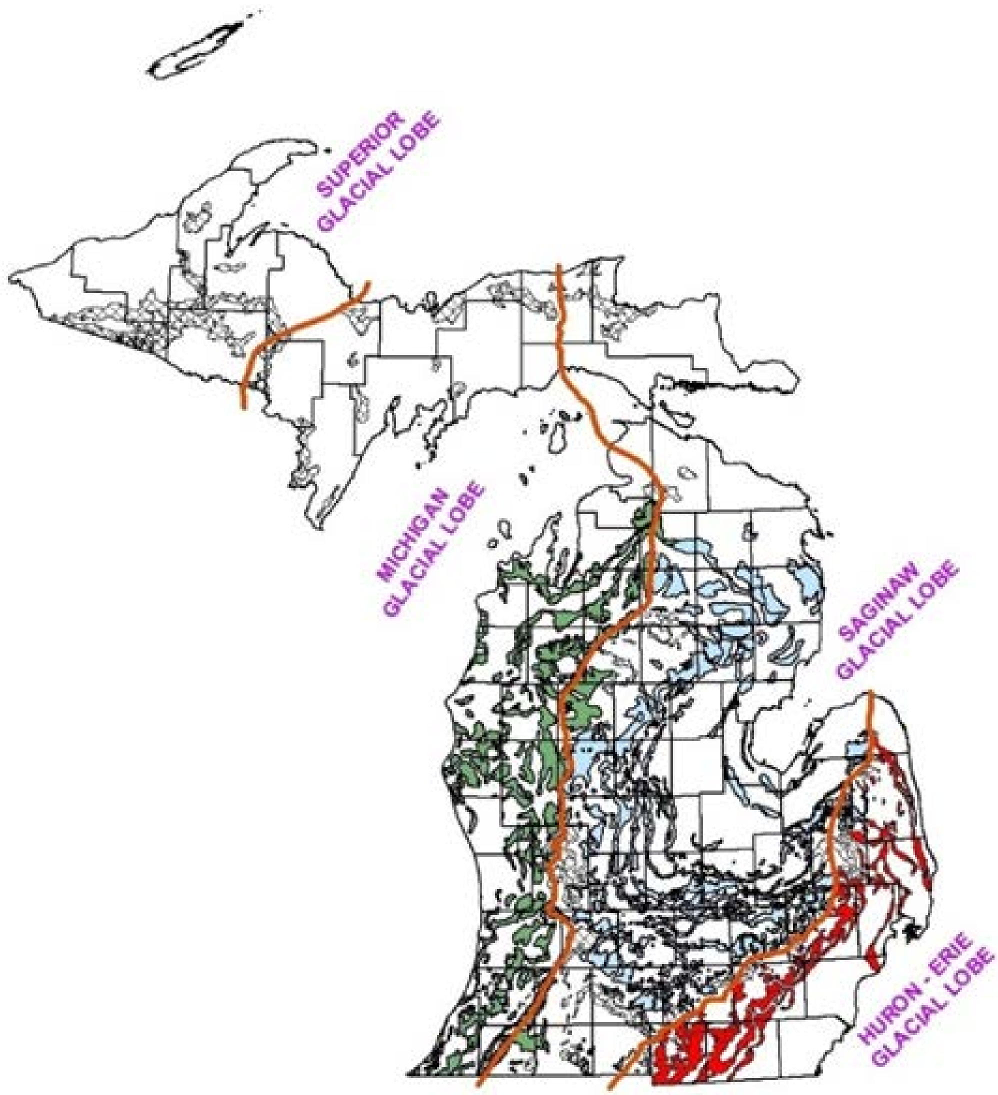
REMEDIATION AND REDEVELOPMENT DIVISION

SOIL BACKGROUND and USE OF THE 2005 MICHIGAN BACKGROUND SOIL SURVEY

RESOURCE MATERIALS



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September 2019

REMEDIATION AND REDEVELOPMENT DIVISION

In order to promote a consistent and informed approach for Michigan Department of Environment, Great Lakes, and Energy (EGLE) staff, this document was developed to provide information to EGLE staff and contractors on methodology and applications for the determination of background concentrations of metals in soil.

This document is available as a technical reference to assist any party interested in the determination of background concentrations of metals in the soil at a site to evaluate if response actions are warranted or if the metals can be attributed to naturally occurring sources.

This document is explanatory and does not contain any regulatory requirements. It does not establish or affect the legal rights or obligations for the determination of background concentrations of metals in the soil. It does not have the force or effect of law and is not legally binding on the public or the regulated community. Any regulatory decisions made by EGLE regarding background concentrations of metals in the soil will be made by applying the governing statutes and administrative rules to relevant facts.

Approved: Kathleen Shirey

Kathleen Shirey, Acting Division Director
Remediation and Redevelopment Division
October 4, 2019

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PURPOSE

The primary goal of Michigan's cleanup programs is to protect human health and the environment from current and potential threats posed by uncontrolled releases of hazardous substances (contamination). Contamination at a site[1] may originate from releases attributable to the site in question, as well as contamination that originated from other sources, including natural sources not attributable to the specific site releases under investigation. In some cases, the same hazardous substance associated with a release is also a background constituent.

If contaminants at a site are the result of a release and exceed generic cleanup criteria, remediation or due care obligations are typically required. If the contaminant is present due to natural conditions, cleanup or due care obligations are not required under Michigan's cleanup statutes, even if the concentrations exceed the risk-based generic cleanup criteria. Consequently, it may be important in the management of a site to determine whether or not the presence of a contaminant represents natural background conditions.

Background has been defined for the Michigan cleanup programs since 1990 as the concentration or level of a hazardous substance which exists in the environment at or regionally proximate to a site that is not attributable to any release at or regionally proximate to the site. The options available to demonstrate that a hazardous substance is not present at a level that exceeds soil background concentration are included with the statutory definition of background[2].

An evaluation of local background soil concentrations may be appropriate at a site whenever it is suspected that metal contaminants detected above applicable cleanup criteria may be equal to, or less than, natural background soil concentrations. Consistent with statutory and rule provisions, when the background concentration for a hazardous substance is greater than the calculated generic cleanup criteria, the criterion is the background concentration[3].

The purpose of this document is to describe the applicability of the 2005 Michigan Background Soil Survey (MBSS) in the demonstration of naturally occurring background metals concentrations for a property. In addition, the 2015 update to the MBSS is included as an appendix to this document and may be used consistent with the provisions for the 2005 MBSS.

Some contaminants, both manmade and natural, are ubiquitous in the environment due to human activities. Examples include polycyclic aromatic hydrocarbons (PAHs), lead, and dioxins. Low levels that exist in the environment due to human activities not associated with any specific release are termed anthropogenic background. Michigan statutes and rules do not recognize comparisons with anthropogenic background concentrations as a basis for determining a cleanup criterion in place of a generic criterion. However, when delineating the boundaries of contamination attributable to a release, anthropogenic background concentrations may be useful. They may be used to help establish the area where liability for cleanup may exist by defining where the chemical concentrations from the release become indistinguishable from concentrations present from other, non-specific sources. Developing background concentrations is also useful in this context (i.e., establishing the nature and extent of the release), despite the somewhat different objective from concentration comparisons with natural background. Developing anthropogenic background concentrations, if useful in this context should be discussed with project managers to ensure its acceptability for site delineation.

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[1] For the purpose of this document, the term "site" is being used as a general reference to a property with environmental contamination and is not intended to be applied as it is statutorily defined in the Natural Resources and Environmental Protection Act (NREPA), PA 451 of 1994, as amended.
[2] Sec. 20101(1)(e)
[3] Sec. 20120a(10); Part 201 Administrative Rules, Cleanup Criteria Requirements for Response Activity, Michigan Administrative Code, 2013 AACS R 299.1 – R 299.50

1.0 INTRODUCTION

In Michigan, metals are commonly detected in soil at sites of contamination. However, the detection of metals in the soil does not necessarily indicate that the metals were released from man-made sources. The presence of metals in Michigan's soil may be naturally occurring as a result of Michigan's unique geology and glacial history.

The 2005 *Michigan Background Soil Survey (2005 MBSS)* is one resource to determine background concentrations for naturally occurring metals. Part 201, Environmental Remediation, of Natural Resources and Environmental Protection Act, 1994 PA 451, was amended in 2015 to include methods to establish background concentrations using the 2005 MBSS. The data provided in the 2005 MBSS is a compilation of soil sampling data from regulated facilities and samples collected and analyzed by the state incorporated into a soil background database. Additional data from the United States Geological Survey (USGS) and the United States Army Corps of Engineers (USACE) is also included in the 2005 MBSS. In 2014, additional soil sampling data from locations that represent background conditions were collected from files of the EGLE Remediation and Redevelopment Division (RRD), and the 2005 MBSS was updated in 2015 by the department. The use of the methods for the 2005 MBSS[4] are appropriate for the 2015 update of the MBSS.

Michigan's unique geology and glacial history has resulted in the deposition of many naturally occurring metals in soils. The ice moving across Michigan followed four individual flow paths, called glacial lobes. Because these glacial lobes have varying points of origin and traverse different types of bedrock, the resulting glacial sediments have varying chemical characteristics based on source rock influences.

The soil metals concentrations presented in the 2005 MBSS were compiled from limited locations across the state and a number of geographic areas did not have background soil information. Due to the variability in the concerns at each of the locations where the soil background samples were collected, different suites of metals were analyzed, and a uniform set of analytical data for each hazardous substance listed is not available.

2.0 USE OF THE 2005 MICHIGAN BACKGROUND SOIL SURVEY

The *2005 MBSS* includes the 25 metals listed below for which there are published typical background ranges.

Aluminum	Cadmium	Lead	Molybdenum	Strontium
Antimony	Chromium	Lithium	Nickel	Thallium
Arsenic	Cobalt	Magnesium	Selenium	Titanium
Barium	Copper	Manganese	Silver	Vanadium
Beryllium	Iron	Mercury	Sodium	Zinc

Statistical analyses of the sample data for each of the compounds listed, where available, was completed with subcategories for topsoil, sand, and clay and defined by Michigan's four glacial lobe areas.

A description of the methods to establish a metal background concentration utilizing the 2005 MBSS is located within the background definition[5]. In Appendix A of this document is a flowchart that outlines the methods for utilizing the 2005 MBSS, or the 2015 update, pursuant to this provision. The *2005*

[4] Sec. 20101(1)(e)(ii)
[5] Sec. 20101(1)(e)(ii)

MBSS, or the 2015 update, may be used to determine background concentrations where there is sufficient information that meets all of the following conditions:

- **Same Glacial Lobe** – Source rock composition is critical in determining the makeup of the glacial drift from which it has originated. The 2005 MBSS identifies four different glacial lobes, Huron-Erie, Saginaw, Michigan, and Superior, with source rock variations that influence the concentrations of metals present in the deposited drift materials. The survey identifies the variations in metals concentrations based upon glacial lobes and depicts the geographic areas affected by each lobe. Background soil evaluation data comparisons should be consistent with the glacial lobe for the geographic area for which the demonstration is being made.

- **Similar Soil Type –** Soil type influences the concentrations of metals present. For simplicity's sake, the 2005 MBSS categorizes soils into three broad types: sand, clay, and topsoil. Sandy soils typically have lower metals concentrations, while clays tend to have higher naturally occurring concentrations of metals. Topsoil can vary depending on the composition of the soil horizons below this layer. When performing a background demonstration, the values published for similar soils should be used.

- **Specific Metal Data Available** – Due to the nature of the data compiled for the 2005 MBSS, the database lacks populations of data for specific metals; there are some areas where no metals samples were collected. For example, antimony was not analyzed in any of the topsoil samples collected across the state. For this case, the use of the 2005 MBSS is not appropriate for demonstrating background concentrations for antimony in topsoil.

Tables 2, 3, and 4 of the 2005 MBSS include the standard deviation of the substances that have an arithmetic or geometric mean in the glacial lobes that have at least nine samples. However, the 2005 MBSS does not contain the two standard deviations of the arithmetic or geometric mean, nor does it include the 97.5 quantile for the hazardous substances with nonparametric medians, both of which are specifically identified in the background definition. Included in Appendix B of this document are updated Tables 2, 3, and 4 with the two standard deviations and the 97.5 quantiles calculated using the data from the 2005 MBSS for each soil type and glacial lobe. Appendix D of this document includes modified Tables 2, 3, and 4 for the MBSS 2015 Update that includes the two standard deviations, 97.5 quantiles and highlighted numbers showing the appropriate number to use for a background concentration.

The 2005 MBSS contains combined statewide data columns on Tables 2, 3, and 4 that are not appropriate for use in demonstrating background concentrations. This is due to significant data gaps across the state, which has widely varied geology, where entire blocks of counties or most of the Upper Peninsula have no information.

Another method to establish background concentrations allows for the use of the 2005 MBSS in a manner that is approved by the department[6]. The sole use of the uppermost value in the typical range of data in Table 1 is not approved unless it is the lesser of the values indicated in 20101(1)(e)(ii)(A) or (B). Contact the EGLE project manager to discuss any other proposed methods to utilize the 2005 MBSS.

Soil analytical data from the area for which the background demonstration is being performed is needed to complete the comparison and show consistency with the conditions described in the *2005 MBSS*.

When a background concentration has been established utilizing the MBSS, site concentrations will generally be compared to the established background concentrations on a point-by-point basis.

[6] Sec.20101(1)(e)(ii)(C)

Statistical analysis of the site metals data may be conducted and used for comparison to the established background concentration; however, the method for the site data statistical analysis must be proposed on a case-by-case basis if EGLE approval of a response action is being sought.

Certain sites may contain more than one metal in the soil. Multiple methods included in the background definition to establish background concentrations may be used for different metals for the same site.

The MBSS may be an appropriate and useful resource for comparing geographic, geological, and analytical information to demonstrate background concentrations in an area that is unaffected by a release of hazardous substances.

NOTE: If a site is also subject to corrective action under Michigan's Hazardous Waste Management Program (Part 111), please be aware that methods for demonstrating compliance with background concentration as defined under Section 324.20101(1)(e) cannot be automatically applied. Such sites may use site-specific background determinations (as approved by the Hazardous Waste Program) or the statewide default background levels listed in the September 28, 2012 Part 201 generic soil cleanup criteria and screening levels (Tables 2 and 3). This distinction is necessary until the U.S. Environmental Protection Agency approves Michigan to use the January 15, 2015 Part 201 definition for background concentration in its Hazardous Waste Management Program.

Appendix A

FLOW CHART

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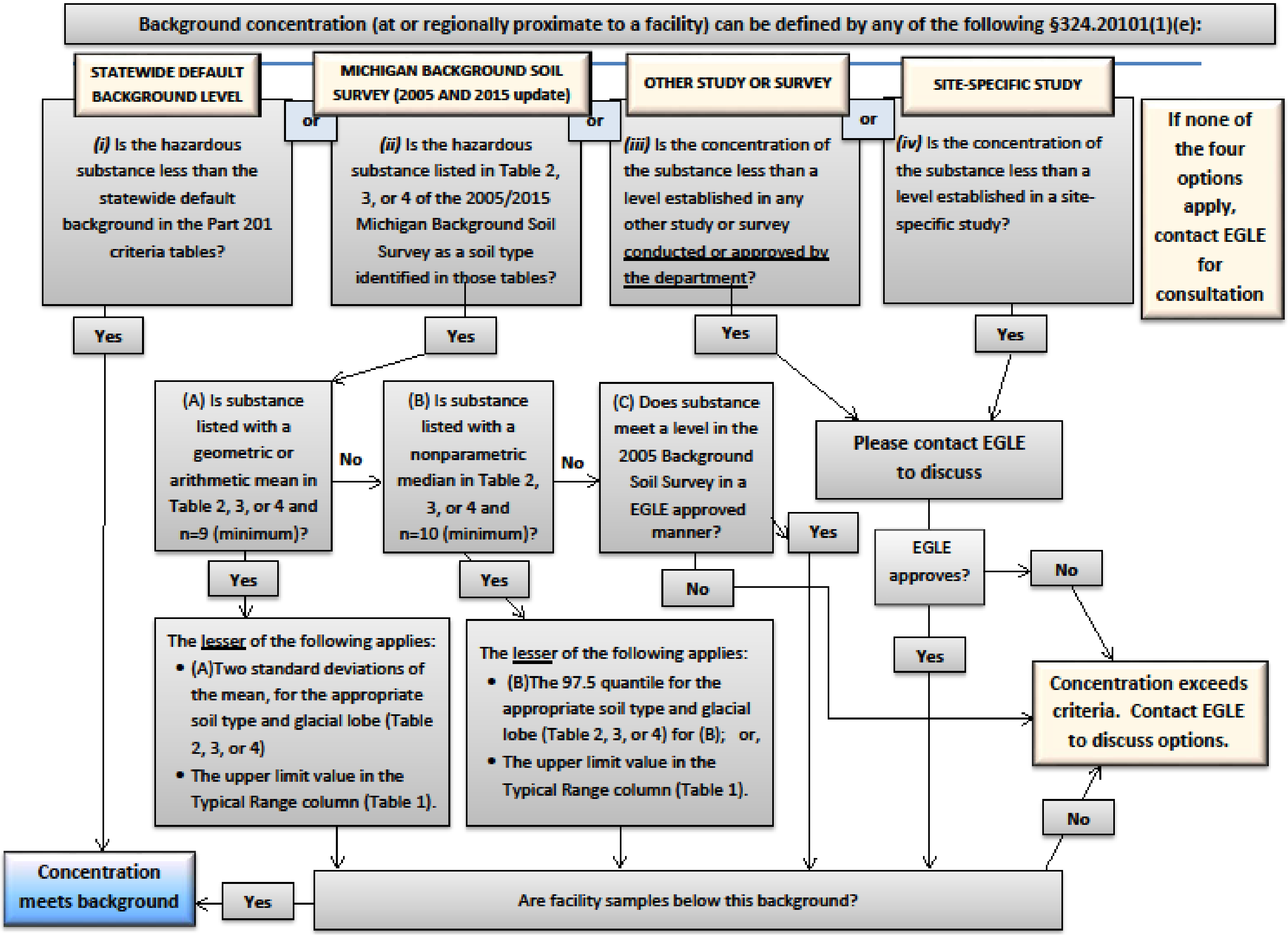
Background Concentration Flowchart

[per 324.20101(1)(e)]



Appendix B

UPDATED TABLES 2, 3, AND 4

2005 Michigan Background Soil Survey

Table 2 - TOPSOIL

METAL	Dist.	Part 201 Statewide Default Background	Table 1 Upper Range Value	HURON - ERIE LOBE n	HURON - ERIE LOBE Two Standard Deviations	HURON - ERIE LOBE 97.5 Quantiles	SAGINAW LOBE n	SAGINAW LOBE Two Standard Deviations	SAGINAW LOBE 97.5 Quantiles	MICHIGAN LOBE n	MICHIGAN LOBE Two Standard Deviations	MICHIGAN LOBE 97.5 Quantiles	SUPERIOR LOBE n	SUPERIOR LOBE Two Standard Deviations	SUPERIOR LOBE 97.5 Quantiles
Al	L	6,900	16,324	10	9,690	#	37	12,531	#	34	3,234	#	16	17,664	#
Sb	non	NA	2.5	0	--	--	0	--	--	0	--	--	0	--	--
As	L	5.8	27.7	47	15.2	#	93	13.2	#	39	4.67	#	18	3.80	#
Ba	L	75	220	15	248	#	42	78.3	#	39	68.1	#	16	163	#
Be	non	NA	1.8	2	--	--	12	#	0.37	0	--	--	0	--	--
Cd	non	1.2	2.5	15	#	2.0	42	#	*100% ND*	38	#	*100% ND*	18	#	*100% ND*
Cr	L	18	55	15	37.3	#	45	32.7	#	39	10.2	#	18	36.4	#
Co	non	6.8	12	10	#	7.0	29	#	6.2	32	#	*100% ND*	16	#	11.7
Cu	L	32	58	15	56.6	#	42	27.5	#	39	13.3	#	18	172	#
Fe	L	12,000	34,233	10	21,218	#	42	31,334	#	38	8,645	#	18	24,099	#
Pb	L	21	45	38	42.5	#	60	34.9	#	39	24.8	#	18	73.4	#
Li	L	9.8	41	10	10.7	#	34	14.7	#	32	#	3.9	18	10.8	#
Mg	L	NA	29875	2	--	--	8	--	--	0	--	--	0	--	--
Mn	L	440	1391	10	2,145	#	42	1,114	#	38	1,083	#	18	965	#
Hg	non	0.13	0.6	15	#	0.17	42	#	0.24	38	#	0.10	18	#	0.12
Mo	--	NA	*100% ND*	2	--	--	12	#	*100% ND*	0	--	--	0	--	--
Ni	L	20	39	11	19.5	#	42	16.6	#	38	--	--	18	70.4	#
Se	non	0.41	1.2	22	#	4.9	42	#	0.50	38	--	--	18	#	0.65
Ag	non	1	2	6	--	--	5	--	--	0	--	--	0	--	--
Na	N	NA	194.5	2	--	--	5	--	--	0	--	--	0	--	--
Sr	non	NA	150	0	--	--	7	--	--	0	--	--	0	--	--
Tl	non	NA	3.8	2	--	--	5	--	--	0	--	--	0	--	--
Ti	N	MNL	217	2	--	--	12	221	#	0	--	--	0	--	--
V	L	NA	89	2	--	--	12	30.5	#	0	--	--	0	--	--
Zn	N	47	75	23	79.0	#	45	61.3	#	39	27.4	#	18	100	#

All data are in mg/kg (ppm)

L	Lognormal distribution
N	Normal distribution
non	Nonparametric distribution
ND	Non-detect

Dist.	Distribution of Data
n	Number of Samples
NA	Not Applicable (no value listed in Part 201)
MNL	Metal Not Listed in Part 201
--	No value calculated (too few samples/detections)
(shaded)	Less than Table 1 Upper Value
#	Not appropriate calculation method
98 - 100% ND	Non-detect percentage too high to estimate a value - use Table 1

2005 MBSS

Table 3 - SAND

METAL	Dist.	Part 201 Statewide Default Background	Table 1 Upper Range Value	HURON - ERIE LOBE			SAGINAW LOBE			MICHIGAN LOBE			SUPERIOR LOBE		
				n	Two Standard Deviations	97.5 Quantiles	n	Two Standard Deviations	97.5 Quantiles	n	Two Standard Deviations	97.5 Quantiles	n	Two Standard Deviations	97.5 Quantiles
Al	L	6,900	16,324.0	2	--	--	54	8,677	#	34	8,449	#	3	--	--
Sb	non	NA	2.5	1	--	--	3	--	--	3	--	--	0	--	--
As	L	5.8	27.7	34	19.6	#	118	26.1	#	53	8.41	#	3	--	--
Ba	L	75	220.0	22	612	#	71	48.9	#	51	67.9	#	3	--	--
Be	non	NA	1.8	3	--	--	51	#	*98% ND*	6	--	--	0	--	--
Cd	non	1.2	2.5	22	#	2.0	67	#	1.6	39	#	2.0	3	--	--
Cr	L	18	55.0	22	20.3	#	90	20.0	#	67	18.4	#	3	--	--
Co	non	6.8	12.0	2	--	--	61	#	6.6	16	#	7.3	3	--	--
Cu	L	32	58.0	22	29.7	#	90	19.0	#	67	22.7	#	3	--	--
Fe	L	12,000	34,233.0	2	--	--	55	16,819	#	17	11,779	#	3	--	--
Pb	L	21	45.0	25	25.3	#	95	24.4	#	52	38.8	#	3	--	--
Li	L	9.8	41.0	2	--	--	62	11.0	#	11	23.3	#	3	--	--
Mg	L	NA	29,875.0	2	--	--	44	13,772	#	13	2,029.8	#	0	--	--
Mn	L	440	1,391.0	2	--	--	62	692	#	24	1,353	#	3	--	--
Hg	non	0.13	0.6	17	#	0.40	66	#	0.10	22	#	0.1	3	--	--
Mo	--	NA	*100% ND*	2	--	--	51	#	*100% ND*	6	--	--	0	--	--
Ni	L	20	39.0	8	--	--	78	22.2	#	40	18.3	#	3	--	--
Se	non	0.41	1.2	18	#	0.50	62	#	0.33	20	#	1.3	3	--	--
Ag	non	1	2.0	8	--	--	48	#	*100% ND*	13	#	0.7	0	--	--
Na	N	NA	194.5	2	--	--	44	166	#	12	168	#	0	--	--
Sr	non	NA	150.0	0	--	--	7	--	--	6	--	--	0	--	--
Tl	non	NA	3.8	3	--	--	46	#	3.6	9	--	--	0	--	--
Ti	N	MNL	217.0	2	--	--	44	207	#	0	--	--	0	--	--
V	L	NA	89.0	2	--	--	51	62.0	#	19	45.1	#	0	--	--
Zn	N	47	75.0	22	65.8	#	80	48.0	#	64	51.4	#	3	--	--

All data are in mg/kg (ppm)

L Lognormal distribution
N Normal distribution
non Nonparametric distribution
ND Non-detect

Dist. Distribution of Data
n Number of Samples
NA Not Applicable (no value listed in Part 201)
MNL Metal Not Listed in Part 201
-- No value calculated (too few samples/detections)
Less than Table 1 Upper Value
Not appropriate calculation method
98 - 100% ND Non-detect percentage too high to estimate a value - use Table 1

2005 MBSS

Table 4 - CLAY

METAL	Dist.	Part 201 Statewide Default Background	Table 1 Upper Range Value	HURON - ERIE LOBE			SAGINAW LOBE			MICHIGAN LOBE			SUPERIOR LOBE		
				n	Two Standard Deviations	97.5 Quantiles	n	Two Standard Deviations	97.5 Quantiles	n	Two Standard Deviations	97.5 Quantiles	n	Two Standard Deviations	97.5 Quantiles
Al	L	6,900	16,324.0	23	12,631	#	51	13,795	#	6	--	--	3	--	--
Sb	non	NA	2.5	8	--	--	0	--	--	12	#	*100% ND*	0	--	--
As	L	5.8	27.7	126	36.6	#	224	17.9	#	17	6.95	#	3	--	--
Ba	L	75	220.0	104	277	#	48	110	#	6	--	--	3	--	--
Be	L	NA	1.8	11	1.9	#	9	--	--	12	#	0.5	0	--	--
Cd	N	1.2	2.5	128	#	3.4	108	#	2.5	16	#	2.0	3	--	--
Cr	L	18	55.0	107	62.8	#	111	37.1	#	17	23.0	#	3	--	--
Co	N	6.8	12.0	29	14.0	#	22	13.4	#	6	--	--	3	--	--
Cu	L	32	58.0	103	48.2	#	103	28.0	#	17	27.0	#	3	--	--
Fe	L	12,000	34,233.0	26	24,544	#	24	29,099	#	6	--	--	3	--	--
Pb	L	21	45.0	126	30.3	#	125	71.5	#	17	47.9	#	3	--	--
Li	L	9.8	41.0	29	40.9	#	22	40.6	#	4	--	--	3	--	--
Mg	N	NA	29,875.0	0	--	--	8	--	--	2	--	--	0	--	--
Mn	L	440	1,391.0	29	767	#	52	584	#	6	--	--	3	--	--
Hg	non	0.13	0.6	97	#	0.63	54	#	*98% ND*	5	--	--	3	--	--
Mo	--	NA	*100% ND*	3	--	--	9	--	--	0	--	--	0	--	--
Ni	N	20	39.0	100	45.0	#	105	36.7	#	6	--	--	3	--	--
Se	non	0.41	1.2	94	#	1.0	43	#	1.3	16	#	1.7	3	--	--
Ag	non	1	2.0	61	#	1.9	28	#	1.0	12	#	1.5	0	--	--
Na	N	NA	194.5	0	--	--	8	--	--	2	--	--	0	--	--
Sr	non	NA	150.0	3	--	--	1	--	--	0	--	--	0	--	--
Tl	non	NA	3.8	8	--	--	8	--	--	1	--	--	0	--	--
Ti	N	MNL	217.0	0	--	--	8	--	--	0	--	--	0	--	--
V	L	NA	89.0	4	--	--	9	62.1	#	2	--	--	0	--	--
Zn	N	47	75.0	126	83.1	#	97	65.7	#	6	--	--	3	--	--

All data are in mg/kg (ppm)

L	Lognormal distribution
N	Normal distribution
non	Nonparametric distribution
ND	Non-detect

Dist.	Distribution of Data
n	Number of Samples
NA	Not Applicable (no value listed in Part 201)
MNL	Metal Not Listed in Part 201
--	No value calculated (too few samples/detections)
(shaded)	Less than Table 1 Upper Value
#	Not appropriate calculation method
98 - 100% ND	Non-detect percentage too high to estimate a value - use Table 1

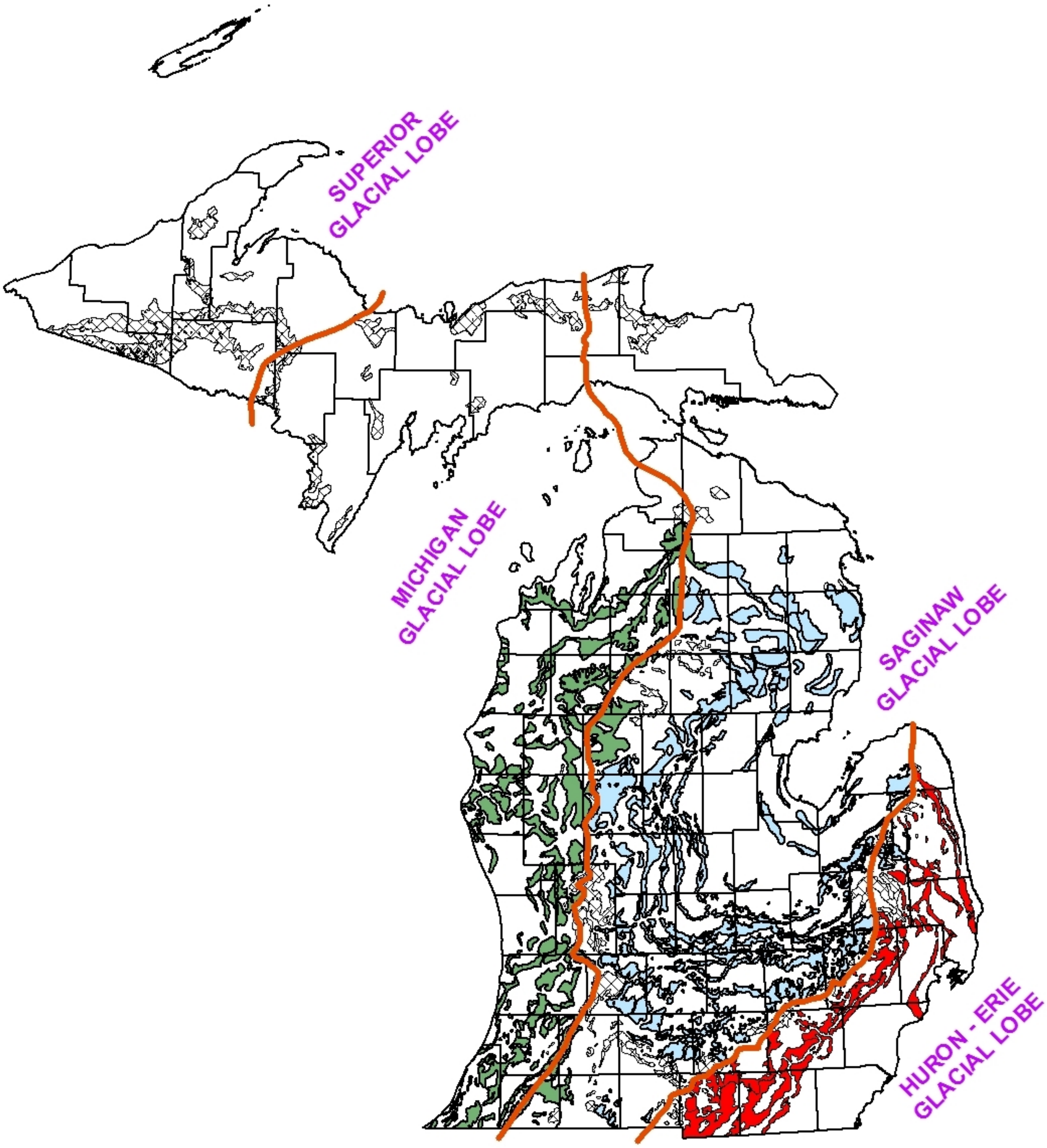
2005 MBSS

Appendix C

Michigan Background Soil Survey (Updated 2015)

The Michigan Department of Environmental Quality (MDEQ) was reorganized and renamed as the Michigan Department of Environment, Great Lakes, and Energy (EGLE) on April 22, 2019. Because this report reflects activities prior to this date, references to DEQ remain and are understood to refer to EGLE.

MICHIGAN BACKGROUND SOIL SURVEY
(Updated 2015)



Permit & Corrective Action Unit
Hazardous Waste Section
Office of Waste Management & Radiological Protection

Michigan Background Soil Survey 2015 Update

Introduction

In 1991, the Michigan Department of Natural Resources (MDNR) released a compilation of soil sampling data that represented what is assumed to be the naturally occurring background concentration of metals in Michigan soils. The data were presented in the "Michigan Background Soil Survey" (MBSS) in April 1991 and after the creation of the Michigan Department of Environmental Quality (MDEQ) the 2005 version was published. In 2014, additional soil sampling data from locations that represent background conditions were collected from files of the Remediation and Redevelopment Division (RRD), and the MBSS 2005 has been updated in 2015 by the MDEQ [(1)].

History

During the mid-1980s, closure plans were submitted to the state pursuant to cleanups and corrective action work at regulated hazardous waste treatment, storage, and disposal facilities. In order to assure that soil removal performed to achieve clean closure was accomplished, standards were established that mandated the removal of contaminants until concentrations were non-detectable or within the naturally occurring background range. Therefore, facilities undergoing closure or corrective action for metals were required to submit analyses of soil from their specific location to determine the criteria to be met, which is statistically equivalent to the local, un-impacted background conditions. In order to evaluate the validity of these site-specific background values, a Michigan soil background database was compiled. That background soils database included information gathered by regulated facilities, as well as samples collected and analyzed by the state.

Background soil data from the regulated facilities were obtained using standard sampling and analytical techniques at the time of collection, which were approved by the state, usually as part of a closure plan or remediation efforts. Common analytical methods from EPA/SW-846 were used (EPA method 200.7, SW-846 method series 6000/7000, etc.). Samples collected by the state were analyzed by an approved contract laboratory, or through the State of Michigan Environmental Laboratory. Some data included was from United States Geological Survey (USGS) and the Army Corp of Engineers. All results represent a total (environmentally available) metals analysis.

Data Reduction

The background soil data for each metal has been reviewed in two basic ways. The first is looking at the data by general soil type. Based usually on a visual observation, and occasionally a soil classification system, soil samples were divided into the following general soil types: topsoil, sand or clay. The other breakdown was by geographic location, using glacial geology distinctions. In Michigan there were several different glacial ice sheets (lobes) that covered distinct areas. The glacial lobes have varying points of origin and traverse differing types of bedrock, and thus the resulting glacial sediments could have varying chemical characteristics based on source rock influences. The assumed boundaries of the glacial lobes have been revised for the 2015 update based on additional information resources [(2)]. Summary statistics are presented for general soil types and for broad geographic areas based on the location of major glacial lobes.

Since the data comes from investigations at different sites, each with various parameters of concern, the suite of metals analyzed was not the same in each case. Depending on how commonly the metal was a pollutant of concern, and the number of samples taken for site-specific background determinations, each metal will have a different total number of individual samples and number of sites/locations the samples came from.

Statistics

A basic statistical analysis was performed for each metal represented in the database [3]. First, the percentage of non-detect values was determined, followed by analysis of the underlying distribution of the data. Finally, summary statistics such as the mean, median, standard deviation, quantiles and the range of concentrations for a metal were calculated with normal, lognormal, or nonparametric methods as appropriate.

In terms of detection limits, metals with 0 – 15 % non-detect results had a value equal to one half (1/2) of the respective detection limit substituted for calculation of summary statistics (Al, As, Ba, Cr, Cu, Fe, Mg, Mn, Sr, Ti, V, Zn). Metals with 15 - 50% non-detect results had summary statistics calculated using Cohen's adjustment (Co, Li, Na, Ni, Pb). For metals with over 50% non-detects, a nonparametric method was used (Ag, Be, Cd, Hg, Mo, Sb, Se, Tl).

The data distribution was analyzed using graphical techniques (histogram, probability plot, box plot) and the Shapiro-Francia or Shapiro-Wilk Goodness-of-Fit test. For simplicity's sake, only normal or lognormal distributions were checked and the best fit to the respective metals' data was chosen. Subsequently, summary statistics were calculated as appropriate for a normal, lognormal, or nonparametric distribution. Tables are attached that list the summary statistics for each metal.

Summary

The MBSS is meant to provide a resource for information regarding the concentration of naturally occurring metals that can be expected in various general soil types and geographic areas of Michigan. Site-specific data is recommended to get the best representation of a local background concentration.

Contact Information

If there are any questions, or a desire to obtain data, please contact those listed below:

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Attachments

Table 1	Statewide Information – all data combined
Tables 2, 3, 4	Topsoil, Sand and Clay - typical range of concentrations
Figure 1	All Sample Locations and glacial lobe boundaries
Figures 2, 3, 4	Topsoil, Sand and Clay - sample locations

TABLE 1 - Statewide Information

METAL	Number of samples	Sites	Percent Non-detect	Assumed Distribution of Data	{a} Mean (mg/kg)	{b} Standard Deviation	Median (mg/kg)	{c} Typical Range of data (mg/kg)
Aluminum (Al)	508	171	0 %	Lognormal	3085	2.317	3205	594 - 16014
Antimony (Sb)	259	82	83.8 %	Non-para	na	na	< 0.30	<0.04 - 11.5
Arsenic (As)	1795	490	6.3 %	Lognormal	2.5	3.088	2.8	< 0.3 - 22.8
Barium (Ba)	1241	401	2.0 %	Lognormal	20.2	2.981	21.7	2.4 - 172
Beryllium (Be)	390	155	71.3 %	Non-para	na	na	< 0.21	<0.09 – 1.0
Cadmium (Cd)	1347	413	69.9 %	Non-para	na	na	< 0.23	<0.05 – 2.0
Chromium (Cr)	861	247	12.5 %	Lognormal	5.7	3.197	6.1	< 0.6 - 55.6
Cobalt (Co)	1161	426	18.4 %	Cen-Log	4.9	2.378	5.1	<0.9 – 26.8
Copper (Cu)	1393	437	7.4 %	Lognormal	6.2	2.920	7.3	<8 - 50.6
Iron (Fe)	568	197	0 %	Lognormal	5533	2.537	5825	86 - 34311
Lead (Pb)	1619	482	18.0 %	Cen-Log	4.0	3.192	5.0	<0.4 - 38.9
Lithium (Li)	312	124	28.5 %	Cen-Log	3.8	3.231	3.5	<0.4 - 37.9
Magnesium (Mg)	248	88	0 %	Lognormal	1884	4.508	1715	98 - 36049
Manganese (Mn)	574	209	0 %	Lognormal	121	3.240	152	12 - 1212
Mercury (Hg)	1168	414	89.1 %	Non-para	na	na	< 0.05	<0.01 - 0.5
Molybdenum (Mo)	275	116	89.1 %	Non-para	na	na	< 1	<0.25 – 5.0
Nickel (Ni)	850	255	18.8 %	Cen-Log	7.4	2.788	8.2	<1- 55.2
Selenium (Se)	1209	420	77.3 %	Non-para	na	na	< 0.44	<0.05 – 1.3
Silver (Ag)	973	320	92.2 %	Non-para	na	na	<0.20	<0.03 – 1.4
Sodium (Na)	216	76	31.9 %	Cen-Log	58.7	3.041	85	<6.6 - 519
Strontium (Sr)	81	51	0 %	Non-para	na	na	31	1.7 - 150
Thallium (Tl)	369	124	90.2 %	Non-para	na	na	< 0.50	<0.08 – 2.7
Titanium (Ti)	97	41	0 %	Normal	118	45.0	108	28 - 208
Vanadium (V)	406	167	1.7 %	Lognormal	9.9	2.500	9.9	1.6 - 59.6
Zinc (Zn)	1392	433	2.2 %	Lognormal	18.3	2.593	22	3 - 118

{a} For lognormal distributions, this represents the geometric mean. For normal distributions this represents the arithmetic mean. The mean was not estimated for data with non-parametric distributions (greater than 50% non-detect).

{b} For lognormal distributions, this represents the geometric standard deviation and is unit-less. The standard deviation is not estimated for data with non-parametric distributions.

{c} Typical range given is the central 95% of the data, or two standard deviations, calculated using the appropriate normal or lognormal formulas. The non-parametric range is based on the 2.5th and 97.5th quantiles of the data set.

na = not applicable for nonparametric data distribution

Non-para = nonparametric (> 50% non-detect)

Cen-Log – censored lognormal (<15 – <50% non-detect)

FIGURE 1

ALL SAMPLING LOCATIONS
Michigan Background Soil Survey 2015

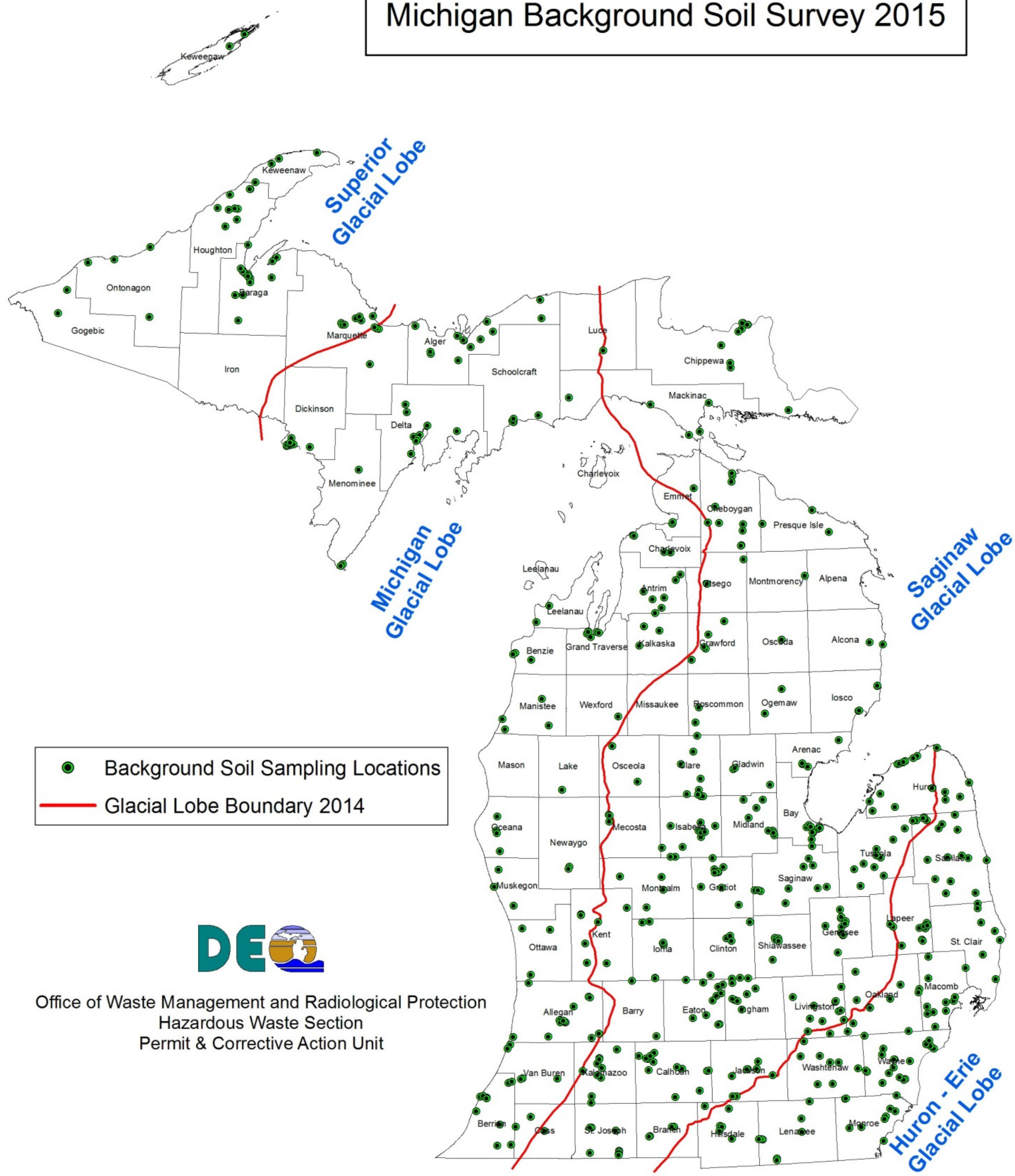


TABLE 2 – TOPSOIL

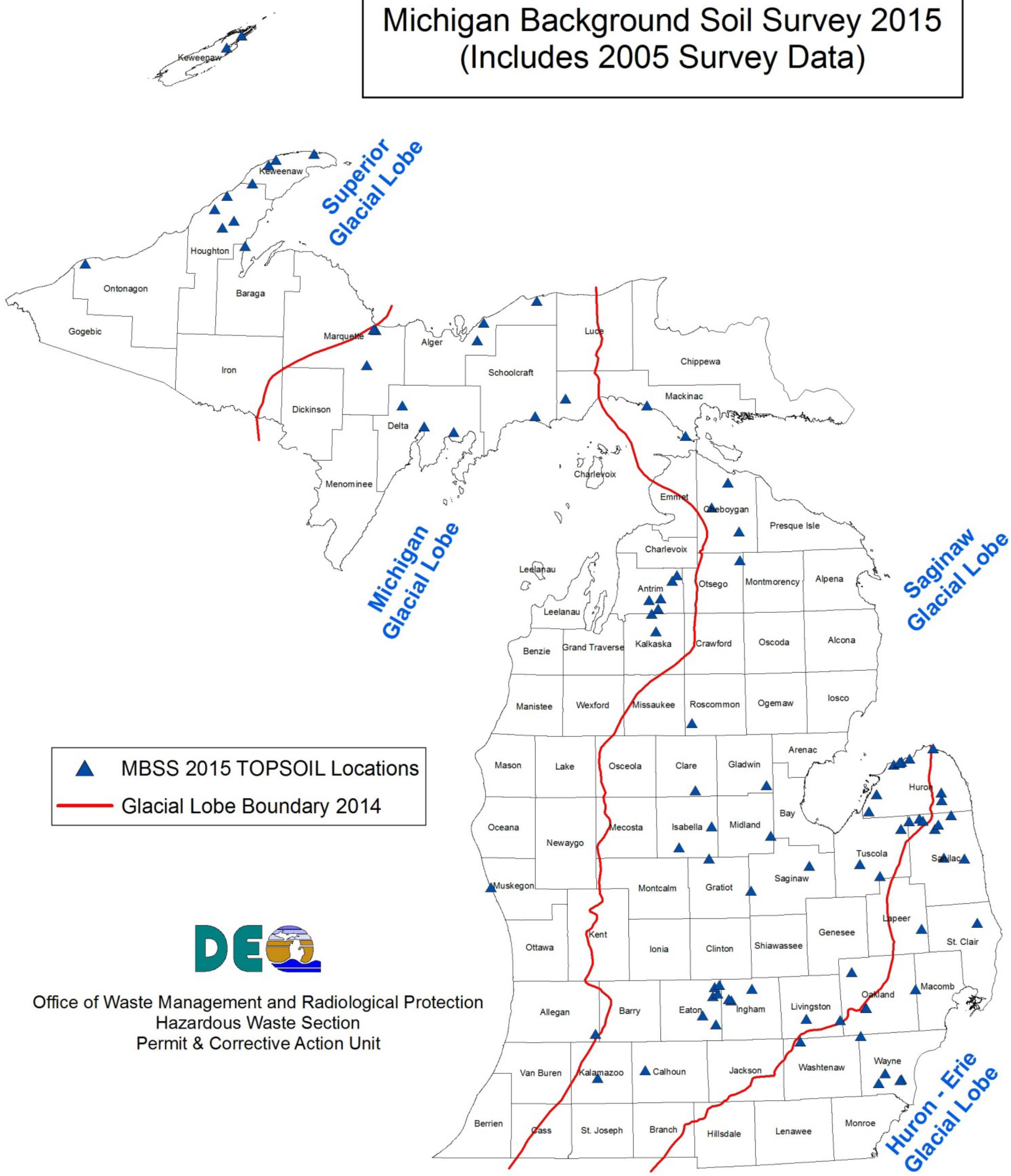
	Dist.	Glacial Lobe Area																				Statewide						
		HURON - ERIE					SAGINAW					MICHIGAN					SUPERIOR					TOPSOIL – Combined Statewide Data						
		n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	min	max	x	SD	1 SD	**2 SD**
Al	L	11	4554	1.439	6553	**9294**	47	2253	2.236	5038	**10908**	25	1041	1.751	1823	**3121**	15	3488	2.110	7360	**15072**	98	340	9950	2141	2.330	4989	**11237**
Sb	Np	0	--	--	--	**--**	1	--	--	--	**--**	0	--	--	--	**--**	0	--	--	--	**--**	1	--	--	--	--	--	**--**
As	L	51	5.7	1.630	9.3	**14.9**	103	2.2	2.357	5.2	**11.8**	29	1.0	2.149	2.1	**4.5**	17	1.4	1.707	2.4	**4.0**	200	<0.25	34	2.4	2.537	6.1	**14.9**
Ba	L	16	40	2.602	104	**261**	52	22.7	1.876	42.6	**77.9**	29	13.5	2.242	30.3	**65.7**	17	41.4	1.749	72.4	**124**	114	<2.2	103	23.6	2.272	53.6	**118**
Be	Np	2	<0.20	--	--	**--**	13	<0.30	--	0.31	**0.71**	0	--	--	--	**--**	0	--	--	--	**--**	15	<0.20	0.84	<0.30	--	0.3	**0.69**
Cd	Np	16	<2.0	--	2.0	**2.0**	52	<2.0	--	<2.0	**<2.0**	29	<2.0	--	<2.0	**<2.0**	17	<2.0	--	<2.0	**<2.0**	114	<0.12	2.0	<2.0	--	<2.0	**2.0**
Cr	L	19	13.1	1.698	22.2	**37.0**	53	5.3	2.459	13.0	**30.9**	29	3.2	1.851	5.9	**10.7**	17	7.7	2.227	17.1	**37.0**	118	<0.70	36	5.7	2.438	13.9	**32.7**
Co	Np	11	<5.0	--	5.7	**7.0**	39	<5.0	--	<5.0	**6.1**	23	<5.0	--	<5.0	**<5.0**	15	<5.0	--	6.1	**11.8**	88	<2.5	14	<5.0	--	<5.0	**7.0**
Cu	L	16	9.9	2.343	23.2	**52.5**	53	4.3	2.377	10.2	**23.5**	29	2.4	2.308	5.5	**12.4**	17	31.3	2.290	71.7	**159**	115	<0.50	82.5	5.6	3.270	18.3	**57.1**
Fe	L	11	9476	1.473	13958	**20244**	51	4439	2.540	11275	**27590**	29	2175	1.840	4002	**7186**	17	5247	2.060	10809	**21632**	108	320	22300	4065	2.431	9882	**23185**
Pb	CL	42	11.6	1.973	22.9	**43.9**	67	8.0	1.968	15.7	**30.2**	29	6.9	1.825	12.6	**22.4**	17	12.1	2.524	30.5	**74.3**	155	<2.3	66.2	9.1	2.048	18.6	**37.1**
Li	V	11	4.3	1.581	6.8	**10.6**	43	2.3	2.581	5.9	**14.8**	23	< 2.0	--	2.3	**3.0**	17	2.9	1.932	5.6	**10.5**	94	<2.0	12	2.2	2.363	5.2	**11.9**
Mg	L	5	3184	2.088	6648	**13489**	5	1410	1.829	2579	**4604**	0	--	--	--	**--**	0	--	--	--	**--**	10	490	8900	2119	2.152	4560	**9517**
Mn	L	11	524	2.224	1165	**2510**	52	113	2.891	327	**905**	29	109	3.441	375	**1228**	17	154	2.413	372	**866**	109	3.0	1500	137	3.154	432	**1302**
Hg	Np	16	<0.10	--	0.10	**0.16**	52	<0.10	--	<0.10	**0.4**	29	<0.10	--	<0.10	**0.10**	17	<0.10	--	<0.10	**0.12**	114	<0.05	0.5	<0.10	--	<0.10	**0.27**
Mo	Np	2	<5.0	--	--	**--**	12	<5.0	--	<5.0	**<5.0**	0	--	--	--	**--**	0	--	--	--	**--**	14	<5.0	<5.0	<5.0	--	<5.0	**<5.0**
Ni	V	12	9.3	3.7	13.0	**16.6**	52	< 5.0	--	9.0	**14.0**	29	<5.0	--	<5.0	**7.1**	17	8.2	3.012	24.7	**71.2**	110	<3.5	47	4.3	2.448	10.5	**24.9**
Se	Np	23	<0.5	--	1.3	**4.7**	51	<0.50	--	<0.50	**0.65**	29	<0.50	--	<0.50	**0.53**	17	<0.50	--	<0.50	**0.65**	120	<0.05	8	<0.50	--	<0.50	**1.3**
Ag	Np	6	<0.25	--	0.75	**1.6**	5	<0.25	--	<0.25	**<0.25**	0	--	--	--	**--**	0	--	--	--	**--**	11	<0.20	1.7	<0.25	--	0.35	**1.4**
Na	V	2	125	--	--	**--**	5	92	24.6	117	**140**	0	--	--	--	**--**	0	--	--	--	**--**	7	<65	130	101	25.9	127	**153**
Sr	Np	0	--	--	--	**--**	7	106	--	148	**156**	0	--	--	--	**--**	0	--	--	--	**--**	7	73	157	106	--	148	**156**
Tl	Np	2	<1.0	--	--	**--**	5	<1.0	--	<1.0	**<1.0**	0	--	--	--	**--**	0	--	--	--	**--**	7	<1.0	<1.0	<1.0	--	<1.0	**<1.0**
Ti	N	2	94.5	--	---	**--**	12	133	43.9	177	**219**	0	--	--	--	**--**	0	--	--	--	**--**	14	73	210	127	42.8	170	**211**
V	L	2	21	--	--	**--**	12	14.1	1.483	20.9	**30.5**	0	--	--	--	**--**	0	--	--	--	**--**	14	<8.0	28	14.9	1.480	22.1	**32.1**
Zn	L	27	39.8	1.770	70.4	**122**	53	18.5	2.057	38.1	**76.1**	29	9.7	2.207	21.4	**45.8**	17	36.7	2.039	74.8	**148**	126	<2.5	99	20.6	2.400	49.4	**115**

Data in mg/kg
Dist. = Distribution of data (CL – Censored Lognormal, L-Lognormal, Np- Nonparametric, N- Normal, V-various).
n = number of samples.
x = arithmetic or geometric mean, nonparametric median (mg/kg).
SD = arithmetic or geometric standard deviation, not applicable for nonparametric.
min = minimum value in data set (mg/kg).
max = maximum value in data set (mg/kg)

Data Range	Lognormal Distribution	Normal Distribution	Nonparametric equivalent
1 SD	(x)(SD)	x + (1)SD	84th quantile
2 SD	$(x)(SD)^{1.96}$	x+ (1.96)SD	97.5th quantile

FIGURE 2

TOPSOIL SAMPLING LOCATIONS
Michigan Background Soil Survey 2015
(Includes 2005 Survey Data)



MDEQ-2015 MBSS

TABLE 3 – SAND

	Dist.	Glacial Lobe Area																				Statewide						
		HURON - ERIE					SAGINAW					MICHIGAN					SUPERIOR					SAND – Combined Statewide Data						
		n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	min	max	x	SD	1 SD	**2 SD**
Al	L	31	3024	1.667	5041	**8233**	162	2265	1.930	4371	**8218**	67	1842	1.850	3408	**6151**	26	5256	2.324	12215	**27446**	286	250	24900	2404	2.031	4883	**9639**
Sb	Np	15	<0.33	--	0.65	**8.7**	58	<0.42	--	< 1.0	**10.8**	50	<0.30	--	<2.9	**5**	57	<0.30	--	0.30	**1.9**	180	<0.08	12.9	<0.30	--	< 1.0	**5.9**
As	L	175	4.1	2.580	10.6	**26.3**	509	1.8	3.140	5.7	**17**	194	0.86	2.630	2.3	**5.7**	87	1.0	2.052	2.1	**4.1**	965	<0.05	40	1.7	3.189	5.4	**16.5**
Ba	L	103	28.1	2.713	76.2	**199**	374	12.4	2.350	29.1	**66.2**	199	8.4	2.784	23.4	**62.5**	85	18.9	2.399	45.3	**105**	761	<0.50	240	13.1	2.713	35.5	**92.6**
Be	Np	31	<0.20	--	0.51	**0.78**	125	<0.20	--	<1.0	**1.0**	74	<0.20	--	<0.50	**1.0**	57	<0.20	--	0.31	**0.86**	287	<0.04	2	<0.20	--	0.50	**1.0**
Cd	Np	97	<0.24	--	2.0	**2.0**	378	<0.2	--	2.0	**2.0**	214	<0.2	--	0.76	**2.0**	79	<0.2	--	0.20	**2.0**	768	<0.01	2.1	<0.20	--	2.0	**2.0**
Cr	L	67	4.1	2.778	11.4	**30.4**	219	3.7	2.347	8.7	**19.7**	100	1.7	3.401	5.8	**18.7**	60	3.1	2.782	8.6	**23.0**	446	<0.25	50	3.1	2.835	8.8	**23.9**
Co	CL	78	6.6	1.666	11.0	**17.9**	376	3.8	2.037	7.7	**15.3**	226	2.9	2.327	6.7	**15.2**	95	7.9	2.137	16.9	**35.0**	775	<0.50	36.7	4.1	2.265	9.3	**20.4**
Cu	L	116	6.5	1.928	12.5	**23.5**	397	3.6	2.412	8.7	**20.2**	210	2.9	3.282	9.5	**29.8**	92	12.7	3.139	39.9	**120**	815	<0.25	375	4.3	2.937	12.6	**35.5**
Fe	L	36	5863	1.934	11339	**21359**	165	4005	2.270	9091	**19972**	80	3032	1.973	5982	**11486**	60	7398	2.270	16793	**36891**	341	100	39000	4351	2.289	9959	**22054**
Pb	CL	132	6.1	2.017	12.3	**24.1**	429	2.8	2.586	7.2	**18.0**	245	1.8	3.206	5.8	**17.7**	155	1.4	4.357	6.1	**25.1**	961	<0.07	36	2.5	3.173	7.9	**24.0**
Li	V	7	3.5	--	7.3	**9.6**	101	2.8	2.232	6.2	**13.5**	22	2.3	2.287	5.3	**11.6**	18	9.7	8.1	17.8	**25.9**	148	<0.80	24.4	2.9	2.575	7.5	**18.5**
Mg	L	18	1411	3.341	4714	**15008**	112	1184	4.016	4755	**18063**	46	1288	3.868	4982	**18255**	26	2010	2.162	4346	**9110**	202	6.9	28000	1312	3.689	4840	**16946**
Mn	L	24	89.2	3.202	286	**873**	170	73.3	3.079	226	**664**	73	64.8	3.478	225	**745**	65	133	3.104	413	**1225**	332	1.0	3600	81.3	3.252	264	**820**
Hg	Np	102	<0.05	--	<0.10	**0.12**	320	<0.05	--	<0.10	**0.23**	188	<0.05	--	<0.10	**0.10**	82	<0.05	--	0.10	**0.11**	692	<0.01	1.2	<0.05	--	<0.10	**0.13**
Mo	Np	17	< 1.0	--	<5.0	**5.0**	95	<5.0	--	<5.0	**5.0**	45	<1.0	--	<5.0	**<5.0**	53	<1.0	--	1.0	**1.4**	210	<0.20	5.0	<1.0	--	<5.0	**5.0**
Ni	V	49	7.8	1.987	15.5	**30.0**	201	4.9	1.968	9.6	**18.5**	128	3.3	2.862	9.4	**25.9**	78	9.3	6.8	16.1	**22.9**	456	<0.08	39.9	4.8	2.469	11.9	**28.2**
Se	Np	109	<0.40	--	0.6	**3.9**	336	<0.35	--	0.54	**1.1**	175	<0.40	--	<0.50	**1.0**	74	<0.20	--	0.47	**0.91**	694	<0.05	4.4	<0.34	--	0.53	**1.2**
Ag	Np	92	<0.20	--	<0.89	**1.2**	296	<0.21	--	<0.50	**<2.0**	185	<0.15	--	<0.50	**0.79**	78	<0.10	--	0.19	**0.50**	651	<0.01	2.0	<0.18	--	<0.50	**1.1**
Na	V	17	<88	--	316	**487**	103	52.6	3.364	177	**567**	40	68.3	41.0	109	**150**	24	43.7	1.750	76.5	**131**	184	<1.9	680	50.9	2.978	152	**432**
Sr	Np	4	28	--	93	**141**	31	28	--	77	**150**	9	4.9	--	70	**94**	15	10	--	16	**72**	59	1.3	150	12.3	--	70	**150**
Tl	Np	39	<0.50	--	<2.7	**3.2**	127	<1.0	--	<1.0	**2.0**	63	<0.50	--	<1.0	**1.7**	58	<0.50	--	0.50	**1.2**	287	<0.02	6.1	<0.50	--	<1.0	**2.8**
Ti	N	4	150	45.5	196	**239**	58	115	40.3	155	**194**	12	111	54.8	166	**218**	0	--	--	--	**--**	74	13	250	117	43.3	160	**202**
V	L	39	9.7	2.020	19.6	**38.5**	145	7.6	2.245	17.1	**37.1**	77	5.2	2.305	12.0	**26.7**	59	15.8	2.251	35.6	**77.5**	320	<0.05	100	8.2	2.412	19.8	**46.1**
Zn	L	115	23.7	1.928	45.7	**85.8**	391	11.3	2.602	29.4	**73.6**	200	9.3	2.509	23.3	**56.4**	91	15.8	2.177	34.4	**72.6**	797	<0.50	95	12.4	2.558	31.7	**78.1**

Data in mg/kg
Dist. = Distribution of data (CL – Censored Lognormal, L-Lognormal, Np- Nonparametric, N- Normal, V-various).
n = number of samples.
x = arithmetic or geometric mean, nonparametric median (mg/kg).
SD = arithmetic or geometric standard deviation, not applicable for nonparametric.
min = minimum value in data set (mg/kg).
max = maximum value in data set (mg/kg).

Data Range	Lognormal Distribution	Normal Distribution	Nonparametric equivalent
1 SD	(x)(SD)	x + (1)SD	84^{th} quantile
2 SD	$(x)(SD)^{1.96}$	x+ (1.96)SD	97.5^{th} quantile

FIGURE 3

SAND SAMPLING LOCATIONS
Michigan Background Soil Survey 2015
(Includes 2005 Survey Data)

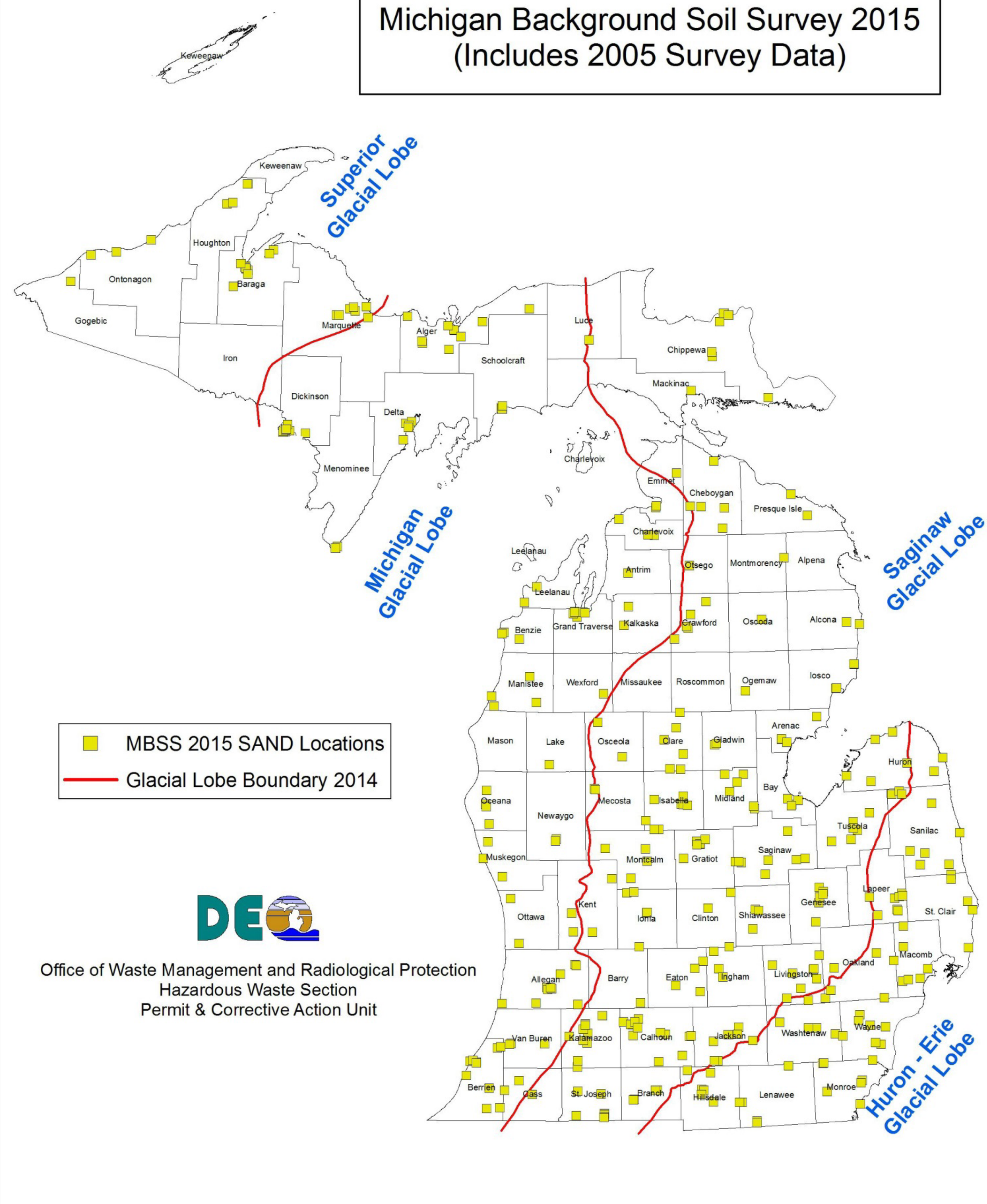


TABLE 4 – CLAY

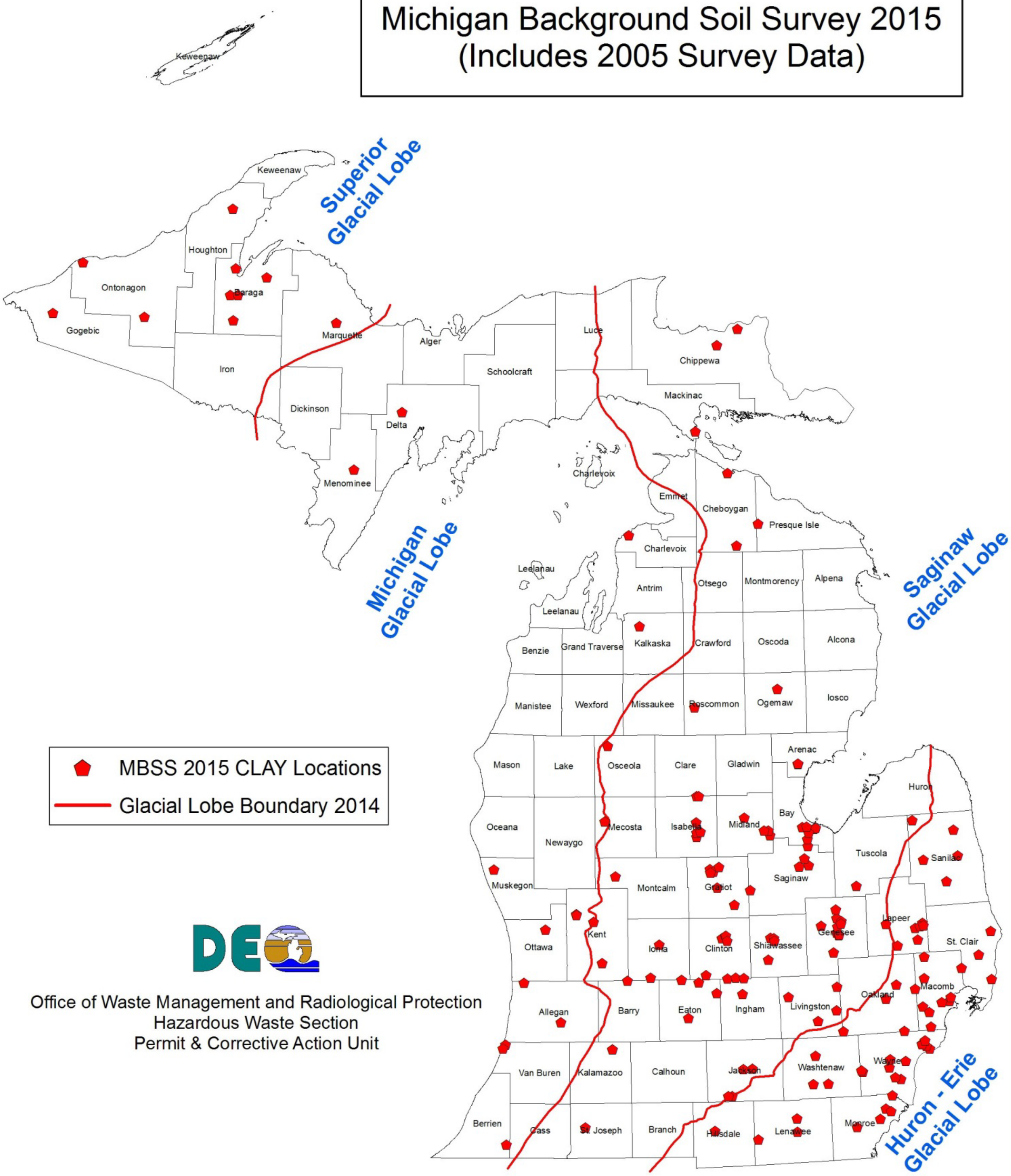
	Dist.	Glacial Lobe Area																				Statewide						
		HURON - ERIE					SAGINAW					MICHIGAN					SUPERIOR					CLAY – Combined Statewide Data						
		n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	x	SD	1 SD	**2 SD**	n	min	max	x	SD	1 SD	**2 SD**
Al	L	56	7445	1.615	12024	**19049**	62	6994	1.451	10148	**14508**	3	10430	1.577	16448	**25470**	3	9490	1.131	10733	**12080**	124	1240	19000	7318	1.530	11197	**16842**
Sb	Np	42	<0.52	--	11.3	**13**	33	<0.03	--	<0.5	**1.0**	3	<0.50	--	<3.6	**<50**	0	--	--	--	**--**	78	<0.04	14.4	<0.40	--	2.2	**13.0**
As	L	237	6.9	2.166	14.9	**31.4**	354	3.7	2.182	8.1	**17.1**	29	2.8	1.783	5.0	**8.7**	10	3.2	1.829	5.9	**10.4**	630	<0.20	88	4.6	2.298	10.6	**23.5**
Ba	L	166	64.4	1.903	123	**227**	171	37.6	2.334	87.8	**198**	25	30.5	1.905	58.1	**108**	4	51.8	3.338	173	**550**	366	<2.5	291	47.5	2.229	106	**229**
Be	V	35	0.48	1.744	0.84	**1.43**	42	0.26	2.608	0.68	**1.70**	5	<0.50	--	1.0	**1.0**	6	<1.0	--	2.2	**2.9**	88	<0.09	3.9	0.36	2.348	0.84	**1.9**
Cd	Np	196	<1.1	--	2.0	**3.1**	240	<0.50	--	2.0	**2.4**	25	<0.13	--	0.21	**2**	4	<1.0	--	<1.0	**<1.0**	465	<0.04	4.7	<0.66	--	2.0	**2.5**
Cr	L	139	16.9	2.168	36.6	**77.0**	141	11.5	1.971	22.7	**43.5**	8	11.0	2.608	28.7	**72.0**	9	29.4	1.543	45.4	**68.8**	297	<0.25	70	14.1	2.138	30.1	**62.5**
Co	CL	98	10.1	1.665	16.8	**27.4**	167	9.4	2.126	20.0	**41.2**	30	7.8	1.904	14.9	**27.6**	19	6.5	2.444	15.9	**37.5**	298	<0.20	85.1	9.3	2.019	18.8	**36.9**
Cu	L	192	14.2	1.840	26.1	**46.9**	232	11.1	1.722	19.1	**32.2**	29	7.9	1.760	13.9	**23.9**	10	19.4	2.066	40.1	**80.4**	463	<0.56	130	12.2	1.825	22.3	**39.7**
Fe	L	59	18110	1.438	26042	**36908**	52	11920	1.814	21623	**38301**	5	10620	1.701	18065	**30082**	3	10970	1.119	12275	**13674**	119	2100	32000	14560	1.690	24606	**40721**
Pb	CL	196	8.6	1.767	15.2	**26.2**	267	8.2	2.327	19.1	**42.9**	29	5.1	1.745	8.9	**15.2**	11	6.2	2.387	14.8	**34.1**	503	<0.86	32	8.1	2.097	17.0	**34.6**
Li	L	32	19.3	1.458	28.1	**40.4**	25	13.5	1.719	23.2	**39.0**	4	13.0	--	16.5	**16.9**	9	14.4	1.596	23.0	**36.0**	70	<3.5	77	15.9	1.611	25.6	**40.5**
Mg	L	20	11760	2.883	33904	**93692**	15	16700	3.269	54592	**170203**	1	24000	--	--	**--**	0	--	--	--	**--**	36	895	140000	13880	3.002	41668	**119706**
Mn	L	53	321	1.725	554	**935**	65	267	1.588	424	**661**	6	243	1.593	387	**605**	9	335	1.517	508	**758**	133	67	1200	290	1.648	478	**772**
Hg	Np	168	<0.06	--	<0.11	**0.58**	164	<0.07	--	<0.10	**0.5**	20	<0.05	--	0.10	**0.70**	10	0.11	--	0.55	**0.61**	362	<0.01	1.2	<0.06	--	<0.10	**0.57**
Mo	Np	14	<2.5	--	4.9	**5.0**	27	<1.0	--	<5.0	**5.0**	4	<3.0	--	<3.0	**<3.0**	6	<3.0	--	<3.0	**<3.0**	51	<0.22	5.0	<2.2	--	<5	**5.0**
Ni	V	140	23.0	10.2	33.2	**43.4**	126	18.9	8.7	27.6	**36.0**	9	10.8	2.001	21.6	**42.1**	9	18.0	6.3	24.3	**30.6**	284	<0.56	53	20.7	9.7	30.4	**40.1**
Se	V	189	<0.50	--	1.0	**1.2**	169	<0.50	--	0.60	**1.1**	27	<0.2	--	0.48	**1.5**	10	0.45	0.11	0.56	**0.67**	395	<0.05	2.4	<0.50	--	0.70	**1.2**
Ag	Np	139	<0.50	--	1.2	**6.0**	148	<0.20	--	<0.50	**1.0**	23	<0.10	--	<0.31	**0.50**	1	<0.5	--	--	**--**	311	<0.02	6.2	<0.25	--	<0.90	**2.8**
Na	V	10	114	240	354	**594**	14	186	1.382	257	**351**	1	--	--	--	**--**	0	--	--	--	**--**	25	<4.5	477	178	129	307	**436**
Sr	Np	6	102	--	150	**150**	1	100	--	--	**--**	2	110	--	--	**--**	6	100	--	150	**150**	15	53	150	100	--	150	**150**
Tl	Np	39	<0.56	--	1.1	**1.7**	33	<1.5	--	<1.5	**<1.5**	3	<0.50	--	<0.50	**<0.50**	0	--	--	--	**--**	75	<0.09	1.8	<0.50	--	<1.0	**1.6**
Ti	N	1	100	--	--	**--**	8	123	67.3	190	**255**	0	--	--	--	**--**	0	--	--	--	**--**	9	42	210	120	63.4	183	**244**
V	L	28	22.9	2.068	47.4	**95.1**	33	16.4	1.742	28.6	**48.7**	5	19.0	2.455	46.6	**110**	6	57.7	1.509	87.1	**129**	72	<4.3	150	21.0	2.050	43.1	**85.8**
Zn	L	218	43.9	1.537	67.5	**102**	212	27.8	1.841	51.2	**91.9**	29	24.0	1.705	40.9	**68.3**	10	26.8	2.819	75.5	**204**	469	<1.5	140	34.0	1.805	61.4	**108**

Data in mg/kg
Dist. = Distribution of data (CL – Censored Lognormal, L-Lognormal, Np- Nonparametric, N- Normal, V-various).
n = number of samples.
x = arithmetic or geometric mean, nonparametric median (mg/kg).
SD = arithmetic or geometric standard deviation, not applicable for nonparametric.
min = minimum value in data set (mg/kg).
max = maximum value in data set (mg/kg).

Data Range	Lognormal Distribution	Normal Distribution	Nonparametric equivalent
1 SD	(x)(SD)	x + (1)SD	84th quantile
2 SD	$(x)(SD)^{1.96}$	x+ (1.96)SD	97.5th quantile

FIGURE 4

CLAY SAMPLING LOCATIONS
Michigan Background Soil Survey 2015
(Includes 2005 Survey Data)



Office of Waste Management and Radiological Protection
Hazardous Waste Section
Permit & Corrective Action Unit

References

(1) Background soil data:

a) The RRD Soil Background Technical Assistance Program Support (TAPS) Team was formed, that includes technical staff with backgrounds in geology, environmental engineering, quality assurance, soil science, chemistry and statistics, including a representative from each of DEQ's District offices. The TAPS Team developed the data collection Data Quality Objective (DQO). This team compiled and analyzed the new data to ensure that it met the data quality objectives specified. This TAPS team will work with stakeholders to ensure that the process is transparent and the results are technically sound.

b) Data was collected, organized, scanned and data entered into spreadsheets by Zachary Spots (student intern from Western Michigan University) and RRD staff in Lansing and the District offices.

c) A Data Quality Objective (DQO) dated September 20, 2013 was developed to describe how to collect new data and accept as valid natural background. Data collection followed this DQO. A separate DQO dated July 10, 2014 was completed address the statistical review of the data.

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Appendix D

MODIFIED TABLES 2, 3, AND 4

2005 Michigan Background Soil Survey UPDATED 2015

Table 2 - TOPSOIL

	Dist.	Part 201 Statewide Default Background	Table 1 Upper Range Value	Glacial Lobe Area											
				HURON - ERIE			SAGINAW			MICHIGAN			SUPERIOR		
				n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles
Aluminum (Al)	L	6,900	16,014	11	**9,294**	#	47	**10,908**	#	25	**3,121**	#	15	**15,072**	#
Antimony (Sb)	Np	NA	11.5	0	--	--	1	--	--	0	--	--	0	--	--
Arsenic (As)	L	5.8	22.8	51	**14.9**	#	103	**11.8**	#	29	**4.5**	#	17	**4**	#
Barium (Ba)	L	75	172	16	**261**	#	52	**77.9**	#	29	**65.7**	#	17	**124**	#
Beryllium (Be)	Np	NA	1	2	--	--	13	#	**0.71**	0	--	--	0	--	--
Cadmium (Cd)	Np	1.2	2	16	#	**2**	52	#	**<2.0**	29	#	**<2.0**	17	#	**<2.0**
Chromium (Cr)	L	18	55.6	19	**37**	#	53	**30.9**	#	29	**10.7**	#	17	**37**	#
Cobalt (Co)	Np	6.8	26.8	11	#	**7**	39	#	**6.1**	23	#	**<5.0**	15	#	**11.8**
Copper (Cu)	L	32	50.6	16	**52.5**	#	53	**23.5**	#	29	**12.4**	#	17	**159**	#
Iron (Fe)	L	12,000	34,311	11	**20,244**	#	51	**27,590**	#	29	**7,186**	#	17	**21,632**	#
Lead (Pb)	CL	21	38.9	42	**43.9**	#	67	**30.2**	#	29	**22.4**	#	17	**74.3**	#
Lithium (Li)	V	9.8	37.9	11	**10.6**	#	43	**14.8**	#	23	**3**	#	17	**10.5**	#
Magnesium (Mg)	L	NA	36,049	5	**13,489**	#	5	**4,604**	#	0	--	--	0	--	--
Manganese (Mn)	L	440	1,212	11	**2,510**	#	52	**905**	#	29	**1,228**	#	17	**866**	#
Mercury (Hg)	Np	0.13	0.5	16	#	**0.16**	52	#	**0.4**	29	#	**0.1**	17	#	**0.12**
Molybdenum (Mo)	Np	NA	5	2	--	--	12	#	**<5.0**	0	--	--	0	--	--
Nickel (Ni)	V	20	55.2	12	**16.6**	#	52	**14**	#	29	**7.1**	#	17	**71.2**	#
Selenium (Se)	Np	0.41	1.3	23	#	**4.7**	51	#	**0.65**	29	#	**0.53**	17	#	**0.65**
Silver (Ag)	Np	1	1.4	6	#	**1.6**	5	#	**<0.25**	0	--	--	0	--	--
Sodium (Na)	V	NA	519	2	--	--	5	**140**	#	0	--	--	0	--	--
Strontium (Sr)	Np	NA	150	0	--	--	7	#	**156**	0	--	--	0	--	--
Thallium (Tl)	Np	NA	2.7	2	--	--	5	#	**<1.0**	0	--	--	0	--	--
Titanium (Ti)	N	MNL	208	2	--	--	12	**219**	#	0	--	--	0	--	--
Vanadium (V)	L	NA	59.6	2	--	--	12	**30.5**	#	0	--	--	0	--	--
Zinc (Zn)	L	47	118	27	**122**	#	53	**76.1**	#	29	**45.8**	#	17	**148**	#

All data in mg/kg (ppm)

Dist.	Distribution of data
L	Lognormal distribution
N	Normal distribution
CL	Censored lognormal distribution
Np	Nonparametric distribution
V	Various distributions

n	Number of samples
SD	Arithmetic or geometric standard deviation, not applicable for nonparametric.
NA	Not Applicable (no value listed in Part 201)
MNL	Metal not listed in Part 201 Criteria
--	No value calculated due to too few samples/detections
#	Not appropriate calculation method
(shaded)	Less than Table 1 Upper Range Value

2005 MBSS
Updated 2015

Table 3 - SAND

	Dist.	Part 201 Statewide Default Background	Table 1 Upper Range Value	Glacial Lobe Area											
				HURON - ERIE			SAGINAW			MICHIGAN			SUPERIOR		
				n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles
Aluminum (Al)	L	6,900	16,014	31	8,233	#	162	8,218	#	67	6,151	#	26	27,446	#
Antimony (Sb)	Np	NA	11.5	15	#	8.7	58	#	10.8	50	#	5	57	#	1.9
Arsenic (As)	L	5.8	22.8	175	26.3	#	509	17	#	194	5.7	#	87	4.1	#
Barium (Ba)	L	75	172	103	199	#	374	66.2	#	199	62.5	#	85	105	#
Beryllium (Be)	Np	NA	1	31	#	0.78	125	#	1	74	#	1	57	#	0.86
Cadmium (Cd)	Np	1.2	2	97	#	2	378	#	2	214	#	2	79	#	2
Chromium (Cr)	L	18	55.6	67	30.4	#	219	19.7	#	100	18.7	#	60	23	#
Cobalt (Co)	CL	6.8	26.8	78	17.9	#	376	15.3	#	226	15.2	#	95	35	#
Copper (Cu)	L	32	50.6	116	23.5	#	397	20.2	#	210	29.8	#	92	120	#
Iron (Fe)	L	12,000	34,311	36	21,359	#	165	19,972	#	80	11,486	#	60	36,891	#
Lead (Pb)	CL	21	38.9	132	24.1	#	429	18	#	245	17.7	#	155	25.1	#
Lithium (Li)	V	9.8	37.9	7	9.6	#	101	13.5	#	22	11.6	#	18	25.9	#
Magnesium (Mg)	L	NA	36,049	18	15,008	#	112	18,063	#	46	18,255	#	26	9,110	#
Manganese (Mn)	L	440	1,212	24	873	#	170	664	#	73	745	#	65	1,225	#
Mercury (Hg)	Np	0.13	0.5	102	#	0.12	320	#	0.23	188	#	0.1	82	#	0.11
Molybdenum (Mo)	Np	NA	5	17	#	5	95	#	5	45	#	<5.0	53	#	1.4
Nickel (Ni)	V	20	55.2	49	30	#	201	18.5	#	128	25.9	#	78	22.9	#
Selenium (Se)	Np	0.41	1.3	109	#	3.9	336	#	1.1	175	#	1	74	#	0.91
Silver (Ag)	Np	1	1.4	92	#	1.2	296	#	<2.0	185	#	0.79	78	#	0.5
Sodium (Na)	V	NA	519	17	487	#	103	567	#	40	150	#	24	131	#
Strontium (Sr)	Np	NA	150	4	#	141	31	#	150	9	#	94	15	#	72
Thallium (Tl)	Np	NA	2.7	39	#	3.2	127	#	2	63	#	1.7	58	#	1.2
Titanium (Ti)	N	MNL	208	4	239	#	58	194	#	12	218	#	0	--	--
Vanadium (V)	L	NA	59.6	39	38.5	#	145	37.1	#	77	26.7	#	59	77.5	#
Zinc (Zn)	L	47	118	115	85.8	#	391	73.6	#	200	56.4	#	91	72.6	#

All data in mg/kg (ppm)

Dist.	Distribution of data
L	Lognormal distribution
N	Normal distribution
CL	Censored lognormal distribution
Np	Nonparametric distribution
V	Various distributions

n	Number of samples
SD	Arithmetic or geometric standard deviation, not applicable for nonparametric.
NA	Not Applicable (no value listed in Part 201)
MNL	Metal not listed in Part 201 Criteria
--	No value calculated due to too few samples/detections
#	Not appropriate calculation method
(grey shading)	Less than Table 1 Upper Range Value

2005 MBSS
Updated 2015

Table 4 - CLAY

	Dist.	Part 201 Statewide Default Background	Table 1 Upper Range Value	Glacial Lobe Area											
				HURON - ERIE			SAGINAW			MICHIGAN			SUPERIOR		
				n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles	n	2 SD	97.5 Quantiles
Aluminum (Al)	L	6,900	16,014	56	19,049	#	62	14,508	#	3	25,470	#	3	12,080	#
Antimony (Sb)	Np	NA	11.5	42	#	13	33	#	1	3	#	<50	0	--	--
Arsenic (As)	L	5.8	22.8	237	31.4	#	354	17.1	#	29	8.7	#	10	10.4	#
Barium (Ba)	L	75	172	166	227	#	171	198	#	25	108	#	4	550	#
Beryllium (Be)	V	NA	1	35	1.43	#	42	1.7	#	5	1	#	6	2.9	#
Cadmium (Cd)	Np	1.2	2	196	#	3.1	240	#	2.4	25	#	2	4	#	<1.0
Chromium (Cr)	L	18	55.6	139	77	#	141	43.5	#	8	72	#	9	68.8	#
Cobalt (Co)	CL	6.8	26.8	98	27.4	#	167	41.2	#	30	27.6	#	19	37.5	#
Copper (Cu)	L	32	50.6	192	46.9	#	232	32.2	#	29	23.9	#	10	80.4	#
Iron (Fe)	L	12,000	34,311	59	36,908	#	52	38,301	#	5	30,082	#	3	13,674	#
Lead (Pb)	CL	21	38.9	196	26.2	#	267	42.9	#	29	15.2	#	11	34.1	#
Lithium (Li)	L	9.8	37.9	32	40.4	#	25	39	#	4	16.9	#	9	36	#
Magnesium (Mg)	L	NA	36,049	20	93,692	#	15	170,203	#	1	--	--	0	--	--
Manganese (Mn)	L	440	1,212	53	935	#	65	661	#	6	605	#	9	758	#
Mercury (Hg)	Np	0.13	0.5	168	#	0.58	164	#	0.5	20	#	0.7	10	#	0.61
Molybdenum (Mo)	Np	NA	5	14	#	5	27	#	5	4	#	<3.0	6	#	<3.0
Nickel (Ni)	V	20	55.2	140	43.4	#	126	36	#	9	42.1	#	9	30.6	#
Selenium (Se)	V	0.41	1.3	189	1.2	#	169	1.1	#	27	1.5	#	10	0.67	#
Silver (Ag)	Np	1	1.4	139	#	6	148	#	1	23	#	0.5	1	--	--
Sodium (Na)	V	NA	519	10	594	#	14	351	#	1	--	--	0	--	--
Strontium (Sr)	Np	NA	150	6	#	150	1	--	--	2	--	--	6	#	150
Thallium (Tl)	Np	NA	2.7	39	#	1.7	33	#	<1.5	3	#	<0.50	0	--	--
Titanium (Ti)	N	MNL	208	1	--	--	8	255	#	0	--	--	0	--	--
Vanadium (V)	L	NA	59.6	28	95.1	#	33	48.7	#	5	110	#	6	129	#
Zinc (Zn)	L	47	118	218	102	#	212	91.9	#	29	68.3	#	10	204	#

All data in mg/kg (ppm)

Dist.	Distribution of data
L	Lognormal distribution
N	Normal distribution
CL	Censored lognormal distribution
Np	Nonparametric distribution
V	Various distributions

n	Number of samples
SD	Arithmetic or geometric standard deviation, not applicable for nonparametric.
NA	Not Applicable (no value listed in Part 201)
MNL	Metal not listed in Part 201 Criteria
--	No value calculated due to too few samples/detections
#	Not appropriate calculation method
(shaded)	Less than Table 1 Upper Range Value

2005 MBSS
Updated 2015