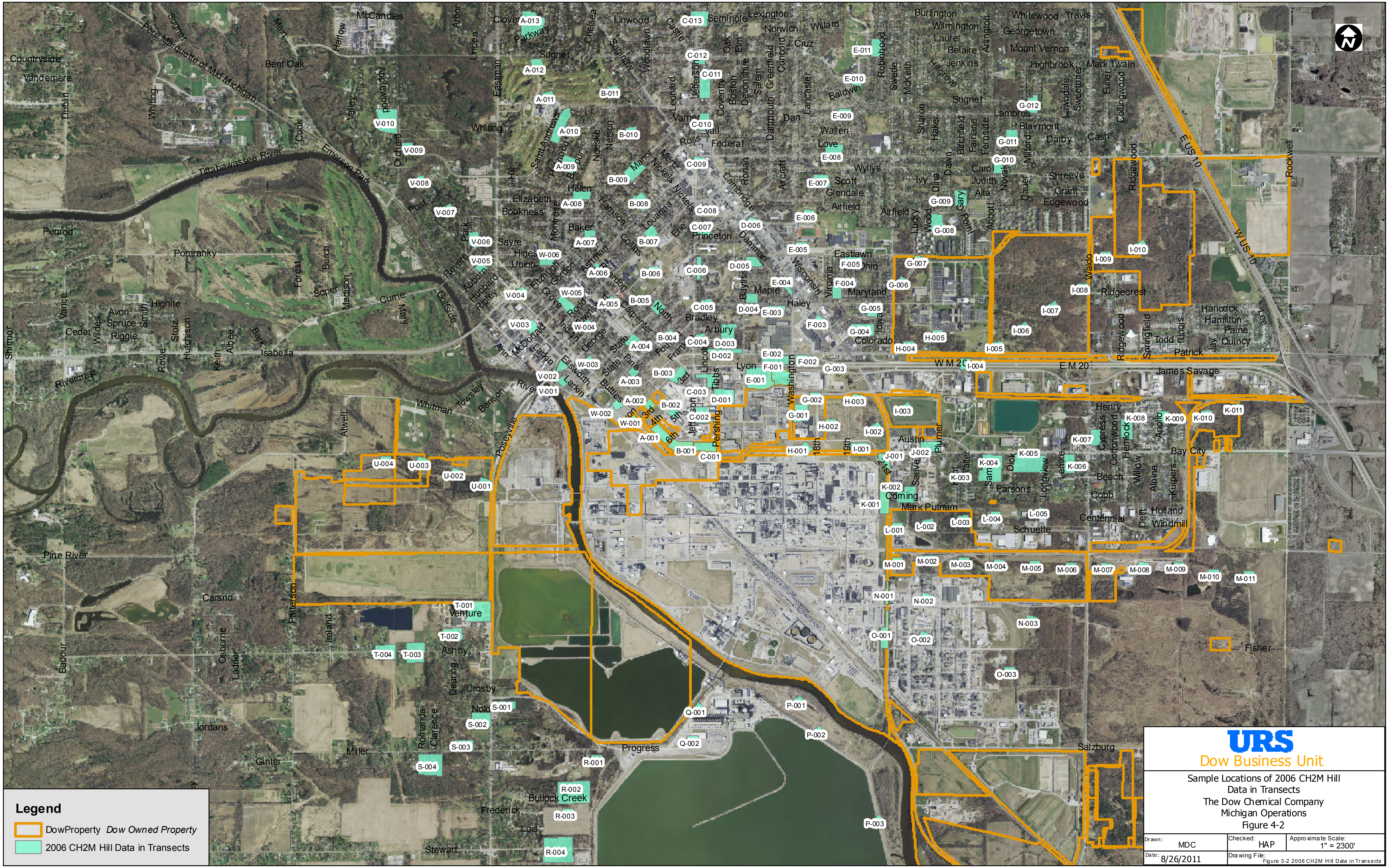
Congener	1998 TEF	2005 TEF
2,3,7,8-TCDD	1	1
1,2,3,7,8-PeCDD	1	1
1,2,3,4,7,8-HxCDD	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01
OCDD	0.0001	0.0003
2,3,7,8-TCDF	0.1	0.1
1,2,3,7,8-PeCDF	0.05	0.03
2,3,4,7,8-PeCDF	0.5	0.3
1,2,3,4,7,8-HxCDF	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1
2,3,4,6,7,8-HpCDF	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01
OCDF	0.0001	0.0003

Sources: Van den Berg et al., 1998; Van den Berg et al., 2006

Notes:
PeCDD = pentachlorodibenzo-p-dioxin
HxCDD = hexachlorodibenzo-p-dioxin
HpCDD = heptachlorodibenzo-p-dioxin
OCDD = octachlorodibenzo-p-dioxin
TCDF = tetrachlorodibenzofuran
PeCDF = pentachlorodibenzofuran
HxCDF = hexachlorodibenzofuran
HpCDF = heptachlorodibenzofuran
OCDF = octachlorodibenzofuran



DOS-23
DOS-6
DOS-7
DOS-22
DOS-5
DOS-3
DOS-4
DOS-26
DOS-18
DOS-19
DOS-20
DOS-21
DOS-8
DOS-2
DOS-1
DOS-16
DOS-15
DOS-17
DOS-11
DOS-13
DOS-14
DOS-12
DOS-10
N
Legend
2005-2006 Dow On-Site Sample Locations
Dow Facility Boundary
URS
Dow Business Unit
Sample Locations of 2005-2006
Dow On-Site (DOS) Data
The Dow Chemical Company
Michigan Operations
Figure 4-1
Drawn: MDC
Checked: HAP
Approximate Scale: 1" = 1000'
Date: 8/26/2011
Drawing File: Figure 2-2 TAL Test Sites.mxd


Legend
DowProperty Dow Owned Property
2006 CH2M Hill Data in Transects
URS
Dow Business Unit
Sample Locations of 2006 CH2M Hill
Data in Transects
The Dow Chemical Company
Michigan Operations
Figure 4-2
Drawn: MDC
Checked: HAP
Approximate Scale: 1" = 2300'
Date: 8/26/2011
Drawing File: Figure 3-2 2006 CH2M Hill Data in Transects

A-002
W-001
PERSHING-001
B-001
F-001
G-001
I-001a
SITE-2
SITE-1
N-001
O-001
Legend
Locations of MDEQ Splits
Facility Boundary
TAL Test Sites
URS
Dow Business Unit
2010 Dow and MDEQ Split Sample Data Set
The Dow Chemical Company
Michigan Operations
Figure 4-3
Drawn: MDC
Checked: HAP
Approximate Scale: 1 inch = 348 feet
Date: 8/26/2014
Drawing File: Figure 6-3 TAL Test Sites.mxd

5.0 Exposure Pathway Evaluation

This section presents the human health exposure pathways and discusses their relevance to the MAS project. For relevant pathways, a preliminary screening level evaluation of available data was performed to determine if a constituent can be eliminated from the TAL or retained for additional consideration, which is further presented in Part II. This preliminary screening was initially presented and discussed in the 2010 Field Pilot Characterization Summary Report (URS, 2011), as well as in the approved May 25, 2012 IRDC.

5.1 Groundwater Exposure Pathways

Exposure to contaminants in groundwater is an incomplete exposure pathway for the MAS project since surface and near-surface soils are the media affected by air emissions and subsequent deposition. There is no exposure point since there are no known groundwater plumes associated with this historic aerial release. There are a limited number of groundwater plumes near the Midland Plant Facility that are being addressed as part of the Facility corrective action program established pursuant to the Operating License. Therefore, the following groundwater exposure pathways were not included for the MAS TAL screening effort and were not included moving forward: drinking water usage, dermal contact, volatilization to indoor air, venting to surface waters, and acute toxicity and physical hazards. However, soil-to-groundwater leaching was evaluated as part of the Soil Exposure Pathways for non-dioxin analytes and is discussed in Part II.

5.2 Soil Exposure Pathways

Given the source and transport mechanisms, the following were identified as potentially relevant soil exposure pathways for consideration at the site:

- Ingestion and dermal contact with soil (direct contact protection);
- Soil volatilization to indoor air inhalation;
- Soil-to-ambient air inhalation of volatiles and particulates;
- Soil-to-groundwater leaching (drinking water protection);
- Soil-to-groundwater leaching to surface water (surface water interface protection);
- Soil-to-groundwater leaching dermal contact (groundwater contact protection); and
- Soil direct transport to surface water (surface runoff)

As discussed in Part II, soil exposure was evaluated by comparing the soil analytical data to the appropriate residential or non-residential Part 201 generic cleanup criteria (March 25, 2011) (MDEQ, 2011), or by comparison to site-specific cleanup criteria. The following discussion presents the potentially relevant exposure pathways and the Part 201 generic cleanup criteria that were used to evaluate each analyte for each relevant exposure pathway in the preliminary screening effort.

5.2.1 Ingestion and dermal contact with soil (Direct Contact Protection)

Exposure to contaminants via ingestion of or dermal contact with impacted soil is the direct contact pathway which is a potentially relevant exposure pathway for the MAS project. The screening effort compared the analytical results of the relevant investigations to the Part 201 Residential Direct Contact Criteria (DCC) in order to assess this exposure pathway.

5.2.2 Soil to Ambient Air Pathway

Contaminants in soil can volatilize to ambient air or be dispersed as dust particles in the ambient air. Human receptors can be exposed to contaminants by inhaling these vapors or particulates. The Part 201 Volatilization to Ambient Air and Residential Inhalation of Particulate Soil criteria was used to evaluate this exposure pathway in the screening effort.

5.2.3 Soil to Indoor Air Pathway

The volatilization from soil into indoor air exposure pathway is incomplete for the MAS project. There is no exposure point present as no residences are located above or adjacent to volatile contaminated soil or groundwater. While this exposure pathway was initially included in the preliminary screening evaluation, this pathway was not included moving forward.

5.2.4 Protection of Drinking Water (Soil Leaching to Groundwater Pathway)

Part 201 Residential Drinking Water Protection was the criteria used to screen analyte concentrations to evaluate the soil leaching to groundwater exposure pathway. This pathway considers the fate and transport of soil contaminants leaching into groundwater that is used as drinking water.

5.2.5 Soil Leaching to Groundwater (Dermal Contact with Groundwater)

This exposure pathway was evaluated using the Residential Groundwater Contact Protection criteria which address contact exposure to COCs in groundwater that have leached from the soil to groundwater.

5.2.6 Soil Leaching to Groundwater Which Vents to Surface Water (GSI Protection)

Part 201 Residential GSI Protection is the criteria used to screen analyte concentrations to evaluate this exposure pathway. This criterion is protective of the fate and transport pathway of soil contaminants leaching into groundwater that vents to surface water.

5.2.7 Exposure to Soil Impacts via Surface Runoff

The potential for exposure to contaminated soil via surface runoff is a potentially relevant pathway for the MAS. Generic numerical criteria do not exist for evaluating the impact of contaminated soil runoff to surface waters. This exposure pathway was considered on a case-by-case basis for commercial properties that share a property boundary with a residential property.

5.2.8 Other Media Exposure Pathways

Exposure to Surface Water and Sediments

Surface water and sediments associated with the Tittabawassee River and its Floodplain will be addressed as a part of the January 2010 Administrative Settlement Agreement and Order on Consent (AOC). The AOC specifies the steps for the RIFS and/or Engineering Evaluation and Cost Analysis (EE/CA), and the Response Design to be taken by Dow, the USEPA and the MDEQ to evaluate current conditions and assess response options for the Tittabawassee River/Saginaw River & Bay Site.

Indirect Exposure via Consumption of Farm Animals Outside of the MRA

Due to the current City of Midland Code of Ordinances, keeping farm animals within the majority of the City is prohibited. The existing Code of Ordinances makes it unlawful to keep or breed any farm animal except for animals in the areas of the City that are zoned agricultural. This potential indirect exposure pathway is not relevant inside of the MRA. However, outside of the MRA, there are currently nine areas of the City that are zoned agricultural, four along the west edge of the city (west of Poseyville Road), and five along the east edge (generally along or near Highway 10). See Part III Section 5.14 and Part III Attachment B for further information on restrictive covenants and how Dow will monitor properties zoned agricultural in the City of Midland in the future.

5.2.9 Ecological Exposure Pathway

The ecological exposure pathway for off-site MAS is potentially relevant but is limited to those ecological receptors that may occur in an urban environment. The ecological exposure pathway was evaluated by comparison of analytical results of the relevant investigations to the USEPA Region 5 Ecological Screening Levels (ESLs) supplemented by the USEPA Ecological Soil Screening Levels (EcoSSLs). Further discussion of the screening process for the ecological pathway is provided in Part II.

6.0 Human Health Soil Exposure Pathway Screening Methodology

The purpose of the human health screening evaluation was to develop a broad TAL of potential COCs, and then narrow that list, through further evaluation and study, to the COCs for the Midland Area Soils.

6.1 Identification of Constituents of Interest and TAL Evaluation

As part of this task, Dow evaluated and took into consideration its raw materials, products, byproducts, and wastes; its material handling and waste management practices; government agency contaminant screening lists; contaminant fate and transport information; historical records reaching back more than 100 years; and extensive on and off-site sampling results for over 200 compounds. This information has been previously reviewed with MDEQ in a series of collaborative meetings. The results of this effort for the soil direct contact exposure pathway were reported in the approved IRDC (Appendix A). A summary of the results of the TAL screening effort for the remaining relevant exposure pathways is presented in Part II.

The following steps were completed as part of the TAL screening effort:

- TAL development;
- Initial evaluation of TAL based on fate and transport and similar information;
- Determine if TAL compounds, in addition to dioxins and furans, are present at sampling areas adjacent to the Michigan Operations site at levels that require further investigation;
- Analyze for contaminants other than dioxins and furans in MAS;
- Screen TAL according to screening criteria; and
- Review and further reduce remaining TAL categories through collaborative meetings with MDEQ and USEPA.

In addition, an evaluation of the dioxin/furan TEQ results was performed during this process.

6.1.1 Data Sets

Over 858 samples were submitted from more than 400 locations for dioxin and furan analysis during soil sampling work in 2005, 2006, and 2010. A subset of this data, representing over 200 samples, also included analysis for over two hundred compounds other than dioxins and furans, including VOCs, SVOCs, metals, herbicides, pesticides, and PCBs.

Overall, the data sets evaluated included historical and current non-dioxin and dioxin data. Three sets of surface and subsurface soil data were compiled, as follows:

- 2005/2006 Dow On-Site (DOS) data set (sample locations are shown in Figure 4-1);
- 2006 CH2M Hill data set (locations of the grid cells are shown in Figure 4-2); and
- 2010 Dow and MDEQ split sample data set (sample locations are shown in Figure 4-3).

These three sets of data were combined and formed the basis for statistical evaluation of the results. See the *2010 Field Pilot Characterization Summary Report* dated 29 August 2011 for the final data set, laboratory quality assurance/quality control (QA/QC) data, and the details on how the data was processed and compiled (URS, 2011).

6.1.2 Development of Summary Statistics

The calculation of summary statistics was part of an Exploratory Data Analysis (EDA) effort, which is the first step of statistical evaluation. The objective of EDA was to discover trends and patterns in the data so that appropriate approaches and limitations in using the data sets could be identified.

A table of basic summary statistics was prepared for non-dioxin data of the combined data set, and similarly, a separate table was prepared for dioxin data. These tables included common statistical parameters, such as mean, standard deviation, minimum and maximum detected values, and minimum and maximum reporting limits (RLs) of nondetects. These statistics were used to make inferences concerning the population from which the sample data were drawn. The number of samples and detection rate (i.e., determining the percentage of the data set that was detected/un-censored) were also included to provide information regarding sample size and detection frequency.

The results of summary statistics are provided in the approved IRDC (Appendix A).

6.2 TAL Screening Criteria

The purpose of the TAL data screening effort was to determine if there are non-dioxin analytes that are potential chemicals of interest, in comparison to the established screening criteria. This section discusses the screening criteria used to determine if a constituent was eliminated from the TAL or retained for additional consideration.

6.2.1 MDEQ Screening Levels

A screening-level evaluation of the available data was performed by comparing each data point to pathway-specific screening criteria for soil. MDEQ Part 201 residential soil criteria were selected whenever available (MDEQ, 2011). USEPA Regional Screening Levels (RSLs) for residential soil were selected whenever MDEQ screening criteria were not available (document release date: June 2011) (USEPA, 2011).

6.2.2 Background

MDEQ State-wide default background values were used as an initial screen for metals, when available. MDEQ also developed and provided a regional background for some metals, which was used as a secondary screen and were presented in the approved IRDC (Appendix A).

6.2.3 Screening of Chemical Groupings

Certain classes of analytes were present in several isomer forms. The isomer-specific concentrations were summed into a total before being compared to the appropriate screening criteria. These classes of analytes included endrins, benzenehexachlorides (BHCs), heptachlors, DDx (dichlorodiphenyldichloroethane [DDD], dichlorodiphenyldichloroethylene [DDE], dichlorodiphenyltrichloroethane [DDT]), endosulfans, chlordanes, and parathions. DDD, DDE and DDT were also evaluated as individual constituents. For PAHs, each result from the seven carcinogenic PAHs (benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene) were multiplied by their respective relative potency factor (RPF), and then summed to achieve the PAH toxicity equivalent quotient (TEQ) (USEPA, 1993). If a sample result was not detected, one half the reporting limit was assumed in the total value. Tables that show the total results for each class of analytes were provided in the *2010 Field Pilot Characterization Study Report* dated 29 August 2011 (URS, 2011).

6.3 TAL Data Screening Categories

6.3.1 Screening Categories

Screening categories ("Groups") were developed as part of the screening effort to group and organize the non-dioxin constituents to facilitate the data review process. The screening categories are briefly described below, and each constituent, through the screening process, was placed into one of the "Groups." The full screening process and the hierarchy of each step are illustrated in the flowchart shown in Figure 6-1.

Below Background (for metals only; compare to background values when available):

- Group A1 – Analytes with all detected concentrations and RLs of nondetects below the Statewide Default Background level.
- Group A2 – Analytes with all detected concentrations and RLs of nondetects below the regional background screening level.

Nondetect Evaluation (for analytes not detected in all collected samples):

- Group B1 – Analytes that were 100% non-detected and all RLs met the MDEQ target detection limits.
- Group B2 – Analytes that were 100% non-detected and all off-site sample RLs met the MDEQ target detection levels.
- Group B3 – Analytes that were 100% non-detected and all RLs were less than or equal to all Part 201 criteria and USEPA criteria for the given analyte.

Identify Criteria (for detected analytes without Part 201 Criteria and USEPA Criteria):

- Group C1 – Analytes that were detected at a frequency less than or equal to 5%, with no Part 201 criteria and USEPA criteria.
- Group C2 – Analytes that were detected at a frequency greater than 5%, with no Part 201 criteria and USEPA criteria.

Criteria Comparison (for detected analytes with Part 201 Criteria or USEPA Criteria):

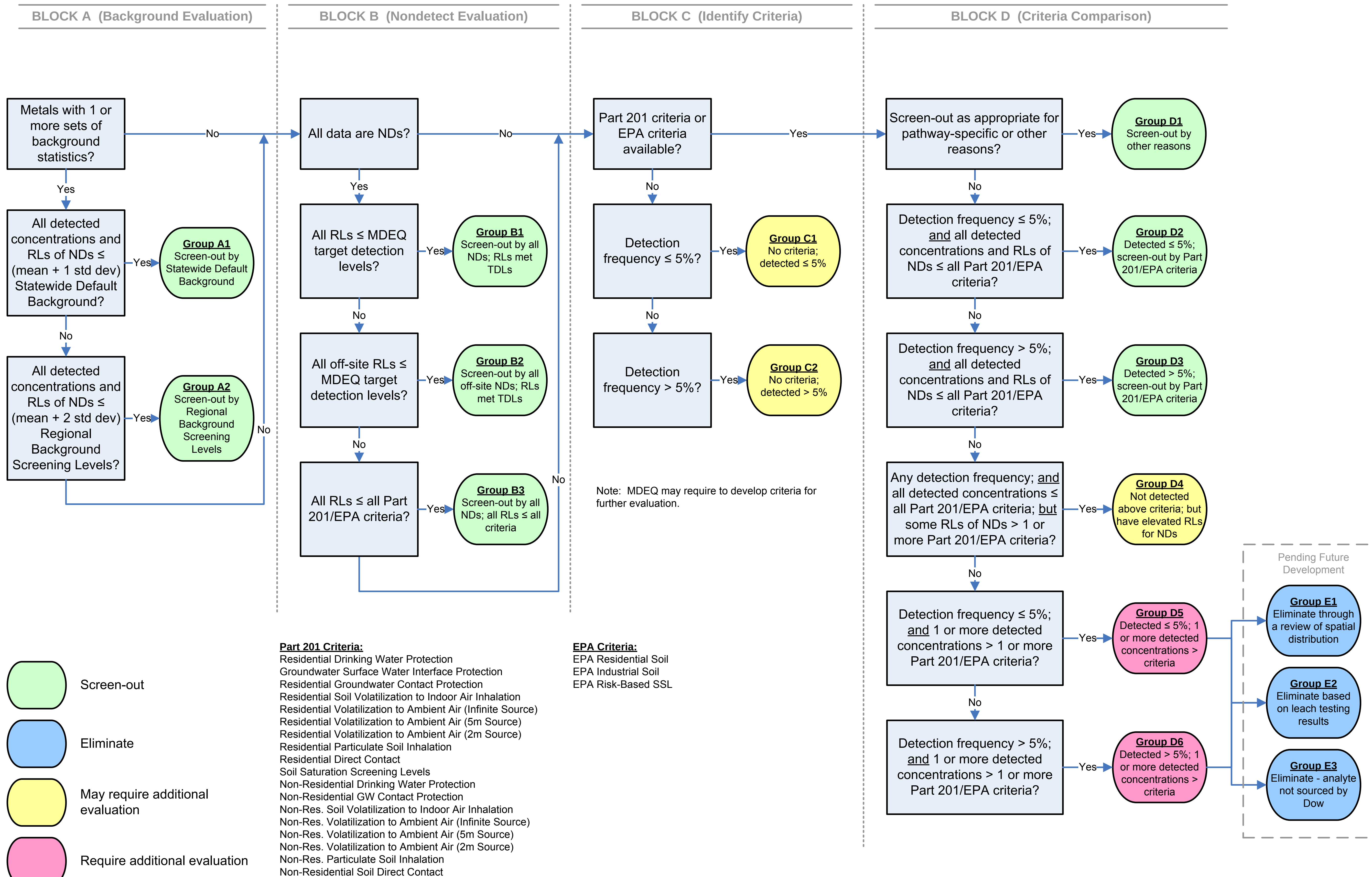
- Group D1 – Analytes that were screened-out based on pathway-specific or other evaluation (no analytes were grouped into this category).
- Group D2 – Analytes that were detected at a frequency of less than or equal to 5%, and all detected concentrations and RLs of nondetects were less than or equal to Part 201 criteria and/or USEPA criteria.
- Group D3 – Analytes that were detected at a frequency greater than 5%, and all detected concentrations and RLs of nondetects were less than or equal to Part 201 criteria and/or USEPA criteria.
- Group D4 – Analytes that were not detected at concentrations greater than Part 201 criteria and/or USEPA criteria, but some RLs of nondetects exceeded the criteria.
- Group D5 – Analytes that were detected at a frequency of less than or equal to 5%, and 1 or more detected concentrations were greater than one or more of the Part 201 criteria and/or USEPA criteria.
- Group D6 – Analytes that were detected at a frequency of greater than 5%, and 1 or more detected concentrations were greater than one or more of Part 201 criteria and/or USEPA criteria.

As shown in Figure 6-1, Groups D4, D5, and D6 underwent further evaluation. Some analytes in these categories were eliminated as follows:

- Group E1 – Analytes that were eliminated through a spatial (map) review of the data (e.g., the sample results were isolated and/or not spatially connected to Michigan Operations, evidencing that the source is something other than Dow).
- Group E2 – Analytes that were evaluated and eliminated based on leach testing results (i.e., the analyte only exceeded leach-based cleanup criteria, but site-specific analysis showed that the analyte was not actually leaching in material amounts).
- Group E3 – If this evaluation is necessary, an analyte may be eliminated if it is determined that it was not sourced by Dow.

Each analyte was categorized and screened as discussed above and the results are shown in the approved IRDC (Appendix A) and are discussed in Part II.

Figure 6-1 Flowchart of Human Health Non-Dioxin Analytes Sreening Process



7.0 Ecological Soil Exposure Pathway Screening Methodology

The purpose of the ecological screening evaluation was to build upon the process used to identify the COCs for the human health exposure pathways to screen the analytical results from the extensive on and off-site sampling results for over 200 compounds and identify COCs for the ecological pathway. This information was reviewed with MDEQ in a series of collaborative meetings.

The following steps were completed as part of this task:

- Screen TAL according to generic ecological screening criteria;
- Develop ecological screening categories based on results of generic screen;
- Determine the appropriate site-specific ecological receptors;
- Calculate site-specific ecological benchmarks, as necessary; and
- Review results of screening evaluation by category through collaborative meetings with MDEQ and U.S. Fish and Wildlife Service (FWS).

The MRA is an urban environment. In a meeting on April 4, 2014 with MDEQ, FWS, Dow and URS, avian receptors were proposed as the primary ecological receptors of interest, specifically the Northern Cardinal and the American Robin. In a meeting on May 16, 2014, MDEQ approved the use of avian receptors for the MAS ecological screening pathway evaluation. Therefore, identification of ESLBs for avian receptors was the focus of the ESLB selection process once the preliminary screen was completed.

7.1 Ecological Pathway Screening Evaluation

The ecological exposure pathway was evaluated for the MAS using a similar screening process as described for the human health evaluation in Section 6.0. The ESLBs represent media-specific concentrations that are protective of ecological receptors. The medium of interest is off-site urban soil. Chemicals for which soil concentrations are equal to or less than the chemical-specific ESLBs were excluded from further evaluation as it was concluded they pose no unacceptable risks. Exceedance of an ESLB did not indicate that an unacceptable risk was present, but rather that further evaluation was warranted.

7.1.1 Data Sets

Soil sampling work was conducted in 2005, 2006 and 2010. For the ecological pathway screening evaluation, a subset of this data was used that represents over 200 samples, and included analysis for over two hundred compounds other than dioxins and furans, including VOCs, SVOCs, metals, herbicides, pesticides, and PCBs. This is the same dataset that was screened for the human health evaluation.

Overall, the data sets evaluated included historical and current non-dioxin data. Three sets of surface and subsurface soil data were compiled, as follows:

- 2005/2006 DOS data set (sample locations are shown in Figure 4-1);
- 2006 CH2M Hill data set (locations of the grid cells are shown in Figure 4-2); and
- 2010 Dow and MDEQ split sample data set (sample locations are shown in Figure 4-3).

These three sets of data were combined and formed the basis for statistical evaluation of the results (the data sets were discussed in more detail in Section 4.0). See the *2010 Field Pilot Characterization Summary Report* dated 29 August 2011 for the final data set, laboratory QA/QC data, and the details on how the data was processed and compiled (URS, 2011).

7.1.2 Development of Summary Statistics

The calculation of summary statistics was part of an EDA effort, which is the first step of statistical evaluation. The objective of EDA was to discover trends and patterns in the data so that appropriate approaches and limitations in using the data sets could be identified.

A table of basic summary statistics was prepared for non-dioxin data of the combined data set. These tables included common statistical parameters, such as mean, standard deviation, minimum and maximum detected values, and minimum and maximum RLs where substances were not detected. These statistics were used to make inferences concerning the population from which the sample data were drawn. The number of samples and detection rate (i.e., determining the percentage of the data set that was detected/un-censored) were also included to provide information regarding sample size and detection frequency. The results of summary statistics are provided in Part II.

7.2 TAL Screening Criteria

The purpose of the ecological TAL data screening effort was to determine if there are non-dioxin analytes that are potential chemicals of interest, in comparison to the established screening criteria. This section discusses the screening criteria used to determine if a constituent was eliminated from the TAL for the ecological pathway or retained for additional evaluation.

7.2.1 Selection of Ecological Screening Benchmarks

The initial screening was based on the use of USEPA Region 5 ESLs (e.g., generic ESLBs), where available. In the absence of a Region 5 ESL, USEPA EcoSSLs were used. Most Region 5 ESLs are based on exposure to the masked shrew and were considered reasonably conservative for the initial generic screen. Compounds that did not get screened out at the first level were evaluated further using ESLBs specific to the avian receptors selected preferentially for the site-specific evaluation.

Detailed below is the hierarchal scheme used for the selection of a single avian ESLB from multiple sources for application in the site-specific MAS ecological pathway screening evaluation. A memorandum proposing the hierarchal scheme for the selection of ESLBs was submitted to the MDEQ in April 2014 and is included as Attachment A. The following table presents sources of ESLBs in a hierarchal manner with the rationale for prioritization.

Prioritization Level	Source	Rationale
Level 1	USEPA (2003-2008) Ecological Soil Screening Levels	The USEPA EcoSSL guidance incorporates a rigorous review of available studies on the toxicity in soils for a variety of inorganic and organic constituents. Given sufficient information, EcoSSLs have been developed for both birds and mammals. EcoSSLs for birds were developed for the dove (herbivore), woodcock (insectivore) and hawk (carnivore). Because avian receptors are the primary receptors of interest, the lowest EcoSSL for birds, if available, was selected preferentially as an ESLB.
Level 2	Los Alamos National Laboratory (LANL) Ecorisk Database (2012 – or most recent)	LANL provides well-documented derivation of ESLs for use as potential ESLBs. ESLs have been derived for several species of both birds and mammals for a much larger group of chemicals than is represented by the EcoSSLs. LANL soil ESLs for birds were developed for the American robin (insectivore) and American kestrel (carnivore). Because the American robin is one of the specific avian receptors of interest, the American robin benchmark was used for screening, if available. If it was not available, the lowest LANL ESL for birds was selected preferentially as an ESLB in the absence of an EcoSSL.

Prioritization Level	Source	Rationale
Level 3	ESLB Calculation	In the absence of ESLBs from the above sources, a literature search was performed for relevant ecological toxicity values for use in calculating ESLBs. The general approach for calculating ESLBs is based on an ingestion exposure model that estimates the amount of contaminant a receptor ingests per day and compares that estimate with a dose, referred to as a toxicity reference value (TRV). An ESLB is derived by calculating the soil concentration that results in an ingested dose equal to the TRV. Details for calculating ESLBs are provided in Attachment A.
Level 4	Discuss in Uncertainty Analysis	There were some instances in which there were no available chemical-specific benchmarks or toxicity values. A closely related chemical was selected to use as a surrogate for the chemical of interest, and the above ESLB selection process was applied. In instances where no ESLB (or surrogate) was identified, a discussion of the implications for interpreting potential ecological risks in the absence of an ESLB is presented in the Uncertainty Analysis in Part II.

7.2.2 Background Concentration

MDEQ State-wide default background values were used as an initial screen for metals, when available. MDEQ also developed and provided a regional background for some metals, which was used as a secondary screen (see Part II). Where State-wide default background and modified urban background values had not been developed, additional data from a study by the U.S. Geological Survey (USGS) Study were used to generate a background value (Boerngen and Shacklette, 1981)

7.2.3 Screening of Chemical Groupings

Certain classes of analytes were present in several isomer forms. The isomer-specific concentrations were summed into a total before being compared to the appropriate screening criteria. These classes of analytes included LMW and HMW PAHs, endrins, BHCs, heptachlors, DDx (DDD, DDE, DDT), endosulfans, chlordanes, and parathions and are discussed further below (see Part II). DDD, DDE, and DDT were also evaluated as individual constituents. If a sample result was not detected, one half the reporting limit was assumed in the total value.

7.3 TAL Data Screening Categories

Dow initially completed the preliminary screening using categories similar to those used in the human health screening effort. These categories are presented in Table 7-1. After a series of meetings held between MDEQ, FWS, Dow and URS, an alternative screening approach based on the initial categories was proposed by FWS on September 23, 2013 (see Attachment A) which was accepted as the path forward in a meeting held on April 8, 2014. These categories are presented below and in Table 7-2.

Screening categories were identified as part of the screening effort to group and organize the non-dioxin constituents to facilitate the data review process. The screening categories are briefly described below, and each constituent, through the screening process, was placed into one of the twelve categories. The full screening process and the hierarchy of each step are illustrated on the ecological screening flowchart shown in Figure 7-1.

Category 1 – If the analyte screened out of the human health screening evaluation and the human health criteria is less than the ESLB, then the analyte can be screened out of the ecological pathway screening evaluation.

Category 2 – If the maximum detected concentration is less than background, then the analyte can be screened out of the ecological pathway screening evaluation.

Category 3 – If all detected concentrations are less than the reporting limit and the reporting limit is less than background, then the analyte can be screened out of the ecological pathway screening evaluation.

Category 4 (eA1) – Analyte not detected and no ESLB is available.

Category 5 (eA2) – Analyte detected and no ESLB is available.

Category 6 (eB1) – Analyte not detected and > 95% RLs meet the ESLB.

Category 7 (eC1) – Analyte detected ≤ 5%; > 95% RLs meet the ESLB.

Category 8 (eD1) – Analyte detected > 5%; screening level Hazard Quotient (HQ) based on the off-site maximum detected concentration ≤ 1.

Category 9 (eB2) – Analyte not detected; > 5% RLs did not meet the ESLB.

Category 10 (eC2) – Analyte detected ≤ 5%; > 5% RLs did not meet the ESLB.

Category 11 (eD2) – Analyte detected > 5%; screening level HQ based on the off-site maximum detected concentration > 1.

Category 12 – Analytes that have not been eliminated.

Each analyte was categorized and screened as discussed above and the results and conclusions of the evaluation are presented in Part II.

Table 7-1
Summary of Initial Ecological Screening Categories
Part I - Remedial Investigation Work Plan
The Dow Chemical Company, Michigan Operations

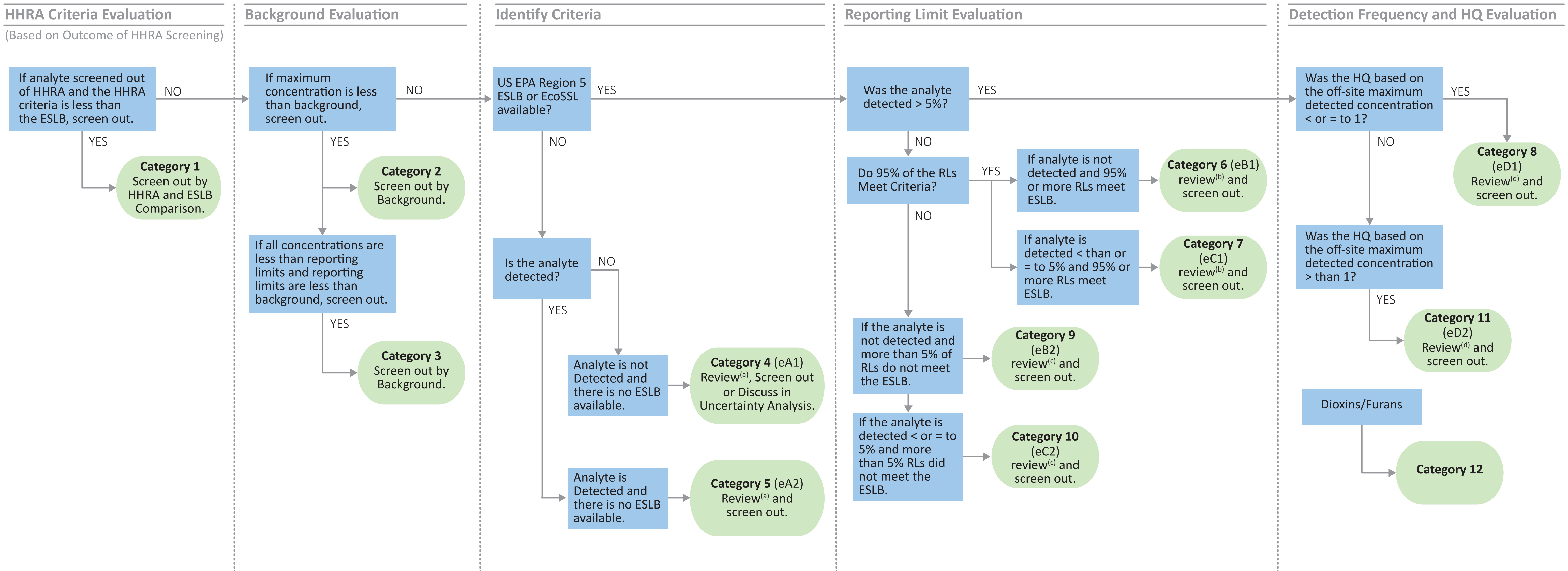
Category	Definition
eBKG1	Metals with all detected concentraitons and reporting limits of non-detects below the Statewide Default Background level.
eBKG2	Metals with all detected concentrations and reporting limits of non-detects below the Modified Urban Background level.
eA1	Analytes that were 100% non-detected and have no Ecological Screening Level Benchmark (ESLB).
eA2	Analytes that were detected but have no ESLB.
eB1	Analytes that were 100% non-detected and 95% or more reporting limits were less than or equal to the ESLB of the given analyte.
eB2	Analytes that were not detected and anywhere from 5% to 100% of reporting limits did not meet the ESLB.
eC1	Analytes that were detected at a frequency less than or equal to 5%, and most (95% or more) reporting limits met the ESLB.
eC2	Analytes that were detected less than or equal to 5% and anywhere from 5% to 100% of reporting limits did not meet the ESLB.
eD1	Analytes that were detected at a frequency of greater than 5%, and HQ based on the off-site maximum concentration is less than or equal to 1.
eD2	Analytes that were detected at a frequency greater than 5% and HQ based on off-site maximum concentration is greater than 1.

Table 7-2
Summary of Current Ecological Screening Categories Based on L. Williams (FWS) Memorandum Dated September 23, 2013
Part I - Remedial Investigation Work Plan
The Dow Chemical Company, Michigan Operations

Category	Definition
1	If screened out of HHRA and HHRA threshold is less than ESLB, screen out of ERA, documenting reasons for screening out of HHRA.
2	If maximum concentration is less than background, screen out of ERA
3	If all concentrations are < RL and RL is less than background, screen out of ERA
4	eA1 (Analyte not detected; no ESLB): Compare RL to ESLB for similar compound or to HHRA for same or similar compound then add reasons for exposure/toxicity differences and/or add safety factors.
5	eA2 (Analyte detected; no ESLB): Compare maximum concentration to ESLB for similar compound or to HHRA for same or similar compound then add reasons for exposure/toxicity differences and/or add safety factors.
6	eB1 (Analyte not detected; 95% or more RLs met ESLB): Probably OK to screen out, spatial distribution if seems too many.
7	eC1 (Detected < or = to 5%; 95% or more RLs met ESLB): Probably Ok to screen out, spatial distribution if seems too many or maximum concentration > ESLB
8	eD1 (Detected > 5%; HQ (based on off-site data) < or = to 1); Probably OK to screen out.
9	eB2 (Analyte not detected; More than 5% RLs did not meet ESLB); see if screened out of HHRA and if same reasoning can be used, e.g. #1-3 above, spatial distribution indicates not Dow or SWAC of RLs in 5 acre worst case homerange circles less than ESLB.
10	eC2 (Detected < or = to 5%; More than 5% RLs did not meet ESLB): see if screened out of HHRA and if same reasoning can be used, e.g. #1-3 above, spatial distribution indicates not Dow or SWAC of RLs, and detections in 5 acre worst case homerange circles less than ESLB.
11	eD2 (Detected > 5%; HQ (based on off-site data) > 1): see if screened out of HHRA and if same reasoning can be used, e.g. #2 above, spatial distribution indicates not Dow, or SWAC of RLs and detections in 5 acre worst case homerange circles less than ESLB.
12	For remaining contaminants - move beyond SLERA, e.g. consider geometric mean of NOAEL and LOAEL instead of just the NOAEL that was used to develop the ESLB, consider LOAEL, develop and ESLB, calculate % of homeranges at risk after cleanup using SWACs.

HHRA Human Health Risk Assessment
ERA Ecological Risk Assessment
ESLB Ecological Screening Level Benchmark
NOAEL No Observable Adverse Effect Level
RL Reporting Limit
SLERA Screening Level ERA
LOAEL Lowest Observable Adverse Effect Level

Figure 7-1 Flowchart of Ecological Non-Dioxin Analytes Screening Process



Review[a]
Calculate NOAEL, if available.
Evaluate Spatial Distribution
Calculate LOAEL, if available.

Review[b]
Was sample location associated with an off-site source not related to MAS historical release?
Calculate NOAEL, if available.
Evaluate Spatial Distribution
Calculate LOAEL, if available.

Review[c]
Was sample location associated with an off-site source not related to MAS historical release?
Calculate NOAEL, if available.
Evaluate Spatial Distribution
Calculate LOAEL, if available.
Uncertainty Analysis

Review[d]
Was sample location associated with an off-site source not related to MAS historical release?
Totals evaluation
USGS Background Evaluation
Calculate NOAEL, if available.
Evaluate Spatial Distribution
Calculate LOAEL, if available.

8.0 Implementation

The activities described in the following parts of this Corrective Action Report were conducted concurrently during this project in a compressed timeframe under the approved *Interim Response Work Plan Designed to Meet Criteria (IRDC)* (URS, 2012). Part II presents and summarizes the results and conclusions of the human health and ecological risk screening evaluations, identifies the COIs for relevant exposure pathways, presents the sampling methodology and decision rules, and documents the results of design sampling. Part III identifies the appropriate remedy that was implemented to mitigate risk for current land use, fully describes the completion of the remedy, and establishes the mechanisms to ensure that changes in the future will not compromise the long term effectiveness of the remedy.

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Attachment A

Ecological Screening Methodology Support Memoranda

Taylor, Al (DEQ)

From: Williams, Lisa <lisa_williams@fws.gov>
Sent: Monday, September 23, 2013 11:15 AM
To: Taylor, Al (DEQ); MacKenzie-Taylor, Deb (DEQ)
Subject: Midland eco risk

Midland eco risk assessment (ERA)

Purpose: quantify residual ecological risk to support remedial decision and explain it to public, management, and NRDA trustees

Notes on possible process steps from our talk, as I recall, plus additional thoughts I've had; would like to talk through these and double-check before something like this would go to Dow:

(1) If screened out of HHRA and HHRA threshold is less than ESLB, screen out of ERA, documenting reasons for screening out of HHRA.
(2) If max conc is less than background, screen out of ERA [assume already done in eBKG2 -Metals Screen-out by Modified Urban Background, but could go to literature for other metals/compounds.]
(3) If all conc are < RL and RL is less than background, screen out of ERA [assume already done in eBKG2 - Metals Screen-out by Modified Urban Background, but could go to literature for other metals/compounds.]
(4) eA1 (Analyte not detected; no ESLB): compare RL to ESLB for similar compound or to HHRA for same or similar compound then add reasons for exposure/toxicity differences and/or add safety factors
(5) eA2 (Analyte detected; no ESLB): compare max conc. to ESLB for similar compound or to HHRA for same or similar compound then add reasons for exposure/toxicity differences and/or add safety factors
(6) eB1 (Analyte not detected; most RLs met ESLB): probably OK to screen out, would like to see examples of "most", then spatial distribution if seems too many
(7) eC1 (Detected ≤ 5%; most RLs met ESLB): probably OK to screen out, would like to see examples of "most", then spatial distribution if seems too many or max conc. > ESLB
(8) eD1 (Detected > 5%; HQ (based on off-site data) ≤ 1): probably OK to screen out
(9) eB2 (Analyte not detected; some or all RLs did not meet ESLB): see if screened out of HHRA and if same reasoning can be used, e.g. #1-3 above, spatial distribution indicates not Dow or SWAC of RLs in 5 acre worst case homerange circles less than ESLB
(10) eC2 (Detected ≤ 5%; some or all RLs did not meet ESLB): see if screened out of HHRA and if same reasoning can be used, e.g. #1-3 above, spatial distribution indicates not Dow or SWAC of RLs, and detections in 5 acre worst case homerange circles less than ESLB
(11) eD2 (Detected > 5%; HQ (based on off-site data) > 1): see if screened out of HHRA and if same reasoning can be used, e.g. #2 above, spatial distribution indicates not Dow, or SWAC of RLs and detections in 5 acre worst case homerange circles less than ESLB
(12) for remaining contaminants - move beyond SLERA, e.g. consider geometric mean of NOAEL and LOAEL instead of just the NOAEL that was used to develop the ESLB, consider LOAEL, develop an ESLB, calculate % of homeranges at risk after cleanup using SWACs

HHRA = human health risk assessment
ERA = ecological risk assessment
ESLB = Ecological Screening Level Benchmark
NOAEL = no observable adverse effect level
RL = reporting limit
SLERA = screening level ERA

SELECTION OF ECOLOGICAL SCREENING LEVEL BENCHMARKS

(April 2014)

Ecological screening level benchmarks (ESLBs) represent media-specific concentrations which are protective of ecological receptors. The medium of interest for this memorandum is soil, with the focus being off-site urban soil. Chemicals for which soil concentrations are equal to or less than the chemical-specific ESLBs are excluded from further evaluation as it is concluded they pose no unacceptable risks. Exceedance of an ESLB does not indicate that an unacceptable risk is present, but rather that further evaluation may be warranted.

The Midland Resolution Area is an urban environment. In a meeting on April 4, 2014 with Michigan Department of Environmental Quality (MDEQ), U.S. Fish and Wildlife Service (FWS), Dow and URS, avian receptors were selected as the primary ecological receptors of interest. Therefore, identification of ESLBs for birds is now the focus of the ESLB selection process. The current screening is based on the use of USEPA Region 5 Ecological Screening Levels (ESLs), where available (supplemented with USEPA Ecological Soil Screening Levels (EcoSSLs) only in the absence of the Region 5 ESL). Most Region 5 ESLs are based on exposure to the masked shrew and were considered reasonably conservative for the screening performed to date. Moving forward, ESLBs specific to avian receptors will be selected preferentially.

The goal of this memorandum is to propose a hierarchal scheme for selection of a single avian ESLB from multiple sources for application in the Midland Area Soils project. The following table presents sources of ESLBs in a hierarchal manner with the rationale for prioritization.

Prioritization Level	Source	Rationale
Level 1	USEPA (2003-2008) Ecological Soil Screening Levels	The USEPA Ecological Soil Screening Level (EcoSSL) guidance incorporates a rigorous review of available studies on the toxicity in soils for a variety of inorganics and organic constituents. Given sufficient information, EcoSSLs have been developed for both birds and mammals. EcoSSLs for birds were developed for the dove (herbivore), woodcock (insectivore) and hawk (carnivore). Because avian receptors are the primary receptors of interest, the lowest EcoSSL for birds, if available, were selected preferentially as an ESLB.

Prioritization Level	Source	Rationale
Level 2	Los Alamos National Laboratory (LANL) Ecorisk Database (2012 – or most recent)	LANL provides well-documented derivation of ESLs for use as potential ESLBs. ESLs have been derived for several species of both birds and mammals for a much larger group of chemicals than is represented by the EcoSSLs. LANL soil ESLs for birds were developed for the American robin (insectivore) and American kestrel (carnivore). Because the American robin is one of the specific avian receptors of interest, the American robin benchmark was used for screening, if available. If it was not available, the lowest LANL ESL for birds was selected preferentially as an ESLB in the absence of an EcoSSL.
Level 3	ESLB Calculation	In the absence of ESLBs from the above sources, a literature search was performed for relevant ecological toxicity values for use in calculating ESLBs. The general approach for calculating ESLBs is based on an ingestion exposure model that estimates the amount of contaminant a receptor ingests per day and compares that estimate with a dose, referred to as a toxicity reference value (TRV). An ESLB is derived by calculating the soil concentration that results in an ingested dose equal to the TRV. Details for calculating ESLBs will be described in a separate memorandum.
Level 4	Discuss in Uncertainty Analysis	There were some instances in which there were no available chemical-specific benchmarks or toxicity values. A closely related chemical was selected to use as a surrogate for the chemical of interest, and the above ESLB selection process was applied. In instances where no ESLB (or surrogate) was identified, a discussion of the implications for interpreting potential ecological risks in the absence of an ESLB is presented in the Uncertainty Analysis.

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MEMORANDUM

To: Steve Lucas, Dow

From: Helen Artz Patton, URS

Date: 13 May 2014, Revised 3 September 2014

RE: Ecological Screening Level Benchmark Calculation

This memorandum details the proposed approach for calculating Ecological Screening Level Benchmarks (ESLBs) for the American robin and Northern Cardinal. The general approach for calculating ESLBs is based on an ingestion exposure model that estimates the amount of contaminant a receptor ingests per day and compares that estimate with a dose, referred to as a toxicity reference value (TRV). The ESLB is a soil concentration at which adverse effects are unlikely to occur (an ESLB based on a no effects level), or above which effects may occur (based on a low-effects level). Because the ESLB is based on conservative assumptions, an exceedance of the ESLB does not mean that a risk is present, but rather that more detailed evaluation may be warranted.

Soil ESLBs are derived using the basic equation USEPA applied in deriving ecological soil screening levels (Eco-SSLs) (USEPA 2005), but modified to allow for multiple food items. The general equation used to estimate risk from exposure through ingestion includes incidental ingestion of soil while feeding, as well as ingestion of food items:

(Eq. 1)

$$HQ_{j=} \frac{[FIR*(Soil_j*P_s+B_{i1j}*P_{i1j}+B_{i2j}*P_{i2j}+..B_{inj}*P_{inj})]}{TRV_j}$$

Where:

HQ_j	=	Hazard Quotient for chemical (j) (unitless)
FIR	=	Food intake rate (kg of food [dry weight] per kg body weight per day)
$Soil_j$	=	Concentration of chemical (j) in soil (mg/kg dry weight)
P_s	=	Proportion of food intake that is soil (mg/kg dry weight)
P_{i1}	=	Proportion of the food intake that is biota type "i"
B_{ij}	=	Concentration of chemical (j) in biota type "i" (mg/kg dry weight)
TRV_j	=	Toxicity reference value for chemical (j) (mg chemical/kg body weight per day [mg/kgBW/day))

The soil concentration that results in an HQ of one is the soil concentration where the dose is equivalent to the selected TRV, which represents the ESLB ($Soil_j$).

Relevant information on behavior and physiology of receptor species is necessary for deriving receptor-specific benchmarks. The following measures of receptor characteristics were identified for the American robin and the northern cardinal:

- Food intake rate (FIR)
- Composition of the diet (P_i)
- Soil ingestion as a proportion of the diet (P_s)
- Body weight (kg, BW)

Measures of receptor characteristics for both receptors are presented in **Table 1.**

The model also requires an estimate of the concentration of the chemical in dietary items (B_{ij}). As noted previously, this is estimated by applying BAFs (or algorithms, as appropriate) for each constituent into each category of food (i.e., plants and invertebrates). The primary sources of uptake factors/algorithms are USEPA's Eco-SSL guidance documents (USEPA 2007), Los Alamos National Laboratory's EcoRisk Database (LANL 2012); Hazardous Substances Data Bank (HSDB) and published literature (for example Oak Ridge National Laboratory [Sample et al. 1998, Bechtel-Jacobs Company 1998]). Moving forward, as chemical-specific ESLBs are calculated (as necessary) uptake factors/algorithms will be provided in separate memoranda detailing the chemical-specific ESLB derivation.

Finally, the model requires an appropriate oral TRV for each chemical. The TRV selected for ESLB derivation may be a no-observed-adverse-effects level (NOAEL), and/or lowest-observed-adverse-effects level (LOAEL). The NOAEL is the highest dose where there is no statistically significant difference from the control response. The LOAEL is the lowest dose that results in a statistically significant effect compared with a control. As chemical-specific ESLBs are calculated for analytes that have no ESLB or for analytes that require further evaluation, chemical-specific TRVs will be provided in separate memoranda detailing chemical-specific ESLB derivation.

Several databases, in addition to the open literature, represent potential sources of TRV information. These include, but are not limited to, the USEPA Eco-SSL documents; LANL’s Ecorisk Database (LANL 2012); USEPA’s ECOTOX database; HSDB; the Integrated Risk Information System (IRIS); U.S. Fish and Wildlife Service Contaminant Hazard Series synopses; Oak Ridge National Laboratory technical reports (e.g., Sample et al. 1996), and available Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles.

USEPA Eco-SSL documents are used preferentially for selection of NOAEL TRVs (the Eco-SSL documents do not derive LOAEL TRVs). LANL has compiled both NOAEL and LOAEL TRVs for a much larger number of constituents than the Eco-SSLs and is also used as a preferential source[1]. The general strategy for selecting (or deriving) a NOAEL or LOAEL TRV for the constituents not covered by the Eco-SSLs or LANL is as follows:

- Studies measuring effects relate to population-level impacts are given priority. Priority endpoints include survival, growth and reproductive effects. Effects such as liver

[1] NOAEL TRVs are consistent between the EcoSSLs and LANL.

damage, carcinogenesis, enzyme induction and histopathology are generally not considered as it is difficult to relate such measures to population-level effects.

- In general, studies with the lowest LOAEL bounded by a NOAEL are preferred. However, LOAEL and NOAELs from different studies may also be considered based on test organism, study design (e.g., dilution series ratio) and availability of information.
- Where values are not available for specific receptors (which is characteristic of the vast majority of literature values), values from surrogate receptors are selected.
- The study duration is given consideration, as well as the toxicological endpoint. Preference is given to studies that are chronic or subchronic over single event or acute exposures. Where data are available for more than one dosing regime, chronic is selected first, subchronic second, and acute only if no other data are available.
- Body weight changes in adult test species is not considered a priority endpoint. However, body weight changes in juvenile individuals are assumed to indicate growth (or lack thereof) and, therefore, are considered a relevant endpoint.
- Studies are considered based on the mode of administrating the dose. Studies in which the dose is administered through diet are given preference. If dietary studies are not available, studies in which the toxicant is administered in water are considered. Studies using gavage, capsules or oral intubation are not used when food studies are available. Intraparitoneal or intravenous studies are generally not used.

If there are no TRVs for a constituent, the absence of the TRV is discussed in an uncertainty analysis. In other instances, TRVs may be limited to endpoints such as the median lethal dose (LD_{50}) or LOAEL. In the absence of other studies, uncertainty factors of 10 and 100 are applied to an LD_{50} to derive a LOAEL and NOAEL respectively. An uncertainty factor of 5 is used to estimate a NOAEL from a measured LOAEL.

In some studies exposures are expressed as a concentration in the diet (mg/kg diet) and not as a dose (mg/kgBW/day). To convert from a diet concentration to a dose, information on body weight and food ingestion rate is used. If body weight and ingestion rate of the test species are reported in the study, those values are used preferentially. If this information is not available, an average body weight and food or water ingestion rate is calculated using species-specific information and allometric equations from USEPA's Wildlife Exposure Factors Handbook (USEPA 1993) or other sources. The following equation is used to calculate a daily dose:

(Eq. 2) $$Calculated\ Dose = \frac{Diet\,(mg/kg) \times Ingestion\ Rate\ (kg/day)}{BW\,(kg)}$$

Ideal ecotoxicological datasets for each chemical generally do not exist, and although a scheme for TRV selection is presented, professional judgment must necessarily be incorporated into the selection strategy. In order to provide transparency, TRV sources are provided for each chemical evaluated. Details regarding application of uncertainty factors and dose calculations are also provided where applied.

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Table 1. Measures of Receptor Characteristics

Receptor of Interest	Body Weight (BW) (kg)	Food Ingestion Rate (FIR) (kg dw/BW-day)	Soil Ingestion (P_s) (proportion of diet) (Decimal Fraction)	Plants (proportion of diet) (Decimal Fraction)	Invertebrates (proportion of diet) (Decimal Fraction)
American Robin	0.077	0.193	0.05	0.045	0.905
Northern Cardinal	0.045	0.225	0.02	0.6	0.38

kg - kilograms
kg dw/BW-day - kilograms (dry weight) per body weight per day

American Robin
BW - 0.077 kg; USEPA (1993); average for male and female in Pennsylvania (all seasons) (USEPA 1993).
FIR - 1.205 g/g-day (avg of 0.89 g/g-day and 1.52 g/g-day; USEPA 1993). Average free-living birds in California and Kansas (USEPA 1993). Converted to dry weight assuming 84% moisture in earthworms; result 0.193 kg/kg BW-day dw.
P_s - 5.0% of diet (dry weight); Galbraith Environmental Sciences LLC (2004); Tittabawassee River Floodplain Screening-Level Ecological Risk Assessment
Diet composition - 93% soil invertebrates, 7% vegetation (spring diet in eastern US; USEPA 1993). Adjusted to 90.5% soil invertebrates and 4.5% vegetation to account for 5% soil ingestion.

Northern Cardinal
AU - 1.18 ha average in Tennessee; Degraaf and Rudis (1983)
BW - 0.045 kg (http://animaldiversity.ummz.umich.edu/accounts/Cardinalis_cardinalis/)
FIR - 0.225 kg/kgBW-day (dw); calculated from BW using allometric equation for passerines (USEPA 1993); FI (g/day) = 0.398 Wt0.850 (g) = 0.010 kg/day (dw)
P_s - No data - 2% assumed; not a ground-feeder
Diet Composition - Vegetable matter (fruits and seeds) 39%, invertebrates 61%; conservative seasonal (spring) diet as reported in Martin et al. (1951). Adjusted to 38% and 61%, respectively to account for 2% soil ingestion.