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ANALYSIS OF [redacted] STREAM TURBIDITY.

A report by

Nicholas Calos (PhD)

and

Lambert Bekessy

for

[redacted],
[redacted].

<u>*Date of issue:*</u> [redacted].

Analysis of [redacted] Stream Turbidity.

EXECUTIVE SUMMARY

The turbidity and silt in a watercourse passing through [redacted] was analysed so as to establish the origin of this silt.

Clay fractions were extracted from samples collected from the affected watercourse and its surrounds. These clays were then subjected to chemical, electron microscopic and X-ray diffraction analysis and relationships between the clay compositions were sought with a view to pinpointing the origin of the silt.

Possible sources of this silt included:

- soils native to the area,
- the [redacted] bentonite stockpile, or
- the earthworks at [redacted] culvert.

Montmorillonite was identified as the appropriate tracer mineral in the silts and soils, whereupon the elemental make-up of this mineral could then be used to define its source.

After accounting for salinity and cation exchange reactions which affect and interfere with the measured clay mineral compositions, each montmorillonite was shown to have a cation exchange capacity unique to its source.

On the basis of this unique cation exchange capacity derived herein, it is the finding of this study that the silt in the watercourse which passes through [redacted] did not originate in the bentonite stockpile or an adjacent settlement pond. The mineralogy of this silt more closely matches that of the soils native to the area, e.g. on which [redacted] is built.

Analysis of [redacted] Stream Turbidity.

The current study was undertaken to establish the source of turbidity in a watercourse which passes through [redacted].

It was possible that the silt and turbidity in the watercourse were derived from a number of sources, namely the native soil, the earthworks of [redacted], or a bentonite stockpile, or combinations thereof, on or outside the property.

The precise origin of the silt among these possibilities could be identified by correlating mineralogical and chemical analyses of the clay fractions derived from the soils and the suspended solids in the local water bodies.

Besides the affected watercourse, soil and water samples were also collected from selected neighbouring sites to establish the local mineralogical characteristics of the soil clays and how these characteristics were reflected in the water bodies in contact with them. Samples were collected on the morning of [redacted]. A map of the sample sites is given in Appendix A.

In each case, a minimum of three grabs constituted the samples taken from the sites.

The water samples were split and submitted for conductivity, pH, suspended solids, and turbidity measurements. The other splits of the water samples were pipetted dropwise onto microscope slides which were then gently dried. This process was repeated until visible layers of the suspended solids were deposited onto the slides.

Soil samples were sonicated without dispersant in deionised water and allowed to settle for 10 minutes. The uppermost water layers were pipetted off and deposited onto microscope slides as per the water samples.

All slides were snapped into two pieces. In each case, one piece was carbon coated for full elemental EDS analysis with a JEOL JEM800 microprobe, and the other piece was submitted to X-ray diffractometry with a Philips PW1050 Bragg-Brentano goniometer. Quantitative Rietveld analysis was then carried out on the X-ray data using the SIROQUANT® package. Operational details of the electron microprobe are given with the EDS data in Appendix B, while the X-ray diffraction data were collected from 3^o to 33^o 2θ using graphite monochromated Cu $K\alpha$ radiation.

The complete output of the EDS analyses is given in Appendix B for reference, while the summarized elemental analyses are given in Table 1.

The X-ray diffraction data are likewise presented in Appendix C, and mineralogical results from the Rietveld analyses are given in Table 2.

Whole water test results are given in Table 3, and the relevant analytical report is given in Appendix D.

According to these water analyses, turbidity strongly correlates with suspended solids (correlation coefficient[1] ρ = 0.885) and pH (ρ = 0.961). The water analyses therefore indicate that turbidity is caused by the suspended solids, and that these suspended solids are most likely clays rather than organic matter, since colloidal organics tend to be acidic, whereas dispersible clays are alkaline.

The clay mineralogies of the suspended solids were identified using X-ray diffraction, and found to be mixtures of montmorillonite, kaolinite and quartz. By way of an overview, all clay fractions analysed herein, including those from the soils, contain mixtures of montmorillonite (the primary component of bentonites), kaolinite and quartz. Amorphous and colloidal matter which is not readily assessable from the X-ray data is also to be expected.

All of the data collected must therefore be treated as a whole, as many inter-related factors are at work in determining a unique solution to the origin of the silt. For instance, sodium measurements from the clays are affected by dissolved salts in the surface waters, while any aluminium and silicon measurements attributed to montmorillonite will include contributions from kaolinite and quartz. Using simple ratios of the minerals can likewise lead to erroneous identification of their source, since they can be concentrated or depleted in their locales according to their dispersibilities, which are affected by particle size, local water flows, local water salinities, etc.

Montmorillonite was therefore chosen as the unique mineralogical marker for identification of silt source, because of its distinctively high levels of alkali metals (see Appendix E for reference compositions of clay minerals).

The marker element which characterized the montmorillonite was nominated on the basis of the chemistry of these clay minerals as follows: Montmorillonite from [redacted] area is broadly and simplistically characterized as either being of the calcium or the sodium variety, as determined by the main exchangeable cation in the mineral. Appendix E lists a set of reference compositions for [redacted] clays, highlighting the differences between local varieties of

[1] The correlation coefficient, ρ, is defined as:

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}},$$

where ρ = +1 for ideal positive relationship between two sets of variables,
ρ = 0 for no relationship between two sets of variables, and
ρ = -1 for ideal inverse between two sets of variables.

sodium and calcium bentonites (and kaolinite). However, while the calcium and sodium ions are readily exchangeable in either species, the framework elements aluminium, silicon, iron and magnesium are generally fixed, and are the major determinants for the mineral's cation exchange capacity.

Since aluminium and silicon are also present in kaolinite and quartz, the ratio of the exchangeable cations to magnesium was calculated as a unique identifier of the montmorillonite in each sample.

Sodium, as an exchangeable cation, was important to this fingerprinting process. Any salinity in the ground or surface waters would therefore have represented an interference in the exchangeable cations assay. However, the electrical conductivities of the whole water samples (Table 3) showed a strong correlation with chloride levels (Table 1); $\rho = 0.875$. This correlation was taken to indicate sodium chloride (salt), and the sodium levels associated with the montmorillonite were adjusted according to the measured chloride levels.

Table 4 gives the resultant adjusted montmorillonitic sodium, calcium and magnesium levels.

Common mineralogical and compositional factors may now be sought using these adjusted compositions, by which the source of the silt in the affected watercourse could be identified.

Montmorillonites, like other clay minerals, are made up of sheet-like molecular structures. These sheets are bound together by the exchangeable sodium and calcium cations, and because of the different sizes of sodium and calcium ions, these two varieties can be distinguished by X-ray crystallographic analysis. Sodium montmorillonites have inter-sheet (basal) spacings between 12.5Å and 14.8 Å, while the calcium varieties have basal spacings between 15.1Å and 15.5Å [Brindley and Brown (1980), "*Crystal Structures of Clay Minerals and Their X-ray Identification*", Mineralogical Society, London, p. 203].

In the present instance, the measured basal spacings of all sampled montmorillonites (Table 2) show a weak negative correlation with the minerals' corrected sodium/calcium ratios (Table 4; $\rho = -0.649$), in accordance with the crystallographic relationship discussed.

By consideration of exchangeable cation ratios alone, all but one of the sampled montmorillonites form a cluster with high basal spacings and low sodium/calcium ratios (see Figure 1). Stockpile montmorillonite is unique in that it alone has the highest sodium/calcium ratio and the lowest crystallographic basal spacing. Conversely, it may be said that the salinity corrections to clay sodium levels are appropriate, because this crystallographic correlation is borne out.

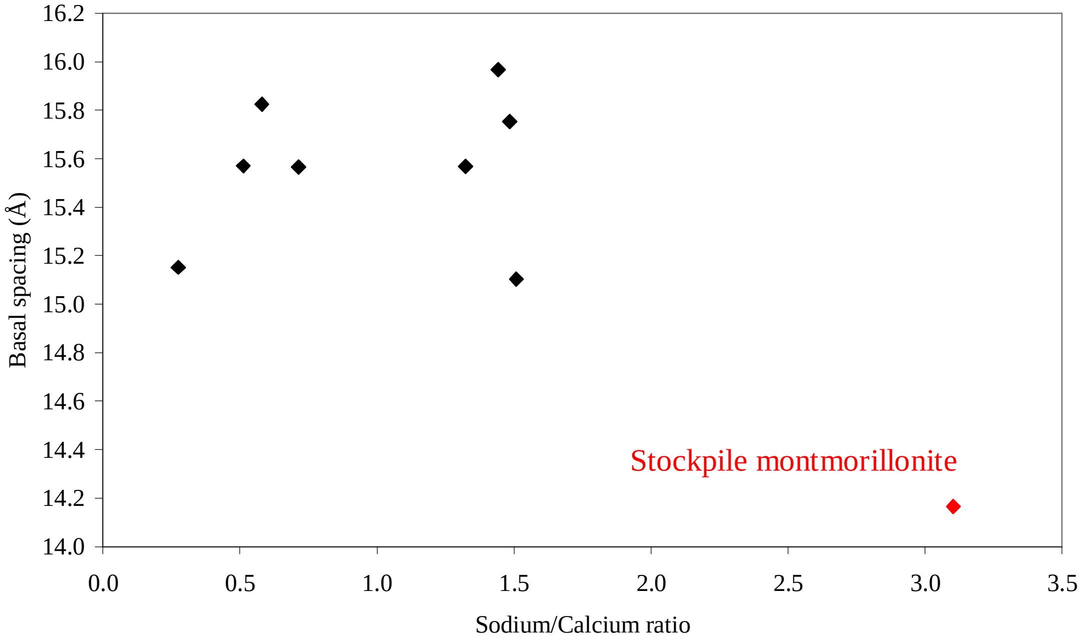


Figure 1: Montmorillonite crystallographic *c*-axis spacing as a function of the ratio of major exchangeable cations. Note the clustering of the non-stockpile montmorillonites at low sodium/calcium ratios, owing to leaching and exchange reactions as a result of extended contact with local water bodies.

On this simplistic basis, migration or distribution of montmorillonite in any way from the stockpile may not be credited.

However, this approach does not take into account any possible leaching or exchange of cations in the event of extended contact of the mineral with the local water bodies, as occurs when it is washed out of the stockpile.

These exchangeable cations must therefore be scaled against a unique framework element as discussed above, since the total cation exchange capacity may not be altered by simple exchange or leaching.

The ratios of total exchangeable cations (i.e. sodium, potassium and calcium) to magnesium could then be calculated. These ratios are presented in Table 4.

With reference to Table 4, the chemical compositions of the montmorillonites sampled are unique to their source. Specifically the stockpile bentonite contains montmorillonite with an exchangeable cation ratio of 0.66. This value is reflected in the montmorillonites sampled in the immediate vicinity of the stockpile, namely the settlement pond dam (ratio = 0.72) and its water (ratio = 0.64). In contrast, the montmorillonites extracted from all other soils and waters show higher cation ratios, ranging from 0.93 to 1.57 in the surrounding areas, to 3.14 in the [redacted] Creek sample, as graphically represented in Figure 2.

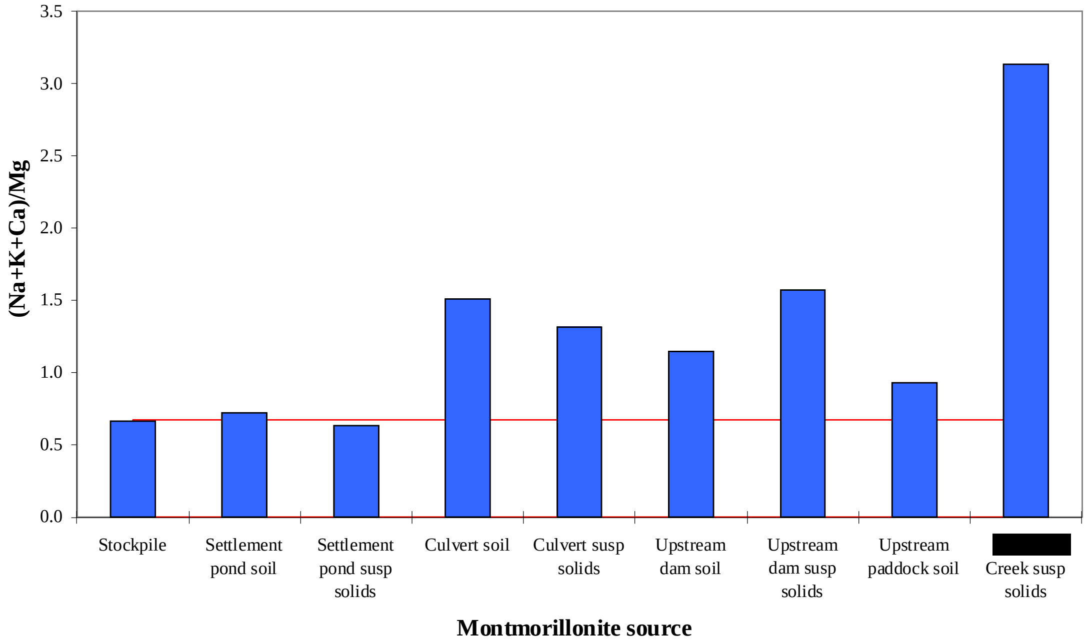


Figure 2: Exchangeable cation ratios of montmorillonites as a function of their source. Note the break between the stockpile and its immediate vicinity, and all other samples. For reference, the horizontal line at (Na+K+Ca)/Mg = 0.67 marks the average value of exchangeable cations in and near the stockpile.

Moreover, by this analysis, the montmorillonites in the surface waters reflect the compostions of those in the contacting soils. Such similarities are to be expected where the cations can freely exchange and equilibrate on extended contact with the water body.

CONCLUSION

On the basis of the crystallographic and chemical analyses presented herein, it is the finding of this study that the silt in the watercourse which passes through [redacted] did not originate in the bentonite stockpile or its settlement pond. The mineralogy of this silt more closely matches that of the soils native to the area, e.g. on which [redacted] is built.

Nicholas Calos (PhD),
Principal Scientist.

Table 1: EDS analytical results for clay fractions from [redacted] water and soil samples (wt %). The balance of the assay is made up of the carbon specimen support and LOI matter.

Sample site	Na_2O	K_2O	MgO	CaO	Al_2O_3	SiO_2	TiO_2	FeO	SO_3	Cl
Soil fines										
Stockpile	1.54	0.17	1.92	0.44	15.41	39.91	0.37	1.73	0.10	0.20
Culvert	0.38	0.11	0.53	0.84	11.18	43.58	1.04	4.59	0.35	0.17
Settlement pond	0.83	0.24	1.16	0.70	20.53	55.02	1.21	5.58	0.13	0.54
Upstream dam	0.36	0.07	0.36	0.35	6.90	23.84	0.65	3.22	0.23	0.18
Upstream paddock	0.35	0.17	0.38	0.17	7.80	39.59	0.79	2.60	0.18	0.12
Suspended solids										
Culvert	2.30	0.60	2.87	2.98	14.65	52.38	0.35	2.32	0.28	0.20
Settlement pond	1.55	0.26	2.71	1.02	19.22	49.16	0.43	2.45	0.09	0.23
Upstream dam	2.05	0.41	1.01	0.84	18.97	48.26	1.13	6.08	0.03	0.92
[redacted] Creek	9.32	1.09	3.47	6.13	2.90	64.18	0.11	0.44	0.33	0.08

Table 2: Mineralogical analyses for clay fractions from [redacted] water and soil samples.

Sample site	Montmorillonite	Kaolinite	Quartz	c_M[1] (Å)
Soil fines				
Stockpile	80.2[2]	11.6	8.2	14.165
Culvert	1.6	30.5	67.9	15.152
Settlement pond	42.1	18.3	39.6	15.569
Upstream dam	23.0	8.8	68.2	15.825
Upstream paddock	40.3	2.7	57.0	15.966
Suspended solids				
Culvert	62.6	32.6	4.8	15.565
Settlement pond	87.9	12.1	0.0	15.568
Upstream dam	16.1	52.5	31.4	15.753
[redacted] Creek	44.8	45.1	10.0	15.104

Notes:

1 c_M is the average crystallographic *c*-axis dimension (*i.e.* the basal spacing) of the montmorillonite.

2 Stockpile montmorillonite is actually an illite-smectite.

Table 3: Chemical characteristics of whole water samples.

Sample site	EC mS/cm	pH	Suspended Solids mg/l	Turbidity NTU
Culvert	0.299	7.15	1675	1100
Settlement pond	0.378	7.45	5595	1800
Upstream dam	0.473	7.00	2520	550
[redacted] Creek	0.206	6.60	233	210

Table 4: Compositional characterization of [redacted] montmorillonites.

Sample site	Montmorillonitic Sodium (Na_2O wt %)	Montmorillonitic Potassium (K_2O wt %)	Montmorillonitic Calcium (CaO wt %)	Montmorillonitic Magnesium (MgOwt %)	Na/Ca	(Na+K+Ca)/Mg
Soil fines						
Stockpile	1.37	0.17	0.44	1.93	3.10	0.66
Culvert	0.23	0.11	0.84	0.53	0.28	1.51
Settlement pond	0.36	0.24	0.70	1.16	0.51	0.72
Upstream dam	0.20	0.07	0.35	0.36	0.58	1.15
Upstream paddock	0.25	0.17	0.17	0.38	1.44	0.93
Suspended solids						
Culvert	2.13	0.60	2.98	2.87	0.71	1.32
Settlement pond	1.35	0.26	1.02	2.71	1.32	0.64
Upstream dam	1.25	0.41	0.84	1.01	1.48	1.57
[redacted] Creek	9.25	1.09	6.13	3.47	1.51	3.14

Appendix A

Map of the silt-affected watercourse at [redacted], and surrounds, showing sampling sites.

[redacted]

Key to sampling sites:

A Upstream dam: a dam roughly in line with the watercourse (during wet seasons) and with a stand of trees between it and the bentonite stockpile. Soil and water samples were collected. The trees precluded the possibility of this area being affected by wind-borne dust contamination from the stockpile.

B Upstream paddock: a native soil sample well away from the possible watercourse, and with trees between it and the bentonite stockpile. A soil sample was collected.

C Bentonite stockpile. A sample of bentonite was collected.

D Settlement pond: runoff water from the bentonite stockpile is captured by this dam. Soil and water samples were collected.

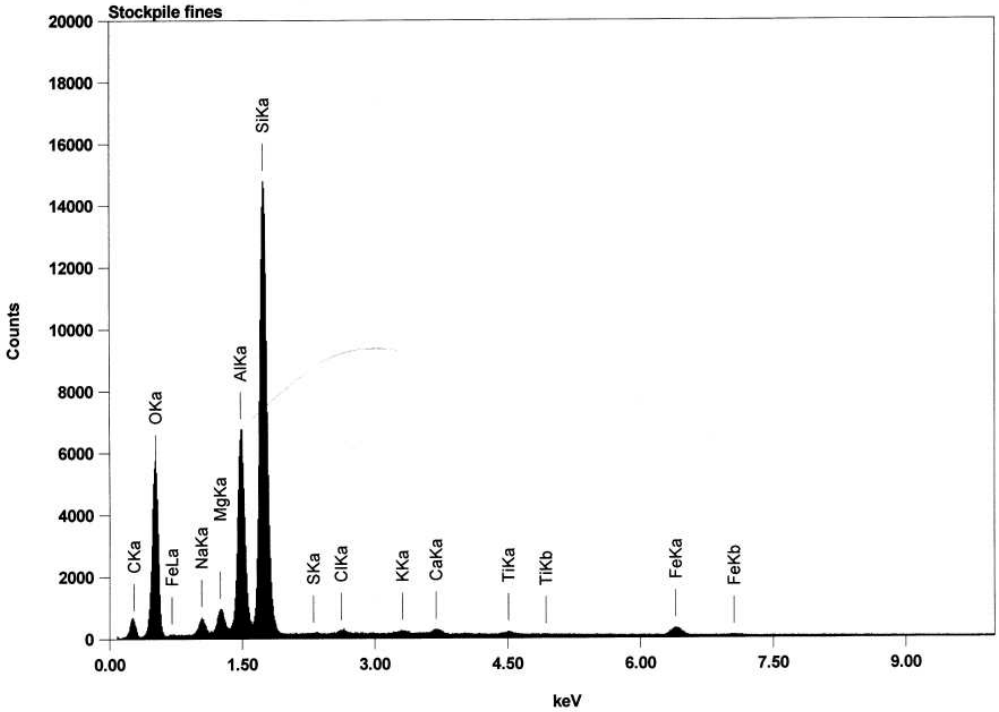
E Culvert: the point at which the watercourse passing by the bentonite stockpile and [redacted] is silt affected. Soil and water samples were collected.

F [redacted] crossing: approximately 1 km from the silt affected culvert. Water sample collected.

Appendix B

EDS analyses of clay fractions from [redacted] suspended solids and soils.

[redacted]



File: Untitled
Specimen ID: Stockpile fines
[redacted]

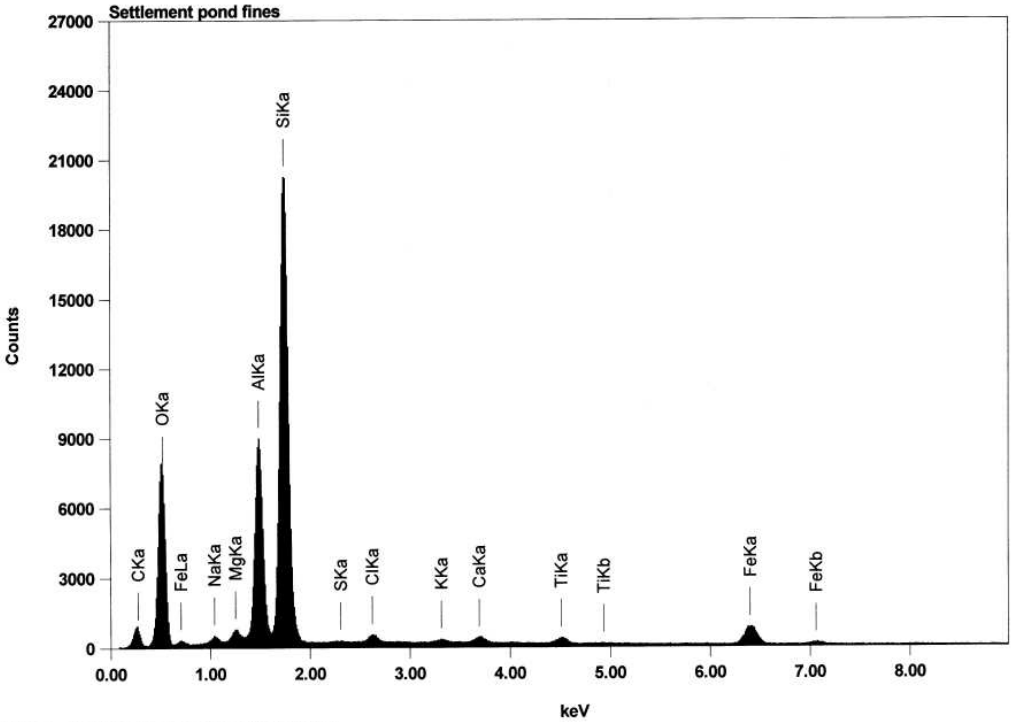
Acquisition Parameter

Acc. Voltage	: 20.0 kV	Probe Current	: 0.60000 nA
Real Time	: 224.76 sec	Dead Time	: 11 %
Live Time	: 200.00 sec	Counting Rate	: 2092 Counts/sec
Preset	: Live Time 200 sec		
Energy Range	: 0 - 20 keV	PHA Mode	: T3

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0601
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	17.71	0.30	61.25	C	17.71	0.00	1.8299
O		30.42						
Na K	1.041	1.14	0.03	1.03	Na2O	1.54	0.63	1.1106
Mg K	1.253	1.16	0.03	1.98	MgO	1.92	0.60	1.1677
Al K*	1.486	8.16	0.03	6.28	Al2O3	15.41	3.82	5.4216
Si K	1.739	18.66	0.03	27.59	SiO2	39.91	8.39	18.8018
S K*	2.307	0.04	0.04	0.05	SO3	0.10	0.02	0.0303
Cl K*	2.621	0.20	0.02	0.23	Cl	0.20	0.00	0.2052
K K*	3.312	0.14	0.02	0.08	K2O	0.17	0.05	0.1460
Ca K*	3.690	0.31	0.03	0.32	CaO	0.44	0.10	0.3147
Ti K*	4.508	0.22	0.04	0.19	TiO2	0.37	0.06	0.1832
Fe K	6.398	1.34	0.05	1.00	FeO	1.73	0.30	1.2813
Total		79.50		100.00		79.50	13.95	

[redacted]



File: Settlement pond fines.eds
Specimen ID: Settlement pond fines

[redacted]

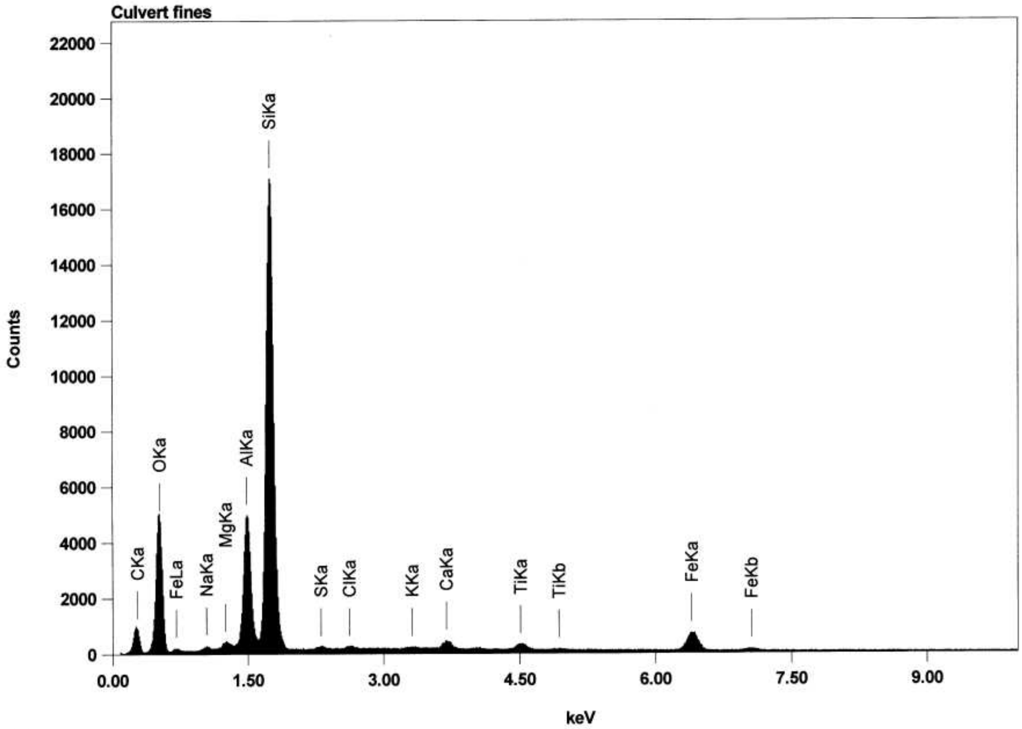
Acquisition Parameter

Acc. Voltage	: 20.0 kV	Probe Current	: 0.60000 nA
Real Time	: 232.36 sec	Dead Time	: 13 %
Live Time	: 200.00 sec	Counting Rate	: 2734 Counts/sec
Preset	: Live Time 200 sec		
Energy Range	: 0 - 20 keV	PHA Mode	: T3

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0570
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	23.16	0.45	60.03	C	23.16	0.00	2.3985
O		41.69						
Na K	1.041	0.61	0.05	0.42	Na2O	0.83	0.25	0.5663
Mg K	1.253	0.70	0.05	0.90	MgO	1.16	0.27	0.6859
Al K*	1.486	10.87	0.04	6.27	Al2O3	20.53	3.71	7.1817
Si K	1.739	25.72	0.05	28.50	SiO2	55.02	8.43	25.9774
S K*	2.307	0.05	0.06	0.05	SO3	0.13	0.02	0.0404
Cl K*	2.621	0.54	0.03	0.48	Cl	0.54	0.00	0.5583
K K*	3.312	0.20	0.04	0.08	K2O	0.24	0.05	0.2081
Ca K*	3.690	0.50	0.04	0.39	CaO	0.70	0.11	0.5025
Ti K*	4.508	0.72	0.06	0.47	TiO2	1.21	0.14	0.6029
Fe K	6.398	4.34	0.08	2.42	FeO	5.58	0.72	4.1508
Total		109.12		100.00		109.12	13.69	

[redacted]



File: Culvert fines.eds
Specimen ID: Culvert fines
[redacted]

Acquisition Parameter

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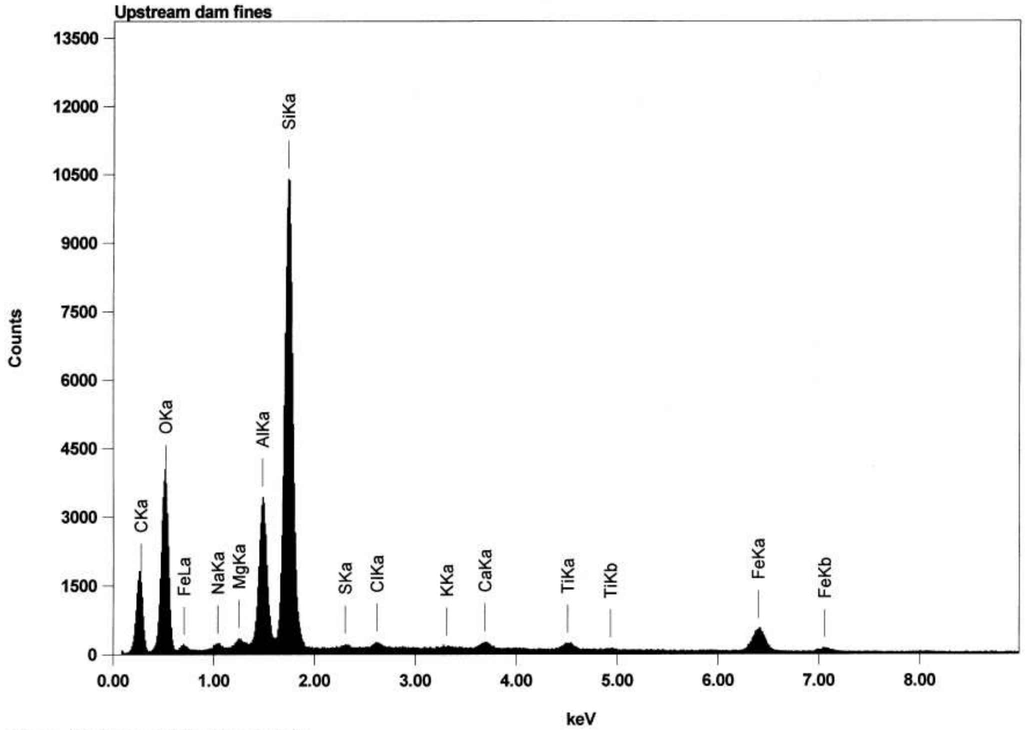
Real Time	: 224.63 sec	Dead Time	: 10 %
Live Time	: 200.00 sec	Counting Rate	: 2115 Counts/sec
Preset	: Live Time 200 sec		
Energy Range	: 0 - 20 keV	PHA Mode	: T3

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0579
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	23.76	0.29	67.40	C	23.76	0.00	2.7182
O		30.69						
Na K	1.041	0.29	0.04	0.21	Na2O	0.38	0.16	0.2625
Mg K	1.253	0.32	0.03	0.45	MgO	0.53	0.17	0.3170
Al K*	1.486	5.92	0.03	3.74	Al2O3	11.18	2.74	3.9516
Si K	1.739	20.37	0.03	24.71	SiO2	43.58	9.07	21.7138
S K*	2.307	0.14	0.04	0.15	SO3	0.35	0.05	0.1079
Cl K*	2.621	0.17	0.02	0.17	Cl	0.17	0.00	0.1824
K K*	3.312	0.10	0.02	0.04	K2O	0.11	0.03	0.1000
Ca K*	3.690	0.60	0.03	0.51	CaO	0.84	0.19	0.6117
Ti K*	4.508	0.63	0.05	0.45	TiO2	1.04	0.16	0.5248
Fe K	6.398	3.57	0.06	2.18	FeO	4.59	0.80	3.4252
Total		86.55		100.00		86.55	13.37	

[redacted]



File: Upstream dam fines.eds
[redacted]

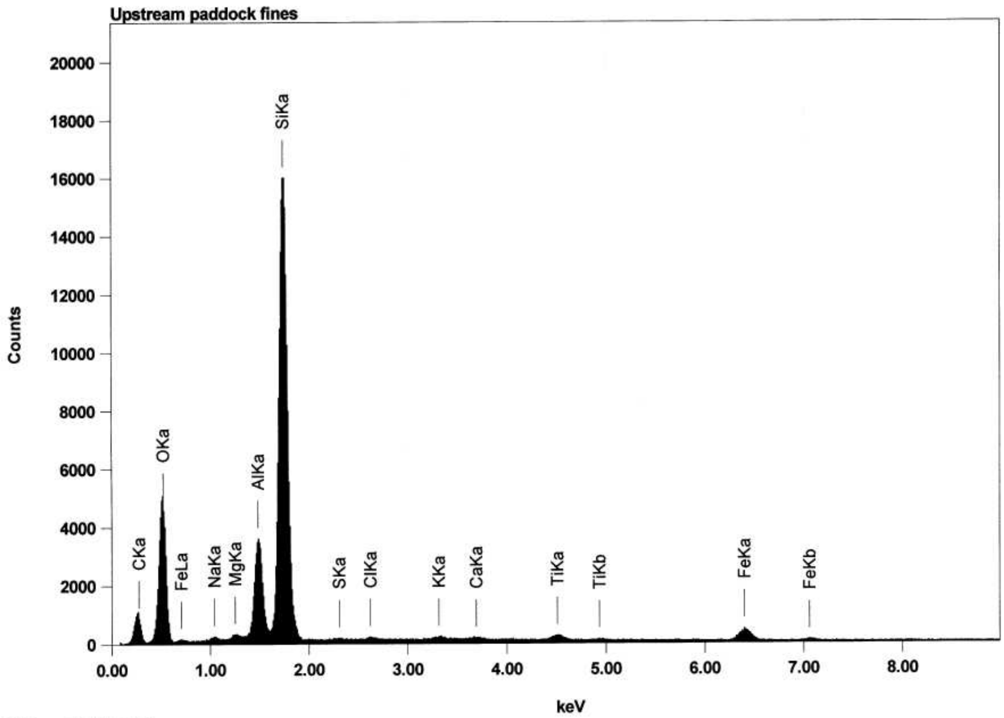
Acquisition Parameter

Acc. Voltage	: 20.0 kV	Probe Current	:	0.63000 nA
Real Time	: 217.40 sec	Dead Time	:	8 %
Live Time	: 200.00 sec	Counting Rate	:	1521 Counts/sec
Preset	: Live Time 200 sec			
Energy Range	: 0 - 20 keV	PHA Mode	: T3	

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0668
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	31.24	0.14	82.62	C	31.24	0.00	5.0072
O		17.41						
Na K	1.041	0.27	0.03	0.18	Na2O	0.36	0.26	0.2582
Mg K	1.253	0.22	0.02	0.28	MgO	0.36	0.20	0.2219
Al K*	1.486	3.65	0.02	2.15	Al2O3	6.90	2.98	2.5312
Si K	1.739	11.15	0.02	12.61	SiO2	23.84	8.75	12.5042
S K*	2.307	0.09	0.03	0.09	SO3	0.23	0.06	0.0799
Cl K*	2.621	0.18	0.01	0.16	Cl	0.18	0.00	0.1985
K K*	3.312	0.06	0.02	0.02	K2O	0.07	0.03	0.0604
Ca K*	3.690	0.25	0.02	0.20	CaO	0.35	0.14	0.2652
Ti K*	4.508	0.39	0.03	0.26	TiO2	0.65	0.18	0.3376
Fe K	6.398	2.50	0.04	1.42	FeO	3.22	0.99	2.4272
Total		67.40		100.00		67.40	13.59	

[redacted]



File: Untitled
Specimen ID: Upstream paddock fines
[redacted]

Acquisition Parameter

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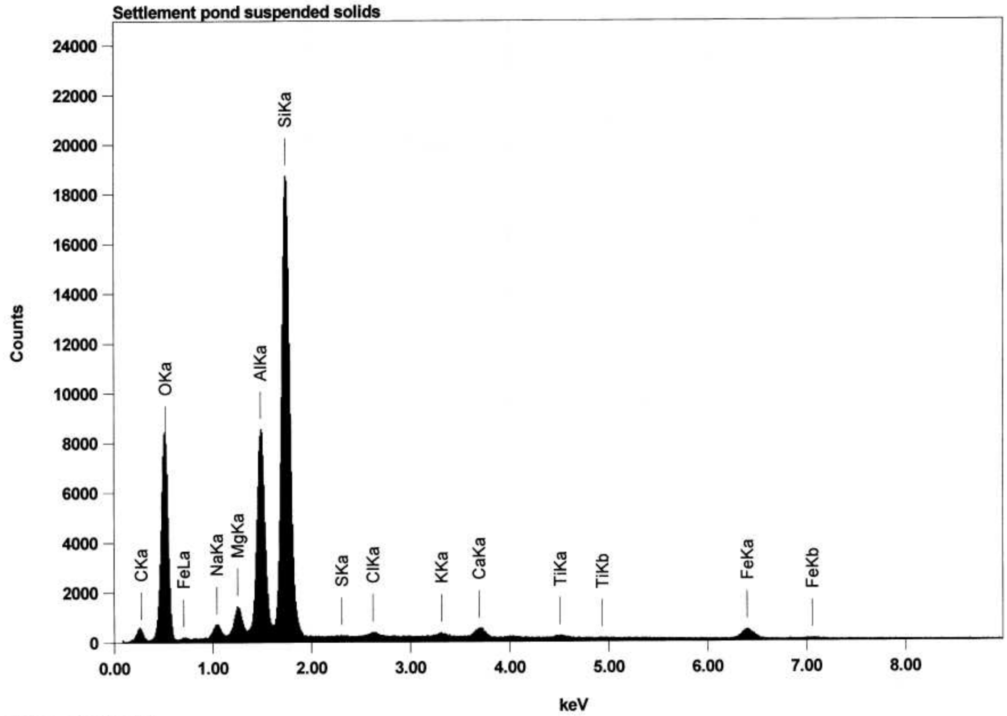
Real Time	: 221.48 sec	Dead Time	: 9 %
Live Time	: 200.00 sec	Counting Rate	: 1879 Counts/sec
Preset	: Live Time 200 sec		
Energy Range	: 0 - 20 keV	PHA Mode	: T3

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0635
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	24.87	0.26	71.95	C	24.87	0.00	2.9720
O		26.08						
Na K	1.041	0.26	0.03	0.20	Na2O	0.35	0.17	0.2468
Mg K	1.253	0.23	0.03	0.32	MgO	0.38	0.14	0.2304
Al K*	1.486	4.13	0.03	2.66	Al2O3	7.80	2.25	2.8344
Si K	1.739	18.51	0.03	22.90	SiO2	39.59	9.70	20.5650
S K*	2.307	0.07	0.04	0.08	SO3	0.18	0.03	0.0554
Cl K*	2.621	0.12	0.02	0.12	Cl	0.12	0.00	0.1322
K K*	3.312	0.14	0.02	0.06	K2O	0.17	0.05	0.1526
Ca K*	3.690	0.12	0.03	0.11	CaO	0.17	0.05	0.1276
Ti K*	4.508	0.47	0.04	0.34	TiO2	0.79	0.15	0.3973
Fe K	6.398	2.02	0.05	1.26	FeO	2.60	0.53	1.9394
Total		77.02		100.00		77.02	13.07	

[redacted]




```
File: Untitled
Specimen ID: Settlement pond suspended solids
```

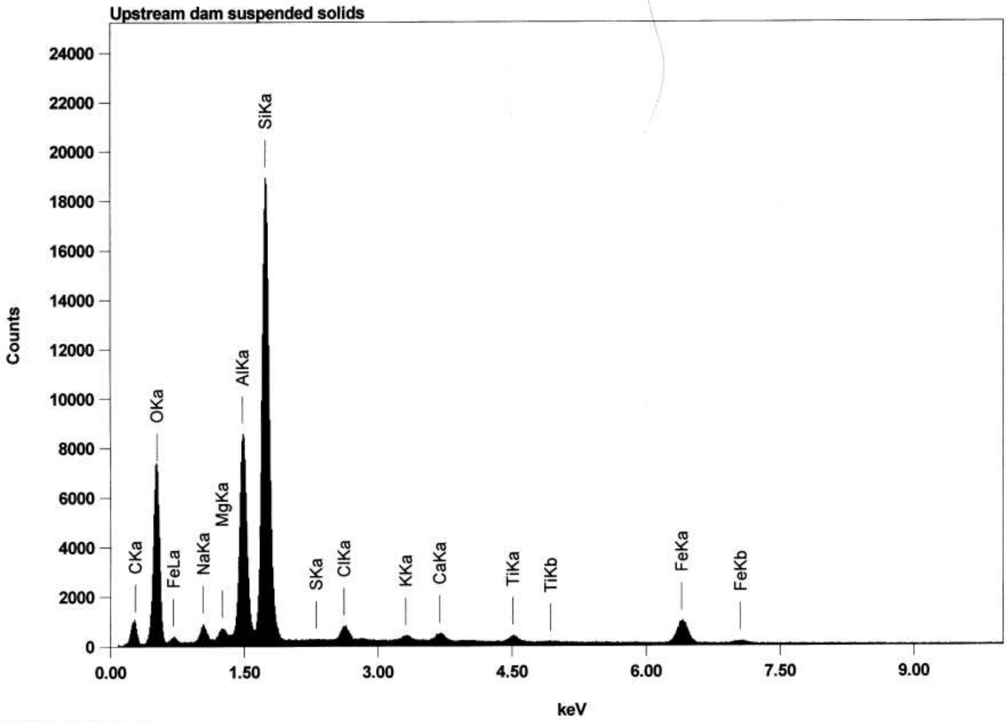
[redacted]

```
Acquisition Parameter
Acc. Voltage    :       20.0 kV          Probe Current    :     0.63000 nA
Real Time       :     230.65 sec         Dead Time        :        13 %
Live Time       :     200.00 sec         Counting Rate    :      2614 Counts/sec
Preset          : Live Time 200 sec
Energy Range    :   0 - 20 keV           PHA Mode         : T3
```

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0549
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	14.18	0.39	50.28	C	14.18	0.00	1.3488
O		37.82						
Na K	1.041	1.15	0.04	1.07	Na2O	1.55	0.51	1.0993
Mg K	1.253	1.63	0.04	2.86	MgO	2.71	0.68	1.6159
Al K*	1.486	10.17	0.03	8.03	Al2O3	19.22	3.83	6.6350
Si K	1.739	22.98	0.04	34.86	SiO2	49.16	8.31	22.5762
S K*	2.307	0.04	0.05	0.05	SO3	0.09	0.01	0.0277
Cl K*	2.621	0.23	0.02	0.28	Cl	0.23	0.00	0.2298
K K*	3.312	0.22	0.03	0.12	K2O	0.26	0.06	0.2192
Ca K*	3.690	0.73	0.04	0.78	CaO	1.02	0.19	0.7252
Ti K*	4.508	0.26	0.05	0.23	TiO2	0.43	0.05	0.2125
Fe K	6.398	1.91	0.07	1.45	FeO	2.45	0.35	1.8102
Total		91.31		100.00		91.31	13.98	

[redacted]



File: Untitled
Specimen ID: Upstream dam suspended solids
[redacted]

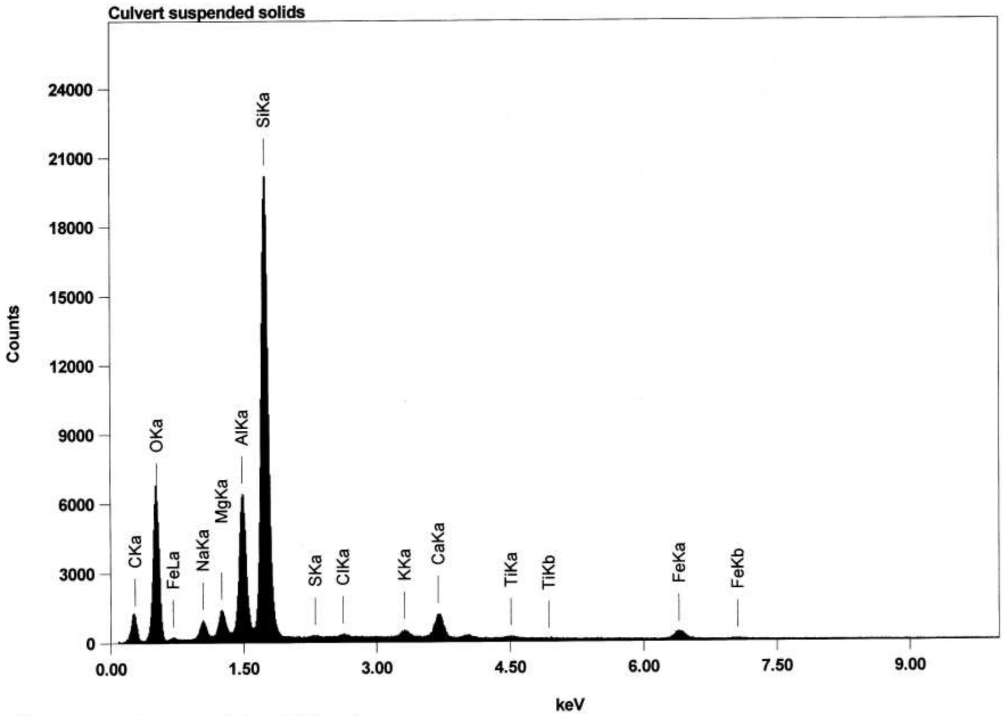
Acquisition Parameter

Acc. Voltage	: 20.0 kV		Probe Current	:	0.63000 nA
Real Time	: 231.89 sec		Dead Time	:	13 %
Live Time	: 200.00 sec		Counting Rate	:	2708 Counts/sec
Preset	: Live Time 200 sec				
Energy Range	: 0 - 20 keV		PHA Mode	: T3	

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0588
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	24.99	0.40	63.59	C	24.99	0.00	2.7088
O		37.68						
Na K	1.041	1.52	0.05	1.01	Na2O	2.05	0.67	1.4015
Mg K	1.253	0.61	0.04	0.76	MgO	1.01	0.25	0.5855
Al K*	1.486	10.04	0.04	5.68	Al2O3	18.97	3.79	6.5607
Si K	1.739	22.56	0.05	24.54	SiO2	48.26	8.18	22.7499
S K*	2.307	0.01	0.05	0.01	SO3	0.03	0.00	0.0080
Cl K*	2.621	0.92	0.02	0.80	Cl	0.92	0.00	0.9640
K K*	3.312	0.34	0.03	0.13	K2O	0.41	0.09	0.3527
Ca K*	3.690	0.60	0.04	0.46	CaO	0.84	0.15	0.6064
Ti K*	4.508	0.67	0.06	0.43	TiO2	1.13	0.14	0.5643
Fe K	6.398	4.72	0.08	2.59	FeO	6.08	0.86	4.5301
Total		104.67		100.00		104.67	14.15	

[redacted]



File: Culvert suspended solids.eds
Specimen ID: Culvert suspended solids
[redacted]

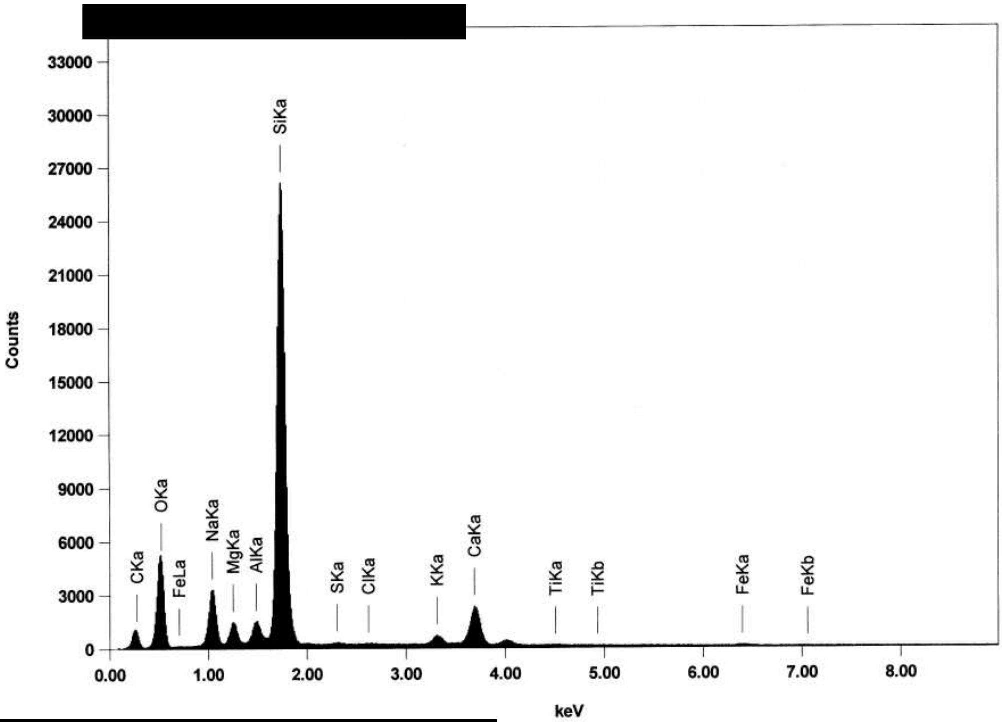
Acquisition Parameter

Acc. Voltage	: 20.0 kV	Probe Current	: 0.60000 nA
Real Time	: 230.64 sec	Dead Time	: 13 %
Live Time	: 200.00 sec	Counting Rate	: 2617 Counts/sec
Preset	: Live Time 200 sec		
Energy Range	: 0 - 20 keV	PHA Mode	: T3

ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0528
Total Oxide : 24.0

Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	30.49	0.34	67.38	C	30.49	0.00	3.5483
O		38.31						
Na K	1.041	1.71	0.04	0.99	Na2O	2.30	0.74	1.6604
Mg K	1.253	1.73	0.04	1.89	MgO	2.87	0.71	1.7366
Al K*	1.486	7.76	0.04	3.81	Al2O3	14.65	2.88	5.1381
Si K	1.739	24.48	0.04	23.13	SiO2	52.38	8.74	25.8370
S K*	2.307	0.11	0.05	0.09	SO3	0.28	0.04	0.0879
Cl K*	2.621	0.20	0.02	0.15	Cl	0.20	0.00	0.2136
K K*	3.312	0.50	0.03	0.17	K2O	0.60	0.13	0.5227
Ca K*	3.690	2.13	0.04	1.41	CaO	2.98	0.53	2.1644
Ti K*	4.508	0.21	0.05	0.12	TiO2	0.35	0.04	0.1751
Fe K	6.398	1.81	0.07	0.86	FeO	2.32	0.32	1.7260
Total		109.44		100.00		109.44	14.14	

[redacted]



[redacted]

Acquisition Parameter

Acc. Voltage	: 20.0 kV	Probe Current	: 0.60000 nA
Real Time	: 232.79 sec	Dead Time	: 14 %
Live Time	: 200.00 sec	Counting Rate	: 2791 Counts/sec
Preset	: Live Time 200 sec		
Energy Range	: 0 - 20 keV	PHA Mode	: T3

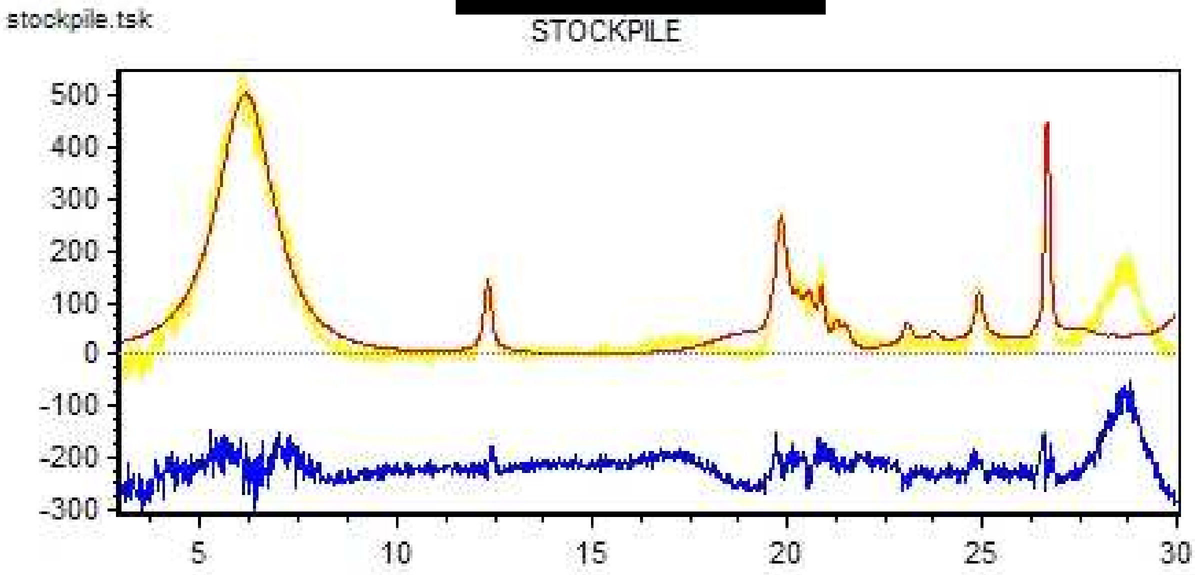
ZAF Method Standard Quantitative Analysis(Oxide)
Fitting Coefficient : 0.0502
Total Oxide : 24.0

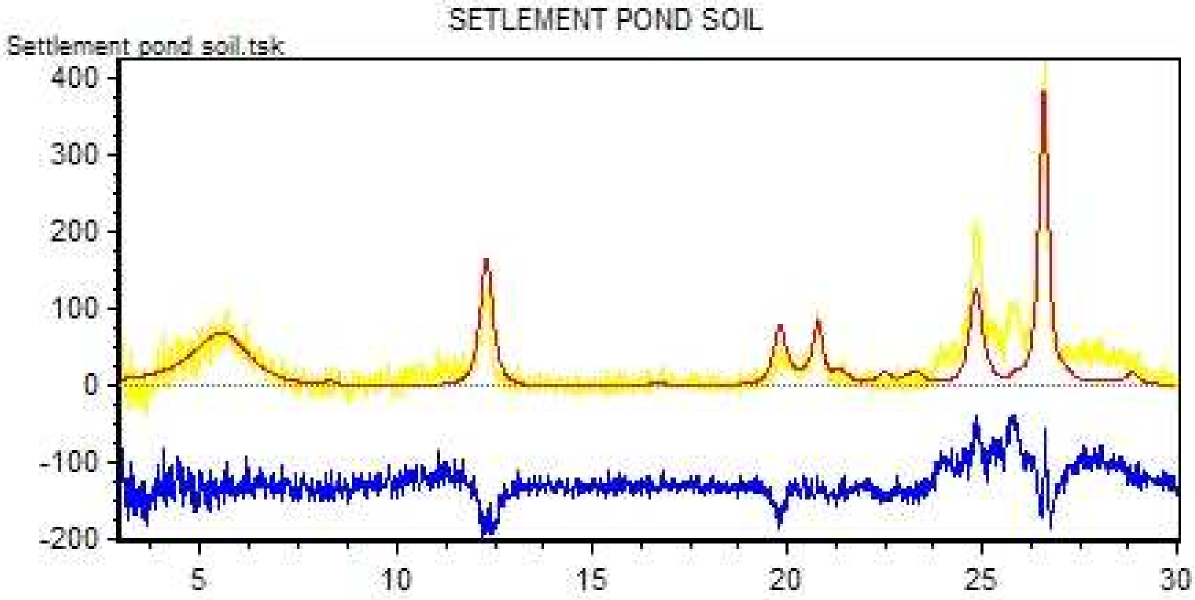
Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
C K	0.277	26.82	0.36	60.34	C	26.82	0.00	3.0231
O		41.60						
Na K	1.041	6.91	0.04	4.06	Na2O	9.32	2.78	6.8491
Mg K	1.253	2.09	0.04	2.33	MgO	3.47	0.80	1.9525
Al K*	1.486	1.53	0.04	0.77	Al2O3	2.90	0.52	0.9569
Si K	1.739	30.00	0.04	28.86	SiO2	64.18	9.86	33.0695
S K*	2.307	0.13	0.05	0.11	SO3	0.33	0.04	0.1015
Cl K*	2.621	0.08	0.02	0.06	Cl	0.08	0.00	0.0786
K K*	3.312	0.91	0.03	0.31	K2O	1.09	0.21	0.9460
Ca K*	3.690	4.38	0.04	2.95	CaO	6.13	1.01	4.4102
Ti K*	4.508	0.07	0.06	0.04	TiO2	0.11	0.01	0.0552
Fe K	6.398	0.34	0.07	0.16	FeO	0.44	0.06	0.3221
Total		114.86		100.00		114.86	15.28	

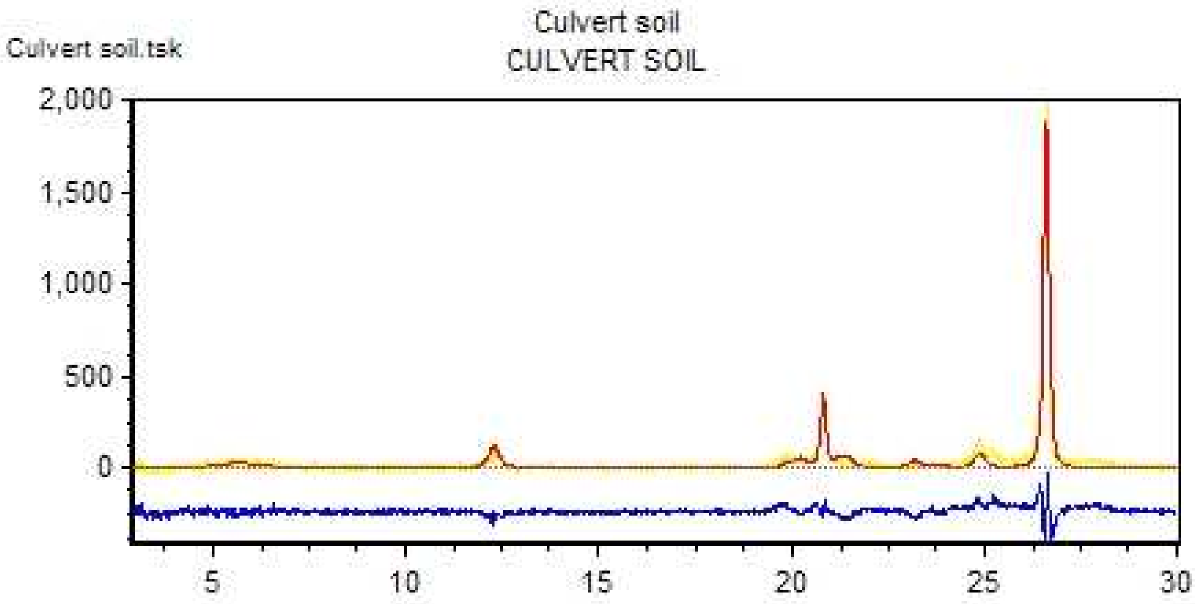
Appendix C

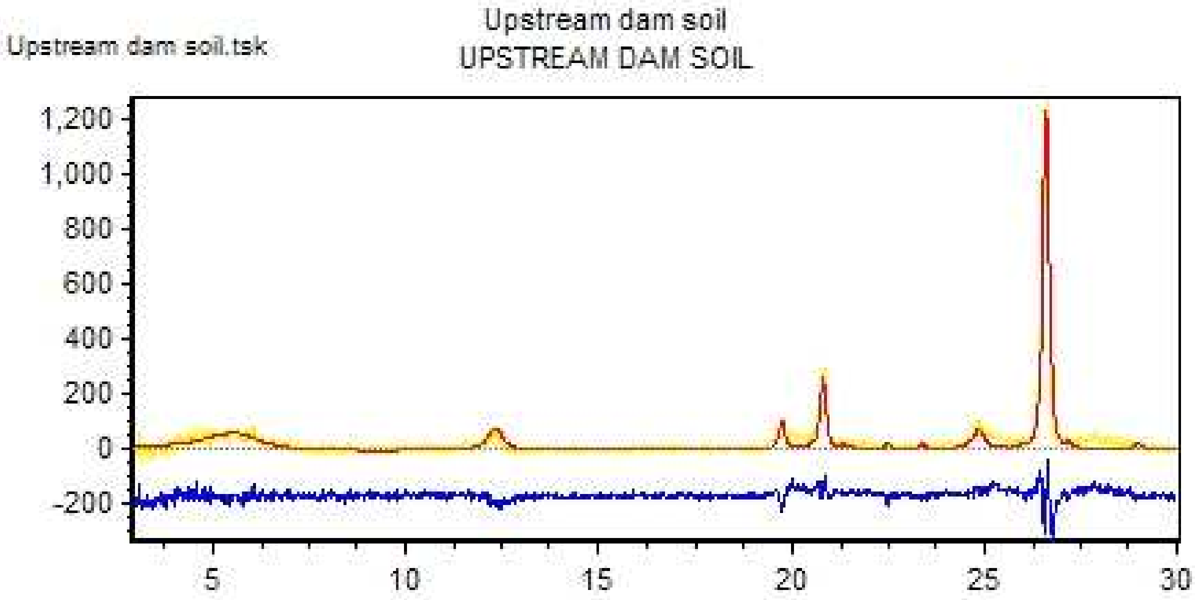
Rietveld plots of clay fractions from [redacted] suspended solids and soils.

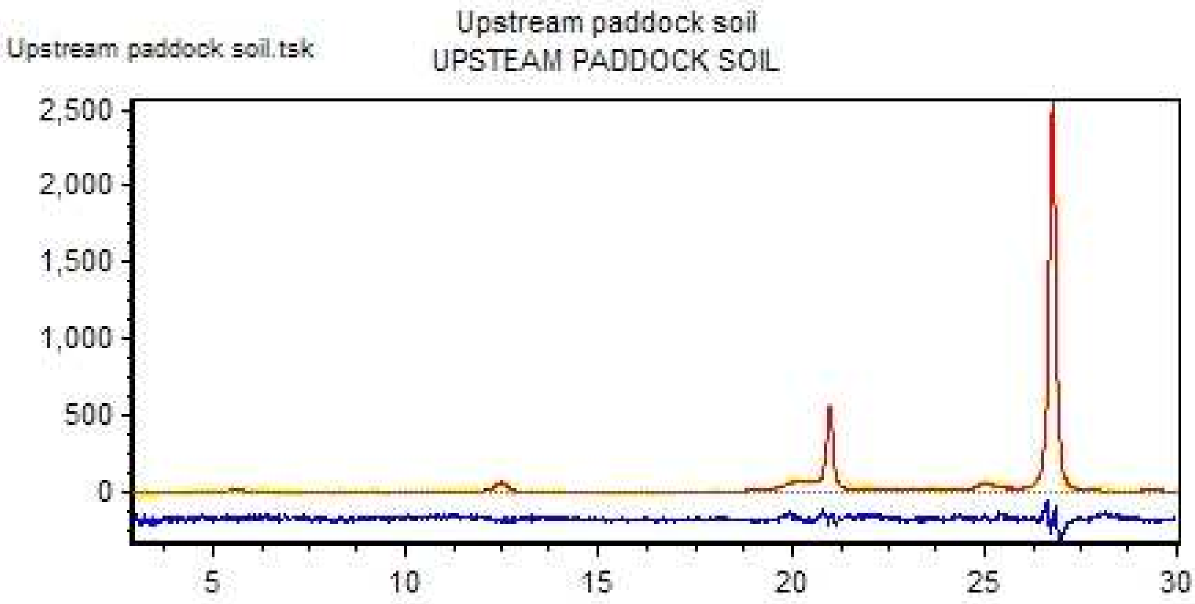
[redacted]

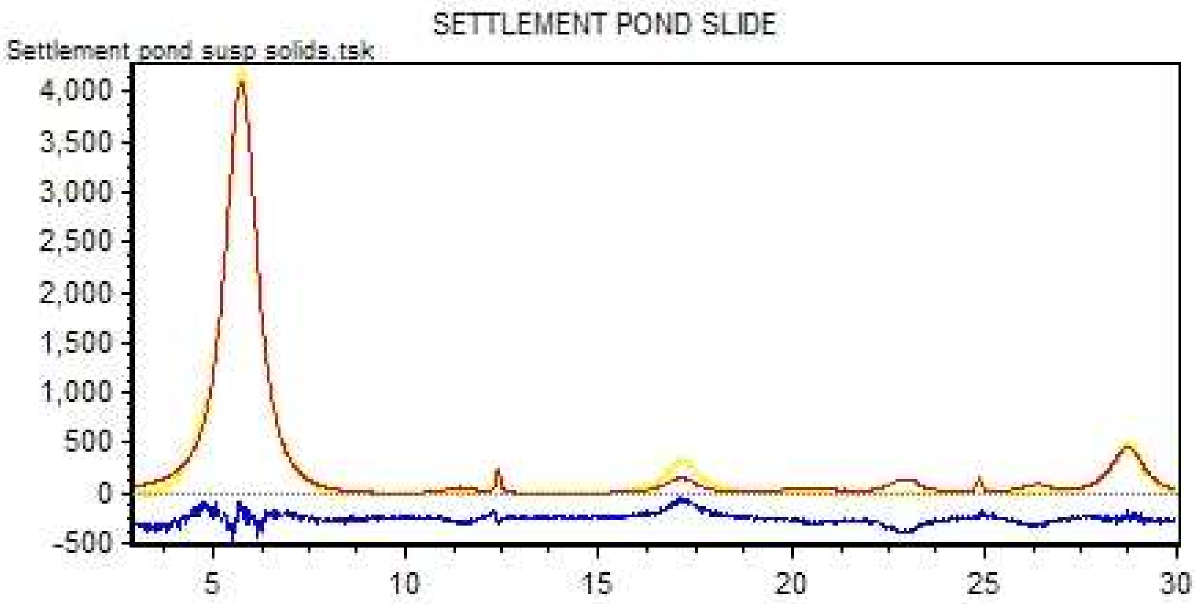

stockpile.tsk
STOCKPILE
500
400
300
200
100
0
-100
-200
-300
5
10
15
20
25
30

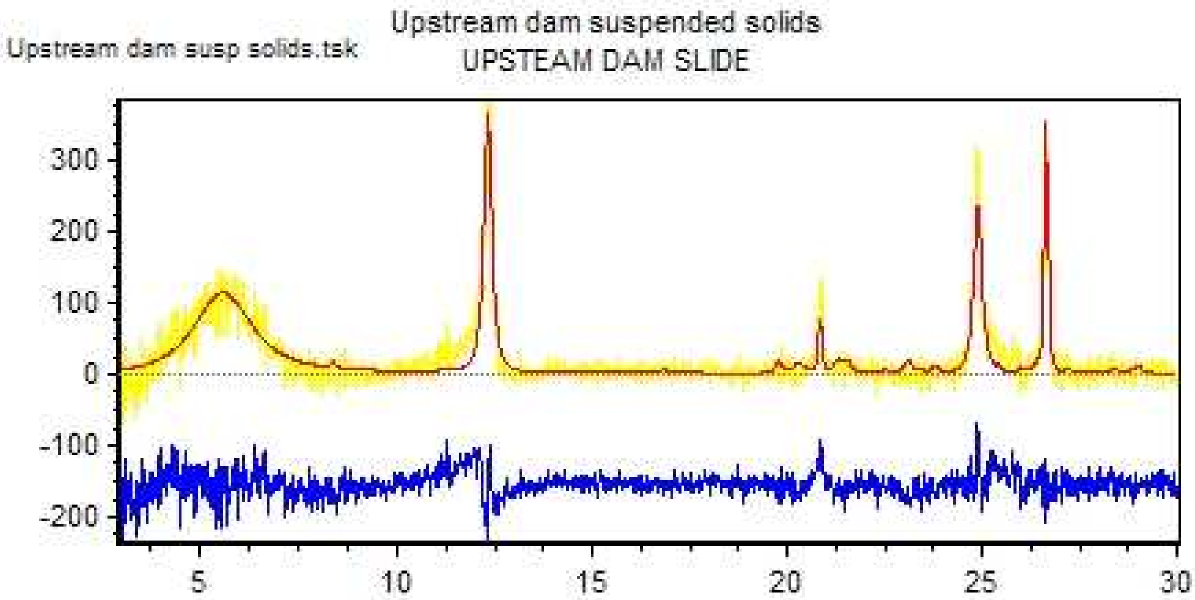

SETLEMENT POND SOIL
Settlement pond soil.tsk
400
300
200
100
0
-100
-200
5
10
15
20
25
30

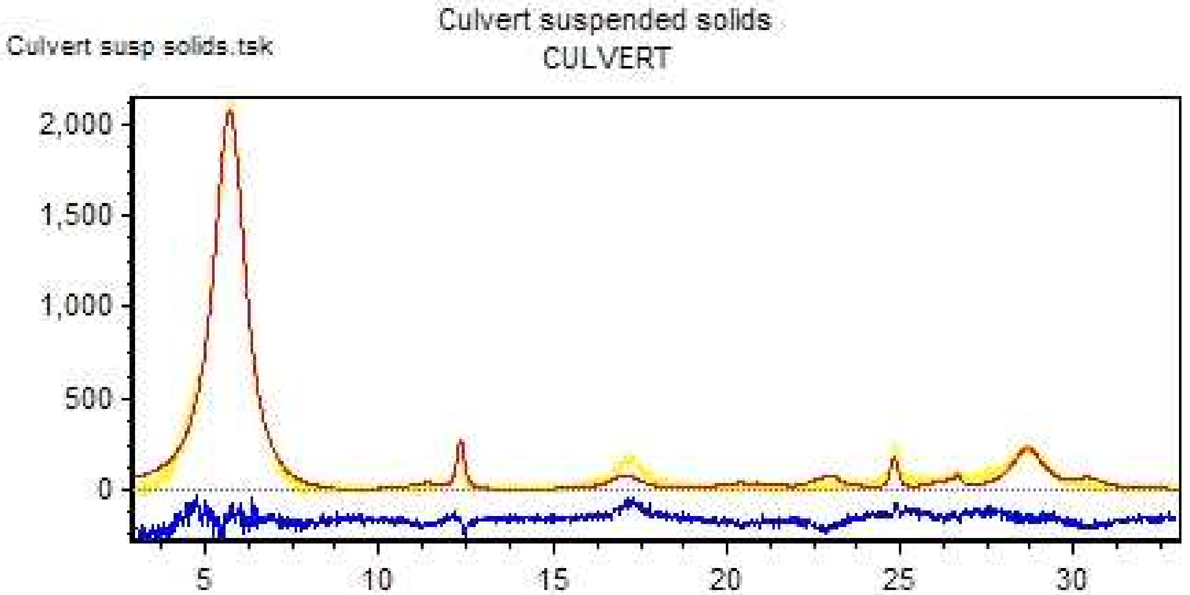

Culvert soil.tsk
Culvert soil
CULVERT SOIL
2,000
1,500
1,000
500
0
5
10
15
20
25
30


Upstream dam soil.tsk
Upstream dam soil
UPSTREAM DAM SOIL
1,200
1,000
800
600
400
200
0
-200
5
10
15
20
25
30

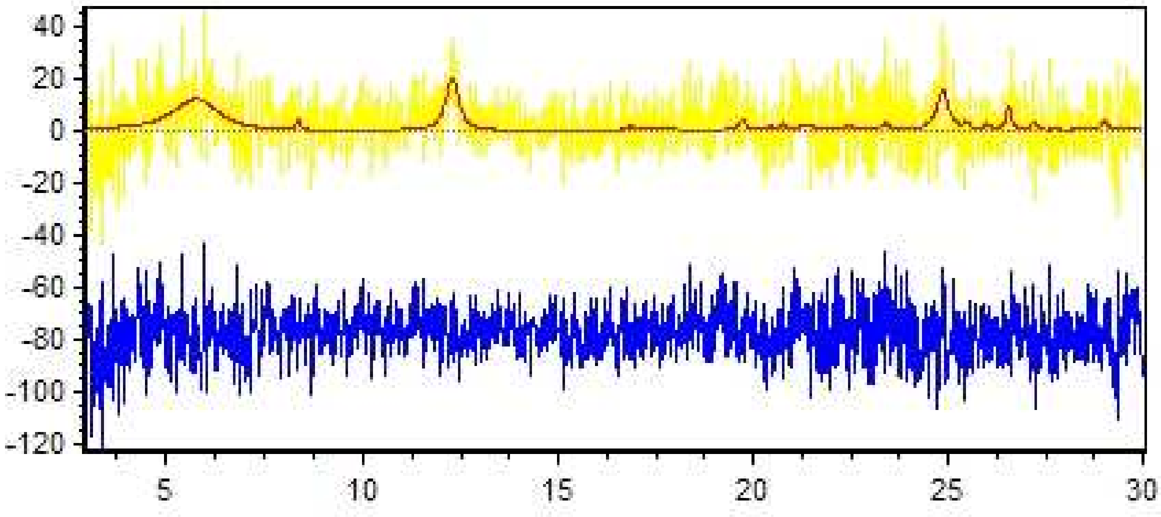

Upstream paddock soil
Upstream paddock soil.tsk
UPSTEAM PADDOCK SOIL
2,500
2,000
1,500
1,000
500
0
5
10
15
20
25
30


SETTLEMENT POND SLIDE
Settlement pond susp solids.tsk
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
-500
5
10
15
20
25
30


Upstream dam susp solids.tsk
Upstream dam suspended solids
UPSTEAM DAM SLIDE
300
200
100
0
-100
-200
5
10
15
20
25
30


Culvert susp solids.tsk
Culvert suspended solids
CULVERT
2,000
1,500
1,000
500
0
5
10
15
20
25
30

[redacted]



Appendix D

Analytical certificate for sampled [redacted] surface waters.

FOOD & AGRICULTURE LABORATORIES OF AUSTRALIA PTY. LTD.

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Laboratory Report

AGR SCIENCE & TECHNOLOGY P/L
P O BOX 210
NEW FARM
QLD 4005

Attention : DR NICHOLAS CALOS

[redacted]

Batch : 2140749 **Order Number : FALA082**

METHODCODE	METHOD NAME	RESULT DESCRIPTION	RESULT	UNITS
Sample No.: 2140749.01 [redacted] ****TURBIDITY, FOLLOWED BY SUSPENDED SOLIDS WITH RECOVERED SAMPLE****				
WAT007	Electrical Conductivity	Conductivity @ 25°C	0.206	mS/cm
WAT006	PH on water	pH units	6.60	@ 20°C
WAT009	Solids (Suspended)	Suspended Solids	233	mg/L
WAT061	Turbidity on water	Turbidity	210	N.T.U
Sample No.: 2140749.02 WATER Sample ID: UPSTREAM DAM **TURBIDITY, FOLLOWED BY SUSPENDED SOLIDS WITH RECOVERED SAMPLE**				
WAT007	Electrical Conductivity	Conductivity @ 25°C	0.473	mS/cm
WAT006	PH on water	pH units	7.00	@ 20°C
WAT009	Solids (Suspended)	Suspended Solids	2520	mg/L
WAT061	Turbidity on water	Turbidity	550	N.T.U
Sample No.: 2140749.03 WATER Sample ID: SETTLEMENT POND **TURBIDITY, FOLLOWED BY SUSPENDED SOLIDS WITH RECOVERED SAMPLE**				
WAT007	Electrical Conductivity	Conductivity @ 25°C	0.378	mS/cm
WAT006	PH on water	pH units	7.45	@ 20°C
WAT009	Solids (Suspended)	Suspended Solids	5595	mg/L
WAT061	Turbidity on water	Turbidity	1800	N.T.U
Sample No.: 2140749.04 WATER Sample ID: CULVERT **TURBIDITY, FOLLOWED BY SUSPENDED SOLIDS WITH RECOVERED SAMPLE**				
WAT007	Electrical Conductivity	Conductivity @ 25°C	0.299	mS/cm
WAT006	PH on water	pH units	7.15	@ 20°C
WAT009	Solids (Suspended)	Suspended Solids	1675	mg/L
WAT061	Turbidity on water	Turbidity	1100	N.T.U

Please note that the above results refer only to the samples tested. Samples were supplied by the customer and responsibility for representative sampling rests with the customer. All tests were performed at various times between the sample received date and the print date on the report.

Checked By : ______________________
DARYL SCURR (DIRECTOR)

P.O. Box 269
ARCHERFIELD QLD 4108
PHONE: (07) 3345 4566
FAX: (07) 3345 4871

ANALYTICAL LABORATORY
CONSULTING CHEMISTS
RESEARCH & DEVELOPMENT

Appendix E

Reference clay mineral and bentonite analyses.

Mineral / source	**Na_2O**	**K_2O**	**MgO**	**CaO**	**Al_2O_3**	**SiO_2**	**TiO_2**	**FeO**	**SO_3**
Type specimen montmorillonite[1]	0.14	0.05	4.20	2.11	25.78	66.73	0.00	0.97	0.00
CMS montmorillonite[2]	2.06	0.40	3.03	1.19	23.82	65.64	0.14	3.73	0.00
CMS kaolinite[3]	<0.15	0.29	0.11	<0.02	37.9	44.4	1.47	0.63	0.00
CMS kaolinite[4]	0.01	0.04	0.02	0.02	38.0	45.0	1.58	0.25	0.00
[redacted] Ca bentonite[5]	0.50	0.30	2.59	1.32	16.5	62.0	0.31	2.26	0.01
Na bentonite	1.38	0.45	2.63	0.47	18.1	67.4	0.34	2.22	0.04
Na bentonite[6]	2.28	0.49	2.59	1.48	22.3	66.8	0.48	2.93	0.08
Na bentonite[7]	2.58	0.41	3.20	2.41	21.5	65.3	0.44	2.86	0.08
kaolinite	0.14	0.17	0.87	0.10	30.4	49.8	0.52	4.32	0.00

1 Type specimen from Montmorillon, France [Deer, Howie and Zussman (1967), "*An Introduction to Rock Forming Minerals*", Longmans, London, p. 252].

2 Clay Minerals Society standard [speclab.cr.usgs.gov/spectral.lib04/DESCRIPT/monmorillonite.cm27.html].

3 Clay Minerals Society standard [speclab.cr.usgs.gov/spectral.lib04/DESCRIPT/kaolinite.cm5.html].

4 Clay Minerals Society standard [speclab.cr.usgs.gov/spectral.lib04/DESCRIPT/kaolinite.kga1.html].

5 [redacted] datasheet.

6 [redacted] datasheet.

7 [redacted] datasheet.