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Correlating Geologic Setting, Engineering and Ground Water Quality at Hazardous and Non-Hazardous Waste Storage, Treatment and Disposal Sites in Ohio

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Introduction

The Ohio Environmental Protection Agency (Ohio EPA) is required to review and, if necessary, amend Ohio's environmental regulations every five years (Ohio Revised Code (ORC) 119.032). Included in this requirement is the review of the non-hazardous solid waste rules as administrated by the Division of Solid and Infectious Waste Management (DSIWM). These rules include the siting and engineering criteria that should be complied with when locating and building a non-hazardous solid waste landfill.

This review is being implemented in a manner consistent with the mission and goals of the Ohio EPA, DSIWM and the Division of Drinking and Ground Waters (DDAGW). The Mission Statement of the Ohio EPA includes the desire to implement "responsible regulation supported by sound science". DSIWM has the long-term goal of developing environmentally sound regulatory strategies. DDAGW has the long-term goal of maximizing the protection of Ohio's ground water.

As part of this review and to implement the goals mentioned above, a study was undertaken to determine if there is a correlation between the impact of a solid and hazardous waste treatment, storage, and disposal facility in the State of Ohio on the ground water quality beneath the facility and the site setting and/or engineering. This study examined Ohio EPA regulated waste treatment, storage, and disposal facilities:

1. Over high yield sand and gravel aquifers and the number of sites impacting the ground water quality of these aquifers;
2. With varying distances of separation between the bottom of the facility and the underlying aquifer system;
3. Underlain with clayey glacial sediments and how many of those facilities have evidence of contaminant migration through these clayey glacial sediments; and
4. That have liners and leachate collection systems and how effective those systems are in preventing ground water contamination.

Ohio Administrative Code (OAC) Rule 3745-27-07 requires permit applicants for a solid waste disposal facility to meet a series of siting criteria. One of these criteria (OAC Rule 3745-27-07(H)(2)(d): One Hundred GPM Aquifer) concerns keeping new and expanding solid waste facilities from being located over high yield sand and gravel aquifers. These aquifers provide a source of ground water for residential and commercial use in quantities that cannot be provided by the underlying bedrock or surrounding clay till sediments. The idea of protecting this

setting was first proposed within the State of Ohio's Ground Water Strategy published in 1986. In 1990, this siting restriction was promulgated into Ohio's solid waste rules.

Another siting criteria (OAC Rule 3745-27-07(H)(2)(e)) requires a solid waste landfill to have a specified distance between the bottom of the liner or waste of the solid waste facility and the aquifer system. This separation distance varies from five feet for a Class 3 residual solid waste landfill to 15 feet for a municipal solid waste landfill. This criterion was required to provide protection to the aquifer system by providing sediments with low permeability to slow contaminant flow from the waste to the aquifer system and to provide sediments with some ability to adsorb the contaminants.

There has been much discussion over the significance of fractures in clayey glacial sediments in the transport of contaminants away from a landfill. Shallow clayey glacial sediments have been shown to be fractured in several areas in Ohio (Strobel, 1992), surrounding states (Herzog, et al, 1989) and Canadian provinces (McKay and Fredericia, 1995). These fractures have been shown to extend downward several meters in the shallow sediments (McKay, et al, 1993) and have been documented below the weathered zone (Kelley, et al, 1986). If these fractures can transmit ground water, then ground water flow through these fractures is much faster than through the surrounding clayey glacial sediments matrix (McKay and Fredericia, 1995). Testing on a site by site basis must be done in order to determine if the fractures can transmit ground water (McKay and Fredericia, 1995). If the fractures that transmit ground water do exist around and beneath a landfill, they can cause contaminants from the landfill to migrate to the aquifer system much faster than one would expect.

All solid waste landfills, with the exception of Class IV residual waste landfills, are required to install a liner system and a leachate collection system. The thickness of the liner varies depending on the class and type of landfill. Class III residual waste landfills are required to have a clay liner three feet in thickness. A municipal waste landfill is required to have a clay liner that is five feet thick and must be accompanied by a flexible membrane liner. No examination has occurred to determine how effective the use of engineered liner systems have been at Ohio hazardous and non-hazardous solid waste treatment, storage, and disposal facilities.

Methodology

Several steps were involved in conducting this study. These steps included determining what information to collect, what sites to examine, as well as collecting, correlating, and presenting the information

What Information to Collect

A worksheet (Appendix II) was developed for acquiring information on the site location, type of site, waste handled at the site, liner and leachate collection system information, hydrogeology of the site, and if present, the type of ground water contamination.

Sites Chosen

Sites included in the study were taken from the DDAGW Solid Waste Landfill Tracking System Database for non-hazardous solid waste sites, and from the DDAGW Hazardous Waste Database for regulated hazardous waste treatment, storage, and disposal sites. Sites regulated by the Division of Emergency and Remedial Response (DERR) were selected from information collected during the promulgation of the rules for the Voluntary Action Program. Sites regulated by the Division of Surface Water (DSW) were selected from examination of DDAGW Central Office files. All sites selected must have had the site hydrogeology characterized and have results from at least one ground water sampling event.

Collection of Information

Information was collected from the following locations: DDAGW-Ground Water Program-Central Office files, DDAGW-Southwest District Office files, and DDAGW-Northwest District Office files. The specific source of the information as well as the collector of the information are noted on the worksheets. While information for DSIWM, DERR and DSW regulated sites was usually collected from inter-office communications from DDAGW to the regulating division, the information for sites regulated by DHWM was collected where possible from the most recently completed RCRA Comprehensive Monitoring Evaluation (CME) relevant to the site.

Correlating the Information

The site information was consolidated onto summary sheets by program (Appendix I). The information was divided into contaminated sites versus uncontaminated sites and the characteristics of the two types of sites were compared. Also an attempt was made to note sites where evidence indicated the migration of contaminants through unconsolidated clay sediments. Finally, the characteristics of sites located over high yield (greater than one hundred (100) gallons per minute) buried valley aquifers were summarized and compared,

Results

General

Of the two hundred eighty-three (283) facilities examined, one hundred eighty-eight (188) sites showed evidence of ground water contamination and ninety-five (95) sites had no evidence of ground water contamination. Eighty (SO) percent of the sites with contamination had evidence of contamination in the uppermost aquifer system (UAS) as well as all significant zones of saturation (SZS) above the UAS. Twenty (20) percent of the contaminated sites examined had contamination only in the SZS.

The sites examined could be divided into several types of facilities. These were lagoons, landfills storage piles or areas, and spills. Table 1 lists the number and the percentage of the total number of sites by type.

Table 1
Number and Percentage of Sites by Type

Site Type	Number of Sites	Percentage of Total
Lagoon	68	24
Landfill	143	51
Storage Pile/Area	17	6
Spill	38	13
Other	17	6
Total	283	100

Engineering

Two hundred thirty-five (235) of the sites examined were designed facilities and could have been constructed with a liner system (Appendix I) due to the nature of the site. This included lagoons, landfills, and storage areas where the site would have been required under current rules and laws to be constructed with a liner. Spills and other sites that are accidental or illegal actions would not be expected to have a liner under normal circumstances and so were excluded. Only twenty-eight (28) percent of the selected sites actually had some form of liner system.

The percentage of contaminated and uncontaminated sites with a liner system is shown in Table 2.

Table 2
Number and Percentage of Relevant Sites by Contamination Status and Liner System Status.

	Number of Sites	Percent Contaminated	Percent Not Contaminated
Have Liner:	65	48%	52%
Partial or Retrofitted Liner; and	41	54%	52%
Full Liner.	24	38%	62%
No Liner	170	68%	32%

Of the sixty-five (65) sites with a liner, forty-one (41) were only partially lined or had a liner retro-fitted to the facility. Seventy-one (71%) percent of the lined sites with contamination were partially lined or retro-fitted with a liner, while only fifty-six (56%) percent of the lined uncontaminated sites were partially lined or retrofitted with a liner. Of the landfill facilities with partial liners and permit-to-install applications approved since 1988, thirty-three (33%) percent have since had ground water contamination detected beneath the site.

Of the sites that were lined when operations began, thirty-eight (3 8%) percent have ground water contamination present under the site. If storage pads are excluded from this group, only twenty-five (25%) percent of the sites lined when operations began have contamination.

Fifty-four (54%) percent of the sites could have been constructed with deachate collection system (Appendix I) due to the nature of the site. This included landfills, and storage areas where the site would have been required under current rules and laws to be constructed with a leachate collection or spill containment system. Spills and other sites that are accidental or illegal actions and lagoons would not be expected to have a leachate collection system under normal circumstances and so were excluded. Of the sites expected to be

constructed with a leachate collections system, forty-two (42%) percent actually had some form of leachate collection system installed. The percentage of contaminated and uncontaminated sites with a leachate collection system is shown in Table 3.

Table 3
Percentage of Relevant Sites by Contamination Status and Leachate Collection System Status.

	Number of Sites	Percent Contaminated	Percent Not Contaminated
Leachate Collection System	**66**	**42%**	**5 8%**
No Leachate Collection System	**89**	**63%**	**37%**

High Yield Sand and Gravel Aquifers

Eighty-four (84) sites were located over high yield (greater than 100 gallons per minute) sand and gravel aquifers (Table 4). Eighty-three (83%) percent of these were contaminated and seventy-four (74%) percent had waste in direct contact with the high yield sand and gravel aquifer. Sixty-four (64%) percent of the sites over high sand and gravel yield aquifers with no contamination had some separation between the waste and the high yield sand and gravel aquifer.

Table 4
Number of Sites Located Over High Yield Sand and Gravel Aquifers and the Amount of Separation Distance Between the Waste/Liner and the High Sand and Gravel Yield Aquifer.

	Number of Sites with Contamination	Number of Sites with No Contamination
Number of sites located over high yield (>100gpm) sand and gravel aquifers.	70	14
Separation distance from high yield sand and gravel aquifer to waste/liner.		
O-5 feet	52	5
5-10 feet	5	1
10-15 feet	3	0
>15 feet	IO	8

Separation Distance

The separation distance between the waste and the UAS was examined and the results are portrayed in Table 5. Seventy-three (73%) percent of the contaminated sites have less than fifteen (15) feet of separation between the UAS and the waste. Eighty (80%) percent of those sites without contamination have greater than fifteen (15) feet of separation between the waste and the UAS. Sixty percent (60%) of those sites with contamination and more than fifteen (15) feet of separation between the waste and the UAS did not have contamination present in the UAS. The contaminated zone is a SZS above the UAS.

Of the sites where only the SZS's are contaminated and the UAS is not, eighty-two (82%) percent of these sites have less than five (5) feet of separation between the waste and the SZS (Table 6). Only four (4%) percent of such sites have greater than fifteen (15) feet of separation between the waste and the SZS.

Table 5
Percentage of Sites According to Amount of Separation Distance Between the UAS and the Waste.

Separation Distance Between UAS and the Waste or Liner	Percentage of Contaminated Sites with Specified Separation Distance	Percentage of Sites with No Contamination with the Specified Separation Distance
0 - 5 feet	50%	11%
5 - 10 feet	13%	3%
10 - 15 feet	10%	6%
> 15 feet	27%	80%

Table 6
Percentage of Sites According to Amount of Separation Distance Between the SZS and the Waste Where the UAS is not Contaminated.

Separation Distance Between the SZS and the Waste	Percentage of SZS Only Contaminated Sites with Specified Separation Distance
0 - 5 feet	82%
5 - 10 feet	3%
10 - 15 feet	11%
> 15 feet	4%

Migration Through Clayey Glacial Sediments

Of the one hundred fifty-three (153) sites underlain by clayey glacial sediments, eighty-one sites (53%) show evidence of contaminant migration through the clayey glacial sediments. Seventy-three (73) of these sites show evidence of contaminant migration only through clayey glacial sediments less than thirty (30) feet below the ground surface.

Eighty-nine (89) sites are underlain by clayey glacial sediments deeper than thirty

(30) feet below the ground surface. Eight (9%) of these sites show evidence of migration through these deep clayey glacial sediments .

Examining the data by the type of facility, the results show that migration through clayey glacial sediments is more likely to occur at a storage area or spill than a landfill or lagoon (Table 7).

Table 7
Percent of Sites Underlain By Clayey Glacial Sediments with evidence of contaminant migration through the unconsolidated clay sediments

Facility Type	Number of Facility Type Underlain by Clay Sediments	Number with Evidence of Contamination Through Clay Sediments	Percent of Relevant Sites with Contaminant Migration
Lagoon	41	27	66
Landfill	78	28	36
Storage Area	15	12	80
Spills	19	14	74

Discussion

Separation Distance Between Waste and the UAS/SZS.

The data indicates that Ohio EPA's position of requiring separation between the liner/waste and the UAS is technically important for preventing ground water contamination by **a** landfill. The Ohio EPA's municipal solid waste landfill rules require that 15 feet of separation exist between the liner/waste and the UAS. This is necessary to provide the maximum protection against contamination for the UAS(Ohio EPA, 1989). This separation distance increases the amount of time during which the contaminants are in contact with the non-UAS formations and maximizes the opportunity for oxidation, adsorption, absorption and other chemical reactions to occur to the leachate contaminants prior to reaching the UAS (Aller, et al, 1985). Table 8 supports, as does the data already presented, the above points in showing that as separation distance increases the percentage of sites with no contamination rapidly increases.

Table 8

Separation Distance (feet) to UAS.	**Percentage of Sites With This Separation Distance and No Contamination in the UAS.**
o-5	10
5-10	11
10-15	24
<15	60

Additional indications of the importance of separation distance can be seen in the data for the sites over high yield aquifers. Seventy-four (74%) percent of the contaminated sites over a high yield aquifer have no separation between the waste and the aquifer, while sixty-four (64%) percent of the uncontaminated sites over the high yield aquifers have greater than five (5) feet of separation.

The engineering data shows that while liners and leachate collection systems will significantly reduce the incidence of contamination, contamination is still possible. The combination of separation distance and engineering or taking a good site and making it better (Ohio EPA, 1989), is the most effective means of preventing contamination.

The data supports the present siting criteria requiring separation between the liner/waste and the UAS at non-hazardous solid waste landfills. The data also supports the DDAGW position on maintaining separation between the bottom of lagoons and the UAS or the first SZS underlying the facility.

Contaminant Migration Through Clayey Glacial Sediments

Clayey glacial sediments are mildly effective in preventing contamination of shallow (less than thirty (30) feet below ground surface) UAS and SZS units and very effective in preventing migration to deeper (greater than thirty (30) feet below ground surface) UAS and SZS units. Forty-seven (47%) percent of the relevant sites examined exhibited no migration of contaminants through shallow clayey glacial sediments, while ninety-one (9 1%) percent of the relevant sites examined showed no evidence of migration through deeper clayey glacial sediments.

Migration through clayey glacial sediments is much more likely to occur at a spill or storage area site than a lagoon or landfill site. Eighty (80%) percent of relevant storage area sites and seventy-four (74%) percent of relevant spill sites exhibited contaminant migration through underlying clayey glacial sediments. Only thirty-six (36%) percent of relevant landfill sites and sixty-six (66%) percent of relevant lagoons had similar indications of contaminant migration through underlying clayey glacial sediments.

The migration of contaminants through clayey glacial sediments is probably occurring via fractures in the sediments as well as animal burrows (Ruland, et al, 199 1). The data indicates that pathways through the clayey glacial sediments are predominately in the shallow (less than 30 feet in depth) clayey glacial sediments . The difference between the results for landfills and lagoons versus spills and storage areas, may reflect the sealing of the pathways through the clayey glacial sediments due to the smearing of the sediments during construction of the lagoon or landfill excavation. In spite of this, the data points to the necessity of constructing a liner even when the site is underlain by a substantial thickness of clayey glacial sediments.

The lack of migration through deep (greater than 30 feet in depth) clayey glacial sediments is consistent with studies conducted in Canada (Ruland, et al, 1991) and with data generated during the permitting of several landfills around Ohio. Isotope and hydrogeolgoic investigations conducted at the Franklin Co. Landfill, Williams Co. Landfill, ClarkCo Landfill in Clark Co., and the Preble Co. Landfill support the results presented here that most deep (greater than 30 feet in depth) clayey glacial sediments are resistant to ground water and contaminant migration.

However seven facilities were located with contaminants in and through deep (greater than 30 feet in depth) clayey glacial sediments. Because of this any proposed facility should be examined to determine if the deep (greater than 30 feet in depth) clayey glacial sediments are truly protective.

Engineering

A greater percentage of uncontaminated sites have liners than contaminated sites (38% vs 2 1%). At first glance this difference, while significant, does not appear to support the use of liners to protect against ground water contamination. A closer look at the data indicates that liners are highly effective when installed prior to the site beginning operations. Sixty-two (62%) percent of sites possessing liners prior to site operations commencing exhibited no indication of ground water contamination. When storage pads are excluded from this comparison the percentage of sites with no underlying ground water contamination increases to seventy-five (75%) percent.

The sites with only partial liners or where a full liner was added after the site had been operated for a period of time are much more likely to have ground water contamination present under them than sites with full liners present when operations began. Seventy-one (7 1%) percent of sites with contamination and a liner were partially lined. Thirty-three (33%) percent of solid waste landfills with a permit-to-install application approved since 1988 with a partial or retro-fitted liner have since had ground water contamination discovered beneath them.

The above discussion indicates the need to carefully examine sites with partial liners prior to issuing an approval of a permit-to-install for an expansion. This information also indicates that some fully lined facilities did fail. Further examination of these sites may be warranted to determine why the liners failed.

Sites with leachate collection systems were more likely to not have contamination than those sites without leachate collection systems. This indicates that removal of leachate via the leachate collection system is effective in reducing the chances that a release will occur from the facility.

High Yield Aquifers

The data for sites located above a high yield (greater than 100 gpm) aquifer again indicate the importance of having some separation distance between the aquifer and the waste. Of the seventy sites with contamination, fifty-two had less than five feet of separation distance between the waste/liner and the high yield aquifer. Table 9 also indicates that the percentage of sites without contamination general

increases with increased separation distance.

Table 9

Separation Distance (feet) to High Yield Aquifer.	**Percentage of Sites With This Separation Distance and No Contamination in the High Yield Aquifer.**
o-5	**9**
5-10	**18**
10-15	0
<15	44

Even with separation between the waste/liner and the high yield aquifer there is little guarantee of not having contamination. Ten sites with more than 15 feet of separation distance between the waste/liner and the high yield aquifer had contamination. Due to this, caution should be exercised prior to locating a waste facility over a high yield aquifer. The site should be carefully characterized as to the amount of separation available at the proposed facility between the waste/liner and the high yield aquifer and to the nature and resistance to contaminant migration that these sediments will provide. Only those sites should be allowed where a demonstration that the hydrogeologic conditions at the site provide the maximum assurance of preventing contamination. Even then extra engineering should be provided above what would normally be required to ensure the protection of the high yield aquifer.

Conclusions

This study examined if there is a correlation between the site setting and/or engineering of a solid and hazardous waste storage and disposal facility in the State of Ohio by observing the impact on the ground water quality beneath the facility. The results indicate the following:

1. The more separation that exists between the bottom of the waste/liner and the UAS or SZS, the less likely that there will be a leachate release to the UAS or SZS; and

2. Contaminant migration through shallow (less than thirty feet from the ground surface) clayey glacial sediments is common. Contaminant migration through deep (greater than thirty feet from the ground surface) clayey glacial sediments is rare; and

3. Liners and leachate collection systems appear to significantly decrease the chance of ground water contamination occurring. However, partially lined sites or sites where the liner was retro-actively installed after the commencement of waste placement were much more likely to have ground water contamination than sites where liners were installed prior to waste placement beginning; and

4. The data generated supports the conclusion that the amount of separation distance between the waste/liner and the high yield aquifer is an important indicator of whether a high yield aquifer will be prone to being contaminated or not. Even where a large amount of separation exists contamination can occur and care should be taken in verifying the protectiveness of the hydrogeology of the site prior to locating a facility over a high yield aquifer.

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Appendix I

Results Summary Tables

Summary of Results

	DERR		DHWM		DSIWM		DSW		Total	
	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.
Number of Sites	34	2	83	33	57	51	14	9	188	95
Number of sites with a liner	2	0	12	4	12	24	5	6	31	34
Number of sites without a liner.	11	1	53	24	45	27	6	3	115	55
Liner not applicable.	21	1	18	5	0	0	3	0	42	6
Sites partially lined or lined recently.	1	0	8	1	11	18	2	0	22	19
Site lined when opened.	1	0	4	3	1	6	3	6	9*	15
DSIWM landfills with partial liner and PTI approved since 1988.	n/a	n/a	n/a	n/a	7	14	n/a	n/a	7	14

* Four of these sites are storage pads.

Summary of Results

	DERR		DHWM		DSIWM		DSW		Total	
	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.
Number of sites with a leachate collection system.	1	0	8	4	18	33	1	1	28	38
Number of sites without a leachate collection system	7	1	8	13	39	18	2	1	56	33
Leachate collection system not applicable	26	1	67	16	0	0	11	7	104	24
Type of Contamination:										
Organic + Inorganic	32	n/a	68	n/a	37	n/a	3	n/a	140	n/a
Inorganic	2	n/a	15	n/a	20	n/a	11	n/a	48	n/a
Facility Type:										
Lagoon	3	0	35	15	0	0	8	7	46	22
Landfill	8	1	12	9	57	51	3	2	80	63
Storage Pile	1	0	12	4	0	0	0	0	13	4
Spill	19	1	15	1	0	0	2	0	36	2
Other	3	0	9	4	0	0	1	0	13	4

Summary of Results

	DERR		DHWM		DSIWM		DSW		Total	
Separation Distance to Uppermost Aquifer System (UAS)	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.
O-5 feet	19	1	33	7	33	1	9	1	94	10
5-10 feet	3	0	11	1	8	1	2	1	24	3
10-15 feet	1	0	13	3	4	3	1	0	19	6
>15 feet	11	1	26	22	12	46	2	7	51	76
Unit Contamination Occurs:										
Significant Zone of Saturation (SZS) Only	4	n/a	21	n/a	9	n/a	4	n/a	38	n/a
UAS only and UAS plus overlying SZS	30	n/a	62	n/a	48	n/a	10	n/a	150	n/a
Separation to SZS if SZS only unit contaminated.										
O-5 feet	3	n/a	18	n/a	7	n/a	3	n/a	31	n/a
5- 10 feet	0	n/a	0	n/a	1	n/a	1	n/a	2	n/a
IO-15 feet	1	n/a	3	n/a	0	n/a	0	n/a	4	n/a
>15 feet	0	n/a	0	n/a	1	n/a	0	n/a	1	n/a

Summary of Results

	DERR		DHWM		DSIWM		DSW		Total	
	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.
Number of contaminated sites with >15 ft of separation to UAS where UAS is not contaminated.	5	n/a	14	n/a	8	n/a	3	n/a	30	n/a
Type of Geologic Material Separating SZS/UAS From Waste/Liner										
Clay/Silt	14	1	52	22	14	42	1	7	81	72
Shale	0	0	0	3	0	3	0	1	0	7
Sandstone	0	0	0	0	0	1	0	0	0	1
Limestone	0	0	0	0	0	0	0	0	0	0
Claystone	0	0	0	0	0	3	0	0	0	3
No Separation	20	1	31	8	43	2	13	1	107	12

Summary of Results

	DERR		DHWM		DSIWM		DSW		Total	
	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.
Number of sites located over high yield (>100gpm) unconsolidated aquifer.	18	1	26	4	18	7	8	2	70	14
Separation distance from high yield aquifer to waste/liner.										
O-5 feet	12	1	17	3	16	0	7	1	52	5
5- 10 feet	2	0	2	0	0	0	1	1	5	1
10-15 feet	0	0	2	0	1	0	0	0	3	0
>15 feet	4	0	5	1	1	7	0	0	10	8

Summary of Results

	DERR		DHWM		DSIWM		DSW		Total	
	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.	Contam.	Not Contam.
Number of sites with contaminant migration through shallow (<30 feet) unconsolidated clay rich sediments.	14	n/a	52	n/a	14	n/a	1	n/a	81	n/a
Number of sites with contaminant migration through deep (>30 feet) unconsolidated clay rich sediments.	1	n/a	4	n/a	3	n/a	0	n/a	8	n/a
Number of sites with no contaminant migration through deep (>30 feet beneath the ground surface) unconsolidated clay sediments* (includes 15 sites with contaminant migration through shallow (<30 feet beneath the ground surface) unconsolidated clay sediments.	5	1	14	15	8	31	3	5	30	52

* Does not include sites with migration through a shallow zone to an SZS or UAS but no evidence that a lower unconsolidated clay sediment unit exists below the UAS/SZS. It does include sites where the waste unit was installed through the shallow unconsolidated clay sediment unit.

Appendix II

Data Collection Worksheets

WORKSHEET

FACILITY INFORMATION	
Name.	Type of Facility: Industrial, Municipal, Other
Address:	If Industrial: Type of Storage/Disposal: Lagoon, Storage Pile, Landfill Type of Waste: Solid, Semi-Solid, Liquid Description of Waste*: Date Opened: Date: Closed: Regulated By: DSIWM, DERR, DHWM, DSW
County:	Source of Facility Information:
Township:	Collector(s) of Information:
Township/Range:	
Latitude/Longitude:	

ENGINEERING INFORMATION Source of Information:	
Liner: Yes No If Yes: Type of Liner: Clay, Synthetic, Composite Thickness of Clay Liner: 0, <1, 1, 2, 3, 4, 5, >5 If Synthetic Used: Plastic, GeoSynthetic, Both	Leachate Collection: Yes No If Yes, Active: Yes No Leachate Outbreaks Present: Yes No Cap: **Yes** **No** If Yes: Type of Cap: Clay, Synthetic, Composite Thickness of Cap: < 1, 1, 2, 3, 4, >4

Hydrogeologic Information Worksheet

Description of Sediment /Rock Units Between Waste/Liner and Uppermost Aquifer System

Facility:
Source of Information:
Information Collected By:

Unit	Sign. Zone of Saturation or Aquitard (SZS/AT)	Rock or Sediment Description (Lmst, sdst, cl till, sand, etc.)	Thickness (0 ft, O-5 ft. ,5-10 ft., 10-15 ft., >15 ft.)	Permeability (cm/sec) (<1X10^{-5}, 1X10^{-5}, 1X10^{-6}, 1X10^{-7}, >1X10^{-7})	Contam-ination (Yes/no)	Contaminates
1						
2						
3						
4						
5						
U.A.S.						

WORKSHEET

DEFINITIONS OF DATA FIELDS

Facility Information:	**Contains general information about the facility. This information is being gathered to identify and locate the facility. Also the information gathered shall identify the wastes taken at the facility as well as the basic operating history of the site.**
Name:	Formal legal name of the facility. Alias' may be listed in parenthesis.
Address:	This should be the address of the facility, not a mail drop. Leave blank if this information is not available.
County:	County facility is located within.
Township:	Township facility is located within.
Township/Range:	Township and Range facility is located as taken from USGS 7-1/2 minute quadrangle maps.
Lat./Long.:	Latitude and Longitude of site if available.
Type of Facility:	This field will identify whether the facility is a captive industrial facility which disposed of only industrial/commercial waste or a municipal waste landfill which disposed of mixed household, commercial **and** industrial waste.
If Industrial:	If the facility is listed as an industrial facility then the following two fields should be completed.
Type of Storage/Disposal:	The field identifies the type of industrial facility being characterized. These facilities shall be listed as lagoons, storage piles or landfills. Lagoons shall be considered ponds used for the disposal or storage of industrial waste. Storage piles are considered temporary storage of waste in a defined area. A landfill shall be considered dry disposal and burial of waste.
Type of Waste:	This data field categorizes the industrial wastes into liquid or solid wastes. Semi-solid waste contains a high moisture content that is not readily released under normal conditions. Liquid wastes and solid wastes characteristics are self-evident.
Description of Waste:	A written description of the waste disposed, or stored at the facility.
Date Opened:	**Date facility began** receiving waste.
Date Closed:	Date facility stopped receiving waste.
Regulated By:	Ohio EPA division responsible for regulating the facility.
Source of Facility Information:	What document(s) were the facility information collected from.

WORKSHEET

Collector(s) of Information:	Name(s) of staff collecting information.
Engineering Information:	**The data fields included in this category are related to the** degree of **protection afforded ground water quality by engineering components of the facility.**
Source of Information:	What document was the engineering information collected from.
Liner*	Does the facility possess an engineered and constructed liner,
If Yes*	If the facility does have a liner than the following data fields should be completed. Type of Liner: Is the facility's liner composed of a recompacted clay liner, **a** plastic synthetic liner or a composite of the two. Thickness of Liner: How thick is the liner. The thickness of the liner should be rounded up to the first whole number and that number should be circled. If Synthetic Used: If a synthetic liner is used within the liner system what type of synthetic liner is it: plastic or a geosynthetic (clay carpet).
Leachate Collection:	Does the facility possess a leachate collection system.
If Yes Status:	If the facility does have a leachate collection system then an indication should be made as to whether the leachate collection system is currently being emptied and maintained (active) or if it is inactive.
Leachate Outbreaks:	Is there a history of surface leachate outbreaks at the facility? Leachate should be considered any fluid or liquid coming from or coming into contact with the waste. A leachate outbreak from a lagoon of liquid waste would be a spill.
Cap:	Does the facility possess a cap.
If Yes:	If the facility possesses a cap the following data fields should be completed. Tvoe of Cap: Does the facility possess a clay cap, a plastic cap or a composite of the two. Thickness Cao: How thick is the cap. The thickness of the cap should be rounded up to the next highest number and that number should be circled.

WORKSHEET

Hydroaeologic Information:	**This section contains data fields for characterizing the thickness and permeability of the material separating the bottom of the facility and the various ground water units monitored at the facility. Also, data fields characterizing the type of the ground water unit and whether the unit is contaminated.**
Facility:	Name of the facility.
Source of Information:	What document was the hydrogeologic information collected from.
Information Collected By:	Name of the person collecting the hydrogeologic information.
Unit*	This column on the worksheet is to number the units between the liner and the uppermost aquifer system (UAS).
S.Z.S. or Aquitard:	This data field characterizes the monitored unit as **a** Significant Zone of Saturation or Aquitard.
Rock or Sed. Description:	A brief written description of the unconsolidated or consolidated sediment composing the S.Z.S. or aquitard.
Thickness:	This data field describes the thickness of the unit described.
Permeability (cm/sec.):	This data field describes the permeability or hydraulic conductivity of the unit described in cm/sec.
Contamination:	Is the ground water unit affected by contaminants from the facility. Contamination caused by sources other than the facility shall not be documented. Only to be filled out if the unit is monitored directly via a well.
Contaminants:	A listing of the contaminants detected within the unit described. Only to be used if the unit is monitored directly via a well.