A Basis for a Leachate Sampling Protocol: Comparison of Allen and Johnson County Landfill Leachate Sampling Results (8-5-13)

by Carl E. Burkhead

The results used in this document were derived from a portion of a pilot study to demonstrate the methodology for Post Closure Care (PCC) Terminations using the Allen County Landfill (ACL) as the pilot site and from a separate leachate sampling effort at the Johnson County Landfill (JCL). Originally, it was planned that either the JCL or the Shawnee County Landfill would be the pilot site but this was changed due to the complexity of these facilities and the accessibility of available on-site data. However, as a side note, when examining the historical leachate data from the ACL, it was realized that the leachate data before and after February 2010 were collected from the leachate storage tank and the leachate storage and evaporation basin (SEB No.1), respectively. These locations are appropriate for the ultimate disposal of the leachate but do not represent the best location for the determination of municipal solid waste (MSW) leachate stability within the various phases making up the landfill operation. This situation led to the planned sampling events at the ACL and JCL.

All seven planned sampling events were conducted to determine the best location and sampling protocol for determining MSW stability [as opposed to the leachate disposal basis of the annual leachate sampling requirement in KAR 28-29-104(i)(6)]. The initial effort was conducted by Charley Bowers of the Bureau of Waste Management (BWM) on 9-27-12, the second by Charley, Carl Burkhead (of BWM) and Daniel Earhart of Burns and McDonnell (B&M) on 10-9-12, the third by Mick Cossairt of the JCL, Carl and Craig Wood of the Johnson County Environmental Department on 10-24-12, the fourth by Mick and Carl on 12-12-12, the fifth by Charley and Carl on 1-3-13, the sixth by Charley, Carl and Jay Kolb of B&M on 4-10-13, and the seventh by Charley and Carl on 7-3-13. An outline of the sampling events and their particular goal(s) are given in Table 1.

Table 1 – Leachate Sampling Goals[1]

Event No.	Sampling Date	Landfill	Regime(s) Sampled	Goal of Sampling Effort[1]
1	9-27-12	ACL	Phase 1A	To determine leachate TSS changes with time.
2	10-9-12	ACL	Phase 1A, Phases I&II & SEB No. 1	To compare BWM and B&M sampling results
3	10-24-12	JCL	Phase 3	To determine leachate quality changes with time.
4	12-12-12	JCL	Phase 5 & Toe Drain	To determine leachate quality changes with time.
5	1-3-13	ACL	Phase 1A & Phases I&II	To compare leachate quality with Events 1 & 2.
6	4-10-13	ACL	Phase 1A, Phases I&II & SEB No. 1	To compare leachate quality with Events 2 and 5; also to compare SEB No.1 samples.
7	7-3-13	ACL	Phases 1A, Phases I&II, & SEB No. 1	To compare leachate quality with Events 2, 5 and 6; also to compare SEB No. 1 samples.

[1]Some unlisted goals were planned but were not achieved, e.g., Events 5 to 7 were to also provide leachate quality changes for Phase 1A with time, i.e., to collect samples at high, medium and low sump levels. The reason that the sampling didn't take place is because of the large amount of leachate in the sump relative to the time available to sample and still get the samples back to the KDHE laboratory on the same day.

ACL Sampling

Event No. 1

The 9-27-12 sampling results are shown in Table 2. **These results indicate that the total suspended solids (TSS) concentration decreases as the leachate is being pumped from the active Phase 1A leachate sump into the SEB No. 1**. The leachate samples were collected from the sump pump discharge piping as it enters the SEB No 1 (see Figure 1). Figure 2 shows the leachate discharge path into SEB No. 1. The level of solids in the leachate is surprisingly low but there were (at the time of this sampling) no other TSS results to compare with since all of the previously collected samples were taken from the SEB No. 1 or the now abandoned leachate storage tank. Subsequent TSS values for later sampling events were 22, 60, 33 and 36 for Events 2, 5 to 7, respectively. The TSS average for all five events is 34 mg/L.

Table 2 –Leachate TSS Decay Results for Phase 1A

AM Time	9:27	11:11	13:01	16:06
Δt (minutes)	-	104	110	125
TSS (mg/L)	19	12	<10	<10

Figure 1 – Discharge Pipe for Phase 1A into SEB No. 1

Figure 2 – Discharge Path for Phase 1A Leachate into SEB No. 1

Typically, leachate samples taken by B&M are obtained by throwing the sampler (a type of bailer) into SEB No. 1, close to where the Phase 1A discharge line, the leachate withdrawal line and the Phases I&II discharge line are located (see Figure 3). Hence, the historic and relatively recent SEB basin samples contained leachate from Phase 1A and closed Phases I&II along with accumulated precipitation less the loss of water by evaporation. Prior to the construction of the SEB No. 1 and the start of Phase 1A, Phases I&II leachate was stored in the leachate tank (see Figure 4). The tank was replaced in February 2010. Samples were taken from an older wet well prior to discharge into the tank and in newer wet well (see Figure 5) that discharges into SEB No.1 (see Figure 3). The leachate volume stored in the tank was not affected by precipitation or evaporation although both storage systems were affected by stabilization reactions which are dependent primarily on temperature. Note that the TSS level in either storage unit would vary with depth and time of storage, i.e., the TSS level would increase with tank depth since the tank was unmixed and SEB No. 1 is only mixed by wind action. A plot of the TSS results is given in Figure 6 for the years 2001 through 2011.[2]

[2]Companion documents which compliment the historical leachate data include a compilation of leachate data from all Subtitle D landfills as requested by Dennis Degner on September 15, 2011 and a leachate sample collection, storage and distribution survey requested by Carl on January 9, 2013. Copies of these results are available upon request.

Figure 3 – B&M Sampler and Leachate Piping in Northeast Part of SEB No. 1 on 4-10-13

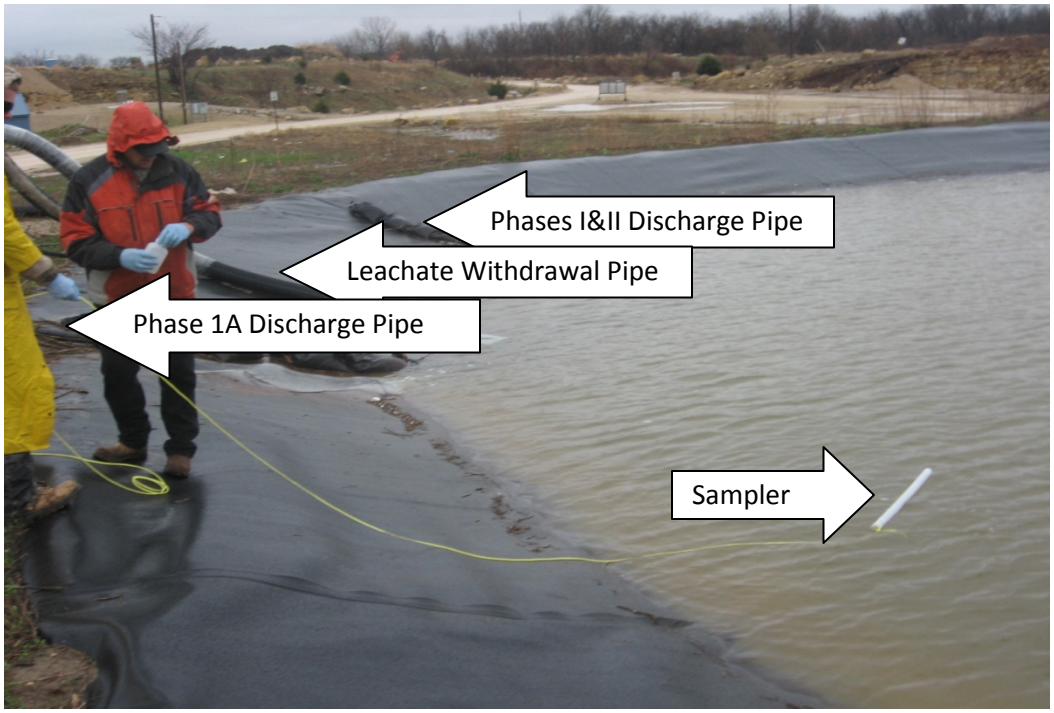

Figure 4 – Old Leachate Storage Tank

Figure 5 – Wet well for Phases I&II Sampling

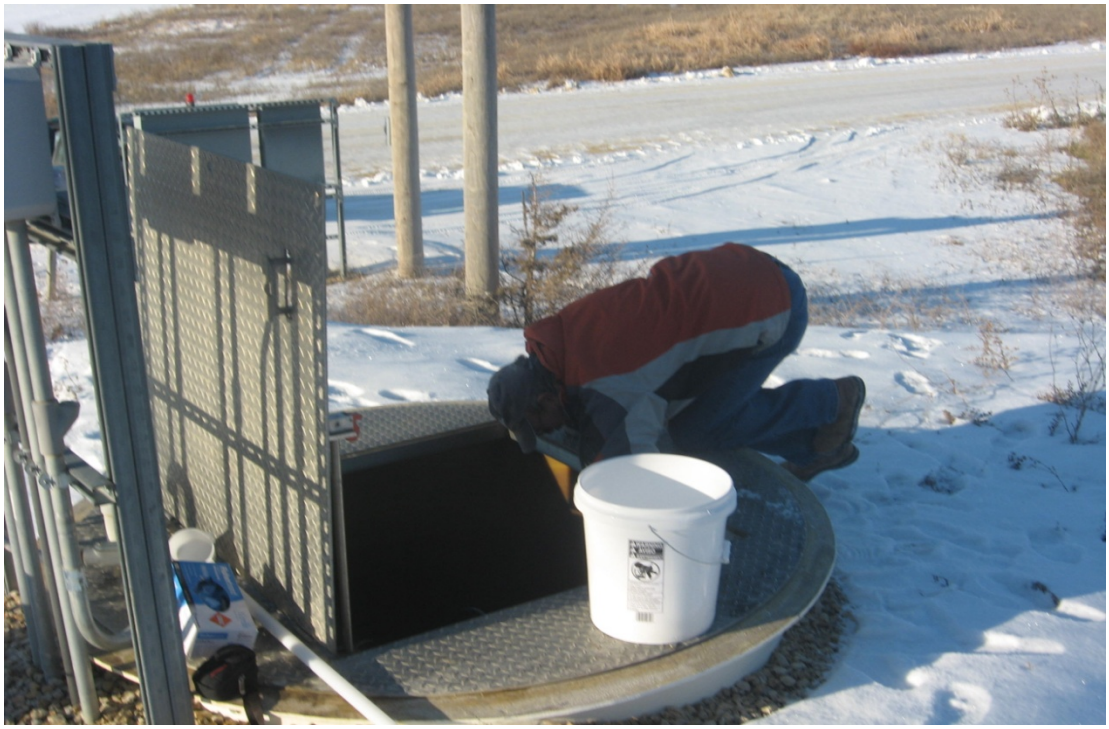

Figure 6 – Historical Leachate TSS Results

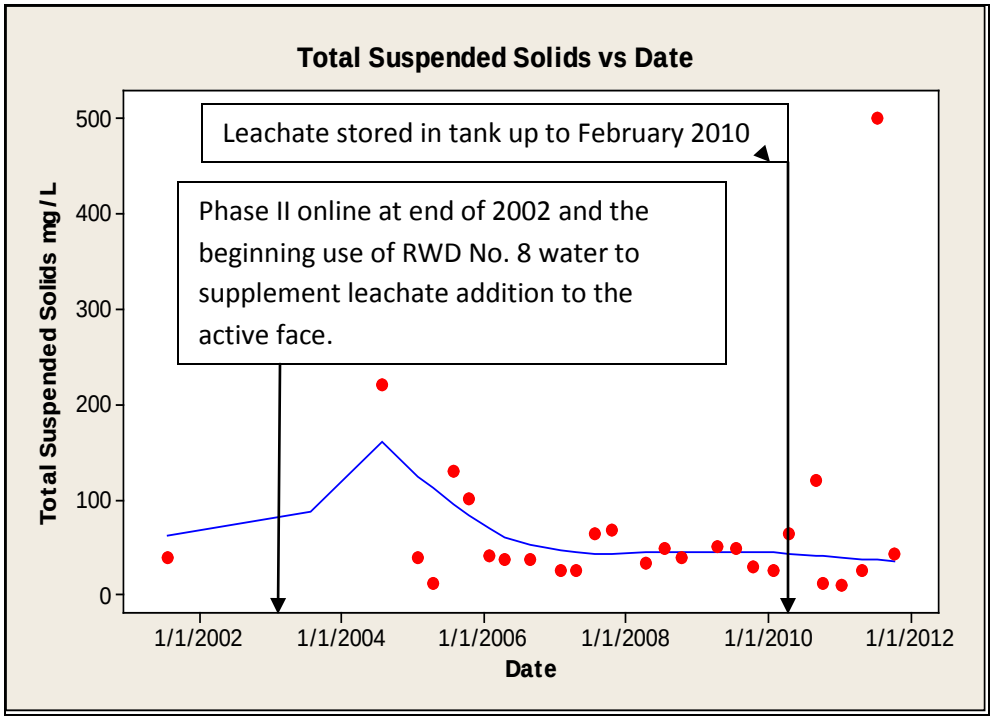

Figure 6 data, as would be expected, are more scattered because they represent the composite of several inputs into the historical storage facilities. Also, they represent single time samples taken on various days as compared to timed samples from a single stream on a particular day as shown in Table 2. The July 19,2011 SEB No. 1 outlier of 500 mg/L TSS likely represents a sample affected by the growth of algae which flourish in the nutrient rich leachate and the summer sun. This fact is apparent from the green color of the stored leachate. Although color was not recorded for B&M sampling events; later sampling events by BWM staff confirm this observation. Also, the B&M bailer approach to sampling results in a surface sample since the bailer floats (see Figure 3) and the upper surface of SEB No. 1 is where the algae are most concentrated.

More recent TSS data not shown in Figure 1 includes B&M sampling results of 1,100, 18 and 13 mg/L for 4-19-12, 10-9-12 and 4-10-13, respectively. It seems unlikely that the 1,100 mg/L figure is due to algae given that the sample was collected in late mid-April; however, the average temperature (using Chanute data) was 58.5 and 62.0 ^{o}F in March and April, 2012, respectively.

In general, there is a downward trend in the TSS level in the leachate tank samples. This seems normal in the sense that the solids level would decline as the phases contributing to the production of leachate would produce less TSS as time passes. The July 17, 2001 outlier to this trend represents the last analysis prior to the start of Phase II and the addition of RWD No. 8 water to supplement the use of leachate recirculation at the active face. Both activities could account for the significant increase in TSS at the start of Phase II operation.

Event No. 2

The 10-9-12 sampling effort was limited to a comparison of three different leachate sources; Phase 1A, Phases I&II and SEB No. 1 samples with duplicate samples of the latter by BWM and B&M personnel using different laboratories. Duplicate samples mean that the samples were taken one after the other within a short period of time (estimated <15 minutes); i.e., they were not split samples. Also, all the samples were taken within a short period of time (estimated at 30 minutes) at the SEB No.1 since the pump levels for the phase samples were near their bottom set points. A comparison of the sampling efforts is shown in Table 3. Without discussing the differences between the SEB No.1 and phase samples, it is apparent that the SEB No. 1 results were similar and different from the phase results which were themselves different from each other. **This conclusion emphasizes the importance of taking actual leachate samples instead of samples from the SEB No. 1 in order to get the best leachate results since the SEB No. 1 samples are affected by evaporation, precipitation and in situ stabilization processes.**

Selected results are discussed below. Similar analytical results are indicated by a yellow highlight and differences from the yellow are indicated by a green highlight. In some cases the different values are similar yet marked green.

Table 3 – Comparison of Leachate Sources and Samplers for 10-9-12 Sampling

Parameter	Units	B&M SEB No.1	BWM SEB No. 1	Phases I&II	Phase 1A
Alkalinity as CaCO3	mg/L	540	576	984	1770
Aluminum	mg/L	NA	0.05	0.05	0.077
Ammonia or Ammonium (N)	mg/L	10	8.9	75	180
Biochemical Oxygen Demand	mg/L	67	30	13	16
Soluble BOD	mg/L	NA	6	6	6
Calcium	mg/L	NA	37	210	150
Chemical Oxygen Demand (COD)	mg/L	370	370	190	370
Soluble COD	mg/L	NA	170	180	350
Chloride	mg/L.	320	320	290	380
Chromium	mg/L	BDL	0.01	0.01	0.023
Copper	mg/L	BDL	0.021	0.030	0.015
Iron	mg/L	2.4	0.99	7.6	14
Kjeldahl Nitrogen	mg/L	28	27	30	93
Lead	mg/L	BDL	0.05	0.05	0.050
Magnesium	mg/L	NA	56	56	68
Manganese	mg/L	NA	0.068	0.64	0.61
Mercury	ug/L	BDL	0.5	0.5	0.53
Nitrate (N)	mg/L	BDL	0.1	0.17	0.37
Nitrite (N)	mg/ L	BDL	0.38	0.092	0.050
Ortho Phosphate (P)	mg/L	NA	0.25	0.25	0.62
Potassium	mg/L	86	81	47	120
Silica	mg/ L	NA	21	30	28
Sodium	mg/L	350	300	270	380
Specific Conductivity	µS/cm	NA	2100	2900	4200
Sulfate	mg/L	42	43	210	0.80
Total Organic Carbon	mg/L	NA	75	52	110
Soluble TOC	mg/L	NA	56	53	100
Total Phosphorus (P)	mg/L	0.52	0.41	0.21	1.1
Total Suspended Solids (TSS)	mg/L	18	19	28	22
pH	pH unit	8.4	8.5	7.3	7.2

The alkalinity is a measure of the buffering capacity of the leachate. The greatest alkalinity is in the youngest leachate which results from its extraction from the more recently stored MSW. The SEB No. 1 alkalinity values are lower than the phase values as a result of alkalinity being consumed by algae in the SEB No. 1, i.e., a bicarbonate shift to dissolved carbon dioxide needed for algal growth.

Ammonia is highest in the youngest leachate similar to the alkalinity data. Ammonia is a result of the deamination of proteins and the endogenous respiration reaction where food-limiting microbial cells are forced to use their own internal substrate as an energy source. The potential for these reactions is greatest in Phase 1A. The lowest ammonia values in SEB No. 1 are a result of ammonia consumption by algae. Its concentration in SEB No. 1 is also affected by precipitation and evaporation.

Nitrite and nitrate values are low because of their consumption in the denitrification reaction. The higher Kjeldahl value in the Phase 1A sample is a result of a higher organic nitrogen value associated with the less stable leachate; however, the Kjeldahl values should be higher than the ammonia values since the former includes the latter plus organic nitrogen. This would suggest an error in Kjeldahl measurement for the phase samples.

Specific conductivity is a measure of the ionic portion of the total dissolved solids (TDS which was not measured) in the leachate. There was a general decline from Phase 1A to Phases I&II to SEB No. 1. This is reflected in the general decline of dissolved ions and organic substances; especially, alkalinity and ammonia, and to a lesser degree with soluble organics (COD and Kjeldahl nitrogen) and chloride, potassium and sodium. The reason for this decline is similar to the alkalinity and ammonia declines.

The organic stability is related to the BOD and ammonia measurements. It appears that the increase in SEB No. 1 BOD which would be due to algal growth with concommitment removal of ammonia needed for algal protoplasm. The phase effluents would be considered the most stable of the various leachates. The two SEB No. 1 samples are probably different because of the difference of solids in the two samples. This would be apparent if B&M had tested for soluble BOD.

The COD results do not follow the same pattern as the BOD values; especially for the phase results. In both phase cases, most of the COD is soluble reflecting the low COD demanding TSS results The higher SEB No.1 results indicate a buildup of non-biodegradable organics, most of it insoluble which is not reflected in the low TSS values, i.e., the COD equivalence of the TSS is low.

The pH of the phases is at a level suitable for anaerobic microbial stabilization. The pH increase in the SEB No. 1 reflects the consumption of the ammonia and the decreased alkalinity.

Event No. 5 (Note: Event 5 is placed out of order because of its common goal to Event 2 and because both events were ACL sampling efforts.)

The 1-3-13 sampling event was an attempt to collect **fresh** leachate samples from Phase 1A and Phases I&II, i.e., the Phase 1A sample was **collected after the leachate pump neared its lowest set point**; the Phases I&II sample was collected from the wet well inlet pipe as was done in Event 2. The purpose of this effort was to see how the leachate qualities compared with those determined in Event No. 2. The weakness in this effort is the assumption that the leachate qualities stayed the same and the difference can be attributed to the freshness test, i.e., the leachate closest to that entering the leachate sump. However, the Phase 1A samples should be different because of the chosen collection time. The comparisons are given in Table 4 and the color code used is the same for comparing the same phase comparisons, i.e., yellow is considered the same and green is a greater value for the 1-3-13 samples.

Table 4 – Comparison of 10-9-12 and 1-3-13 Leachate Samples

		Phases I&II		Phase 1A	
Parameter	**Units**	**10/9/2012**	**1/3/2013**	**10/9/2012**	**1/3/13**
Alkalinity as CaCO3	mg/L	984	954	1770	1700

Aluminum	mg/L	<0.050	<0.050	0.077	0.051
Ammonia or Ammonium (N)	mg/L	75	NA	180	NA
Biochemical Oxygen Demand	mg/L	13	16	16	8.8
Soluble BOD	mg/L	<6	<6	<6	<6
Calcium	mg/L	210	200	150	170
Chemical Oxygen Demand (COD)	mg/L	190	250	370	470
Soluble COD	mg/L	180	260	350	380
Chloride	mg/L.	290	440	380	420
Chromium	mg/L	0.01	<0.010	0.023	0.023
Copper	mg/L	0.030	0.012	0.015	<0.010
Iron	mg/L	7.6	7.8	14	24
Kjeldahl Nitrogen	mg/L	30	160	93	190
Lead	mg/L	0.05	<0.050	0.050	<0.050
Magnesium	mg/L	56	72	68	80
Manganese	mg/L	0.64	0.57	0.61	0.580
Mercury	ug/L	0.5	NA	0.53	NA
Nitrate (N)	mg/L	0.17	0.40	0.37	0.42
Nitrite (N)	mg/ L	0.092	<0.050	0.050	<0.050
Ortho Phosphate (P)	mg/L	0.25	<0.25	0.62	0.59
Potassium	mg/L	47	65	120	130
Silica	mg/ L	30	34	28	28
Sodium	mg/L	270	410	380	450
Specific Conductivity	µS/cm	2900	3700	4200	4600
Sulfate	mg/L	210	240	0.80	150
Total Organic Carbon	mg/L	52	73	110	120
Soluble TOC	mg/L	53	72	100	120
Total Phosphorus (P)	mg/L	0.21	0.059	1.1	1.0
Total Suspended Solids (TSS)	mg/L	28	24	22	60
pH	unit	7.3	7.7	7.2	7.6

The general conclusions reached concerning Event 2 remain the same for Event 5. **With regard to the objective of the latter sampling event (i.e., to get the freshest sample), all the indicated green results for the fresh or 1-3-13 sample were greater than the 10-9-12 samples.** Phases I&II BOD was greater as was Phase 1A TSS level. The former would be expected rather than the latter although the BOD values are close. These general increases would be expected because the freshest should be the strongest except for pH. The higher pH could indicate that the methane formers had removed more organic acids resulting in a higher pH; thus, indicating a more balanced microbial population. The TOC differences are similar to the COD data which are explainable because of the COD equivalence of the compounds containing the carbon are similar. The COD to TOC ratios range from 3.4 to 3.9.

Although there are only two consecutive sets of samples about three months apart, it is apparent that the variation in the results is not as great as the leachate results obtained from samples taken from the SEB No. 1 and the leachate tank over several years (see Burns & McDonnell Transmittal Memorandum entitled **Allen County Water Quality Monitoring Program: Annual 2012 Landfill Leachate Analytical Results** dated January 29, 2013 with enclosed CD). The former phase samples are not affected by evaporation, precipitation and/or stabilization processes external to the MSW mass.

Johnson County Landfill

Event No. 3

The 10-24-12 sampling event was similar to Event No. 1 for the ACL in that samples were collected from Phase 3 at different times. A picture of the Phase 3 sampling site is shown in Figure 7. The various BWM/JCL/JCED samples were taken at eleven different times over an 85 minute time interval. However, only selected parameters are shown Figures 8 and 9 to illustrate how key parameters changed with time.

Figures 8 and 9 indicate that although there is a drop in the TSS level with time, there is an increase in organic matter with time. This increase is reflected in the changes in the COD and TOC results. The BOD change is small compared to the COD and TOC changes which mean that the non-biodegradable portion of the COD and TOC increased while the BOD remained relatively stable. **The significant change in non-biodegradable organics appears to be related to release of soluble complex organics** (based on comparison of total and soluble COD data results) **from the MSW mass since there is no concomitant release of TSS and BOD.** This could be the physical extraction of high molecular weight compounds which are soluble but are not digestible. The COD to TOC ratios vary from 3.0 to 3.8.

Figure 7 – Phase 3 Wet Well with Discharge Line to Leachate Storage Tank

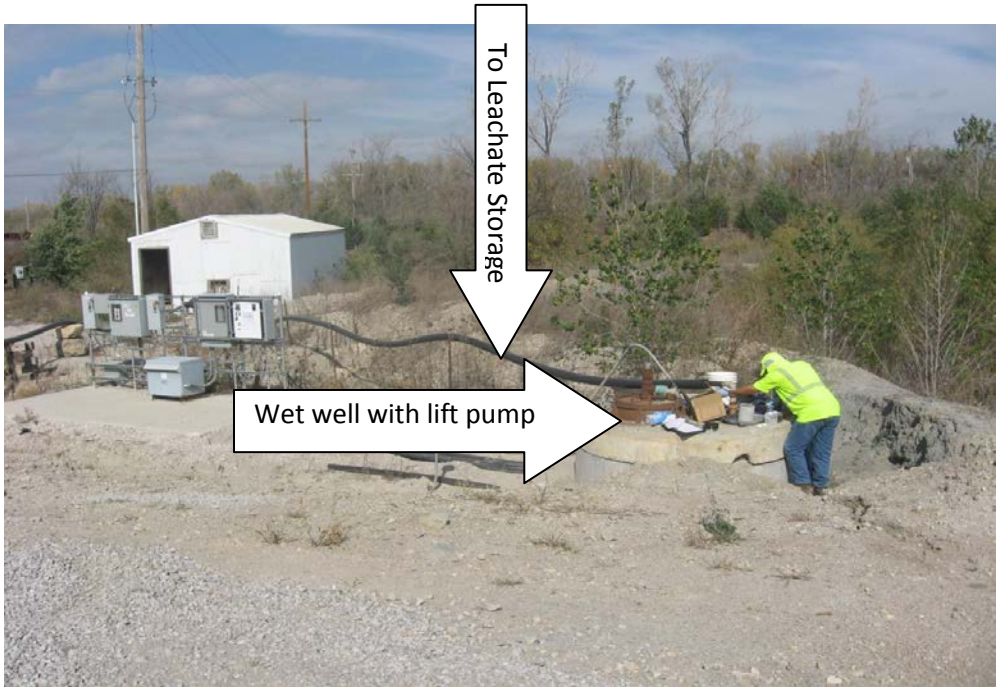

Figure 8 – Water Quality Changes for Phase 3 Leachate Parameters

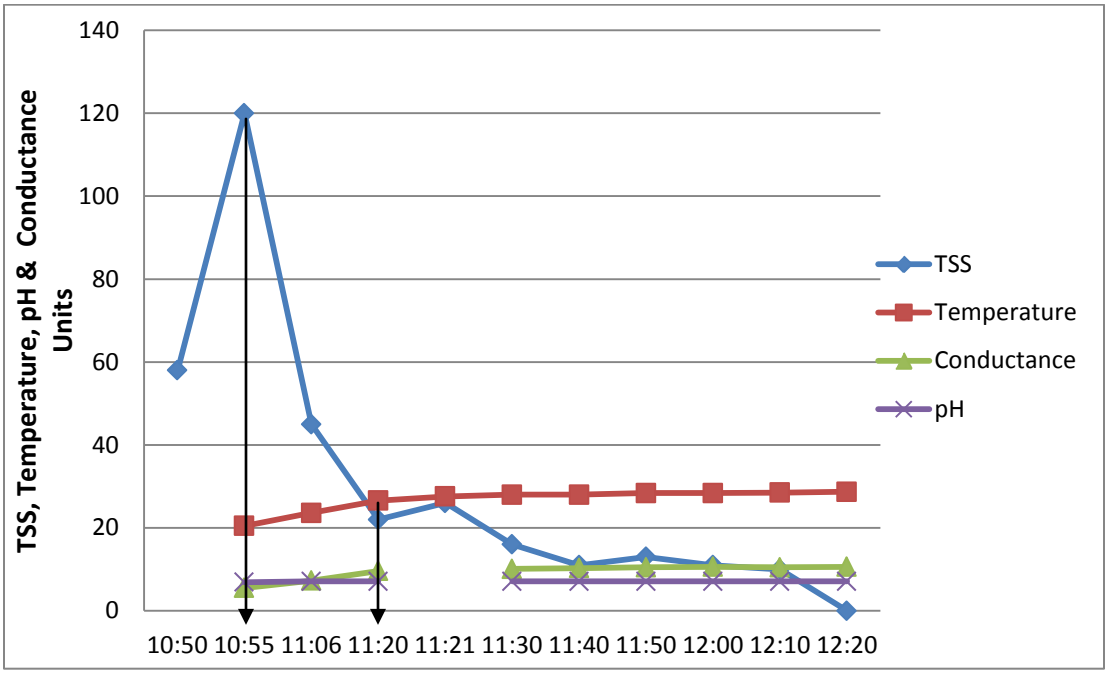

Figure 9 – Water Quality Changes for Phase 3 Leachate Parameters

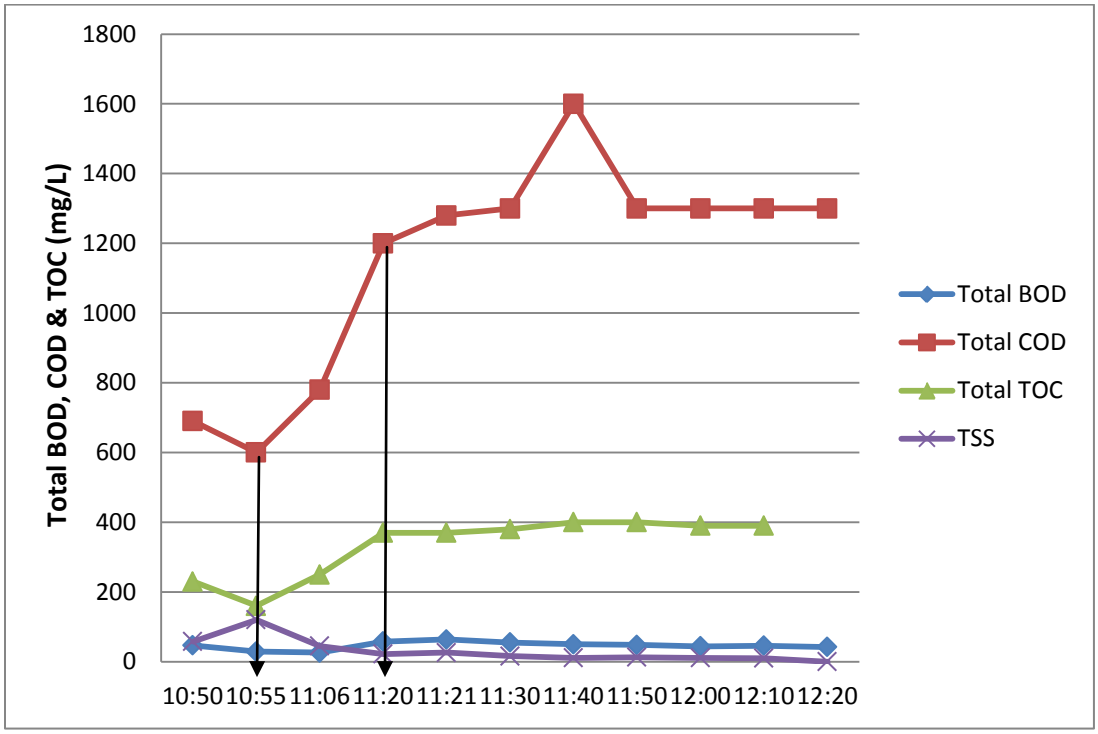

Table 5 – Comparison of Time Similar Samples Tested by Different Laboratories

Parameters	Units	JCL (10:50)	BWM (10:55)	BWM (11:20)	JCED (11:21)
Alkalinity as CaCO3	mg/L	2300	1860	3120	3550
Ammonia as N	mg/L	340	240	460	675
Kjeldahl Nitrogen as N	mg/L		260	580	628
BOD	mg/L	47	29	58	64
COD	mg/L	690	600	1200	1280
Chloride	mg/L	530	360	1100	1100
Iron, total	mg/L	4.1	13	2.3	2.400
Lead, total	mg/L		<0.050	<0.050	<0.01000
Nitrate + Nitrite as N	mg/L		0.81	0.78	0.33
pH	SU	7.3	7.7	7.6	7.2
Potassium, dissolved	mg/L	180	130	310	313
Sodium, dissolved	mg/L	650	490	1100	1100
Specific Conductance	uS/cm		5100	9500	9890
Sulfate	mg/L	200	280	37	39
Temperature in field	^{o}F		20.5	26.6	27.6
Total Dissolved Solids	mg/L	2900	2700	4500	4460
Total Suspended Solids	mg/L	58	120	22	26
TOC	mg/L	230	160	370	370

Table 5 is a comparison of what could be considered two sets of duplicate (as defined previously) sample results for a selected array of parameters. JCL samples were taken at 10:50 and the BWM samples at 10:55; and the BWM samples at 11:20 and the JCED samples at 11:21. Each entity (JCL, BWM and JCED) sent their respective samples to their own labs for analysis. As expected there is a greater difference between the first two sets of data taken five minutes apart than the latter two sets taken one minute apart. This is apparent from the time lines drawn in Figures 5 and 6 for the BWM sample results.

Similar to the discussion of Event 2 data, the yellow highlighted BWM 11:20 results indicate an increase in concentration during the 25 minute period. This increase can be attributed to presence of fresher leachate being discharged with a concomitant decrease in TSS.

Finally, comparison of Tables 3 and 4 with Table 5 shows that the JCL leachate is stronger than the ACL; especially, for alkalinity, ammonia, Kjeldahl nitrogen, COD and specific conductance.

Event No. 4

The 12-12-12 sampling event is similar to JCL Event No. 3, in that, it was an attempt to determine how the leachate quality would change with time for JCL Phase 5. This sampling effort did not go as planned since only two samples were collected before the sampling exercise had to be

concluded because of time constraints needed to get the samples to the KDHE lab. Also, the sampling did not begin as soon as expected because the leachate buildup in the sump was not as great initially. However, there was a time series collection of leachate samples where limited parameters were measured in the field. These results are presented in Table 6. An unplanned result was the collection of toe drainage liquid which is introduced into the leachate sump of Phase 5 [Note: Charley Bowers provided analytical results for the ACL toe drain but they are not shown here because the three results (5-29-96, 6-20-97 and 3-9-04) were just for volatile organics] . The sampling site, the KDHE measured sample results for Phase 5 and the toe drainage, and a comparison of Phase 5 with Phase 3 results are shown in Figure 10, Tables 7 and 8, respectively; where TP = Toe Drain Sampling Port and LP = Leachate Sampling Port in Figure 10.

Table 6 – Field Results for Phase 5 Sampling

Time (PM)	Temperature (^oC)	Conductivity (S/cm)	pH	Turbidity (NTU)
1:04	23.2	7.8	6.8	4.8
1:09	24.8	7.8	6.8	3.16
1:19	25.6	8.7	6.9	2.76
1:25	25.8	10.0	6.9	2.75
1:32	25.9	10.5	6.9	2.74
1:39	25.2	10.8	7.0	3.16
1.48	25.6	11.4	7.0	ca 2.7 ?

The 44 minute change (1:04 to 1:48 PM) resulted in an increase in temperature with a slight decrease at the end; an increase in conductivity, a slight increase in pH and a decrease in turbidity except for the 1:39 PM sample.

The slight decreases in temperature at the end of the sampling period involve a variation of only 0.7 degrees in the last five measurements versus 2.7 overall. Perhaps the increase is related to the warmer leachate reaching the surface from the the leachate pool with a slight cooling because of the ambient temperature. Conductivity increases were substantial and are related to higher level of ions in the "fresher leachate." The slight increase in pH reflects the change in conductivity in that the increase in the dissolved ions neutralized the pH; perhaps by the presence of greater alkalinity in the "fresher leachate." Finally turbidity levels dropped as experienced earlier in Events 1 (ACL) and 3 (JCL). **In summary, since there is a decrease in turbidity as time passes, it can be inferred that there is a concurrent decrease in the TSS levels. This conclusion would be in agreement with Events 1 and 3 field results where TSS was measured instead of turbidity.**

Figure 10 - Johnson County Landfill Phase 5 Leachate Riser Piping

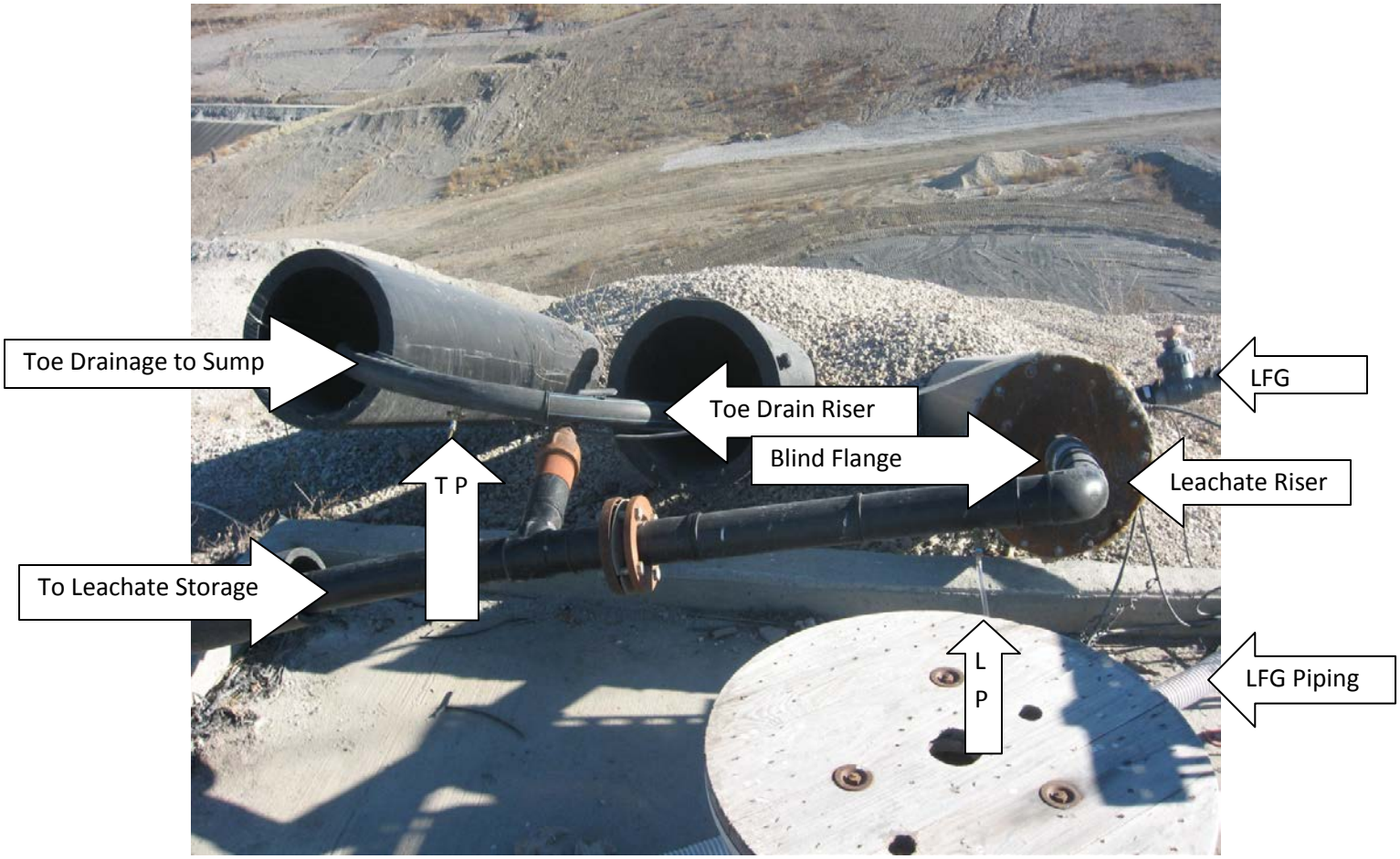

Table 7 – KDHE Lab Results for Phase 5 and Toe Drain Sampling Efforts

Parameters	Units	Phase 5 (1:01 PM)	Phase 5 (1:45 PM)	Phase 5 (% Change)	Toe Drain (1:30 PM)
Alkalinity *as* CaCO3	mg/L	2960	4410	49	1400
Aluminum	mg/L	< 0.050	< 0.050		0.051
Ammonia (N)	mg/L	380	840	121	2.1
Antimony	mg/L	< 0.050	< 0.050		< 0.050
Arsenic	mg/L	0.078	0.10	28	< 0.050
Barium	mg/L	1.7	2.6	53	0.034
Beryllium	mg/L	< 0.0010	< 0.0010		< 0.0010
Total BOD	mg/L	27	36	33	< 6.0
Soluble BOD	mg/L	8	13	63	NA
Boron	mg/L	22	27	23	4.2
Bromide	mg/L	5.0	7.7	54	0.58
Cadmium	mg/L	<0.005	<0.0050		< 0.0050
Calcium	mg/L	51	38	-25	87
Total COD	mg/L	740	880	19	< 30
Soluble COD	mg/L	590	890	51	NA

Chloride	mg/L	800	1200	50	210
Chromium	mg/L	0.035	0.040	14	< 0.010
Cobalt	mg/L	0.017	0.022	29	< 0.010
Copper	mg/L	0.092	0.016	-83	0.043
Fluoride	mg/L	2.2	2.4	9	2.0
Iron	mg/L	0.65	0.72	11	0.22
Kjeldahl Nitrogen	mg/L	96	120	25	0.31
Lead	mg/L	< 0.050	< 0 050		< 0.050
Magnesium	mg/L	84	92	10	54
Manganese	mg/L	0.047	0.033	-30	0.086
Molybdenum	mg/L	< 0.020	< 0 020		0.051
Nickel	mg/L	0.13	0.17	31	< 0.050
Nitrate (N)	mg/L	< 0.10	<0 10		< 0.10
Nitrite (N)	mg/L	< 0.080	0		< 0.050
Ortho Phosphate (P)	mg/L	0.97	1.7	75	< 0.25
Potassium	mg/L	230	280	22	15
Selenium	mg/L	< 0.050	< 0 050		< 0.050
Silica	mg/L	33	36	9	20
Silver	mg/L	< 0.010	< 0 010		< 0.010
Sodium	mg/l	1200	1300	8	890
Specific Conductivity	µS/cm	7200	10000	39	4200
Strontium	mg/L	2.9	2.9	0	3.6
Sulfate	mg/L	380	210	-45	870
Thallium	mg/L	< 0.050	< 0 050		< 0.050
TDS	mg/L	4600	5800	26	3000
Total Hardness	mg/L	470	470	0	440
Total TOC	mg/L	190	260	37	2.6
Soluble TOC	mg/L	200	260	30	NA
Total Phosphorus (P)	mg/L	1.8	2.1	17	0.039
TSS	mg/L	< 10	<10		<10
Turbidity	NTU	57	93	63	5.1
Vanadium	mg/L	< 0.0050	0.0050		< 0.0050
Zinc	mg/L	0.020	0.0024	-88	0.040
pH	pH unit	7.2	7.4	3	7.2

NA means for the toe drain results that the BOD, COD and TOC soluble values are the same as the total results.

The highlighted (yellow) results in Table 7 show the differences between the surrogate organic measurements. There was a residual BOD in the leachate with a significant amount of non-biodegradable organics as measured by the COD test. The latter test shows a much higher soluble portion than found in the BOD. The TOC confirms the COD results although the TOC indicates that most of the organic matter is soluble similar to the 1:45 PM COD result. **The other highlighted items (orange for differences > 50% and red for >100%) show what has been contented all along that the initial leachate quality from a sump is different (in this case weaker since there are only five minus and 29 plus values) from that pumped later**; although, an exception to this is that the TSS levels showed no significant change. This is because the TSS levels in Phase 5 samples were so low (perhaps if they were taken earlier, the TSS levels would have been higher). The other differences are especially apparent

with metals and nutrients (ammonia and ortho phosphate). The Kjeldahl nitrogen values should be greater than the ammonia values.

The toe drain results reveal a significant difference than the Phase 5 results. This is because toe drain liquid is groundwater which accumulates below the bottom of the landfill phase. The effect of blending the toe drain flow with the leachate flow is not known since the volume of the former flow is unknown. The toe drain flow dilutes the leachate quality depending on their relative volume.

Table 8 – Comparison of Phases 5 and 3 Results with Relative Time Differences (44 vs. 25 minutes)

Parameters	Units	Phase 5 (1:01 PM)	Phase 3 (10:55 AM)	Phase 5 (1:45 PM)	Phase 3 (11:20 AM)
Alkalinity *as* CaCO3	mg/L	2960	1860	4410	3120
Aluminum	mg/L	< 0.050	1.4	< 0.050	0.23
Ammonia (N)	mg/L	380	240	840	460
Total BOD	mg/L	27	29	36	58
Calcium	mg/L	51	210	38	52
Total COD	mg/L	740	600	880	1200
Chloride	mg/L	800	360	1200	1100
Chromium	mg/L	0.035	0.022	40	0.041
Copper	mg/L	0.092	0.043	16	0.029
Fluoride	mg/L	2.2	1.2	24	2.7
Iron	mg/L	0.65	13	72	2.3
Kjeldahl Nitrogen	mg/L	96	260	120	580
Lead	mg/L	< 0.050	< 0.050	< 0 050	< 0 050
Magnesium	mg/L	84	51	92	44
Manganese	mg/L	0.047	0.67	33	0.2
Ortho Phosphate (P)	mg/L	0.97	0.38	3	1.3
Potassium	mg/L	230	130	280	310
Silica	mg/L	33	33	36	48
Sodium	mg/l	1200	490	1300	1100
Specific Conductivity	µS/cm	7200	5100	10000	9500
Sulfate	mg/L	380	280	210	37
TDS	mg/L	4600	2700	5800	4500
Total TOC	mg/L	190	160	260	370
Total Phosphorus (P)	mg/L	1.8	1.7	2.1	2.3
TSS	mg/L	< 10	120	<10	22
pH	pH unit	7.2	7.7	7.4	7.6

Referring to Table 8, both Phases show concentration increases as time passes (highlighted in yellow). Similar to previous time change events for Phase 5, there is an increase in Phase 3 results for key stabilization parameters except for sulfate which would be expected to decrease because of its use as a source of oxygen and TSS because of the flushing of solids from the first part of the accumulated leachate in the leachate sump. However, note that the TSS increased as time passed in Table 7; but, field measurements of turbidity showed a general decrease as shown in Table 5. Conductivity and pH changes were similar in both tables except the field pH measurements were less which would be

expected due to handling of the samples for the KDHE lab measurements. The surrogate organic increases are explained as suggested previously.

Event 5 (see discussion given on page 8)

Events 6 and 7

The BWM goal for Event 6 was to continue the collection of Phases I&II and 1A samples as well as the comparison of BWM sampling of SEB No. 1 with B&M; but, at the diagonal end of the basin from where they sampled. Both SEB No. 1 samples were taken on the surface with the bailer shown in Figure 3. Another goal was to demonstrate the effect of time on Phase 1A leachate sampling similar to that done in Event 1 and for the JCL in Events 3 and 4. This was not possible because leachate production was higher than any other previous sampling event; thus, preventing the collection of multiple samples.

As it turns out, the sampling goals were the same for Event 7 as for Event 6. [A difference was that B&M sampling personnel were not involved; hence, a different bailer was used as shown in Figure 11 to collect the surface samples at the diagonal locations (NE vs. SW ends of SEB No. 1; see Figure 12)]. Because of the goals were the same, the results of the two events are compared in Table 9 [but, B&M below detection limit (BDL) results are excluded along with comparable results not available from BWM analyses].

Figure 11 – Hand Held Bailer (with other sampling supplies)

Figure 12 – SW Sampling Location for SEB No. 1 looking toward the NE corner

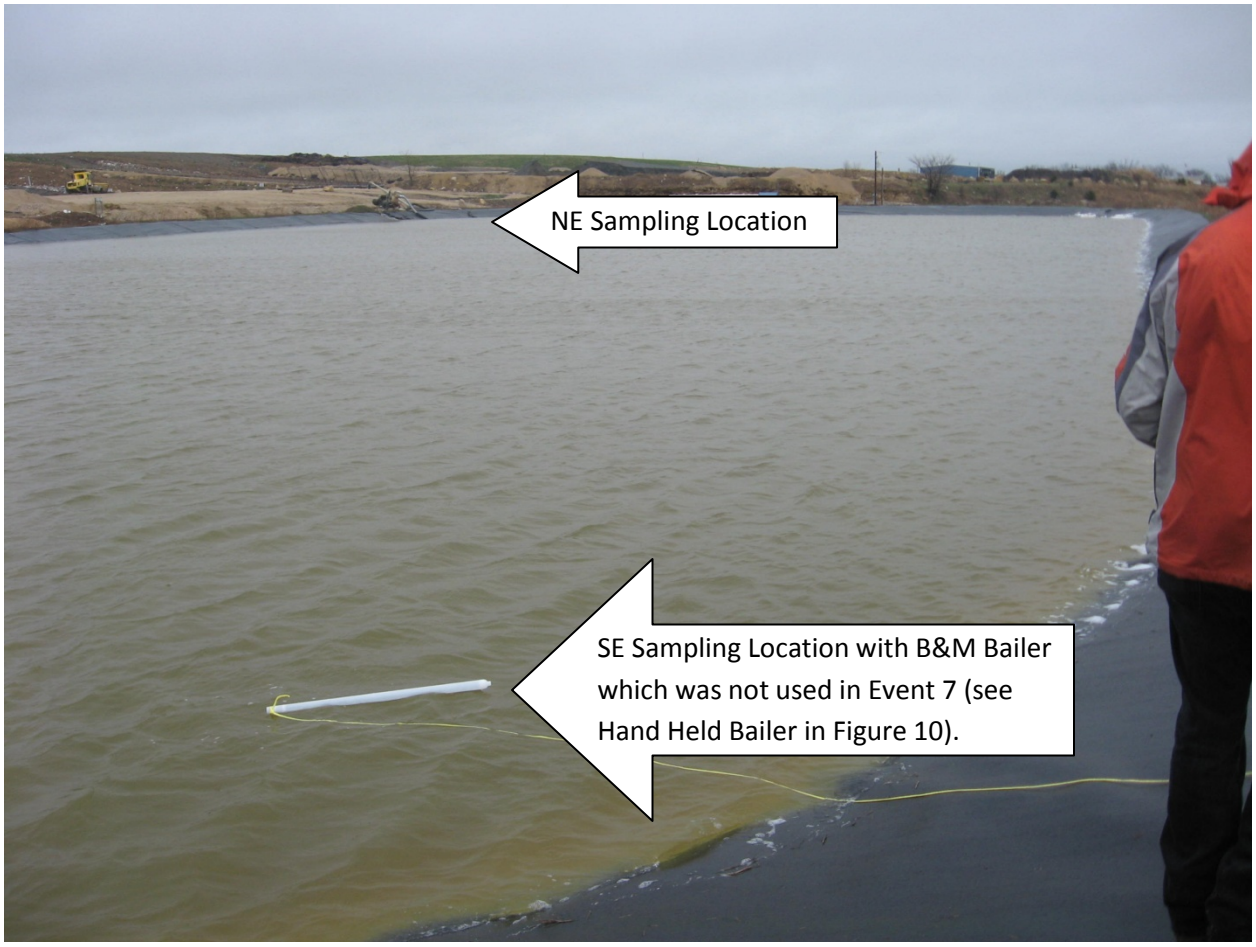

Table 9 – Comparison of Selected SEB No. 1 B&M and BWM Results for 4-10-13 and 7-3-13

		4-10-13		7-3-11	
		NE End	SW End	NE End	SW End
Parameter	**Units**	**(B&M)**	**(BWM)**	**(BWM)**	**(BWM)**
Alkalinity as CaCO3	mg/L	630	565	479	480
Ammonia (N)	mg/L	22	31	21	20
Biochemical Oxygen Demand	mg/L	15.0	18	20	19
Calcium	mg/L	84	88	NA	NA
Chemical Oxygen Demand (COD)	mg/L	150	160	150	150
Chloride	mg/L	250	240	200	200
Iron	mg/L	1.6	1.6	NA	NA
Kjeldahl Nitrogen	mg/L	32	38	26	27
Nitrate & Nitrite (N)	mg/L	0.43	0.61	<0.28	<0.28
Potassium	mg/L	58	61	NA	NA
Sodium	mg/L	230	240	NA	NA

Specific Conductivity	µS/cm	NA	2,000	1,500	1,600
Sulfate	mg/L	90	89	27	43
Total Dissolved Solids	mg/L	1,100	1,100	NA	NA
Total Hardness	mg/L	NA	430	NA	NA
Total Organic Carbon	mg/L	NA	43	43	43
Total Phosphorus (P)	mg/L	0.18	0.32	0.19	0.80
Total Suspended Solids (TSS)	mg/L	13	11	29	27
Turbidity	NTU	NA	18	62	63
pH	pH unit	8.0	8.1	8.2	8.1
Temperature	^{o}C	NA	13	25.5	26.0
Color		NA	NA	Light Green	Light Green

For Events 6 and 7, the two samples, taken at opposite ends of the SEB No. 1 and about 25 and 10 minutes apart, respectively, showed similarities in the latter samples (highlighted in yellow**).** Perhaps the strong prevailing wind toward the BWM sample point, the fullness of the pond and the relatively shallow depth of the pond (the design depth to top of rip rap is five feet) provided enough mixing to equalize the results. Where the results were not equalized, the differences can be explained by the difference in temperature where the higher temperature stimulates the growth of algae with a consumption of alkalinity, nitrogen forms, conductivity and sulfate. The increase in TSS and turbidity reflects this change.

Although available B&M toe drain results are not shown, they are similar to the SEB No. 1 leachate results of B&M and BWM (as shown above). This observation is different than the toe drain comparison for the JCL as discussed in Event 4 which revealed a more dilute toe drain quality. It is not clear why this should be the case.

The other goal for Events 6 and 7 was to compares the results for Phases I&II and Phase 1A as shown in Tables 10 and 11, respectively. The greater values are highlighted in yellow.

Table 10 – Comparison of Leachate Results for Phases I&II

Parameter	Units	10-9-12	1-3-13	4-10-13	7-3-11
Alkalinity as CaCO3	mg/L	984	954	865	972
Ammonia (N)	mg/L	75	NA	50	48
Biochemical Oxygen Demand	mg/L	13	16	17	16
Calcium	mg/L	210	200	210	NA
Chemical Oxygen Demand (COD)	mg/L	190	250	110	140
Chloride	mg/L	290	440	230	240
Iron	mg/L	7.6	7.8	17	NA
Kjeldahl Nitrogen	mg/L	30	160	42	45
Nitrate & Nitrite (N)	mg/L	0.262	<0.450	<0.168	<0.150
Potassium	mg/L	47	65	29	NA

Sodium	mg/L	270	410	210	NA
Specific Conductivity	µS/cm	2,900	3,700	2,300	2,400
Sulfate	mg/L	210	240	96	15
Total Dissolved Solids	mg/L	NA	2,000	1,400	NA
Total Hardness	mg/L	NA	NA	750	NA
Total Organic Carbon	mg/L	52	73	39	52
Total Phosphorus (P)	mg/L	0.21	0.059	0.16	0.12
Total Suspended Solids (TSS)	mg/L	28	24	39	32
Turbidity	NTU	NA	NA	100	120
pH	pH unit	7.3	7.7	7.5	6.8
Temperature	^{o}C	NA	NA	NA	20.0
Color	Subjective	NA	NA	NA	Colorless

For Phases I&II, BOD and TSS levels were low and consistent versus higher ammonia values that were decreasing and not in agreement with the Kjeldahl values which should be larger for the corresponding ammonia values; pH values were inconsistent without explanation. The greater yellow values were predominately during the cold part of the sampling year where bioactivity and precipitation infiltration were diminished leaving the higher values affected by lack of contaminant removal and dilution.

Table 11 – Comparison of Leachate Results for Phases 1A

Parameter	Units	10-9-12	1-3-13	4-10-13	7-3-11
Alkalinity as CaCO3	mg/L	1,700	1,700	633	1,350
Ammonia (N)	mg/L	180	NA	50	160
Biochemical Oxygen Demand	mg/L	16	8.8	130	100
Calcium	mg/L	150	170	150	NA
Chemical Oxygen Demand (COD)	mg/L	370	470	220	320
Chloride	mg/L	180	420	110	330
Iron	mg/L	14	24	5.7	NA
Kjeldahl Nitrogen	mg/L	93	190	48	160
Nitrate & Nitrite (N)	mg/L	<0.420	<0.470	<0.150	<0.150
Potassium	mg/L	120	130	36	NA
Sodium	mg/L	380	450	110	NA
Specific Conductivity	µS/cm	4,200	4,600	1,700	3,400
Sulfate	mg/L	0.80	150	44	<0.50
Total Dissolved Solids	mg/L	NA	2,500	870	NA
Total Hardness	mg/L	NA	120	480	NA
Total Organic Carbon	mg/L	110	120	50	120
Total Phosphorus (P)	mg/L	1.1	1.0	0.29	0.59
Total Suspended Solids (TSS)	mg/L	22	60	33	36

Turbidity	NTU	NA	NA	71	88
pH	pH unit	7.2	7.6	7.2	6.9
Temperature	^{o}C	NA	NA	21	21.5
Color	Subjective	NA	Darker than Phases I&II	NA	Very light brown

Table 11 results for Phase 1A showed similar results to Table 10. A significant difference between the two tables is the very high BOD in the last two sampling periods for Phase 1A. The BOD/COD ratios for Phase 1A, they were 0.043, 0.019, 0.59 and 0.31 (versus 0.068, 0.064, 0.080 and 0.11 for Phases I&II) from the first to last sampling events. The order of magnitude jump for Phase 1A may be related to the higher moisture conditions encountered during the last two sampling events. The COD:TOC ratios are 3.4, 3.9, 4.4 and 2.7 do not show the bump with the last two values.

Conclusions

It is clear from the previously presented and discussed results that leachate quality changes with sump pump time. Phase 3 results demonstrate this fact better than Phase 5 for the JCL sampling efforts since there were eleven sampling times versus two, respectively. Also, these results are more conclusive than the ACL results shown in Table 2. Another conclusion is that each phase for both landfills has a different leachate quality and the JCL trends are similar for the compared parameters. **In general, to determine landfill stability, one must compare the best leachate quality values (ideally, when the discharge line has been purged and *fresh* leachate is sampled) over time for a given phase.** If there is no sump pump, as with ACL Phases I&II, then the leachate quality should be based on a sample of the gravity flow entering the wet well transfer station; not the discharge from the wet well. **In no case should the leachate values collected from storage ponds/lagoons and tanks be used to judge the leachate stability since these results are affected by factors besides landfill stability**. The results of the recent Leachate Survey (see footnote 2 on page 3) show that seven of nineteen Subtitle D landfills are collecting this latter type of sample.

Future Plans

The preceding efforts conclude the laboratory portion of the ACL pilot study. Other data (e.g., leachate haul, RWD No. 8 usage, weather, etc.) previously collected, need to be updated before a final version of the pilot study report can be prepared. Also, the previously published "principles" paper [**Post Closure Care (PCC) Termination Plans: Principles and Needs** presented last at the A&WM meeting in Overland Park, February 19, 2013] should be redone to incorporate the latest information. If and when this is done, a final report could be sent to the PCC Work Group. However, Dennis wants to use the results of this document to complete the following tasks mentioned in his February 7, 2013 memo presented at the BWM staff meeting. The modified tasks include the following:

- Evaluation of feedback from Jeremy Morris based on documents sent to him after the A&WM Conference held in February at the Overland Park Convention Center.
- The completion of the leachate sampling protocol document. **Note that a draft document has been prepared.**

- The completion of guidance documents for previously prepared documents: **Note that draft documents have been prepared.**
    - MSWLF Guidance for PCC Termination
    - A Policy Statement for Variant PCC Termination
    - Annual Report Guidance for RD&D Approved MSWLFs **A draft guidance document has been prepared for the preparation of a RD&D proposal.**
    - Leachate Sampling for MSWLFs (based on previous bullet)
- Preparation of draft regulations related to selected guidance documents.
- Integration of financial assurance into the whole PCC termination methodology with performance and time-based benchmarks and a detailed rolling phase approach to termination as proposed by Bill. **Note that this concept has been incorporated in the draft PCC Termination document.**
- Other possible activities are the offering of an on-line training course (as per Jessica) for helping landfill owner/operators get started on PCC plans and the sharing of what we have done with other states and organizations.