Interim Final – August 2, 2006

RRD OPERATIONAL MEMORANDUM NO. 4

SITE CHARACTERIZATION AND REMEDIATION VERIFICATION

ATTACHMENT 3 - SEDIMENTS

Key definitions for terms used in this document:

NREPA:	The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended
Part 201:	Part 201, Environmental Remediation, of the NREPA
Part 213:	Part 213, Leaking Underground Storage Tanks, of the NREPA
MDEQ:	Michigan Department of Environmental Quality
RRD:	Remediation and Redevelopment Division
U.S.EPA:	United States Environmental Protection Agency
Benthic Community:	Aquatic organisms adapted for living near, on and within sediment
Bioaccumulative Chemicals:	Chemicals that tend to accumulate in the tissues of aquatic and terrestrial organisms as defined in R 323.1043(l) and Table 5 of R 323.1057
Contamination:	Includes hazardous substances that have been released and are present above criteria
Criteria or criterion:	Includes the cleanup criteria for Part 201 of the NREPA and the Risk Based Screening Levels as defined in Part 213 of the NREPA and R 299.5706a(4)
Facility:	Includes "facility" as defined by Part 201 of the NREPA and "site" as defined by Part 213 of the NREPA
Release:	Includes "release" as defined by both Part 201 and Part 213 of the NREPA
Sediment:	Particulate matter that exists at or has settled to the bottom in surface water bodies including those of intermittent streams, creeks, brooks, ditches, drains or wetlands
Surface Water:	Surface waters of the state as defined in R 323.1044(v) and R 323.1043(s)

TABLE OF CONTENTS **Page No.**

1.0 INTRODUCTION 3

2.0 CHARACTERIZATION 4
- 2.1 Identification or confirmation of a release to sediments 4
- 2.2 Initial characterization of the nature and extent of sediment contamination 4
- 2.3 Sediment toxicity testing 5

3.0 SITE-SPECIFIC SEDIMENT CRITERIA DEVELOPMENT 6
- 3.1 Development of site-specific sediment criteria for protection of aquatic life 6
- 3.2 Development of site-specific sediment criteria for protection of other potential use impairments 6

4.0 REMEDIATION 6
- 4.1 Presumptive remedy 6
- 4.2 Response action monitoring and verification of remediation 6

APPENDIX A. Tables 1 and 2, Sediment Quality Guidelines, from the U.S. EPA's *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volumes III*, December, 2002. 8

APPENDIX B. U.S.EPA, Region 5, RCRA Ecological Screening Levels 13

1.0 INTRODUCTION

The particulate matter that exists at, or has settled to the bottom in lakes, ponds, streams, wetlands, and other surface water bodies is called sediment. Sediment represents an essential element of aquatic ecosystems, providing nutrients and habitat for aquatic flora and fauna essential in the aquatic and aquatic-dependent food web. Contamination of sediments by a wide variety of toxic and bioaccumulative chemicals can negatively impact aquatic ecosystems, aquatic dependent wildlife (birds, reptiles and mammals) and human health. Many contaminants, which may be found in only trace amounts in the water column, can accumulate to elevated levels in sediments. Many of these, such as organochlorine pesticides and polychlorinated biphenyls may have been released long ago, but they continue to persist in the environment. In addition to being sinks for contaminants, sediments can also serve as potential sources of pollutants as conditions change in the receiving water system (such as periods of anoxia, inundation/scouring from severe storms or human activity).

At any Part 201 facility or Part 213 site at which surface waters or sediments have been contaminated or at which there is the potential for contamination to have reached surface waters or sediments, characterization of the nature and extent of contamination must address surface water sediments in accordance with R 299.5730, which requires:

> **Rule 730.** (1) Any remedial action plan that addresses surface water or sediments associated with waters of the state shall include site-specific cleanup criteria established <u>by the department</u> on the basis of sound scientific principles and evaluation of bulk sediment chemistry, sediment toxicity and benthic community populations. Criteria shall be established considering the need to eliminate or mitigate the following use impairments, as appropriate to the facility in question:
>
> (a) Restrictions on fish or wildlife consumption.
> (b) Tainting of fish and wildlife flavor.
> (c) Degraded fish or wildlife populations.
> (d) Fish tumors or other deformities.
> (e) Bird or animal deformities or reproductive problems.
> (f) Degradation of benthos.
> (g) Restrictions on dredging activities.
> (h) Eutrophication or undesirable algae.
> (i) Restrictions on drinking water consumption or taste or odor problems.
> (j) Beach closings.
> (k) Degradation of aesthetics.
> (l) Added costs to agriculture, industry, or a local unit of government.
> (m) Degradation of phytoplankton or zooplankton populations.
> (n) Loss of fish and wildlife habitat.
> (o) Unacceptable risk through human contact as a result of absorption of hazardous substances through the skin or by incidental ingestion of sediments.
> (p) Other unacceptable risks to human receptors exposed to hazardous substances in sediments.
>
> (2) The basis for, and information used by the department to develop, cleanup criteria under this rule shall be made available to the public upon request.

In addition to the required analysis of bulk sediment chemistry, sediment toxicity and benthic community populations, the characterization of nature and extent of contamination at a facility where sediment contamination is or may be present should include an assessment of the presence of any of the above-listed use impairments.

There are no generic sediment cleanup criteria. Due to the wide range of potential use impairments, development of site-specific sediment criteria may require addressing multiple exposure scenarios. Each may require different sampling strategies for criteria development and compliance for the protection of aquatic life, wildlife, human health and the ecosystem.

In order for the MDEQ to develop site-specific sediment cleanup criteria as required by R 299.5730(1) and provide the public information as required by R 299.5730(2), any proposal for response activities that includes the development of site-specific sediment criteria must be submitted to the RRD project manager for MDEQ review and approval.

2.0 CHARACTERIZATION

Proper characterization of sediment must determine the potential for contaminated sediments to result in violations of water quality standards (Section 20120a(15)) or use impairments specified in R 299.5730(1) and the nature and extent of contamination. Phasing the sediment characterization may be beneficial. Useful information on evaluating contaminated sediments can be found in U.S.EPA's *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volumes I, II, and III*, December, 2002. (EPA-905-B02-001-A, B, and C). http://www.cerc.usgs.gov/pubs/sedtox/guidance_manual.htm.

2.1 Identification or confirmation of a release to sediments

Where it is suspected that sediment contamination is present, it may be advisable to conduct preliminary sampling to confirm whether there is any sediment contamination. Such initial sampling should be targeted to those areas where sediment contamination is likely to have concentrated. Such areas may include locations of groundwater contamination discharge; locations where contaminated soils, water, or waste materials entered the surface water body; and locations where fine grained materials tend to accumulate such as pools, backwaters, and the inner portions of river bends. Upstream locations, outside the impact area of the facility should also be sampled, to differentiate the impact of the facility from that of upgradient sources or background. Results from this preliminary sampling effort should be used only to evaluate the presence or absence of contamination. This preliminary sampling effort is not intended to provide sufficient information to evaluate the risk posed by contaminants or the need for further response activities where hazardous substance contamination is present.

2.2 Initial characterization of the nature and extent of sediment contamination

Where sediment contamination exists, a work plan must be prepared to determine the lateral and vertical extent of the hazardous substances contamination. Guidance for preparing a sediment sampling plan is available in U.S.EPA's *Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses*: Technical Manual, October 2001. (EPA 823-B-01-002). http://www.epa.gov/waterscience/cs/collectionmanual.pdf
Where it is known that multiple sediment contaminants, significant "unknown" contaminants or

bioaccumulative contaminants are present, it may be prudent to conduct the sediment toxicity or bioaccumulation testing discussed in Section 2.3 below in the initial phase of characterization and include the results with the characterization report.

Because the results of this characterization will form the basis for development of site-specific sediment cleanup criteria by the MDEQ, the work plan must be submitted to the RRD project manager for MDEQ review and approval prior to implementation.

In the initial sediment evaluation phase, the analytical data can be compared to published sediment chemical quality guideline information, which are used as screening values for the potential that the presence of hazardous substances will cause water quality standards violations or any of the use impairments identified in R 299.5730(1). Chemical values for screening sediment chemical sampling results may be found in:

Appendix A:
U.S.EPA's *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volumes III*, December, 2002, Tables 1 and 2. (EPA-905-B02-001-C). http://www.cerc.usgs.gov/pubs/sedtox/guidance_manual.htm.

Appendix B:
U.S.EPA, Region 5, *RCRA Ecological Screening Levels* http://www.epa.gov/RCRIS-Region-5/ca/ESL.pdf

Upon completion of the sediment characterization and comparison of the concentrations of contaminants to screening values, all of the sampling results and comparisons as well as identification of the presence any of the use impairments specified in R 299.5730(1) must be provided in a report to the RRD project manager. MDEQ staff will review the report to determine its approvability and whether additional sediment analysis and site specific sediment criteria development is necessary.

2.3 Sediment toxicity testing

If upon review of the sediment characterization report, the MDEQ determines that the sediment concentrations indicate the potential for toxicity to aquatic life and/or the bioaccumulation of sediment contaminants, appropriate sediment toxicity tests must be performed to determine whether violations of water quality standards may be occurring. A sediment toxicity sampling and analysis work plan must be submitted to the RRD project manager for prior MDEQ review and approval. Guidance for preparing an appropriate plan is available in the U.S. EPA's *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates*, March 2000, EPA600/R-99/064. http://www.epa.gov/ost/cs/freshfact.html.

Upon completing the sediment toxicity sampling and analysis, a sediment toxicity and/or bioaccumulation report must be submitted to the RRD project manager. MDEQ staff will review this report to determine whether there is a potential water quality violation, and whether the development of site-specific sediment criteria is appropriate.

3.0 SITE-SPECIFIC SEDIMENT CRITERIA DEVELOPMENT

3.1 Development of site-specific sediment criteria for protection of aquatic life

If upon review, MDEQ determines that violations of water quality standards are likely to occur, site-specific sediment cleanup criteria will be developed by the MDEQ and documented along with the basis for the criteria. Response action(s) taken at a facility will need to address sediments that exceed site-specific cleanup criteria (Sec. 20118).

3.2 Development of site-specific sediment criteria for protection against other potential use impairments

Site-specific chemical criteria developed to protect aquatic life may not sufficiently address all potential use impairments. The MDEQ will: 1) determine if ecological risks for other than aquatic life need further evaluation; 2) assess the potential for unacceptable risk through human contact as a result of absorption of hazardous substances through the skin or by incidental ingestion of sediments; 3) determine whether additional review of use impairments may be necessary where there is no established basis for calculating numeric or qualitative criteria (e.g., aesthetics), or if conditions warrant further consideration to address Rule 730 elements. Where appropriate, site-specific sediment criteria will be developed to protect against such other potential use impairments.

4.0 Remediation

4.1 Presumptive remedy

Where after site characterization the nature and extent of sediment contamination above screening levels and any use impairments are well defined, and bioaccumulative contaminants are not an issue, it may be more cost effective or otherwise appropriate to proceed with remedy design and implementation to address contamination above the screening levels, rather than proceed with extensive toxicity testing and site-specific criteria development. Although screening levels would not be considered enforceable cleanup criteria, with the exception of bioaccumulative contaminants they would be protective and if they were met and any use impairments addressed, further response action to address sediment contamination would not be required.

4.2 Response action monitoring, and verification of remediation

Facilities with sediment contamination require significant planning for remediation, operation and maintenance, monitoring, and remedy verification. A monitoring plan should be developed and included in any plan for response action involving contaminated sediments. Things that need to be considered in a monitoring plan include:

- The media affected (e.g., sediment, surface water, floodplain soils, surface water, groundwater, biota);
- The variety of contaminants of concern and (potentially ongoing) sources of those contaminants;
- The area and ecological and physical conditions where remediation and monitoring will need to be performed;
- The spatial and temporal variability of sediments and biota to be monitored;
- The nature of the relationship between contaminant levels in sediment and biota; and

- At large facilities, the impact and effectiveness of multiple response actions across the facility.

In some situations nonnumeric parameters such as color or the presence of waste may need to be used to monitor the effectiveness of individual actions.

Physical, chemical and biological monitoring all may play a part in evaluation of the effectiveness of a response action. If remediation is designed for removal of sediments to a specific depth or some erosion-resistant surface (e.g., hardpan), bathymetric or geophysical surveys could be used to determine compliance with the design. Where response action is designed to meet specific concentration criteria, monitoring to assess the effectiveness of response action should include chemical concentrations in sediment, surface water or biota with comparison to cleanup criteria or to environmental and health standards. Verification of the effectiveness of response action may also need to include evaluation of any of the use impairments identified in R 299.5730(1) to assess improved conditions over time.

Response actions conducted to address contaminated sediments may require a variety of permits or compliance with the substantive requirements of the relevant permitting programs (e.g., State Part 301 permits for most sampling, dredging or containment activities in surface water bodies, Federal Section 404 permits for dredging and containment activities, NPDES permits for discharge from dewatering activities).

For further information regarding sediment remediation, operation and maintenance and remedy verification see, the U.S. EPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites,* December, 2006 (EPA-540-R-05-012, OSWER 9355.0-85), http://www.epa.gov/superfund/resources/sediment/pdfs/guidance.pdf.

APPENDIX A

Tables 1 and 2, Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems

From U.S.EPA's *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volumes III*, December, 2002. (EPA-905-B02-001-C). http://www.cerc.usgs.gov/pubs/sedtox/guidance_manual.htm .

Table 1. Sediment quality guidelines that reflect threshold effect concentrations (TECs; i.e., below which harmful effects are unlikely to be observed; from MacDonald *et al.* 2000b).

Substance	*Threshold Effect Concentrations*						
	TEL	LEL	MET	ERL	TEL-HA28	SQAL	Consensus-Based TEC
Metals (in mg/kg DW)							
Arsenic	5.9	6	7	33	11	NG	9.79
Cadmium	0.596	0.6	0.9	5	0.58	NG	0.99
Chromium	37.3	26	55	80	36	NG	43.4
Copper	35.7	16	28	70	28	NG	31.6
Lead	35	31	42	35	37	NG	35.8
Mercury	0.174	0.2	0.2	0.15	NG	NG	0.18
Nickel	18	16	35	30	20	NG	22.7
Zinc	123	120	150	120	98	NG	121
Polycyclic Aromatic Hydrocarbons (PAHs; in µg/kg DW)							
Anthracene	NG	220	NG	85	10	NG	57.2
Fluorene	NG	190	NG	35	10	540	77.4
Naphthalene	NG	NG	400	340	15	470	176
Phenanthrene	41.9	560	400	225	19	1800	204
Benz[a]anthracene	31.7	320	400	230	16	NG	108
Benzo(a)pyrene	31.9	370	500	400	32	NG	150
Chrysene	57.1	340	600	400	27	NG	166
Dibenz[a,h]anthracene	NG	60	NG	60	10	NG	33.0
Fluoranthene	111	750	600	600	31	6200	423
Pyrene	53	490	700	350	44	NG	195
Total PAHs	NG	4000	NG	4000	260	NG	1610

Table 1. Sediment quality guidelines that reflect threshold effect concentrations (TECs; i.e., below which harmful effects are unlikely to be observed; from MacDonald *et al.* 2000b).

Substance	*Threshold Effect Concentrations*						
	TEL	LEL	MET	ERL	TEL-HA28	SQAL	Consensus-Based TEC
Polychlorinated Biphenyls (PCBs; in µg/kg DW)							
Total PCBs	34.1	70	200	50	32	NG	59.8
Organochlorine Pesticides (in µg/kg DW)							
Chlordane	4.5	7	7	0.5	NG	NG	3.24
Dieldrin	2.85	2	2	0.02	NG	110	1.90
Sum DDD	3.54	8	10	2	NG	NG	4.88
Sum DDE	1.42	5	7	2	NG	NG	3.16
Sum DDT	NG	8	9	1	NG	NG	4.16
Total DDTs	7	7	NG	3	NG	NG	5.28
Endrin	2.67	3	8	0.02	NG	42	2.22
Heptachlor epoxide	0.6	5	5	NG	NG	NG	2.47
Lindane (gamma-BHC)	0.94	3	3	NG	NG	3.7	2.37

TEC = Threshold effect concentration (from MacDonald *et al.* 2000a).
TEL = Threshold effect level; dry weight (Smith *et al.* 1996).
LEL = Lowest effect level, dry weight (Persaud *et al.* 1993).
MET = Minimal effect threshold; dry weight (EC & MENVIQ 1992).
ERL = Effects range low; dry weight (Long and Morgan 1991).
TEL-HA28 = Threshold effect level for *Hyalella azteca*; 28 day test; dry weight (USEPA 1996).
SQAL = Sediment quality advisory levels; dry weight at 1% OC (USEPA 1997).
NG = No guideline; DW = dry weight.

Table 2. Sediment quality guidelines that reflect probable effect concentrations (PECs; i.e., above which harmful effects are likely to be observed; from MacDonald *et al.* 2000b).

Substance	*Probable Effect Concentrations*					
	PEL	SEL	TET	ERM	PEL-HA28	Consensus-Based PEC
Metals (in mg/kg DW)						
Arsenic	17	33	17	85	48	33.0
Cadmium	3.53	10	3	9	3.2	4.98
Chromium	90	110	100	145	120	111
Copper	197	110	86	390	100	149
Lead	91.3	250	170	110	82	128
Mercury	0.486	2	1	1.3	NG	1.06
Nickel	36	75	61	50	33	48.6
Zinc	315	820	540	270	540	459
Polycyclic Aromatic Hydrocarbons (PAHs; in µg/kg DW)						
Anthracene	NG	3700	NG	960	170	845
Fluorene	NG	1600	NG	640	150	536
Naphthalene	NG	NG	600	2100	140	561
Phenanthrene	515	9500	800	1380	410	1170
Benz[a]anthracene	385	14800	500	1600	280	1050
Benzo(a)pyrene	782	14400	700	2500	320	1450
Chrysene	862	4600	800	2800	410	1290
Fluoranthene	2355	10200	2000	3600	320	2230
Pyrene	875	8500	1000	2200	490	1520
Total PAHs	NG	100000	NG	35000	3400	22800
Polychlorinated Biphenyls (PCBs; in µg/kg DW)						
Total PCBs	277	5300	1000	400	240	676

Table 2. Sediment quality guidelines that reflect probable effect concentrations (PECs; i.e., above which harmful effects are likely to be observed; from MacDonald *et al.* 2000b).

Substance	*Probable Effect Concentrations*					
	PEL	SEL	TET	ERM	PEL-HA28	Consensus-Based PEC
Organochlorine Pesticides (in µg/kg DW)						
Chlordane	8.9	60	30	6	NG	17.6
Dieldrin	6.67	910	300	8	NG	61.8
Sum DDD	8.51	60	60	20	NG	28.0
Sum DDE	6.75	190	50	15	NG	31.3
Sum DDT	NG	710	50	7	NG	62.9
Total DDTs	4450	120	NG	350	NG	572
Endrin	62.4	1300	500	45	NG	207
Heptachlor Epoxide	2.74	50	30	NG	NG	16.0
Lindane (gamma-BHC)	1.38	10	9	NG	NG	4.99

PECs = probable effect concentrations (from MacDonald *et al.* 2000a)
PEL = Probable effect level; dry weight (Smith *et al.* 1996).
SEL = Severe effect level, dry weight (Persaud *et al.* 1993).
TET = Toxic effect threshold; dry weight (EC & MENVIQ 1992).
ERM = Effects range median; dry weight (Long and Morgan 1991).
PEL-HA28 = Probable effect level for *Hyalella azteca*; 28-day test; dry weight (USEPA 1996a).
NG = No guideline; DW = dry weight.

APPENDIX B

U.S.EPA, Region 5, RCRA Ecological Screening Levels, August 22, 2003

http://www.epa.gov/RCRIS-Region-5/ca/ESL.pdf

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Acenaphthene	83-32-9		**38**[a]	6.71[r]	6.82 e+5
Acenaphthylene	208-96-8		4.84 e+3[b]	5.87[r]	6.82 e+5
Acetone	67-64-1	959	**1700**[a, c, z]	**9.9**[z]	2500[w]
Acetonitrile	75-05-8	17.1	**12 e+3**[d, z]	**56**[z]	1370[w]
Acetophenone	98-86-2		-----	-----	3 e+5
Acetylaminofluorene [2-]	53-96-3		535[b]	15.3	596
Acrolein	107-02-8	0.578	**0.19**[c, z]	**1.52 e-3**[z]	5270[w]
Acrylonitrile	107-13-1	0.797	**66**[a]	**1.2**	23.9[w]
Aldrin	309-00-2		**1.7 e-2**[a, z]	2[t]	3.32[x]
Allyl chloride	107-05-1	1.22		-----	13.4
Aminobiphenyl [4-]	92-67-1			-----	3.05
Aniline	62-53-3		**4.1**[d]	**0.31**	56.8[w]
Anthracene	120-12-7		**0.035**[f]	**57.2**[u]	1.48 e+6
Antimony (Total)	7440-36-0		**80**[c]		142
Aramite	140-57-8		3.09[g]	1.11 e-3	1.66 e+5
Arsenic (Total)	7440-38-2		**148**[f]	**9790**[u]	5700
Azobenzene [p-(dimethylamino)]	60-11-7		1.65[b]	318	40
Barium (Total)	7440-39-3		**220**[d, z]		1040
Benzene	71-43-2	9.76	114[f]	142	255
Benzo[a]anthracene	56-55-3		**0.025**[c, z]	**108**[u]	5210

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Benzo[a]pyrene	50-32-8		0.014[h]	**150**[u]	1520
Benzo[b]fluoranthene	205-99-2		9.07[b]	1.04 e+4	5.98 e+4
Benzo[ghi]perylene	191-24-2		7.64[b]	170[t]	1.19 e+5
Benzo[k]fluoranthene	207-8-9		-----	240[t]	1.48 e+5
Benzyl alcohol	100-51-6		**8.6**[h, z]	**1.04**[z]	6.58 e+4
Beryllium (Total)	7440-41-7		**3.6**[d, k, z]		1060
BHC [alpha-]	319-84-6		12.4[b]	6[t]	99.4
BHC [beta-]	319-85-7		0.495[b]	5[t]	3.98[x]
BHC [delta-]	319-86-8		667[g]	7.15 e+4	9940
BHC [gamma-]	58-89-9		**0.026**[a]	**2.37**[u]	5[x]
Bromodichloromethane	75-27-4			-----	540
Bromoform	75-25-2	9.11	**230**[d, z]	**492**[z]	1.59 e+4
Bromophenyl phenyl ether [4-]	101-55-3		1.5[h]	1550	
Butylamine [N-Nitrosodi-n-]	924-16-3		-----	-----	267
Butylbenzyl phthalate	85-68-7		**23**[d, z]	**1970**[z]	239
Cadmium (Total)	7440-43-9		**0.15**[i, j, k]	**990**[u]	2.22
Carbon disulfide	75-15-0	3.67	**15**[d, z]	**23.9**[z]	94.1
Carbon tetrachloride	56-23-5	1.41	**240**[d]	**1450**	2980
Chlordane	57-74-9		**4.3 e-3**[j]	**3.24**[u, z]	224[x]
Chlorethyl ether [bis(2-]	111-44-4		**19 e+3**[l]	**3520**	2.37 e+4[w]

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Chloro-1-methylethyl)ether [bis(2-]	108-60-1		-----	-----	1.99 e+4
Chloroaniline [p-]	106-47-8		232[g]	146	1100
Chlorobenzene	108-90-7	120	**47**[a]	**291**	1.31 e+4
Chlorobenzilate	510-15-6		7.16[g]	860	5050
Chloroethane	75-0-3	20	-----	-----	
Chloroform	67-66-3	1.34	**140**[d]	**121**	1190
Chloronaphthalene [2-]	91-58-7		0.396[b]	417	12.2
Chlorophenol [2-]	95-57-8		**24**[a]	**31.9**	243
Chlorophenyl phenyl ether [4-]	7005-72-3			-----	
Chloroprene	126-99-8	4.16 E-2		-----	2.9
Chromium^{+3} (Total)	7440-47-3		42[j, k]	**4.34 e+4**[u]	400[y]
Chrysene	218-1-9		-----	**166**[u]	4730
Cobalt (Total)	7440-48-4		**24**[d]	5.00 e+4[t]	140
Copper (Total)	7440-50-8		**1.58**[j, k, z]	**3.16 e+4**[u]	**5400**
Cresol [4,6-dinitro-o-]	534-52-1		**23**[m]	**104**	144
Cresol [m-]	108-39-4		**62**[d]	**52.4**	3490
Cresol [o-]	95-48-7		**67**[c]	**55.4**	4.04 e+4
Cresol [p-chloro-m-]	59-50-7		34.8[g]	388	7950
Cresol [p-]	106-44-5		**25**[a]	**20.2**	1.63 e+5
Cyanide	57-12-5		5.2[a]	0.1[t]	1330[w]

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
DDD [4,4'-]	72-54-8		-----	**4.88**[u, z]	758
DDE [4,4'-]	72-55-9		4.51 e-9[e]	**3.16**[u]	596
DDT [4,4'-]	50-29-3		**1.1 e-5**[a, z]	**4.16**[u]	**3.5**[z]
Di-n-butyl phthalate	84-74-2		**9.7**[a]	**1114**	150
Di-n-octyl phthalate	117-84-0		30[f]	4.06 e+4	7.09 e+5
Diallate	2303-16-4		-----	-----	452[w]
Dibenzofuran	132-64-9		**4**[a, z]	**449**[z]	
Dibenz[a,h]anthracene	53-70-3		-----	**33**[u]	1.84 e+4
Dibromo-3-chloropropane [1,2-]	96-12-8	0.32	-----	-----	35.2
Dibromochloromethane	124-48-1		-----	-----	2050
Dibromoethane [1,2-]	106-93-4	176	-----	-----	1230
Dichloro-2-butene [trans-1,4-]	110-57-6	4.03		-----	
Dichlorobenzene [m-]	541-73-1	273	**38**[a, z]	**1315**[z]	3.77 e+4
Dichlorobenzene [o-]	95-50-1	270	**14**[h]	**294**	2960
Dichlorobenzene [p-]	106-46-7	275	**9.4**[d, z]	**318**[z]	546
Dichlorobenzidine [3,3'-]	91-94-1		**4.5**[a, z]	**127**	646
Dichlorodifluoromethane	75-71-8	1550		-----	3.95 e+4
Dichloroethane [1,1-]	75-34-3	1240	47[h]	0.575	2.01 e+4
Dichloroethane [1,2-]	107-6-2	29.7	**910**[h]	**260**	2.12 e+4
Dichloroethene [1,1-]	75-35-4	0.303	**65**[a, z]	**19.4**[z]	8280

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Dichloroethylene [trans-1,2-]	156-60-5	29.1	**970**[d]	**654**	784
Dichlorophenol [2,4-]	120-83-2		**11**[d, z]	**81.7**[z]	8.75 e+4
Dichlorophenol [2,6-]	87-65-0			-----	1170
Dichloropropane [1,2-]	78-87-5	70.6	**360**[a, z]	**333**[z]	3.27 e+4
Dichloropropene [cis-1,3-]	10061-1-5	5.89	-----	-----	398
Dichloropropene [trans-1,3-]	10061-2-6	5.89	-----	-----	398
Dieldrin	60-57-1		**7.1 e-5**[a]	**1.9**[u, z]	2.38
Diethyl O-2-pyrazinyl phosphorothioate [O,O-]	297-97-2			-----	799
Diethyl phthalate	84-66-2		**110**[a]	**295**	2.48 e+4
Dimethoate	60-51-5		-----	-----	218
Dimethyl phthalate	131-11-3		-----	-----	7.34 e+5
Dimethylbenzidine [3,3'-]	119-93-7			-----	104
Dimethylbenz[a]anthracene [7,12-]	57-97-6		0.548[b]	6.64 e+4	1.63 e+4
Dimethylphenethylamine [alpha,alpha-]	122-9-8			-----	300
Dimethylphenol [2,4-]	105-67-9		100[b]	304	10[x]
Dinitrobenzene [m-]	99-65-0		**22**[d]	**8.61**	655
Dinitrophenol [2,4-]	51-28-5		**19**[a]	**6.21**	60.9
Dinitrotoluene [2,4-]	121-14-2		**44**[d, z]	**14.4**[z]	1280
Dinitrotoluene [2,6-]	606-20-2		**81**[d]	**39.8**	32.8

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Dinoseb	88-85-7		**0.48**[a]	**14.5**	21.8
Dioxane [1,4-]	123-91-1	367	**22 e+3**[a]	**119**	2050[w]
Diphenylamine	122-39-4		412[b]	34.6	1010
Disulfoton	298-4-4		4.02 e-2[e]	324	19.9
D [2,4-]	94-75-7		**220**[a]	**1273**	27.2
Endosulfan I	959-98-8		**0.056**[j]	**3.26**	119
Endosulfan II	33213-65-9		**0.056**[j]	**1.94**	119
Endosulfan sulfate	1031-7-8		2.22[b]	34.6	35.8
Endrin	72-20-8		**0.036**[a]	**2.22**[u, z]	10.1
Endrin aldehyde	7421-93-4		0.15[b]	**480**[z]	10.5
Ethyl methacrylate	97-63-2	356		-----	3 e+4
Ethyl methane sulfonate	62-50-0			-----	
Ethylbenzene	100-41-4	304	**14**[o, z]	**175**	5160
Famphur	52-85-7			-----	49.7
Fluoranthene	206-44-0		**1.9**[f, z]	**423**[u]	1.22 e+5
Fluorene	86-73-7		**19**[d]	**77.4**[u]	1.22 e+5
Heptachlor	76-44-8		**3.8 e-3**[j]	0.6[r]	5.98
Heptachlor epoxide	1024-57-3		**3.8 e-3**[j]	**2.47**[u]	152
Hexachlorobenzene	118-74-1		**3 e-4**[a]	20[t]	199
Hexachlorobutadiene	87-68-3		**0.053**[a, z]	**26.5**[z]	39.8

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Hexachlorocyclopentadiene	77-47-4		77[b]	901	755
Hexachloroethane	67-72-1		**8**[a, z]	**584**[z]	596
Hexachlorophene	70-30-4		0.228[e]	2.31 e+5	199
Hexachloropropene	1888-71-7		-----	-----	
Hexanone [2-]	591-78-6	105	**99**[h, z]	**58.2**[z]	1.26 e+4
Indeno (1,2,3-cd) pyrene	193-39-5		4.31[b]	200[t]	1.09 e+5
Isobutyl alcohol	78-83-1	32.8	-----	-----	2.08 e+4[w]
Isodrin	465-73-6		3.09 e-2[e]	55.2	3.32[x]
Isophorone	78-59-1		**920**[d]	**432**	1.39 e+5
Isosafrole	120-58-1			-----	9940
Kepone	143-50-0		0.132[e]	3.31	32.7
Lead (Total)	7439-92-1		**1.17**[j, k, z]	**3.58 e+4**[u]	53.7
Mercury (Total)	7439-97-6		1.3 e-3[a]	174[r]	100[y]
Methacrylonitrile	126-98-7	3.38		-----	57[w]
Methane [bis(2-chloroethoxy)]	111-91-1		-----	-----	302[w]
Methapyrilene	91-80-5			-----	2780[w]
Methoxychlor	72-43-5		**0.019**[h]	**13.6**	19.9
Methyl bromide	74-83-9	26.5	**16**[d]	**1.37**	235[w]
Methyl chloride	74-87-3	2.63		-----	1.04 e+4[w]
Methyl ethyl ketone	78-93-3	642	**2200**[a, z]	**42.4**[z]	8.96 e+4[w]

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Methyl iodide	74-88-4	11.7		-----	1230
Methyl mercury	22967-92-6		2.46 e-3[e]	0.01	1.58
Methyl methacrylate	80-62-6	87.1	2800[g]	168	9.84 e+5[w]
Methyl methanesulfanate	66-27-3			-----	315[w]
Methyl parathion	298-0-0			-----	0.292
Methyl-2-pentanone [4-]	108-10-1	45.9	**170[h, z]**	**25.1[z]**	4.43 e+5
Methylcholanthrene [3-]	56-49-5		8.91 e-2[b]	8.19 e+6	77.9
Methylene bromide	74-95-3	344		-----	6.5 e+4[w]
Methylene chloride	75-9-2	4780	**940[a]**	**159[z]**	4050[w]
Methylnaphthalene [2-]	91-57-6		330[b]	20.2[r]	3240
Naphthalene	91-20-3	80.1	**13[a, z]**	**176[u]**	99.4
Naphthoquinone [1,4-]	130-15-4		-----	-----	1670
Naphthylamine [1-]	134-32-7		-----	-----	9340
Naphthylamine [2-]	91-59-8			-----	3030
Nickel (Total)	7440-2-0		**28.9[j, k, z]**	**2.27 e+4[u]**	1.36 e+4
Nitroaniline [m-]	99-9-2			-----	3160
Nitroaniline [o-]	88-74-4			-----	7.41 e+4
Nitroaniline [p-]	100-1-6			-----	2.19 e+4
Nitrobenzene	98-95-3		**220[a, z]**	**145[z]**	1310
Nitrophenol [o-]	88-75-5		-----	-----	1600

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Nitrophenol [p-]	100-2-7		**60**[a]	**13.3**	5120
Nitroquinoline-1-oxide [4-]	56-57-5			-----	122
Nitrosodiethylamine [N-]	55-18-5		768[g]	22.8	69.3[w]
Nitrosodimethylamine [N-]	62-75-9			-----	0.0321[w]
Nitrosodiphenylamine [N-]	86-30-6		-----	-----	545
Nitrosomethylethylamine [N-]	10595-95-6			-----	1.66[w]
Nitrosomorpholine [N-]	59-89-2			-----	70.6[w]
Nitrosopiperidine [N-]	100-75-4			-----	6.65[w]
Nitrosopyrrolidine [N-]	930-55-2			-----	12.6[w]
Parathion	56-38-2		**0.013**[a, d]	**0.757**	0.34[y]
Pentachlorobenzene	608-93-5		**0.019**[a, z]	**24**[z]	497
Pentachloroethane	76-1-7	0.68	56.4[g]	689	1.07 e+4
Pentachloronitrobenzene	82-68-8		-----	-----	7090
Pentachlorophenol	87-86-5		**4.0**[j, p, z]	**2.3 e+4**[z]	119
Phenacetin	62-44-2		-----	-----	1.17 e+4
Phenanthrene	85-1-8		**3.6**[f]	**204**[u]	4.57 e+4
Phenol	108-95-2	4.31	**180**[c]	**49.1**	1.2 e+5
Phenylenediamine [p-]	106-50-3			-----	6160[w]
Phorate	298-02-2		3.62[g]	0.861	0.496
Phthalate [bis(2-ethylhexyl)]	117-81-7		**0.3**[q, z]	182[r]	925

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Picoline [2-]	109-6-8	140	-----	-----	9900[w]
Polychlorinated biphenyls	1336-36-3		**1.2 e-4**[a, z]	**59.8**[u]	0.332
Polychlorinated dibenzo-p-dioxins	PCDD-S		2.78 e-7[b]	**0.011**	1.99 e-4
Polychlorinated dibenzofurans	51207-31-9		-----	-----	0.0386
Pronamide	23950-58-5		-----	-----	13.6[x]
Propionitrile	107-12-0	1.87	-----	-----	49.8[w]
Propylamine [N-nitrosodi-n-]	621-64-7			-----	544
Pyrene	129-0-0		0.3[g]	**195**[u]	7.85 e+4
Pyridine	110-86-1	13.7	2380[g]	106	1030[w]
Safrole	94-59-7		-----	-----	404
Selenium (Total)	7782-49-2		5[j]		27.6
Silver (Total)	7440-22-4		**0.12**[f, z]	500[t]	4040
Silvex	93-72-1		**30**[a, z]	**675**[z]	109[x]
Styrene	100-42-5	0.946	**32**[d, z]	**254**[z]	4690
Sulfide	18496-25-8				3.58
Tetrachlorobenzene [1,2,4,5-]	95-94-3		**3**[a, z]	**1252**[z]	2020
Tetrachlorodibenzo-p-dioxin [2,3,7,8-]	1746-1-6		**3 e-9**[a, z]	**1.2 e-4**[z]	1.99 e-4
Tetrachloroethane [1,1,1,2-]	630-20-6	22.5	-----	-----	2.25 e+5
Tetrachloroethane [1,1,2,2-]	79-34-5	353	**380**[a]	**850**	127
Tetrachloroethene	127-18-4	69	**45**[a]	**990**	9920

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Tetrachlorophenol [2,3,4,6-]	58-90-2		**1.2**[a, z]	**129**[z]	199
Tetraethyl dithiopyrophosphate	3689-24-5		13.9[b]	560	596
Thallium (Total)	7440-28-0		**10**[a]		56.9
Tin (Total)	7440-31-5		**180**[d]		7620
Toluene	108-88-3	1040	253[f]	**1220**[z]	5450
Toluidine [5-nitro-o-]	99-55-8			-----	8730
Toluidine [o-]	95-53-4			-----	2970[w]
Toxaphene	8001-35-2		**1.4 e-4**[a, z]	**0.077**[z]	119
Trichlorobenzene [1,2,4-]	120-82-1		**30**[a, z]	**5062**[z]	1.11 e+4
Trichloroethane [1,1,1-]	71-55-6	4170	**76**[d, z]	**213**[z]	2.98 e+4
Trichloroethane [1,1,2-]	79-0-5	11.6	**500**[a, z]	**518**[z]	2.86 e+4
Trichloroethylene	79-1-6	1220	**47**[h, z]	**112**[z]	1.24 e+4
Trichlorofluoromethane	75-69-4	5150		-----	1.64 e+4
Trichlorophenol [2,4,5-]	95-95-4			-----	1.41 e+4
Trichlorophenol [2,4,6-]	88-6-2		**4.9**[d]	**208**	9940
Trichloropropane [1,2,3-]	96-18-4	3.32	-----	-----	3360
Trichlorphenoxyacetic acid [2,4,5-]	93-76-5		686[g]	5.87 e+4	596
Triethyl phosphorothioate [O,O,O-]	126-68-1		58.2[b]	189	818
Trinitrobenzene [Sym-]	99-35-4			-----	376[w]
Vanadium (Total)	7440-62-2		**12**[a, z]		1590

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Vinyl acetate	108-5-4	359	248[g]	13	1.27 e+4[w]
Vinyl chloride	75-1-4	0.221	**930**[a]	**202**	646
Xylenes (total)	1330-20-7	135	**27**[d, z]	**433**[z]	1 e+4[x]
Zinc (Total)	7440-66-6		**65.7**[j, k, z]	**1.21 e+5**[u]	6620[y]

[a] = Michigan water quality standards, Rule 57 water quality values, July 23, 2003. Available at: http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-11383--,00.html. The water ESL data for acenaphthene, BHC (gamma), cyanide and parathion are Michigan (final chronic value or FCV) Tier I criteria. Likewise, water ESL data for dieldrin, dioxin, DDT, endrin, hexachlorobenzene, hexachlorobutadiene, mercury, PCB's and toxaphene represent wildlife values (see Notes at end of these footnotes for dioxin, DDT, mercury and PCB's). All of the remaining data are Tier II values.

[b] = Water Ecological Screening Level (ESL) based on exposure to a mink (*Mustela vison*).

[c] = Indiana water quality standards, Title 327, Article 2, of the Indiana Administrative Code, Feb. 4, 2002. Available at: http://www.ai.org/legislative/iac/t03270/a00020.pdf The water ESL for toxaphene is from the Indiana chronic aquatic criterion for all waters outside of mixing zones (see Table 1 under Rule 1 of 327 IAC 2-1-6 Minimum Surface Water Quality Standards at the above Internet site). The remaining water ESL data are either wildlife values (for dioxin, DDT, mercury and PCB's) or Tier II values for the Indiana Great Lakes Basin (see Great Lakes Basin Criteria and Values Table as developed under Rule 1.5 of 327 IAC Article 2 as referenced above).

[d] = Ohio water quality standards, Chapter 3745-1 of the Ohio Administrative Code, Dec. 30, 2002. Available at: http://www.epa.state.oh.us/dsw/rules/3745-1.html The water ESL data for endrin and parathion are Ohio aquatic life Tier I criteria from the Outside Mixing Zone Average (OMZA). Wildlife values are available for dioxin, DDT, mercury and PCB's. All of the remaining data are Ohio aquatic life Tier II values from the OMZA. See Ohio summary tables for water quality criteria and values along with reference on the development of Tier I criteria and Tier II values.

[e] = Water ESL based on exposure to a belted kingfisher (*Ceryle alcyon*).

[f] = Minnesota water quality standards, Rule 7052.0100, Subpart 2 (water ESL data for arsenic & benzene represents aquatic life chronic standards and dioxin, DDT, mercury and PCB's represents wildlife values), April 13, 2000. Rule 7050.0222, Subpart 2, Feb. 12, 2003. Available at: http://www.revisor.leg.state.mn.us/arule/7050/0100.html and http://www.revisor.leg.state.mn.us/arule/7052/0222.html

[g] = Region 5, RCRA Interim Criteria, based on Aquire database with acceptable review codes and endpoints (life cycle). Must have eight or more acceptable studies (i.e., chronic and/or acute).

[h] = GLWQI Tier II value as presented in: Suter, G.W. II and Tsao, C.L. 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota, 1996 Revision. ES/ER/TM-96/R2. Available at: http://www.esd.oml.gov/programs/ecorisk/ecorisk.html

[i] = U.S. EPA 2001 Update of Ambient Water Quality Criteria for Cadmium (EPA 822-R-01-001).
[j] = U.S. EPA National Recommended Water Quality Criteria: 2002 (EPA 822-R-02-047)
[k] = For hardness-dependent metals (beryllium, cadmium, chromium^{+3}, copper, lead, nickel and zinc), freshwater chronic criteria are based on soft water with a total hardness of 50 mg/L as $CaCO_3$. Soft water is common within Region 5 and this water ESL may be recalculated when site specific water hardness is less than 50 mg/L.
[l] = U.S. EPA Ambient Water Quality for Chloroalkyl Ethers (EPA 440/5-80-030). No definitive data available concerning chronic toxicity. The water ESL is based on no adverse effects for a chronic toxicity embryo-larval test of the fathead minnow.
[m] = U.S. EPA Ambient Water Quality for Nitrophenols (EPA 440/5-80-063). The acute value of 230 ug/l was adjusted with an uncertainty factor of ten for 2,4-dinitrophenol and 4,6-dinitro-o-cresol since no chronic criteria are available.
[n] = Wisconsin Surface Water Quality Criteria and Secondary Values for Toxic Substances, NR 105.07(1)(b), Sept.1, 1997. Available at: http://www.legis.state.wi.us/rsb/code/nr/nr100.html
[o] = Illinois water quality standards, Title 35, Part 302.208, Dec. 20, 2002. Available at: http://www.ipcb.state.il.us/SLR/IPCBandIEPAEnvironmentalRegulations-Title35.asp
[p] = The criterion for pentachlorophenol is pH dependent and is based on a pH of 6.5.
[q] = U.S. EPA Ambient Water Quality for Phthalate Esters (EPA 440/5-80-067). A chronic value of 3 ug/L that resulted in significant reproductive impairment was adjusted with an uncertainity factor of ten.
[r] = Environment Canada. September 1994. Interim Sediment Quality Assessment Values. Ecosystem Conservation Directorate. Evaluation and Interpretation Branch.
[s] = Unless noted otherwise, all Sediment ESLs were derived using equilibrium partitioning (EqP) equation and the corresponding water ESL. Note: Sediment ESL = K_{oc} x Water ESL x 0.01.
[t] = Ontario Ministry of the Environment. August 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.
[u] = Consensus based threshold effect concentrations (TEC) as presented in MacDonald et. al. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch Environ Contam Toxicol 39:20-31 (see Table 2). The TEC for mercury had a high incidence of toxicity and was not used. These values do not consider bioaccumulation nor biomagnification.
[v] = Unless noted otherwise, all Soil ESLs are based on exposure to a masked shrew (*Sorex cinerus*).
[w] = Soil ESL is based on exposure to a meadow vole (*Microtus pennsylvanicus*).
[x] = Soil ESL is based on exposure to a plant.
[y] = Soil ESL is based on exposure to soil invertebrates (e.g., earthworms).
[z] = New ESL data is lower than the previous table.

Notes: New ESL data are displayed in bold font and a dashed line (e.g., -----) is used to show when data was deleted from the previous table (i.e., supporting data was inadequate). All six states in EPA Region 5 have the same water ESL's for dioxin, DDT, mercury and PCB's which are based on a wildlife value. A summary report will be created on the development of soil benchmarks including equations, criteria and references. Likewise, a report will be prepared on the development of water benchmarks that are based on mink and belted kingfisher exposure.