The Dow Chemical Company
Interim Response Activity Plan Designed to Meet Criteria

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Executive Summary

Pursuant to its Part 111 Hazardous Waste Management Facility Operating License (License), 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 Interim Response Activity Plan Designed to Meet Criteria Work Plan (Work Plan) is to provide an overview of the investigation activities to date; summarize how the analytical data from those investigations was screened; identify the exposure pathways and contaminants of concern; propose a sampling plan; and describe the response activities that will be presumptively applied to Midland Area Soils. This Work Plan presents a waiver request of the requirement to develop and implement a Feasibility Study (FS) to evaluate response activity alternatives. The presumptive remedy described in this Work Plan was designed to address dioxins and furans in soil protective of the direct contact exposure pathway, and is the most effective means of doing so.

An evaluation of the analytical data from the investigations performed to date was completed to identify exposure pathways and contaminants of concern. Dioxins and furans were identified as a contaminant of concern (COC) in soil for the direct contact exposure pathway. The presence of dioxins and furans is due to airborne emissions from historic waste management practices at the Michigan Operations facility.

This work plan proposes the following to address this COC and pathway:

- A site-specific action level (SSAL) of 250 ppt TEQ;
- Identifies the Midland Resolution Area which includes properties to the north and east of the facility;
- A sampling plan based on incremental composite sampling;
- A presumptive remedy that includes removing and replacing the top twelve (12) inches of soil for residential properties that exceed the SSAL and returning the yard to same or better conditions;
- The establishment of a trust fund to address any properties where owners do not wish to participate at this time; and

- A schedule for completion of this work and all Midland Area Soils Corrective Action related to the historic airborne releases from The Dow Chemical Company.

Implementation of the presumptive remedy activities will begin during 2012. Annual progress reports will be prepared and provided to MDEQ, summarizing activities performed through each year.

1.0 Introduction

Pursuant to its Part 111 Hazardous Waste Management Facility Operating License (License), 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 Interim Response Activity Plan Designed to Meet Criteria Work Plan (Work Plan) is to provide an overview of the investigation activities to date; summarize how the analytical data from those investigations was screened; identify the exposure pathways and contaminants of concern; propose a sampling plan; and describe the response activities that will be presumptively applied to Midland Area Soils and as appropriate, indoor dust. This Work Plan details substantial corrective actions which are intended to be the final remedy for the soil direct contact exposure pathway. The final Remedial Action Plan (RAP), and associated Completion Report will describe how each of the exposure pathways have been addressed for current and reasonably anticipated future use; thereby fulfilling Dow's obligations with respect to the historic airborne releases from the Michigan Operations Facility. Additional information on schedule and future report submittals for the project are provided in Section 10 and Attachment A.

1.1 Summary of Report

This Work Plan summarizes and presents the following information for the Midland Area Soils:

- Site history;
- Summary of prior investigations and studies;
- Exposure pathways;
- Data evaluation and identification of contaminants of concern (COCs);
- Site-specific action level;
- Presumptive remedy;
- Implementation of presumptive remedy; and
- Schedule.

Annual summary reports that summarize both the implementation of the presumptive remedy for the prior construction season and future work plans will be submitted to MDEQ. Additional deliverables are summarized in the next section. The schedule is summarized below.

Schedule Summary

Year 1 of the presumptive remedy activities will be implemented during the field season of 2012 (considered from approval of Work Plan through October). The summary report for Year 1, along with a description of Year 2 implementation of the presumptive remedy will be submitted by December 15, 2012. This schedule is dependent upon receiving MDEQ approval of this Work Plan prior to June 1, 2012. Further schedule details are presented in Section 8 of this Work Plan.

1.2 License Procedure

This Work Plan has been prepared to meet the requirements of the License for the implementation of corrective action in Midland Area Soils. "Corrective action" is action that is necessary to protect public health or the environment, including the investigation and cleanup of contaminants. A more detailed discussion of the License and Michigan law is found in Attachment A. Condition IX.B of the License requires corrective action for releases of contaminants that have migrated beyond the boundary of the licensed facility. "Midland Area Soils" is specified as one such area. Condition XI.B.2. Under the terms of the License and as allowed by Michigan law, site-specific cleanup criteria can be proposed for use in connection with corrective action. Condition IX.B.3(b)(iv). Site-specific cleanup criteria are criteria that use site-specific information and updated science, as appropriate, to revise state-wide generic cleanup criteria. The License and Michigan law also allow for the use of an "interim response activity" (IRA) "designed to meet cleanup criteria," which is an action that is undertaken before the final remedial action is undertaken, but, nevertheless, is stringent enough that no further remedial action will be required. In accordance with License Condition XI.I, Dow is requesting that MDEQ grant a waiver of the requirement to develop and implement a Feasibility Study (FS) to evaluate response activity alternatives. The presumptive remedy described in this Work Plan was designed to address dioxins and furans in soil protective of the direct contact exposure pathway, and is the most effective means of doing so. This Work Plan is an "IRA Work Plan" pursuant to Condition XI.G.1 of the License. The annual summary reports discussed later in this Work Plan are meant to fulfill the requirement to submit "IRA Reports" upon the completion of response activities.

2.0 Site History

2.1 Historical Plant Operations

The Dow Chemical Company's Michigan Operations began operations in 1897. Expansion in production operations during the past century resulted in growth of Michigan Operations from 25 to approximately 1,900 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 plant location and layout are depicted in Figure 2-1.

Initially, manufacturing involved extracting brine from groundwater pumped from production wells ranging in depth from 1,300 to 5,000 feet below ground surface, and using the brine to make various chemicals. Over the time of its operation, Michigan Operations has produced over 1,000 different inorganic and organic chemicals in varying quantities ranging from experimental batches to full commercial scale production.

Currently, Michigan Operations consists of approximately 30 production plants and a centralized Research & Development campus that serves Dow's global operations. Michigan Operations has been and remains a major research and development center for Dow.

2.2 Dioxin and Furan Emissions

Dioxins and furans are by-products of incineration, uncontrolled burning and certain industrial processes, such as the manufacture of chlorinated organics. Dow has examined the history of these potential sources at Michigan Operations in order to inform the investigation and guide the response action for Midland Area Soils.

Historic waste burning and waste incineration appear to be the primary source of elevated dioxins and furans found in surface soil in the Midland Area Soils, as reported in "Point Sources and Environmental Levels of 2,3,7,8-TCDD (2,3,7,8–tetrachlorodibenzo-p-dioxin) on the Midland Plant Site of The Dow Chemical Company of Midland, Michigan, November 5, 1984" (1984 Agin Study) (Agin et al., 1984). This study conducted by Dow was "a comprehensive search for all critical point sources of 2,3,7,8-TCDD to the air, soil, and water in the Midland area." The results of the study were submitted to federal, state, and local governmental agencies.

The 1984 Agin Study contains details about historic manufacturing processes and waste management practices, focusing on 2,3,7,8-TCDD.

2.3 Historic Air Emissions Management

2.3.1 Process Emissions

Historically, waste process gases were vented to the atmosphere. Dow chemists and engineers viewed waste materials as process inefficiencies. As a result, over time, efforts have been focused on recovering wastes for reclamation and reuse (Agin et al., 1984; Haynes, 1945a; Haynes, 1945b; Haynes, 1948; Haynes, 1949; Haynes, 1954a: Haynes 1954b). Beginning in the late 1960s, Dow aggressively pursued reduction in emissions from its process vents through process changes or elimination, implementation of material recovery and reuse (Agin et al., 1984; Dow, 2006a). More recently, changes in environmental regulations and more stringent emission standards resulted in installation of air pollution control technologies and have further driven efforts to successfully achieve and demonstrate significant emission reductions. As a whole, dioxin and furan emissions from process vents were likely relatively minor sources compared to waste incineration emissions.

Coal combustion is another potential source of dioxins and furans. Due to Michigan Operations' high demand for electrical power, Dow has historically supplied its own power needs using onsite power generation plants. As of 1984, the onsite 60 megawatt 2 million pound per hour steam cogeneration plant burned 2,000 tons of coal per day. Non-halogenated liquid process waste (tars) were also periodically burned for energy recovery. Exhaust gases and particulates were directed through an economizer prior to stack exhaust to the atmosphere. The powerhouse was retrofitted with baghouse filters in October 1982 to remove 99 percent of the flyash previously discharged to the environment (Agin et al., 1984).

2.3.2 Early Combustion of Liquid Waste Tars

As early as 1930, Michigan Operations disposed of organic liquid tars by incineration. Burning liquid tars can generate dioxins and furans. Two basic types of incineration were used: liquid tar burners (in several different configurations) and rotary kiln solid waste incineration. Improvements in burn efficiency and environmental controls have been consistently made over time. In 2003, Dow completed upgrades to its incinerator to meet USEPA Maximum Achievable

Control Technology (MACT) standards for industrial incineration devices (Agin et al., 1984; Dow, 2006a).

In the mid 1930s, two tar burners were installed northwest of the present Michigan Operations waste incinerator. Liquid tars were burned inside vertical brick lined towers with combustion exhaust gases and particulates vented directly to the atmosphere. Fuel oil was used to assist in start-up and maintenance of the burner flame (Agin et al., 1984).

In 1951, a new vertical tar burner replaced these two units. Within the new 15-foot-diameter by 50-foot-tall brick-lined tower, four tangential feed nozzles dispersed process wastes in the unit, blended with supplemental fuel oil, for incineration. Combustion exhaust gases and particulates were vented directly to the atmosphere. This unit was removed from service in 1974 and demolished in the late 1970s (Agin et al., 1984).

In 1957, the 707 Building tar burner was constructed just east of the present Dow Michigan Operations waste incinerator. This unit provided air exhaust scrubbing equipment to reduce hydrogen chloride emissions when burning chlorinated tars. Depending on the materials undergoing incineration, the vent emissions could be diverted directly to a 125-foot stack or to a water quench chamber prior to venting to the atmosphere. This unit was removed from service in 1975 (Agin et al., 1984).

High temperature (approximately 1,000 degrees Celsius [°C], or higher) combustion of organic liquid tars began in 1968 with construction of the 830 Building tar burner. This unit operated at a temperature of 900 to 1,000°C with a tar feed rate of 10 gallons per minute (gpm). Combustion exhaust gases and particulates (30,000 cubic feet per minute [cfm]) were directed through a water quench system, venturi scrubber, and demister before stack discharge.

In 1975, chlorinated waste tars were directed to the afterburner of the rotary kiln incinerator (discussed below). In 1981, this unit was placed in standby mode to be used only for tar inventory control. The unit has not operated since December 1982 (Agin et al., 1984).

2.3.3 Combustion of Solid Wastes

Prior to 1948, solid wastes were either landfilled on the Michigan Operations site or stockpiled for open air burning. In 1948, a rotary kiln incinerator was placed in service to burn rubbish, waste solids, packs, and liquid tars. Solids were manually shoveled into the feed chute and various liquids were sprayed into the front of the kiln. Combustion exhaust gases and particulates were vented directly to the atmosphere (Agin et al., 1984).

In 1958, this original rotary kiln was replaced with a new dual rotary kiln system (703 Building Kiln No. 1 and Kiln No. 2) to burn paper and wood trash, solid chemical waste, chemically contaminated waste equipment, and a variety of liquid wastes. From 1958 to 1975, only Kiln No. 1 was used. This unit provided increased capacity and improved burner control. The operating temperatures in the rotary kiln ranged between 500 and 900°C with a 30-to 45-minute bulk solid residence time. Combustion exhaust gases and particulates were directed through a water-spray quench system before discharge to the atmosphere. In 1970, to reduce stack particulate emissions, a secondary combustion unit afterburner (using natural gas for supplemental fuel) was installed between the kiln and the quench chamber.

In 1975, Kiln No. 2 was placed into service and Kiln No. 1 was shut down. The Kiln No. 2 system included a rotary kiln, an improved afterburner and an air pollution control system consisting of a water quench system, venturi scrubber, and demister. Beginning in 1978, in response to research studies indicating that a higher temperature was needed to minimize formation of chlorinated dibenzo-p-dioxins and to assure their efficient destruction, natural gas was added to the afterburner to increase the temperature control point to approximately 1,000°C. In 1981, the addition of a wet electrostatic precipitator to the Kiln No. 2 system resulted in further reduction of particulate emissions to the atmosphere. By 1984, further improvements, including process computer control, increased the afterburner operating temperatures between 1,000 and 1,100°C with a residence time of a few seconds. Liquid wastes and tars were atomized either directly into the kiln or directed to the afterburner, with higher British thermal unit (BTU) liquid feeds and dichlorophenol distillation wastes sent directly to the afterburner and higher ash-containing feed directed first to the kiln. Mass flow measurements of 2,3,7,8-TCDD levels in the incinerator system in 1984 showed that the incinerator ash captured about one-half of the 2,3,7,8-TCDD and the exhaust scrubber equipment captured 95 percent of the remaining half (Agin et al., 1984).

Historically, wet kiln ash was lifted from the ash trough by conveyor belt to dump trucks for transport to onsite landfill disposal. In 1982, a building was constructed around the ash transfer operation to totally enclose the conveyor and truck loading operation. Ash handling methods were also implemented to prevent drying and dusting of kiln ash at all stages of loading, transport, and landfilling (Agin et al., 1984).

Prior to 1985, liquid waste being fed to the secondary combustion chamber burner of the kiln was atomized through the use of an air fan. The type of burner nozzle was changed to employ the use of steam atomization, which was more efficient, thereby lowering the amount of 2,3,7,8-TCDD that was formed. To lessen the amount of particulates, several improvements were added to the 703 incinerator in the 1987-1988 timeframe. The venturi scrubber was modified to employ a variable throat, which created a greater pressure drop. A series of high-efficiency water nozzles were added to the entrance into the quench tower. This greatly improved the efficiency of the venturi scrubber (Dow, 2006b).

In 1988, the secondary combustion chamber of the 703 incinerator was reconfigured. A high-efficiency vortex burner was installed just after the rotary kiln. This installation increased the secondary combustion zone residence time significantly and employed a highly efficient burner. These changes yielded 99.99 to 99.999 percent destruction and removal efficiencies (Dow, 2006b).

In 1990, another rotary kiln incinerator, 830, replaced the existing 830 tar burner. This unit had a 60-foot-long rotary kiln with two 30 million BTU per hour (BTU/hr) burners, and a large secondary combustion chamber with over 2 seconds residence time. This chamber was fitted with two 30 million BTU/hr vortex burners. From the combustion chamber, gases flowed through the following units: a rapid quench chamber, a hydrochloride (HCl) absorber, a variable throat venturi scrubber, a demister, an initial fan, four ionizing wet scrubbers, a second fan, and then to the stack. The air permit for this unit required 99.999 percent destruction and removal efficiency (Dow, 2006b).

Planning for the new, state-of-the-art 32 Building rotary kiln began in the late 1990s. The kiln was designed to burn both solid and liquid wastes. The kiln, which had two 35 million BTU/hr burners, was outfitted with carbon seals on both ends to greatly minimize the possible occurrence of fugitive emissions. Where older kilns often had less than 0.25 inch of water vacuum on the combustion chamber, the new kiln was designed to run at greater than 1 inch of water vacuum (Dow, 2006b).

By 2003, Dow had completed upgrades to its 32 Building rotary kiln incinerator to meet the USEPA MACT standard for industrial incineration devices. Exhaust gases from the rotary kiln pass into a large circular secondary combustion chamber having a 3.5 second retention time where three 30 million BTU/hr burners fire tangentially into the chamber. After the secondary combustion chamber, the gasses pass into a nitrogen oxides (NOx) reduction system then into a rapid quench designed to minimize dioxin formation. From the quench chamber, the flue gases pass into a packed condenser tower which removes most of the hydrochloric acid that is formed in the combustion process. The condenser tower also aids with the pre-treatment of particulates prior to entering the high-energy venturi scrubber. After the venturi, which removes the bulk of particulates in the gas stream, the flue gases pass into a packed tower chlorine scrubber. Sodium hydroxide is used to react with any remaining residual chlorine in the gas stream. After the chlorine scrubber, the gases are pulled through the first induced draft fan. From the fan, the gases pass through nine ionizing wet scrubber (IWS) units, which remove the last of the fine particulates from the gas stream. From the IWSs, the gases pass through a second induced draft fan and then up a 200-foot stack. At the stack, oxygen, carbon monoxide, sulfur oxides (SOx) and NOx are continuously monitored (Dow, 2006b).

Operation of the 32 Incinerator is required, through its current hazardous waste management facility operating permit (Condition VII.A.6), to comply with its Air Quality Division Renewable Operating Permit Number MI-ROP-A4033 and 40 CFR Part 63, subpart EEE, hazardous waste combustor MACT. Comprehensive Performance Tests of the 32 Building incinerator are required to demonstrate performance every 61 months of operation (roughly every 5 years). Dow completed Comprehensive Performance Tests for the 32 Building incinerator in 2003 and again in 2009. Both tests successfully demonstrated dioxin and furan emissions from the incinerator are substantially below federal and state emission requirements.

Since 1995, Dow has reduced dioxin emissions to the air by over 95 percent (Dow, 2006a). Accordingly, there is no material risk of further contamination or, after cleanup, of re-contamination via airborne emissions from Michigan Operations to Midland Area Soils.

After starting up the 32 Building kiln in 2003, the 703 Building and 830 Building incinerators were closed pursuant to Part 111 of NREPA. Whereas the older units were permitted to process 85 million BTU/hr and 60 million BTU/hr, the new 32 Building kiln was permitted to operate at 130 million BTU/hr. This reduction in capacity was possible because Dow had implemented new technologies to recycle wastes as useful raw materials (Dow, 2006b).

2.3.4 Airborne Deposition and Fugitive Dust Emissions

Exhaust constituents from process vents, power generation, and thermal incineration processes may have deposited onto plant soils. During dry periods, these soils may have been disturbed by equipment or vehicles and blown by the wind, resulting in fugitive dust emissions. Samples of Michigan Operations soils at the facility fence line generally show higher levels of dioxins than soils located further away in the City of Midland. Current information indicates that concentrations in Michigan Operations soils decrease radially from inside the plant outward, evidencing a windborne mechanism of dispersion. The Michigan Operations soils with the highest concentrations of dioxin were located near historic chlorophenolic production areas, the waste incinerator, and combustion ash handling facilities.

Fugitive dust control has been in progress at the Midland Facility since 1986. Dow is currently required by its Hazardous Waste Management Facility Operating License and its Renewable Operating Permit (Section 1, IX.4) to provide and regularly update an operating program to control fugitive dust sources or emissions. The current fugitive dust control program requires semi-annual review and updates. In addition, fugitive dust emissions from Michigan Operations are monitored on an ongoing basis along the plant perimeter pursuant to the "Soil Box Data

Evaluation Plan," approved by MDEQ on September 23, 2011. Monitoring began in 2004 and continues to show the fugitive dust control program for the facility is effective.

3.0 Summary of Investigations and Studies

The understanding of hazardous substances in Midland Area Soils prior to the current License was based largely on studies conducted by Dow in 1984 (Agin et al., 1984) and 1998 (Dow, 2000), U.S. Environmental Protection Agency (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 volatile organic compounds (VOCs), semivolatile organic compounds (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 target analyte list (TAL) development (discussed in Section 4.0), include the 2005/2006 Dow on-site (DOS) samples, the 2006 CH2M Hill samples and the 2010 Dow and MDEQ split sample results. Soil and household dust sampling results have been provided by the University of Michigan Dioxin Exposure Study (UMDES). Each of these investigations/studies are summarized below.

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 toxic equivalent (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 parts per trillion (ppt). The mammalian TEFs developed by the World Health Organization (WHO) are provided in Table 3-1. 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 3-1).

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 concluded 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 specifically recommends further actions:

1. <u>Additional incinerator emissions testing</u>

Incinerators that existed at the time have been closed. A modern incinerator was constructed and permitted in 2003. As noted above, 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 and again in 2009. Dow will continue to complete emissions testing in accordance with their current permit.

2. <u>Dust suppression program</u>

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. As described above, 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. <u>Point source and environmental monitoring programs</u>

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 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 Dow On-Site (DOS) Data Set—In September 2005 and June 2006, surface (0 to 1 inch below ground surface [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, polychlorinated biphenyls (PCBs), pesticides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and dioxins and furans.

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.

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.

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.

Data from the 2005/2006 Dow On-Site (DOS), 2006 CH2M Hill, and 2010 Dow and MDEQ split sample data sets were used to inform the Work Plan. 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.

4.0 General Site Setting, Land Use and Exposure Pathways

This section summarizes information on the general site setting, current land use, and human health exposure pathways.

4.1 General Site Setting

4.1.1 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 2000, the population of the City increased from 1,160 to 41,685 (U.S. Department of Agriculture, 1997; Dee, 2005). The city currently encompasses approximately 28 square miles.

4.1.2 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 (NOAA, 2010 and 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 4-1. The data used to develop the wind rose were obtained for the years 1987 through 1991 from a meteorological station located at Michigan Operations.

4.1.3 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, and constructed ditches used to store and convey storm water from developed properties. These ditches discharge water to the Tittabawassee River and associated tributaries. 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.

Natural watercourses other than the Tittabawassee River remaining in the area are concentrated northeast of Michigan Operations and the City. The flows from these creeks and drains enter the Tittabawassee River immediately upstream of Michigan Operations. A small tributary enters the Tittabawassee River downstream of Michigan Operations.

Small, natural ponds (less than 5 acres) and constructed retention and detention ponds are scattered throughout the area. Figure 4-2 depicts surface water bodies and the general topography in and around the area.

4.1.4 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 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.

4.1.5 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 Midland Resolution Area, 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.

4.2 Midland Land Use

The current land use within the study area was based on general knowledge of local conditions, evaluated by touring the area and reviewing aerial photographs and 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 study area is called the Midland Resolution Area. The Midland Resolution Area covers a total of approximately 1,700 acres. Land uses within the Midland Resolution Area include residential land use and non-residential land use. Figure 4-3 shows the land use areas within the Midland Resolution Area. The predominant land uses are defined and described further in the following subsections. The Midland Resolution Area is also described in further detail in Section 7.0.

The concentration of dioxin in the soil in the remainder of the City of Midland beyond the Midland Resolution Area is, based on current data, below the residential site-specific action level (see Section 6) and so will likely not require any work under this Work Plan. However, as explained in Section 9, the final boundary for the Midland Resolution Area will be adjusted, as necessary, based on soils data generated during implementation of the work and the physical features of the area.

4.2.1 Non-Residential Land Use

The area in the Midland Resolution Area 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. This is the area with the highest measured dioxin concentrations, although the concentrations are almost all below the generic non-residential direct contact criteria (DCC).

Properties with industrial or commercial land use within the Midland Resolution Area cover approximately 1,275 acres. The aerial extent of these areas with predominantly industrial and commercial uses is shown on Figure 4-3.

4.2.2 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 and therefore these properties will be managed as a residential use under this Work Plan. 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 uses for purposes of this Work Plan:

- 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.
- 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. Therefore, these uses will be managed as non-residential for purposes of this Work Plan:

- 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).

- 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 Midland Resolution Area, approximately 425 acres is residential land use. The aerial extent of the Midland Resolution Area is shown on Figure 4-4.

4.2.3 Outlier Areas

Three outliers have been identified where elevated discrete sample results have been measured that are inconsistent with adjoining results. All three areas were identified from the results of the 2006 blinded sampling activities. The first area (designated E-007) falls outside of the currently defined Midland Resolution area to the North, shown in Figure 4-5. It is generally located in a residential area southwest of the intersection of Washington St. and Ashman with a TEQ of 320 ppt. The second outlier (designated I-008) is located within, but along the northeast boundary of the Midland Resolution Area, shown on Figure 4-6. It is located within a wooded area owned by The Dow Chemical Company along the western side of Waldo Rd., across from Ridgecrest Rd., with a TEQ of 360 ppt. The final outlier (designated I-010) falls outside of the currently defined Midland Resolution Area to the northeast, shown in Figure 4-6. It is an undeveloped wooded area owned by The Dow Chemical Company, roughly ¼-mile east of Waldo Rd, north of Eagle Ridge Technology Park, with a TEQ of 290 ppt.

4.2.3.1 Zoning

The Midland Resolution Area 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.
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.

The zoning map for Midland is included as Attachment K to this Work Plan and current maps can be accessed online at:

http://www.midland-mi.org/government/departments/planning/planning/Zoningordinance.htm.

As further discussed in Section 7, the response actions discussed in this Work Plan have been selected to be consistent with and appropriate for the uses and zoning of property in the Midland Resolution Area.

4.3 Human Health Exposure Pathways

The primary source of hazardous substances from The Dow Chemical Company in the nearby Midland Area Soils is airborne deposition of particulates (USEPA, 1985). This section discusses the conceptual site model and human health soil exposure pathways.

4.3.1 Conceptual Site Model

A conceptual site model (CSM) describes the network of relationships between 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). The sources and transport and fate mechanisms are described below. The exposure pathways relevant for human exposure are depicted in the conceptual site model on Figure 4-6. The exposure pathway model reflects emphasis on dioxins/furans, which have been identified as the COC for this Work Plan. If determined to be necessary through on-going evaluation, other pathways and/or COCs will be addressed according to the proposed schedule presented in Section 10.2.

4.3.1.1 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 TEQ concentrations are predominantly found to the northeast (downwind) of Michigan Operations.

As part of developing the sampling strategy for the 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 ppt TEQ in the Midland Area Soils (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, 2007). 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 Midland Resolution Area.

4.3.1.2 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 VOCs) occur only in the vapor phase; concentrations of VOCs in air typically do not have an effect on surface soil. 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.

4.3.2 Exposure Pathways

Given the above-described source and transport mechanisms, the following are the 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).

Soil exposure is 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 comparing to site-specific cleanup criteria developed for particular contaminants. Because dioxins and furans do not volatilize and do not leach in material amounts into ground or surface water, only the first pathway described above (direct contact protection) is considered relevant for this Work Plan.

The groundwater medium is not included in this report since surface and near-surface soils are the media affected by air emissions and subsequent deposition. Soil-to-groundwater leaching is being evaluated for non-dioxin analytes. Section 5.0 of this report discusses the evaluation for potential non-dioxin COCs.

The formal evaluation of other pathways and/or COCs is on-going. Documentation of the conclusions and recommendations for additional measures or controls, if necessary, will be completed in accordance with the proposed schedule presented in Section 10.2.

5.0 Data Evaluation and Identification of Contaminants of Concern

5.1 Purpose

A significant effort has been undertaken to identify potential contaminants of concern (COCs) in relation to Midland Area Soils. The purpose was to develop a broad Target Analyte List (TAL) of potential COCs, and then narrow that list, through further evaluation and study, to the COCs for the Midland Area Soils. 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. In addition, a December 2010 investigation and follow up studies and analysis conducted by Dow will provide additional data to help determine if potential COCs other than dioxins and furans have the potential to leach to groundwater above applicable criteria. If the potential is demonstrated to exist, an additional corrective action to address to soil-to-groundwater leaching pathways may be required.

The following steps were completed as part of this task:

- Target Analyte List (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 Midland Area Soils;
- Screen TAL according to screening criteria; and
- Review and further reduce remaining TAL categories through collaborative meetings with MDEQ and U.S. EPA.

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

5.2 TAL Evaluation

5.2.1 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 5-1).
- 2006 CH2M Hill data set (locations of the grid cells are shown in Figure 5-2).
- 2010 Dow and MDEQ split sample data set (sample locations are shown in Figure 5-3).

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 3.0). 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).

5.2.2 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 Table 5-1 (metals), Table 5-2 (metals and all other non-dioxin constituents), and Table 5-3 (dioxin congeners and TEQs using the 2005 WHO TEFs) (Van den Berg et al, 2006, see Table 3-1).

5.2.3 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.

5.2.3.1 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).

5.2.3.2 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 (see Table 5-1).

5.2.3.3 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 chlordanes, endosulfans, methylphenols (cresols), PAHs, and xylenes and are discussed further below. 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).

5.3 TAL Data Screening Categories/Rules and Results

5.3.1 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 5-4.

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

- Group A1 – Analytes with all detected concentrations and reporting limits of nondetects below the Statewide Default Background level.
- Group A2 – Analytes with all detected concentrations and reporting limits 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 reporting limits met the MDEQ target detection limits.
- Group B2 – Analytes that were 100% non-detected and all off-site sample reporting limits met the MDEQ target detection levels.
- Group B3 – Analytes that were 100% non-detected and all reporting limits were less than or equal to all Part 201 criteria and EPA criteria for the given analyte.

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

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

Criteria Comparison (for detected analytes with Part 201 Criteria or EPA 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 reporting limits of nondetects were less than or equal to Part 201 criteria and/or EPA criteria.
- Group D3 – Analytes that were detected at a frequency greater than 5%, and all detected concentrations and reporting limits of nondetects were less than or equal to Part 201 criteria and/or EPA criteria.
- Group D4 – Analytes that were not detected at concentrations greater than Part 201 criteria and/or EPA criteria, but some reporting limits 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 EPA 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 EPA criteria.

As shown in Figure 5-4, 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 – Pending – Analytes that may be 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). The findings for Group E2 will be concluded in the RI Final Report.

- Group E3 – If this evaluation is necessary, an analyte may be eliminated if it is determined that it was not sourced by Dow. The findings for Group E3 will be concluded in the RI Final Report.

Each analyte was categorized and screened as discussed above and the results are shown in Table 5-4. The details of the screening process can be found in Table 5-1 (metals) and Table 5-2 (metals and all other non-dioxin constituents).

5.3.2 Results of Category Discussions

Screening categories C1, C2, D4, D5, and D6 were retained for further consideration and each of the analytes were evaluated through a series of meetings and conference calls that were attended by various MDEQ staff, EPA staff, Dow staff and their consultants. During these meetings, analytes were eliminated from the TAL based on a review of the following information:

- Statewide and/or regional background concentrations reported by MDEQ, supplemented by USGS and ATSDR;
- Fate and transport parameters;
- Spatial distribution; and
- Consideration of reported NOAEL values.

The resulting status of each analyte, and all of the supporting documentation, was provided in the *2010 Field Pilot Characterization Summary Report* (URS, 2011).

5.4 Findings of TAL Screening

The TAL evaluation confirmed that dioxins and furans are the COCs driving the presumptive remedy for the Midland Area Soils to address the direct contact pathway. Aside from dioxins and furans, arsenic is the only TAL analyte that has any sample results that exceed the residential direct contact pathway. Therefore, arsenic has been retained as a COC. A statistical evaluation was performed to determine if the locations of the arsenic direct contact exceedances correlate with dioxin/furan TEQ exceedances, and a correlation was found. Refer to Table 5-5, which provides a statistical demonstration of the correlation found between the dioxin/furan TEQ and arsenic. This evaluation demonstrates that soil that may exceed the generic DCC for arsenic also exceeds the proposed site-specific action level for dioxin/furan TEQ. This relationship was further confirmed by DEQ analysis of retained Midland soil samples for arsenic. No soil samples with TEQ less than the site-specific action level contained arsenic at levels above the generic DCC. Based on the correlation between the two analytes, any location that indicates that a presumptive remedy is necessary based on a dioxin/furan TEQ concentration, would also address the potential presence of arsenic. Therefore, samples will only require analysis for dioxin/furan TEQ to determine the need for a presumptive remedy.

The TAL analysis also ruled out a number of potential exposure pathways, including volatilization pathways. The conclusions for the remaining pathway (e.g., soil-to-groundwater leaching) for non-dioxin analytes will be presented in the RI Final Report.

5.5 Evaluation of Dioxin TEQ Results

Seventeen dioxin and furan congeners were analyzed for the three data sets (2005/2006 Dow On-Site [DOS] data set, 2006 CH2M Hill data set, and 2010 Dow and MDEQ data set), and the results for these congeners were used to calculate dioxin TEQ for each individual sample using the 2005 WHO TEFs (Van den Berg et al, 2006, see Table 3-1). The calculated dioxin TEQs were then used for subsequent data and statistical evaluation.

A table of summary statistics for dioxin TEQs by depth and by data set is presented in Table 5-6. The majority of the dioxin TEQ data were originated from the 2006 CH2M Hill set, and 2010 Dow and MDEQ set. The number of samples from the 2005/2006 Dow On-Site (DOS) set was very small (n=28), and it was evident that the dioxin TEQs were as much as two orders of magnitude higher than the other two sets. Thus, the 2005/2006 Dow On-Site (DOS) set (i.e., inside the Dow's plant) was deemed to be non-representative of the dioxin concentrations existing in the City of Midland soils (i.e., outside the Dow's plant). The following evaluation and discussion excluded the dioxin TEQs obtained from the 2005/2006 Dow On-Site (DOS) sampling event.

5.5.1 Determination of Depth of Dioxin and Furan Impacts

Table 5-7 shows the summary statistics of the combined 2006 CH2M Hill data set and 2010 Dow and MDEQ data set by depth for dioxin TEQs, and Figure 5-5 shows the box-and-whisker plot of this combined data set. Data from 0 to 1 inch bgs had the largest number of samples (n=361), followed by 1 to 6 inch bgs (n=173) and 6 to 12 inch bgs (n=138). The number of samples collected from greater than 1 foot bgs was also large (n=154), with the deepest depth at 4 feet bgs. It should be noted that data from the two deeper levels were exclusively collected from the 2010 event.

As shown in Figure 5-5, the highest dioxin TEQs appeared to be observed in the 1 to 6 inch bgs level, with a mean of 303 ppt and a median of 155 ppt. Given the data were positive skewed and not normally distributed, a non-parametric multiple comparison test using the Steel-Dwass method at a 5 percent significance level was performed to compare the four depth levels. The Steel-Dwass test is a non-parametric version of Tukey multiple comparison test, for which the alpha is sized for all differences among the means of different groups. The statistical outputs and results of this test are also shown in Figure 5-5.

The result of the multiple comparison test showed that the top two depth levels (0 to 1 inch bgs and 1 to 6 inch bgs) were not significantly different from each other. However, concentrations decreased in the third depth level (6 to 12 inch bgs), which appeared to be different and lower in concentration from the top two depth levels. A continued decrease in concentration was identified in the fourth depth level (>1 foot bgs).

Table 5-7 also shows percentage of dioxin TEQs exceeding 250 ppt and exceeding 300 ppt. Based on the percentage of exceedance, it appeared that the top three depths levels (i.e., from 0 to 12 inches bgs) have some exceedances. The fourth depth level, >1 foot bgs, had very limited exceedances. All the locations with samples >250 ppt at a depth >1 foot bgs have identified historic surface disturbances from industrial activity and possible filling based on a review of historical aerials (see Attachment 1 of the 2010 Field Pilot Characterization Summary Report [URS, August 2010]). Two locations are specifically known to have had filling take place, where cleaner materials have been placed over historic land surfaces. Based on the observed distribution of contaminants and what is known about the history of these areas, concentrations of dioxins and furans above 250 ppt are not evidenced or expected to be present in the deeper Midland Area Soils (greater than one foot from surface).

5.5.2 Determination of Small Scale Variability of Dioxins and Furans

Variograms were developed to evaluate the pattern and scale of spatial variability in dioxin TEQ concentrations. A variogram provides a means of quantifying the commonly observed relationship that samples close together tend to have more similar (correlated) values than samples far apart. The pattern of spatial correlation exhibited in a variogram helps to understand how homogeneous or heterogeneous the field of measurements (i.e., data set) is.

The *2010 Field Characterization Pilot Study Summary Report* provides a discussion of key components of a variogram, the data used to develop variograms for this study, and the actual variograms that were developed. The main findings are discussed below.

5.5.2.1 Findings of Variogram Analysis

The calculated points on the variograms in Figures 5-6 through 5-8 show a large degree of scatter around a fitted model. This is a reflection of significant random variability or noise (including potential measurement errors) between samples located close together (short-scale variability).

A nugget in a variogram is a measure of short-scale spatial variability, including random measurement error. Discrete points for a variogram plat are calculated using available sample data. A “best-fit” line is then drawn to fit these points. The nugget is estimated by the intercept of this line on the y-axis.

The nugget estimated for this study accounted for some 40% of the total variability in the long-range variogram. This is a further indication of sample measurements with significant short-scale variability. Given this significant short-scale variability in Midland Area Soils, measuring concentrations at individual sample locations would be highly variable. Measuring average concentrations over a larger area such as a property would help reduce the influence of the short-scale variability and hence would be more reliable.

5.5.2.2 Spatial Trend Discussion of the 2006 Transect Data

In 2006, CH2M Hill collected surface soil samples from the communities within the City of Midland on 21 transects radiating from Michigan Operations (but outside the plant’s boundary). These transects were labeled from A to W (Transect P and Q had no data), with the majority of them radiating to the northerly and easterly directions to reflect prevailing winds. There were between one and twelve stations in each transect, and each station was approximately 300 feet by 300 feet. The sampling locations of these transects are shown in Figure 5-2. Because the exact locations for a number of samples were "blinded," the number of available data points was actually less than what is shown in Figure 5-2.

Although a strong spatial continuity was not shown by the variogram evaluation discussed above, a qualitative inspection of the dioxin TEQ values for surface samples along each transect indicated a general downward spatial trend when the sample locations were moving further away from Michigan Operations. This general observation appeared to be more prominent for Transects B, C, E, I, and M. For example, for Transect B, the dioxin TEQ concentration for Station B-001 was reported to be 379 ppt. The dioxin TEQ concentration continued an apparent monotonic decline along Transect B until it reached 75 ppt at Station B-009. (Note: Stations B-010 and B-011 were "blinded.") For Transect M, if one excluded the first station (Station M-001), the dioxin TEQ concentration declined from 915 ppt at Station M-002 to 44 ppt at Station M-011.

6.0 Summary of the Basis for the Residential Site-Specific Action Level

This section presents the basis for the residential property site-specific soil direct contact action level (SSAL) developed and proposed for dioxin/furan TEQ. The SSAL will serve as the threshold trigger level for requiring presumptive response activities at a particular residential property. The proposed SSAL is 250 ppt TEQ. For the City of Midland, a SSAL for dioxin/furan TEQ of 250 ppt TEQ (based on the 2005 WHO TEFs [Van den Berg et al, 2006]) is protective of the public health, safety and welfare and appropriately takes certain updated and site-specific information into account while leaving a protective margin of safety. This action level will serve as a "site-specific cleanup criterion" as described in Part 201 of Michigan's Natural Resources and Environmental Protection Act.

The SSAL is a site-specific criterion that applies in lieu of the MDEQ's default generic direct contact criterion for dioxin/furan TEQ of 90 ppt. The default and site-specific parameter inputs and equations are shown below:

Parameter Inputs		MDEQ Default	Site-Specific
TR	target risk (unitless)	1.00E-05	1.00E-05
AT	averaging time (days)	25550	25550
CF	conversion factor (ng/kg)	1.00E+12	1.00E+12
SF	cancer slope (mg/kg-day)-1	7.50E+04	7.50E+04
EFi	ingestion exposure frequency for soil and dust (days/yr)	350	260
IF	age-adjusted soil ingestion factor (mg-yr/kg-day)	114	114
AEi	ingestion absorption efficiency (unitless)	0.5	0.38
EFd	dermal exposure frequency for soil and dust (days/yr)	245	260
DF	age-adjusted soil dermal factor (mg-yr/kg-day)	353[a]	353
AEd	dermal absorption efficiency (unitless)	0.03	0.032
SDCF	soil and dust contribution factor (unitless)	--	0.5
EFi-dust only	ingestion exposure frequency for dust only (days/yr)	--	90
EFd-dust only	dermal exposure frequency for dust only (days/yr)	--	90
RDSF	relative dust:soil concentration factor (unitless)	--	0.5
Parts per trillion (ppt) TEQ[b]		**9.0E+01**	**2.6E+02**

Note:
[a] MDEQ originally used an age-adjusted DF of 2,442 mg-yr/kg-day when the generic direct contact criterion of 90 ppt TEQ was developed. However, MDEQ has since adopted and promulgated an updated DF of 353 mg-yr/kg-day.
[b] TEQ is calculated based on the 2005 WHO TEFs ([Van den Berg et al, 2006], see Table 3-1).

$$MDEQ\_Algorithm = \frac{TR \times AT \times CF}{SF \times \left[\left(EF_i \times IF \times AE_i \right) + \left(EF_d \times DF \times AE_d \right) \right]}$$

$$Site-Specific\_Algorithm = \frac{TR \times AT \times CF}{SF \times \left[\begin{array}{l} SDCF\left(EF_i \times IF \times AE_i \right) + SDCF\left(EF_i \times IF \times AE_i \times RDSF \right) + \left(EF_{i-dustonly} \times IF \times AE_i \times RDSF \right) \\ + SDCF\left(EF_d \times DF \times AE_d \right) + SDCF\left(EF_d \times DF \times AE_d \times RDSF \right) + \left(EF_{d-dustonly} \times DF \times AE_d \times RDSF \right) \end{array} \right]}$$

The SSAL is based on the following modifications to the exposure variables that MDEQ used to calculate the state-wide generic cleanup criterion in order to better reflect the best available information.

- ***Relative Dust:Soil Concentration Factor (RDSF)***

  Based on data from the University of Michigan's Dioxin Exposure Study, concentrations of dioxins in house dust in the City of Midland are consistently lower than in composited outdoor soil samples surrounding the house. Specifically, the UMDES linear regression model indicates that indoor house dust dioxin concentrations are between 19% and 35% of the outdoor soil concentrations. Paired dust and soil TEQ values from the UMDES study are not available at this time. An evaluation of unpaired summary statistics indicates that the dust:soil concentration ranges up to approximately 50% (fractional TEQ concentration 0.30 - 0.54). Therefore, the default dust:soil concentration ratio of 1 is too high. The fractional concentration of TEQ for dust from soil in the site-specific equation is 0.5, to better represent site-specific information.

- ***Exposure Frequency (EF) and Soil:Dust Contribution Factor (SDCF)***

  The MDEQ generic direct contact calculation assumes incidental ingestion of contaminated soil 350 days per year based on the rationale that incidental ingestion of indoor dust can occur on "indoor" weather days, replacing the outdoor soil ingestion assumed for those days. This value also assumes that dioxin concentrations in outdoor soil and indoor dust are the same. It is appropriate to adjust for the site-specific relationship between indoor dust and outdoor soil in Midland, taking into consideration site-specific weather data. Based on local weather data, soil exposure frequency (incidental ingestion and dermal contact) of 260 outdoor days per year and a dust exposure frequency of 350 days per year are appropriate. Soil and dust exposure each contribute half of the soil/dust exposure for the 260 outdoor days (hence a soil and dust contribution factor [SDCF] of 0.5), and the other 90 days (indoor days) are 100% dust exposure. Therefore, Midland-specific weather data is being used to adjust the EFi (for soil and dust) from 350 to 260 days per year with the addition of an "indoor" EFi (dust only) of 90 days per year. The EFd (for soil and dust) is being adjusted from 245 days to 260 days per year with the addition of an "indoor" EFd (dust only) of 90 days per year.

- ***Ingestion Absorption Efficiency (AEi)***

  The current generic AE_i for dioxin is set at 50%. Dow has conducted site-specific rat and juvenile swine studies to determine the relative bioavailability (RBA) of dioxin in Midland soil. MDEQ's evaluation of the studies determined that both animal studies appear equally valid, and therefore has suggested that a midpoint value of the studies be used. Accordingly, the AE_i is reduced from the default of 50% to 38%.

- ***Age-Adjusted Soil Dermal Factor (DF)***

  When MDEQ calculated the generic direct contact criterion of 90 ppt TEQ, MDEQ used an age-adjusted soil dermal factor (DF) of 2,442 mg-yr/kg-day, which was the default value at that time. Subsequently, MDEQ has adopted an updated default DF of 353 mg-yr/kg-day, which it has used for all subsequent direct contact criterion calculations for many compounds. This updated DF is based primarily on MDEQ's adoption of lower soil adherence factors (AF) for the DF calculation, from an AF of 1.0 mg/cm^2 for both children and adults, to new values of 0.2 mg/cm^2 for children and 0.07 mg/cm^2 for adults. These changes are consistent with the recommendations of U.S. EPA in its dermal risk assessment guidance. The updated DF of 353 mg-yr/kg-day is used for this site-specific calculation.

- ***Dermal Absorption Efficiency from Soil (AE_d)***

  The AEd represents the fraction of the contaminant that is assumed to penetrate the skin after contact. For dioxin, the generic value is currently set at the compound-based value of 3%, representing an upper bound value of two study approaches supporting values of 0.95 and 2.5%. MDEQ has previously recognized that both approaches appear equally valid, and therefore has suggested that a midpoint value of 1.75% be used in place of 3%. Dow has provided information showing the relatively high percentage of organic content in Midland soil, which further supports using a value less than the upper bound value of 3%, and lends additional site-specific support to MDEQ's earlier suggestion to use 1.75%. However, the EPA dermal guidance recommends the soil dermal absorption rate be divided by the feed absolute bioavailability value (EPA, 2004). Therefore, the value recommended as the best available information for dermal absorption efficiency is the 0.0175 soil dermal absorption rate divided by the feed absolute bioavailability value (ABS_{GI}) of 0.55, which results in a relative bioavailability rate of 0.032. The ABS_{GI} value of 0.55 was derived from the rat feed results from the pilot bioavailability study (Dow, 2005).

Adoption of all of the above changes results in a calculated dioxin action level of >250 ppt TEQ. The SSAL that is proposed for the City of Midland is 250 ppt TEQ. A SSAL of 250 ppt TEQ is protective of the public health, safety, and welfare and appropriately takes updated and site-specific information into account, while leaving a margin of safety. The SSAL will only apply to residential properties (and "residential-like" properties, such as daycare centers). For non-residential properties within the Resolution Area, the State's generic soil direct contact criterion for non-residential properties of 990 ppt TEQ will be applied.

7.0 Exposure Management and Response Action Summary

Response actions will be applied for specific areas in proximity to Michigan Operations that have elevated concentrations of dioxins and furans TEQ or a presumptive remedy described below. Land uses in these specific areas include residential, commercial/industrial, retail commercial, public/semi-public, and parks and recreation. Requirements for management of exposure to surface soil contamination are dependent on current and reasonably anticipated future land use. Response actions will be performed to address direct contact exposure to dioxins and furans in soils and as necessary, dust accumulated in dwelling(s) ducts where soil is demonstrated to be above the action level relevant to land use, as described below. In conjunction with the response actions, institutional controls such as zoning and land use changes will be incorporated.

Figure 7-1 presents an overview of the area that has been initially identified as the Midland Resolution Area (described below). The boundaries of this area will be refined based on data collected during the design sampling work. This area has been initially defined based on previous soil sampling results and an analysis of fate and transport information, which indicate that areas outside the Resolution Area are unlikely to be contaminated above action levels. Design sampling will verify this and adjustments will be made to the area as new data are collected, as described in Section 9. Outlier areas, which have the potential for concentrations of dioxins and furans above the SSAL, have also been identified and will be managed as described in this Work Plan. If additional outlier areas are identified from new information, they will be addressed in the same manner.

7.1 Midland Resolution Area

The Midland Resolution Area covers approximately 1,700 total acres. Of the 1,700 acres, approximately 425 acres are in residential or residential-like land use. Approximately 1,275 acres are in industrial/commercial land use. The Midland Resolution Area includes portions of the City of Midland where land use is primarily residential and others near Michigan Operations where a limited number of residential properties (some not conforming with existing zoning) are intermixed among predominantly commercial or industrial uses. The predominantly residential areas are in large part located to the north of the facility, in addition to a second smaller area to the east of the facility. Figures 7-2 and 7-3 present an overview of the two predominantly residential areas within the Midland Resolution Area. Figure 7-4 presents an overview of the area with predominantly industrial/commercial land use within the Midland Resolution Area. The Midland Resolution Area is largely contiguous to Michigan Operations to the north and east of the fenceline. The boundaries of the Midland Resolution Area are generally:

- Bound to the north by East Nelson Rd. and East Lawn Rd.;
- Bound to the west by Rodd St.;
- Bound to the east by Waldo Ave; and
- Bound to the south by East Patrick Rd and East Indian St.

Implementation of the presumptive remedy will begin in areas that are the closest to Michigan Operations and then progress outwards in bands across the Midland Resolution Area in subsequent years. Some residential properties close to the plant site will be addressed during the second year of work rather than the first year (note that these properties previously received or were offered interim response activities [IRAs] to control exposure in 2005).

The Midland Resolution Area will be subdivided into large property grouping, based on the number of properties that may be reasonably addressed based on current knowledge of the area within one construction season (April-October). The intent is for all field activities – from sampling and analysis to implementation of the remedy – for the property grouping to be addressed within one construction season. Changes to the schedule through the Adaptive Management Process (Section 9) may be made during the project; if improvements or efficiencies can be made; or if other factors make it appropriate to do so.

Figure 7-5 shows the proposed property groupings designated by current block designation for implementation (A, B, C, etc.). The property groupings presented in this Plan were selected based on distance from the site. The plan for Year 1 implementation is discussed in detail in Section 8.0, and is shown on Figure 7-5 as the “A” property grouping. As the implementation proceeds farther away from the Michigan Operations facility, adjustments may be made to the schedule or property groupings. The boundaries of the Midland Resolution Area may be adjusted in consultation with oversight and approval from MDEQ as necessary to meet work plan objectives. The table below presents details for each property grouping, including the total number of properties, number of residential properties, and acreage.

Property Group	Total Number of Parcels	Residential Parcels	Total Area (acres)	Residential Acres
A	113	106	38.6	Housing = 28.3 Parks & Rec = 3.75
B	336	299	78.5	Housing = 59.6 Parks & Rec = 6.9 Public/semi-public = 0.8
C	302	268	80.5	Housing = 57 Parks & Rec = 3.2 Public/semi-public = 8.6
D	347	330	100.5	Housing = 80.7 Parks & Rec = 10.8
E	184	178	58.2	Housing = 42.3 Parks & Rec = 0.9 Public/semi-public = 14.8
F	121	115	89.4	Housing = 34.9 Parks & Rec = 3.7 Public/semi-public = 50.1

7.2 Outlier Areas

During the 2006 blinded transect sampling activities, transect sampling areas E-007, I-008 and I-010 were sampled and each exhibited a detected concentration of dioxin and furan TEQ at a level greater than 250 ppt in a discrete sample. E-007 is located north of the currently defined Midland Resolution Area. The specific location of this area is identified in Figure 4-5. I-008 is located along the east boundary of the currently defined Midland Resolution Area, and I-010 is roughly ¼-mile to the east of the boundary, as shown in Figure 4-6.

The outlier areas will be assessed following the same decision rules as presented in Section 7.4.4. For the properties in E-007, if results of composite sample testing are less than the SSAL, no further action is required beyond notification to the property owners of the results of testing. If a composite sample testing result from a property in E-007 is greater than the SSAL, the following actions will occur:

- Remedy will be implemented consistent with that described in Section 7.3; and
- Composite samples from adjoining properties will be obtained and tested for dioxin and furan TEQ.

Outlier areas I-008 and I-010 are each owned by The Dow Chemical Company. Each will be evaluated as a single 2-acre DU (per Section 7.4.3.1) for the purposes of confirmation sampling. If results of composite sample testing from the I-008 or I-010 DUs are less than the SSAL, no further action is required. No further sampling will be required when the available information indicates that the outliers either are shown to be less than 250 ppt TEQ or have been bounded. For E-007, this will include a buffer of at least three properties that have a consistent pattern (based on analytical results) of concentrations below 250 ppt TEQ, contiguous to any property above 250 ppt TEQ. Any recommendation for no further sampling or adjustments to the outlier boundary area will be based on trends identified by the analytical results, as well as the physical features and age of property development of each area.

If a composite sample result from either I-008 or I-010 DU is greater than the SSAL, a workplan will be submitted for MDEQ review and approval to complete the definition of the Midland Resolution Area boundary in this area, including a schedule for implementation.

7.3 Current Land Use

The Midland Resolution Area includes approximately 1,750 total properties that are broken generally into the following land uses:

- 1,330 residential properties.
- 40 residential-like properties (park, school).
- 380 non-residential (commercial, industrial, public).

The properties designated as residential-like properties include daycares, schools for children, and parks with playgrounds (see Section 4.2.2). These properties are being addressed as residential based on the assumption that exposures are similar to or consistent with those at residential properties. All remaining areas are classified as "non-residential." Figure 4-3 shows general land use areas within the Midland Resolution Area.

7.4 Response Action Addressing Residential Land Use

The remedial objective for the Midland Resolution Area for residential and residential-like properties is to reduce the dioxin and furan TEQ in impacted areas to a concentration that is below the SSAL. The objective will be achieved by implementing a presumptive remedy for any area that has dioxin and furan TEQ concentrations greater than the SSAL in the top six inches of soil as determined by incremental composite sampling. A phased approach that involves sampling and analysis to identify properties where a presumptive remedy will be implemented will be used to methodically work through the properties located within the Midland Resolution Area. The sampling and analysis will be accomplished through incremental composite sampling, following methods that were optimized by the results of a pilot study documented in the *Incremental Composite Sampling Pilot Study Report* (January 2012). The samples collected will be analyzed for dioxins and furans. Decision rules establish standards for determining whether or not the presumptive remedy may be warranted for a property and are discussed in further detail later in this section. The Decision Rules will guide the use of analytical results to identify properties that are either below or equal to the SSAL or require implementation of the presumptive remedy.

In general, the presumptive remedy for residential and residential-like properties would consist of removal of soil to a minimum depth of one foot and replacement with clean soil. This remedy is appropriate, based on the understanding of depth of dioxin and furans and the effectiveness of the remedy. Confirmation sampling will not be implemented as part of the remedy. The presumptive remedy removes soil to a depth where SSAL exceedances could occur and replaces soil with clean fill. Therefore, confirmation sampling is not necessary. Lawns and landscaping will be restored to existing conditions. Implementation and other special conditions, are described in detail in the following sections.

For those properties where remedy is determined to be necessary, an evaluation of whether the presumptive remedy needs to include additional action to address dust accumulated in the duct work of the dwelling(s) will be performed. If necessary, the presumptive remedy for addressing accumulated dust is duct cleaning. This is further discussed in Section 7.4.7.1.

To address where property owners decline to provide access for the sampling or remedial work, Dow will establish a trust to fund the performance of the remedial work in the future. The trust fund is described in Section 7.5.1.

7.4.1 Decision Unit

A decision unit (DU) is an area for which an individual remedial decision is made. A DU is equivalent to an exposure area or may represent an agglomeration of exposure areas with similar characteristics. Typically, a DU will consist of one residence. A DU will extend to the farther of the property line, an adjoining fence, curb line, pavement edge, or the top edge of a drainage ditch or creek, including outlawns associated with the property that are not owned by the property owner but are functional parts of the owner's property, provided that separate sampling access for these areas is obtained. Wooded areas above a specified size (as defined in Section 7.4.3.1) will not be included as part of the residential use DU and will be managed as a separate DU. Decision rules will be utilized to compare the results of soil testing at each DU to determine if the presumptive remedy will be implemented at that DU.

7.4.2 Obtaining Access from Current Property Owners

Dow will use best efforts to obtain appropriate access from property owners to conduct sampling on their property. For the purposes of this presumptive remedy, best efforts are defined as follows: an initial letter, a first and second follow-up telephone call, certified letter, and an in-person visit. A meeting will be requested with the current property owner to review the proposed actions and to obtain an access agreement and permission to permit Dow to conduct sampling activities and the remedial work (if applicable) specified in this Work Plan. An example agreement form (Midland Soils Sampling Agreement Form) is presented in Attachment D. Dow and its contractors will work closely with property owners to inform them of the planned process, the implications of the field implementation, in addition to providing the results of the sample analysis.

7.4.3 Soil Testing

This section describes how information is gathered for the remedy determination. Sampling is based on current land use, physical attributes of the property and DU area size. Individual DUs that are in residential use include both single and multi-family dwellings. Properties that are being treated as residential-like include such categories as parks, schools for children, daycare centers, and playground areas, as discussed in Section 4.2.2, and other public areas on a case-by-case basis.

7.4.3.1 Sample Collection

Samples obtained from an individual DU are collected from a number of locations (increments) and combined into a single sample (composite) representative of the entire DU. This technique is commonly referred to as incremental composite sampling (IS). The increment collection locations within each DU are generated using a systematic random approach. In the systematic-random pattern, a random starting point is generated and then subsequent increment locations are established on an even spacing within the remainder of the DU. The increment collection locations are created in Geographic Information System (GIS) in advance of the sampling activity. The planned sampling locations for a DU are loaded into handheld global positioning system (GPS) units for use by field teams to identify sampling locations. In the field, each increment collection location will be clearly identified by a member of the field team with a survey flag prior to the sample collection. After a soil core has been collected at a location, the survey flag will be removed to help verify all planned increments have been collected.

At each DU, actual conditions may differ from those understood during sample plan generation. The field team will make best efforts to sample at the planned locations, but will necessarily use the following guidelines in the field to adjust increment locations on an as-needed basis:

- Increments will not be located under or within paved or impervious areas or stationary structures (e.g., decks, porches, pools).
- Increment locations shall be no closer than three feet (3’) from existing structures or wooden utility poles.
- Increment locations will be selected no closer than twelve inches (12”) from existing roads and paved parking lots and paved driveways.
- Increment samples will not be collected in areas visually observed to be impacted by oil or other petroleum products.
- Increment locations will be no closer than three feet (3’) from in-yard garbage/compost piles, burn containers, vehicles in repair or abandoned, or other “junked” items.
- Increment locations will be offset from identified utility or sprinkler locations.

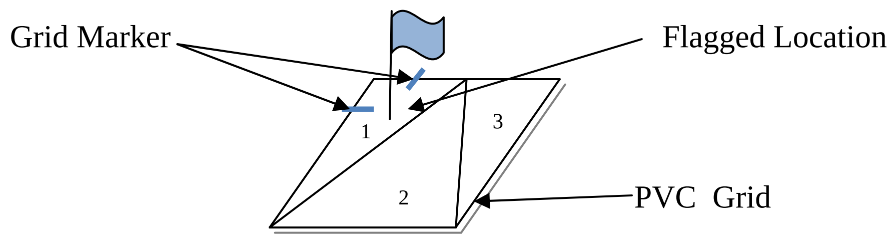
- Increment locations will not be within drainage ditches and creeks.
- Increment locations will not be taken immediately adjacent to tree trunks or large bushes.
- Increment locations will be offset from raised bed gardens.
- Increment locations will be offset from other possible interferences which may prevent the collection of a representative sample.
- Increments will be offset from areas where access has not been granted.

Before field teams collect any sample, polyethylene sample collection bags and a sample collection log are labeled with:

- Unique Sample Identification;
- Field sampler's initials;
- Date (mm/dd/yy); and
- Time of sample collection (military format).

Soil cores (increments) will be collected using stainless steel push samplers or an Enterprise Venture Corporation (EVS) Incremental Sampling tool (or equivalent) to ensure that each increment is collected at the same depth and volume. Each increment is collected from 1" diameter cores to a depth of 6" below ground surface. For properties where the property owner provides information establishing that the existing lawn has been significantly landscaped or fill placed across much of the property, a second set of increments to a depth of 12" below ground surface will be collected. The individual increments are field composited.

Increments will be collected at consistently off-set positions from the flagged increment collection location using a custom made polyvinylchloride (PVC) grid, divided equally into a flag placement location and three (3) cells (equal to the number of increments to be collected for replicate samples for each location within a sampling unit). One corner of the grid is marked as the placement location and each cell within the grid is labeled consecutively with a number from 1 to 3 (see sketch below). Field replicates for incremental samples are not field splits; they are independently collected incremental samples from the same decision unit.



At each increment collection location the placement corner marked on the grid will be lined up with the increment collection flag. Then an increment will be collected from the approximate center of each cell in the grid and added to the composite while in the field. Increment collection will not be biased to avoid vegetation. However, vegetation will not be included in the analysis of the soil sample. Increments from each location will be obtained as field teams move their way across the decision unit, removing the increment location flags as samples are collected.

After field collection, increment samples will be brought back to a clean designated workspace for further processing before compositing and delivery to the laboratory. At a minimum, each sample will be sieved before packaging for laboratory delivery. During this step the vegetation will be broken in smaller pieces to release trapped particles and then will be extracted from the soil sample. The majority of vegetation (mostly grass and roots) typically does not pass through the sieve and therefore is not part of the subsample extracted for analysis.

The following procedures will be employed when processing samples:

1. ¼” sieves and bowls will be decontaminated prior to use, and in-between each composite sample.
2. The field sample (or portion of the field sample) will be carefully emptied onto the sieve placed on the large stainless steel or aluminum bowl. If the entire sample cannot be placed on the sieve at once, portions of the sample will be sieved into the large stainless steel or aluminum bowl.

3. The soil material will be pushed around the sieve and the sieve will be agitated to move the soil through the sieve and retain the vegetation on the sieve. A clean pair of nitrile gloves will be worn by the field technician. The retained vegetation will be disposed.

Once the samples are processed, all samples will be packed for delivery to the Dow laboratory. Processed samples will be returned to the original polyethylene sampling bag if possible or into a new clean polyethylene sampling bag. All samples will be double bagged by placing the sample in an outer polyethylene sampling bag, labeled as described above. Samples will be placed in coolers with chain-of-custody forms and delivered to the laboratory for login and storage.

Three replicate incremental composite samples will be obtained from each DU, with the number of increments based on its area. The area for a DU is determined as the area not covered by buildings, large immovable features (decks or pools) and paved areas. A single composite will be obtained from ten (10) increment locations for DUs less than or equal 1/4-acre. A single composite from twenty (20) increment locations will be obtained for DUs greater than 1/4-acre, but less than 1 acre.

Specific sample plans will be developed for DUs that are larger than one acre on a case-by-case basis prior to sampling each year. Properties may be divided and sampled separately as multiple decision units (where splitting the DU is logical) or individually with >30 increments per DU.

Some properties within the Midland Resolution Area have densely wooded areas within the property boundaries. Exposure and land use are different for wooded areas than exposure and land use for mowed and maintained lawns and may require separate evaluation as described below.

The minimum lot size that can be developed by building a structure as a residence within the City of Midland is 7,200 square feet. Wooded areas less than 7,200 square feet on active residential lots are considered de minimis and will be sampled as part of the residential DU. Wooded areas comprising an entire parcel (or nearly so), with no active residential use will be identified as non-residential, and will be addressed according to Section 7.4.6.

Wooded areas larger than 7,200 square feet on an individual parcel with a current land use of residential or residential-like are considered non-residential areas, due to their limited use for the purposes of this project; and will be addressed as a separate DU. Samples will be collected from this area upon approval of the property owner.

A property owner may provide permission for sampling for the residential DU, woodland DU or both at their discretion. These options for sampling will be discussed with the owner during individual meetings, as described in Section 7.4.2.

Quality assurance for soil testing (including replicate and split sampling procedures) is used to validate analytical methods, but is not included in remedial decisions. Specific procedures are outlined within the Quality Assurance Project Plan (QAPP, Attachment C).

7.4.3.2 Laboratory Sub-Sampling

When the soil samples are delivered to the laboratory, the compounds of interest must be extracted from the soil and transferred to a liquid for injection into a gas chromatogram (GC). For this study, up to 3kg samples may be delivered to the laboratory, and an extraction performed on a 30g subsample. Sub-sampling in the laboratory will be accomplished by taking the entire 3kg sample as delivered in the polyethylene bag, and mixing in the bag. Individual ~1g subsamples will be obtained using a lab spatula, mixing the bag between subsamples. This will be repeated until a total of ~30g are obtained for extraction. Recent field pilot studies have confirmed the effectiveness of this technique (URS, January 2012).

7.4.3.3 Analytical Methods

A method has been developed by Dow analytical chemists by adaptation of existing EPA Method 8280 for rapid determination of polychlorinated dibenzo-p-dioxins (PCDDS) and dibenzofurans (PCDFs) in soil by high resolution gas chromatography/high or low resolution mass spectrometry (HRGC/HRMS or HRGC/LRMS). It is specific to the Midland Area Soils (MAS). This method was developed to decrease the time necessary for each laboratory analysis. The Standard Operating Procedure (SOP) for Method 8280 was submitted to MDEQ and EPA on June 29, 2011 and was approved for use on October 21, 2011. A copy of the SOP is included as Attachment B.

This is referred to as the Method 8280 Midland Area Soils (MAS) Site-Specific Fast Analysis method and it will be the principal means used for laboratory analyses. Additional methods, such as EPA Method 1613b with additional chromatographic column confirmation, will be performed as required. In cases where interferences are identified, analytical options and performance criteria are discussed in detail in the Method 8280 MAS Site-Specific Fast Analysis Method Quality Assurance Project Plan (QAPP). The QAPP is contained in Attachment C, a draft of which was previously submitted for review on September 6, 2011.

7.4.4 Decision Rules for Residential Land Use

This section sets forth the decision rules for the response actions and how the information obtained will be used to inform them. At the scale of the DU, soil testing results will be used to determine if the presumptive remedy is warranted.

As shown on Figure 7-6, the first of the three composites collected in a single DU will be tested at the laboratory by Method 8280 MAS. If the result indicates that a concentration less than or equal to 220 ppt TEQ (30 ppt less than action level), soil testing is complete and cleanup of the property will not be necessary. If the result determines a concentration greater than 280 ppt TEQ (30 ppt above the action level), soil testing is complete and the presumptive remedy will be performed at the DU as specified in the Work Plan. Concentrations measured greater than 220 ppt TEQ and less than or equal to 280 ppt TEQ will result in testing of all three replicates by EPA Method 1613b with additional column confirmation analyses. A 95% Upper Confidence Limit (UCL) will be developed from the three analytical results. The 95% UCL will be compared to the SSAL of 250 ppt TEQ. If the 95% UCL is less than or equal to 250 ppt TEQ, performance of the presumptive remedy at the property will not be necessary. If the 95% UCL is greater than 250 ppt TEQ, performance of the presumptive remedy will be implemented as specified in this Work Plan at that DU.

As shown on Figure 7-7, for properties where the property owner provides information establishing that the existing lawn has been significantly landscaped or fill placed across much of the property, the standard decision rules established above are supplemented to verify that impacted soils are not present in the upper 12” of soil. Additional evaluation is necessary if the upper 6” is less than 280 ppt TEQ. In that case, one of the 0-12” samples (Section 7.4.3.1) will be tested at the laboratory by Method 8280 MAS, and a concentration for the 6-12” interval will be determined (see Note 1 on Figure 7-7). If the result indicates that concentrations of the 0-6” and 6-12” intervals are less than or equal to 220 ppt TEQ (30 ppt less than action level), soil testing is complete and cleanup of the property will not be necessary. If the result determines a concentration greater than 280 ppt TEQ (30 ppt above the action level), soil testing is complete and the presumptive remedy will be performed at the DU as specified in the Work Plan. Concentrations of either interval determined to be greater than 220 ppt TEQ and less than or equal to 280 ppt TEQ will result in testing of all three replicates for the interval with the highest concentration by EPA Method 1613b with additional column confirmation analyses, and subsequent derivation of a 95% UCL (see Note 2 on Figure 7-7). If the 95% UCL is greater than 250 ppt TEQ, performance of the presumptive remedy will be implemented as specified in this Work Plan at that DU. If the detected concentration at the DU is less than or equal to the SSAL, dust accumulated in the dwelling(s) duct work will not require a remedy. If the detected concentration at the DU is greater than the SSAL, further evaluation of exposure to dust accumulated in the dwelling(s) duct work will be performed as per Section 7.4.7.1.

7.4.5 Communication of Results to Property Owner

Dow will provide written notification of the results of soil testing to the individual property owners in a timely manner. The written communication will briefly describe the next steps for the property owner based on the testing results. Written notification will include contact information for both MDEQ and Dow representatives who will be available to discuss the information reported to the property owners. Example letters that may be used to communicate results to the property owners are presented in Attachment E.

7.4.6 Property-Specific Plan for Presumptive Remedy

The presumptive remedy for each residential or residential-like property undergoing remediation will include removal of the upper twelve inches (12”) of existing landscaping and soil, followed by replacement with new soil, lawn, and landscaping. Adjustments to this default plan will be made for properties as required to preserve non-replaceable plants and mature trees.

Wooded areas as defined in Section 7.4.3.1 will not have a presumptive remedy applied until land use is changed by an owner from wooded area to residential use. Discernible, accessible and maintained trails, fire pits, and other actively used portions of wooded areas will receive targeted exposure control measures (such as placement of groundcover or replacement of soils in play areas or fire pits) where the wooded area or the maintained portion of the residential property are determined to be above the action level. Funding for future remedy will be addressed through the Trust (discussed in Section 7.6.1). In the unlikely event that a wooded area as defined in Section 7.4.3.1 is determined to be greater than generic non-residential direct contact criteria, the property will be addressed as defined for non-residential properties (Section 7.5.1).

For properties where the presumptive remedy is required, Dow will make best efforts to obtain appropriate access from the property owners for implementation of the property-specific presumptive remedy. During a property visit, Dow will communicate details regarding the presumptive remedy sampling effort and possible implications based on analytical results. Dow, along with the property owner, will develop and document property-specific remedy plans that meet the work plan objectives and address special concerns of the property owner. At this time, the property owner will have the opportunity to communicate specific concerns regarding unique features of their property. These unique features will be documented on the agreement form (see Midland Soils Cleanup Agreement Form in Attachment D).

During the property visit and after the site-specific plans are identified, Dow or its contractors will ask the property owners to grant access to Dow, MDEQ and the implementation contractor to implement the presumptive remedy activities. Approval to access the property to implement actions and complete follow-up activities will be documented on the agreement form (see Midland Soils Cleanup Agreement Form in Attachment D).

A schedule of field activities will be provided to the property owner. Coordination of field activities will be planned in a manner to minimize impact to property owners and to complete work in the same construction season in which the samples were collected, to the best of Dow's ability.

7.4.7 Completion of Presumptive Remedy

Remedy implementation will include utility identification, erosion control, soil removal and management, backfill and site restoration and vegetation replacement. In addition, duct cleaning will be offered as specified in this plan.

Prior to conducting any excavation, Dow's contractors will notify Michigan's One-Call Utility Notification Organization (MISS DIG) that fieldwork has been scheduled. MISS DIG will be notified of the impending site work via phone (800-482-7171, or 811) or through the MISS DIG website (http://www.missdig.net/). MISS DIG will mark public underground utilities. Property owners will be asked to identify any additional underground features that they are aware of that may not be identified by MISS DIG.

Storm water protection will be implemented throughout the project as necessary, in accordance with permits and the Project Soil Erosion and Sedimentation Control Plan, included as Attachment I. A Soil Erosion and Sedimentation Control (SE\SC) permit will be obtained for the approximately 1,700 acres that make up the Midland Resolution Area in accordance with Part 91 of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended. A Notice of Coverage will be obtained for the Midland Resolution Area, to meet the requirements of Part 31 of the NREPA, 1994 PA 451, as amended.

When using heavy equipment during excavation and/or construction, diesel emissions will be minimized, to the extent practicable (see Attachment L). Where feasible, soils will be removed by hand digging and/or mechanical excavation to a minimum depth of 12 inches. Several homes include decks, above ground pools, or similar structures that cover soil. These structures are considered part of the foot print of the homes and therefore, no excavation of surface soils will be conducted beneath these structures. In the cases where decks are elevated to the degree that they reasonably allow for use of the ground beneath them, excavation will be completed to the extent necessary and practical. In some cases, new cover and/or a barrier may be placed to reduce contact to the existing soils. Soils adjacent to other structures (e.g., sidewalks, garages, slab foundations and homes) will be excavated at a slope that will not undermine the structures. Surface soils adjacent to mature trees will be removed in a "cone" method to prevent damage to the root system. Soils will be removed to the extent possible between the trunk and the drip line (approximate extent of canopy) which will not cause an adverse effect to the tree. A temporary construction barricade (orange safety fencing) will be placed around the excavation to prevent unpermitted entry, while construction crews are not present.

The excavated soils will be placed into trucks for transport to the Michigan Operation plant site for re-use or to an appropriate disposal facility. After loading, the trucks will be tarped for transport. Restoration of disturbed areas will include backfilling and replacing vegetation. New topsoil and backfill will be imported by the contracting firm from a borrow location that is outside the area possibly impacted by releases from the Dow Michigan Operations Facility, transported to the site and placed by mechanical equipment and hand tools. To ensure backfill and topsoils are suitable for use, topsoil from borrow sources will be tested for the presence of dioxins and furans as well as metals, and/or index properties such as organic content and grain size as a measure of topsoil quality. The final four to six inches of surface backfill materials will be topsoil. Deeper replacement soils may be clean fill soil. Excavated areas will be re-vegetated with sod or seed, as appropriate for the area. Previously landscaped areas will be replanted with similar plants (flower gardens, etc.) and all structures (swing sets, etc.) displaced during the removal process will be replaced, consistent with the property-specific plan developed with the property owner.

Dust management and trackout control measures will be performed for the duration of the project on all areas involved in the soil removal work. Dust will be managed with water and/or dust palliatives. Trackout will be managed by removing all visible soil from vehicles and equipment prior to exiting the work site. Soil removal will be performed with brooms, brushes, shovels, etc., but no water will be used. All soil removed during this process will be placed in trucks and sent to Michigan Operations for reuse or properly disposed of. A wet vacuum street sweeper will be utilized to clean the roadway in the event of observable trackout.

Workers will be provided with hand wash stations and restroom facilities. Rubber boots or project-specific footwear and/or disposable track mats will be used by workers to prevent track-out of impacted soils into vehicles. Typical construction clothing (work clothing and leather or fabric gloves) is adequate to protect workers, as noted in the project Health and Safety Plan, included for reference as Attachment J.

7.4.7.1 Construction Quality Assurance

Construction activities will be documented by property to record the details of construction, ensure they are consistent with the presumptive remedy, and note exceptions. Documentation will take the form of a log that is kept for each DU. An example log is included as Attachment F. The area of soil removal will be recorded on the log. The depth of removal will be measured and recorded at approximately three (3) to nine (9) locations per DU, depending on size and geometry of the excavation. The number of truck loads of soil removed from each property will be recorded. CQA documentation will be maintained throughout the project for MDEQ review.

Portions of each DU will remain undisturbed by any necessary cleanup activities (such as soil remaining beneath appurtenant structures such as decks and pools). However, the average concentration of dioxin and furan TEQ on the property after clean up will be less than the SSAL. A demonstration of DU weighted average concentration will be provided in the annual report for each DU where excavation and replacement is done. The total undisturbed and/or inaccessible areas will be assumed to be equal to the concentration determined for the DU prior to cleanup. Remedy areas will be assumed to have the concentrations from the borrow source. Land under permanent in ground structures such as houses and driveways will not be considered in the calculation. This evaluation will also confirm the percentage of undisturbed remaining soil post-remedy and will identify if remedy is required for accumulated dust, as described below.

If the undisturbed limited-use wooded areas (as defined in 7.4.3.1) were sampled, the evaluation will be made using the known concentration for the wooded areas. If the wooded areas were not sampled, the evaluation will use the concentration measured for the maintained portion of that parcel prior to cleanup.

Upon completion of the remedy, an evaluation of possible exposure to dust accumulated within dwelling(s) ducts will be completed by utilizing the analytical result for the DU (soil concentration) and the percent undisturbed remaining soil. These site-specific parameters and the same assumptions defined in Section 6, will be used in the site-specific algorithm equation to solve for target risk (TR). Duct cleaning will be offered for all DUs with calculated TR values greater than 1E-05. If remedy of accumulated dust is warranted, Dow will provide the property owner with a voucher and a list of vendors that conduct duct cleaning. The owner may schedule the duct cleaning service at their convenience at any time during the six months following issuance of the voucher. Dow will receive an invoice and pay for the service. This invoice will be provided in the Annual Report to document completion of dust remedy.

7.4.7.2 Post Remedy Care and Maintenance

During construction activities, vegetation and landscaping will be replaced in disturbed areas. Maintenance activities including post construction watering will be completed by Dow to allow the new vegetation to become established. Periodic inspection of the new vegetation will occur until the end of the growing season. Replacement of plants or trees that do not survive until the next construction season will be performed, as described in the site-specific remediation plan for each DU. Watering services will be provided at Dow's expense after construction and will continue into the fall of the construction year in which the planting was performed. A final communication will be provided to the property owner when the post remedy maintenance has ended.

7.5 Response Actions Addressing Non-Residential Land Use

Measured concentrations of dioxin and furan TEQ beyond the Dow Plant site within the Midland Resolution Area are below MDEQ generic non-residential Direct Contact Criteria (990 ppt TEQ). With a limited exception described below concentrations of dioxins and furans TEQ on non-residential property in the Resolution Area will not require additional evaluation under this work plan. Current delineation of non-residential land use is based on a preliminary review of the properties. As the work progresses, site visits or surveys will be conducted as necessary to verify that non-residential properties (e.g., businesses) are not currently also used as a residence or in a manner which constitutes residential-like use (as described in Section 4.2.2). Additionally, non-residential properties bordering residential properties will be evaluated for the potential for soil and sediment erosion and transport by surface water runoff. Figure 7-8 presents the approximate schedule during which a more thorough evaluation of site use will be conducted. A non-residential property will be addressed as a residential property under this Work Plan, if it is used as a residence or in a residential-like manner.

Property that is currently used for non-residential purposes but is located in a zoning district that allows residential uses will take potential future use into consideration, and will be addressed in one of the following ways, as appropriate to the circumstances, in most cases, appropriate institutional controls or use restrictions will be applied to limit future use to non-residential uses (as described in Section 7.6). In limited cases, the property may be sampled and addressed as a residential property or be included in the Trust Fund to provide for sampling and remediation if the property is converted to residential use in the future. Limited sampling of some non-residential property may occur to more clearly define and limit appropriate boundaries for application of institutional controls, or to define the boundary of the Midland Resolution Area.

Discrete samples from three Dow-owned properties that fall within the land use area that is predominantly industrial/commercial exhibited detected concentrations of dioxin and furan TEQ that exceeded the MDEQ generic non-residential Direct Contact Criteria of 990 ppt TEQ. Figure 7-9 presents the sample locations that were collected in 2010. All are located near the Michigan Operations Facility. A sample location at Site 1 exhibited a detected concentration greater than 990 ppt TEQ (1,150 ppt TEQ). However, the 95% UCL for the analytical results in the 0-6" depth range at this site is 558 ppt TEQ. Therefore, no further action is necessary to address this sample. Site F1 had two detected concentrations that were greater than 990 ppt TEQ (1,770 and 1,130 ppt TEQ). However, the 95% UCL for the analytical results in the 0-6" depth range at this site was 575 ppt TEQ. Therefore, no further action is necessary to address this sample location.

In an area that was formerly a rail track spur, a discrete sample from location B1-03R10_1"-6", obtained from Site B-01 on 11/12/2010 had a measured concentration of roughly 10,600 ppt TEQ. A number of additional discrete soil samples were obtained from Site B-001 in July 2011, with a resulting 95% upper confidence level (UCL) of 1,384 µg/Kg. Dow submitted the *Work Plan for Site B-001 Remediation Project to* MDEQ for review on September 27, 2011. This work plan proposed targeted remedial activities for this site where the 95% UCL exceeded 990 ppt TEQ. Response Actions were implemented per that Work Plan beginning on October 5 and were completed November 11, 2011. Dow submitted the *Work Plan Addendum for Site B-001*

Remediation Project on November 9, 2011 to address the MDEQ approval stipulation that Dow must propose a plan and schedule to investigate concentrations of dioxins and furans along the former rail spur to the north of Austin Street to determine if additional remediation is necessary. The Addendum is incorporated with this Work Plan as Attachment H. As indicated, the work identified in the Attachment H will be implemented on the same schedule as the Year 1 Midland Area Soils activities.

7.5.1 Decision Rules for Non-Residential Property

As discussed above, current data indicate that non-residential property in the Resolution Area, with two exceptions described below where more data is needed, is below the non-residential DCC and, therefore, no further evaluation or remedial action is necessary. This section sets forth remedial decisions for two exceptions: 1) the rail track spur area discussed above, and 2) densely wooded areas greater than 7,200 square feet (based on zoning code, see Section 7.4.3.1) with no active residential use. At the scale of the DU, soil testing results will be used to determine if the presumptive remedy is warranted at such properties.

One composite sample and two replicates will be collected from these non-residential properties and will be tested at the laboratory by Method 8280 MAS. If results of testing indicate that a concentration greater than 990 ppt TEQ for the DU, either the DU will be demonstrated to be below an appropriate action level for non-residential use incorporating appropriate site-specific exposure assumptions or a presumptive remedy will be implemented as specified in this Work Plan (Section 7.4.7).

7.6 Presumptive Remedy Addressing Future Land Use

Throughout this project and into the future, changes in land use may be expected. The remedy within the Midland Resolution Area must also address reasonably anticipated future use. The mechanisms to address this include institutional controls/land use restrictions or, in limited cases, sampling and remediation as a residential property and the funding of a trust to provide for the remedy at such a time as land use changes. For properties that are not addressed as set forth above, identification of changes in land use will be accomplished through appropriate monitoring.

7.6.1 Trust Fund

As described above, some property owners may decline to allow the presumptive remedy to be implemented at their property, or may wish to defer the remedy for a period of time. In such cases, the property owner, or future owners, will retain the option to have the presumptive remedy performed at a later date of the owner's choosing. In addition, heavily wooded lots that have not been sampled or where remedy was declined or deferred and are zoned to allow residential-like use will be included in the Trust. Dow will establish a trust fund to assure that funds are available to carry out the presumptive remedy work in the future (Trust Fund). The Trust Fund will be funded by Dow in an amount equal to the average cost of performing the presumptive remedy at residential properties (as determined in the first construction season) multiplied by the number of properties that deferred or declined to have the remedy implemented (including wooded properties, as discussed below). Dow will fund the Trust pursuant to the schedule in Section 10 of this Work Plan.

In addition to the properties described above, the remedy will automatically be deferred to heavily wooded areas. However, as long as they remain wooded, property owners or future owners may desire to remove the timber to facilitate residential development. In such a case, Dow will perform the presumptive remedy after the owner has removed the timber for further residential development. In some cases, non-residential property that is located in a zoning district that allows residential uses may also be included in the Trust Fund so that such property can be converted to residential use in the future. In such a case, the Trust Fund will be funded with an additional amount equal to the average cost of performing the presumptive remedy at residential properties.

7.6.2 Institutional Controls

Institutional controls and use restrictions impose land or resource restrictions to: (1) limit or prohibit activities that interfere with the integrity or effectiveness of response action activities; (2) limit or prohibit activities that may result in exposure to a hazardous substance at a site; (3) provide notice about the presence of a hazardous substance at a site (MDEQ, 2007). Typically, institutional controls and use restrictions take the form of ordinances and restrictive covenants (RCs), respectively.

The remedy is designed to be consistent with zoning ordinances in the City of Midland. Areas that are zoned "industrial," "commercial" and "residential" will be able to maintain industrial, commercial, and current residential uses, respectively. See Section 4.2.3 for a discussion of zoning districts in the City. However, some potential future uses may need to be prohibited through the implementation of zoning or the recording of restrictive covenants (RCs). For example, some residential-like uses that are currently authorized in commercial districts in the Midland Resolution Area may have to be prohibited in the future.

If the final remedy for a property relies on the property being restricted to non-residential uses, and all residential or residential-like uses are not already prohibited by City ordinance, then the property will be restricted in one of two ways: 1) a RC will be filed for the property which prohibits residential and residential-like use; or 2) the applicable City ordinance will be amended to prohibit residential and residential-like uses for the area where that property is located. The details of each will be approved by MDEQ prior to implementation.

7.6.3 Monitoring

Properties which are classified non-residential will not be sampled. However, some businesses are located in areas that may allow for conversion to residential or residential like use in the future. Institutional controls are planned for implementation to prevent residential or residential like use of these properties. Prior to that time, it is possible some businesses could be converted to residential use. To address this possibility, non-residential properties within the Resolution Area will be identified and monitored for changes to residential or residential like land use until appropriate institutional controls prohibiting this use are in place. Wooded areas also may be converted by the owner in the future into residential use. These areas will also be identified and monitored for changes in land use. Properties identified for duct-cleaning that did not utilize the voucher provided by Dow (e.g., Dow did not receive an invoice for the duct cleaning services) will be added to the list for monitoring. In conjunction with the evaluation of non-residential land use described in Section 7.5, monitoring during the project may consist of:

- An initial site visit and interview with property owner to verify use is non-residential;
- An annual review of tax records to identify ownership changes;

- Communication to new property owners to verify use is non-residential; and
- Add a deed notice on the property.

Properties where owners decline participation in the program and wooded areas with limited current use properties will have the remedy deferred and funding placed into a Trust. These properties will be monitored for change in ownership and/or changes in use. If changes in ownership or use are identified the owners will be advised of options for cleanup. A Monitoring Plan for these properties will be submitted prior to completion of the project which will identify specific properties subject to monitoring and provide methods and details of monitoring.

7.7 Final Delineation of Midland Resolution Area

The outer extent of the Midland Resolution Area has been described based on existing data and evaluations. A significant amount of new dioxin and furan TEQ concentration data will be generated during the implementation process. An assessment of this data will be used to establish the final boundary of the Area (see Section 9).

Because of the release mechanism (aerial dispersion and deposition), data for each DU sampled are anticipated to reflect the pattern of a typical air deposition "plume." Concentrations close to the source are relatively higher, with concentrations decreasing with distance away from the source. At some distance from the source, concentrations in the soils should be consistently below the action level. The final boundary will be defined when the available incremental compositing data show that areas beyond the proposed boundary will be less than 250 ppt TEQ. This will generally be accomplished where three properties in a row, moving outward from the Michigan Operations plant, are determined to be below the SSAL (taking physical features and age of property development into account). Roadways will not be counted as a "property" for this purpose, but may be used to delineate the final boundary if clean properties are on either side. The final boundary will be proposed by Dow and will be subject to MDEQ approval. Results of all sampling completed during the construction year will be reviewed at the end of the season when evaluating the outer boundary.

A significant portion of the current northeast boundary of the Midland Resolution Area does not contain residential property. Because widespread sampling that will otherwise take place within residential areas is not anticipated here, this portion of the current boundary is further considered as described below. Properties directly north and east of the current Midland Resolution Area, shown on Figure 7-10, will be proposed for sampling to verify the boundary under either of the following circumstances:

- Either I-008 or I-010 to the northeast are confirmed to be greater than the SSAL (section 7.2); or
- Remedy is required for the properties outlined in Figure 7-10, located generally between Sweede Rd and Carolina and Iowa Streets.

The final boundaries will be designed based on the results of sampling and evaluation through an Adaptive Management process, described further in Sections 7.2 and 9, Outliers and Adaptive Management, respectively.

8.0 Project Implementation for Year 1

Year 1 implementation is currently scheduled to begin in 2012 upon approval of the Work Plan. Work in Year 1 will be implemented on a DU-by-DU basis. Year 1 focuses on the properties that are within the closest distance from the Michigan Operations facility within the Midland Resolution Area. The Year 1 implementation plan addresses approximately 30 acres with a total of 113 properties. This initial year focuses on a smaller area than what is currently anticipated for the following years of implementation, to allow for a shorter than normal field season and make provision for lessons experienced in the field during initial implementation. The results of the implementation of Year 1 field work will serve to further refine and improve the methods and plans for the following years, as described in Section 9.

Year 1 encompasses the areas described below, totaling approximately 30 acres of property that is in residential (25 acres) or residential-like (3 acres) use. Roughly 2 acres in this area are in non-residential use. The aerial extent of the Year 1 implementation area to the northwest of the Midland Facility is:

- Bound to the north by Grove St. and Pine St.;
- Bound to the west by Cronkright St., George St., and Mill St.;
- Bound to the east by East Patrick St and State St.; and
- Bound to the south by E. Indian St. and Buttles St.

The aerial extent of the Year 1 implementation area to the east of Michigan Operations is:

- Bound to the north by Bay City Road;
- Bound to the west by Kent Street;
- Bound to the east by Walter Street and a fenceline observed between Walter and Sam St.; and
- Bound to the south by Mark Putnam Rd.

Table 8-1 presents the properties included in the Year 1 Implementation activities. These areas are also shown on Figures 8-1 and 8-2.

8.1 Sampling Plans

For the purposes of the Year 1 work, a DU is defined as an individual limited use woodland greater than 7200 square feet or an individual residential property. The following sections present the specific details for those DUs in the area described above. The preliminary sampling information is provided in Table 8-2, including property size and the number of increments. Attachment G presents drawings showing the planned increment sample locations for each individual DU.

8.1.1 Residential DUs < 1 Acre

There are 103 DUs in the Year 1 Area (Group A) that are less than one (1) acre in size. Of these, there are approximately 79 DUs that are ¼-acre or smaller, where ten (10) increments will be collected. There are 24 DUs remaining that are greater than ¼-acre, where twenty (20) increments will be collected, as listed in Table 8-2.

Not listed on Table 8-2 is an unclaimed parcel in this area that resulted from abandonment from Grove Street. For purposes of sampling, this abandoned land will be combined with adjacent parcel 14-21-10-344. All parcels adjacent to this abandoned land are owned by the City of Midland.

8.1.2 Residential DUs > 1 Acre

There are 2 Residential DUs in the Year 1 Area (Group A) that are greater in size than one (1) acre. Parcels 14-21-10-308 (1.2 acres) and 14-21-10-410 (1.3 acres) are grassed lots that are currently zoned for Residential B and Community, along the Business 10 corridor. Samples will be obtained using thirty (30 increments) from each area.

8.1.3 Properties with Woodland Areas

There are twelve (12) DUs in the Year 1 Area (Group A) that have tentatively been identified to contain wooded areas with limited current use greater than 7,200 square feet, as shown in Table 8-2. Final confirmation will be made during a site visit.

8.1.4 Non-Residential DUs

In the Year 1 Area (Group A), there are five (5) non-residential properties which will be addressed under the Monitoring Program (Section 7.6.3). Parcel 14-23-50-060 (2.05 acres) is a vacant wooded lot and fenced-in pump station currently zoned Industrial at the south end of Kent

Court owned by the City of Midland. Residential use is not currently allowable under current zoning nor is the property residential like in nature; therefore sampling will not be conducted at this property. Parcel 14-23-60-160 (1.58 acres) is grassed land with some commercial operations currently zoned both Regional Commercial and Residential B. The property is owned by a local contracting firm, and is not in current residential use nor is it residential like in nature. Sampling will not be conducted at this property. Parcel 14-21-10-344 is an office building currently zoned Office Service (OS). Parcel 14-21-80-499 is currently a paved parking lot, currently zoned OS. Parcel 14-21-10-398 is a local business building, currently zoned Residential B. These properties are not currently being used as a residence, nor are they residential-like in nature; therefore, they will be included in the Monitoring Program (Section 7.6.3).

9.0 Adaptive Management

Due to the significant extent of the area in scope for this project and the large number of individual property owners involved, completion of the sampling and presumptive remedy phases are projected to be implemented over several years. To address uncertainties in soil concentrations or variability in the residential properties themselves, an iterative approach to planning and implementation will be utilized to maximize efficiencies to the greatest extent practicable. This effort involves utilizing an adaptive management approach for the project which provides the opportunity for improvement throughout the life of the implementation effort however the depth of remediation (12 inches) and SSAL will not change. There are a number of aspects of the work that may be proposed and submitted for approval, depending on the results of previous or on-going work, such as:

- Property owner communication methods;
- Specific properties scheduled for evaluation including modifications to property groupings;
- Decision Unit definitions;
- Means and methods to conduct the remedy;
- Decision Rules (not action level);
- Number of increments in a composite sample;
- Number of sample replicates;
- Sample processing techniques;
- Sampling of non-residential properties;
- Monitoring and management of undisturbed and limited use woodland properties;
- Boundary of Resolution Area; and
- Annual schedule.

9.1 Rationale for Changes

A number of aspects of this project have been designed to manage the uncertainty related to the distribution of dioxin and furan TEQ in soils within the Resolution Area. During this project, a large amount of soil concentration data will be obtained from residential areas, beginning nearest the plant and working outward. As the data set grows, the uncertainties will diminish, allowing changes to the design and plans that are no longer necessary or appropriate. As an example, non-residential properties will not have soil testing performed early in the project, because surrounding residential properties will. In some cases, property use restrictions are necessary for non-residential land (to prevent it from becoming residential in the future). It may be possible to infer which non-residential properties would require restriction based on the surrounding residential data obtained over the next few years. Some areas may be able to be eliminated, based on the soil data obtained, while others may require sampling. The data collected early on will inform how to manage long-term use of non-residential areas.

Similarly, replicate data obtained in early phases of the project will inform our current understanding of spatial variability and sampling techniques. Future years may be able to reduce the number of replicate analyses, alter the decision rules related to further testing, or agglomerate properties into larger DUs, rather than a single DU per property.

The current multi-year property groupings (Group A thru F) are largely based on distance from Dow's Midland Plant. Soil dioxin and furan TEQ distribution data obtained in early years may support focusing during subsequent years on those areas most likely to require remedy, which would result in a modification of the groupings shown in Figure 7-4.

9.2 Incorporation of Findings into Implementation Plans

A summary of work completed, data evaluation and findings from each field season will be compiled and submitted to the regulatory agencies at the end of each year. A review of the summary report for each field season will inform understanding of the scope of work required to meet the objectives of this project, and will enable the project team to streamline implementation to focus on the work that is necessary as well as avoid delays, minimize cost, and maximize positive impact to the community. Specific changes or adaptations identified during data evaluation from previous efforts will be incorporated into updated implementation plans for each year of the project. Although these findings will be presented in the annual summary report, communication with MDEQ will be frequent throughout the implementation of the project. If necessary, more frequent updates to the plans will be coordinated with MDEQ to resolve issues that require more timely adaptation.

9.3 Midland Resolution Area Boundary

As described in Section 7.7, the boundary of the Midland Resolution Area has been established based on current data. The boundary may change, using data collected during this project. Each year, the study areas designated for sampling (A thru F, see Section 7.1) will be fully investigated. All available data will be reviewed annually to determine if the boundary needs to be modified. Each year, the area designated for sampling will be fully implemented. In the summary report, changes to the boundary will be effectively made according to the following example.

The purpose of the boundary is to definitively establish an area beyond which no remedy is offered. The final boundary will be defined when the available incremental compositing data show that areas beyond the proposed boundary will be less than 250 ppt TEQ. This will generally be accomplished where three properties in a row, moving outward from the Michigan Operations plant, and determined to be below the SSAL (taking physical features and age of property development into account). Roadways will not be counted as a "property" for this purpose, but may be used to delineate the final boundary if clean properties are on either side. Along the currently defined northeastern boundary, where limited residential property is available, additional consideration will be made, as described in Section 7.7. The final boundary will be proposed by Dow and will be subject to MDEQ approval.

10.0 Reporting and Schedule

Properties within the Resolution Area have been divided into property groups for Years 1 through 6 of remedy implementation. Each year of implementation includes sampling, analysis, a review of analytical data results and determination of the necessity for implementing the remedy, and implementation of any necessary remedy, all within a seasonal window that allows for this effort to take place, roughly from late spring to early fall.

10.1 Reporting

For Interim Response Activities, Operating License Condition XI.G.6 specifies submittal of monthly written progress reports to the MDEQ Division Chief. For this project, an alternate communication strategy is proposed. Due to the collaborative nature of the project, periodic project coordination meetings will take place between Dow and MDEQ approximately every two weeks during the field season. To facilitate the exchange of information, a progress tracking log that is frequently updated will be made available to MDEQ on a continual basis. Access to the tracking log is being provided in lieu of a monthly written progress report. An annual written report will be prepared and submitted, summarizing the activities that took place during that year.

10.2 Schedule

Year 1 is scheduled for implementation beginning upon approval of the Work Plan. Approval is currently anticipated prior to June 1, 2012. If approval occurs after that date the proposed Year 1 schedule may require adjustment. Additional implementation activities are scheduled for subsequent calendar years. At the conclusion of the field implementation each year, an annual Remedial Implementation Summary Report will be prepared to document the findings of the implementation effort and to describe implementation plans for the next year.

Proposed Schedule of Remedial Implementation

Year of Implementation	Activity	Months of Activity/Report Submittal Date
Year 1	Best Efforts to Obtain Access Sampling & Data Evaluation Remedy and Post Remedy Care Begin Interim Monitoring*	April – July 2012 June – August 2012 August – October 2012 October – November 2012
	Year 1 Summary Report (documentation of findings)	December 2012
	Year 2 Adaptive Management and Implementation Plan	January 2013
Year 2	Best Efforts to Obtain Access Sampling & Data Evaluation Remedy and Post Remedy Care	March – June 2013 May – August 2013 August – October 2013
	Year 2 Summary Report (documentation of findings)	December 2013
	Year 3 Adaptive Management and Implementation Plan	January 2014
Year 3	Best Efforts to Obtain Access Sampling & Data Evaluation Remedy and Post Remedy Care	March – June 2014 May – August 2014 August – October 2014
	Year 3 Summary Report (documentation of findings)	December 2014
	Year 4 Adaptive Management and Implementation Plan	January 2015
Year 4	Best Efforts to Obtain Access Sampling & Data Evaluation Remedy and Post Remedy Care	March – June 2015 May – August 2015 August – October 2015
	Year 4 Summary Report (documentation of findings)	December 2015
	Year 5 Adaptive Management and Implementation Plan	January 2016
Year 5	Best Efforts to Obtain Access Sampling & Data Evaluation Remedy and Post Remedy Care	March – June 2016 May – August 2016 August – October 2016
	Year 5 Summary Report (documentation of findings)	December 2016
	Year 6 Adaptive Management and Implementation Plan	January 2017
Year 6	Best Efforts to Obtain Access Sampling & Data Evaluation Remedy and Post Remedy Care	March – June 2017 May – August 2017 August – October 2017
	Year 6 Summary Report (documentation of findings)	December 2017
Year 7	Trust Funding	March 2018
	Long Term Monitoring Plan	March 2018
	Institutional Control Proposal	March 2018

* For non-residential properties and those properties where property owners declined participation or remedy.

Additional years of work may be necessary if the boundary of the Midland Resolution Area is expanded. As mentioned in Section 1 and discussed further in Attachment A, additional regulatory deliverables are necessary to meet the requirements of the License. A schedule for submittal of those documents is provided below:

Proposed Regulatory Deliverable Schedule

Task	Timeframe/Duration
Midland Area Soils Leachability Testing Study	June 1, 2012
Revised SOW and RI Work Plan	December 2013
RI Final Report	December 2013
Provide a schedule for both RAP and RAP completion report	December 2013

11.0 References

Adriaens, P., P. Goovaerts, and S. Swan. 2006. Geostatistical Analysis of PCDD and PCDF Deposition from Incineration Using Stack Emissions and Soil Data. 26th International Symposium on Halogenated Persistent Organic Pollutants, Oslo, Norway. August.

Agin, R.J., V.A. Atiemo-Obeng, W.B. Crummett, K.L. Krumel, L.L. Lamparski, T.J. Nestrick, C.N. Park, J.M. Rio, L.A. Robbins, S.W. Tobey, D.I. Townsend, and L.B. Westover. 1984. Point Sources and Environmental Levels of 2378-TCDD (2,3,7,8-Tetrachlorodibenzo-p-Dioxin) on the Midland Plant Site of the Dow Chemical Company and in the City of Midland, Michigan. November.

CH2M Hill, March 2007. Data Evaluation Report in Support of Bioavailability Study, Midland Area Soils.

CH2M Hill, October 2007. Midland Area Soils Remedial Investigation.

Countess, R. 2003. Reconciling Fugitive Dust Emission Inventories with Ambient Measurements. Presented at the 12th Annual Emission Inventory Conference, "Emission Inventories – Applying New Technologies," San Diego, April 29 through May 1.

Dee, Jean/U.S. Census Bureau. 2005. Email correspondence with Carolyn Fehn/CH2M HILL regarding population of City of Midland, Michigan. October 19 and 20.

The Dow Chemical Company, The (Dow). 2000. Soil Sampling Summary Report (Revised). March.

Dow. 2002. Dow Chemical Michigan Operations Operating License Reapplication, Section III: Hydrogeological Report (Revised). June.

Dow. 2005. Pilot Study Report: Oral Bioavailability of Dioxins/Furans in Midland and Tittabawassee River Flood Plain Soils. Prepared by Exponent.

Dow. 2006a. Remedial Investigation Work Plan for Midland Areas Soils. December.

Dow. 2006b. Dow Company Website, www.dow.com, accessed July 2006.

Etyemezian, V., D. Nikolic, J. Gillies, H. Kuhns, G. Seshadri, and J. Veranth. 2003. Reconciling Fugitive Dust Emissions with Ambient Measurements Along the Unpaved Road. Presented at the 12th Annual Emission Inventory Conference, “Emission Inventories – Applying New Technologies,” San Diego, April 29 through May 1.

Haynes, W. 1945a. *American Chemical Industry: A History, Volume II, 1912-1922.* D. Van Nostrand Company, New York, New York.

Haynes, W. 1945b. *American Chemical Industry: A History, Volume III, 1912-1922.* D. Van Nostrand Company, New York, New York.

Haynes, W. 1948. *American Chemical Industry: A History, Volume IV, 1923-1929.* D. Van Nostrand Company, New York, New York.

Haynes, W. 1949. American Chemical Industry: A History, Volume VI, Company Histories to 1948. D. Van Nostrand Company, New York, New York.

Haynes, W. 1954a. *American Chemical Industry: A History, Volume I, 1609-1911.* D. Van Nostrand Company, New York, New York.

Haynes, W. 1954b. *American Chemical Industry: A History, Volume V, 1930-1939.* D. Van Nostrand Company, New York, New York.

Michigan Department of Environmental Quality (MDEQ). 1997. Summary of 1996 Midland Dioxin Study Results. Working Draft of Document for Public Release. Waste Management Division. March.

MDEQ. March 2011. Michigan Department of Environmental Quality Part 201 Generic Cleanup Criteria and Part 213 Risk-based Screening Levels (RBSLs), Document Release Date: March 25, 2011, downloaded from MDEQ website March 2011: http://www.michigan.gov/deq/0,1607,7-135-3311_4109_9846_30022-251790--,00.html.

Michigan Department of Natural Resources (MDNR). 1988. Michigan Department of Natural Resources Remedial Action Plan for Saginaw River and Saginaw Bay Area of Concern. September.

Michigan State Climatologists Office. 2010. 30 Year Summary of Annual Values for Midland WWTP Station #5434. http://climate.geo.msu.edu/Stations/5434/

NOAA, 2012. Climatography of the United States, National Climatic Data Center, National Oceanographic and Atmospheric Administration. http://www.ncdc.noaa.gov/oa/ncdc/html.

URS Corporation (URS). August 2010. 2010 Field Pilot Characterization Plan. August 16, 2010.

URS. August 2011. 2010 Field Pilot Characterization Summary Report. August 29, 2011.

URS. January 2012. Draft Composite Sampling Pilot Study Summary Report. January 18, 2012.

U.S. Department of Agriculture (USDA). 1997. 1997 Census of Agriculture, County Profile. Michigan Agricultural Statistics Service.

U.S. Environmental Protection Agency (USEPA). 1985. Soil Screening at Four Midwestern Sites. EPA-905/4-85-005. June.

USEPA. 1988. Response to Public Comments on Risk Assessment for Dioxin Contamination at Midland, Michigan (EPA-905/4-88-005) and Proposed Risk Management Actions for Dioxin Contamination at Midland, Michigan. Appendices A, B, and C. Region 5. EPA 905/4-88-005. December.

USEPA. 1992. Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised. EPA 454/R 92 019. October.

USEPA. 1995. *AP 42.* Fifth Edition, Volume I. Chapter 13: Miscellaneous Sources; 13.2, Introduction to Fugitive Dust Sources.

USEPA. 1999. Persistent Bioaccumulative Toxic (PBT) Chemicals; Lowering of Reporting Thresholds for Certain PBT Chemicals; Addition of Certain PBT Chemicals; Community Right-to-Know Toxic Chemical Reporting. *Federal Register,* 64(209): 58665-58753. October 29.

USEPA. 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), EPA/540/R/99/005, OSWER 9285.7-02EP PB99-963312.

USEPA. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Final. Office of Solid Waste and Emergency Response. EPA A530-D-98-001. July.

University of Michigan. 2006. Measuring People's Exposure to Dioxin Contamination Along the Tittabawassee River and Surrounding Areas. Findings from the University of Michigan Dioxin Exposure Study. August.

USEPA, June 2011. *EPA Regional Screening Levels (RSLs) June 2011*, downloaded from EPA website June 2011:
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.

Van den Berg et al: The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, ToxSci Advance Access, 7 July 2006.