Yukon Geological Survey Miscellaneous Report 15

Technical report: A comparison of aerochem and traditional stream sediment sampling

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Published under the authority of the Department of Energy, Mines and Resources, Government of Yukon http://www.emr.gov.yk.ca.

Printed in Whitehorse, Yukon, 2016.

Publié avec l'autorisation du Ministères de l'Énergie, des Mines et des Ressources du gouvernement du Yukon, http://www.emr.gov.yk.ca.

Imprimé à Whitehorse (Yukon) en 2016.

In referring to this publication, please use the following citation:
Hildes, D. and Turanich-Noyen, C., 2016. Technical report: A comparison of aerochem and traditional stream sediment sampling. Yukon Geological Survey, Miscellaneous Report 15, 20 p. plus digital appendices.

TECHNICAL REPORT:
A COMPARISON OF AEROCHEM AND TRADITIONAL STREAM SEDIMENT SAMPLING

KLUANE FIRST NATIONS CATEGORY A SETTLEMENT LAND, WEST OF KLUANE LAKE Yukon, Canada

FIELD WORK PERFORMED:
August 19 – 26, 2015

Prepared for:
YUKON GEOLOGICAL SURVEY
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EXECUTIVE SUMMARY

Stream sediment sampling is a commonly practiced method in early-stage exploration. Aerochem is an airborne sampling system (patent pending) that reduces the helicopter overhead inherent with conventional sampling, particularly in difficult to reach areas such as rugged terrain or dense vegetation.

The airborne system must maintain the integrity of the sample material and render cross-sample contamination insignificant. To this end, a comprehensive wash method is developed and a successful contamination test recorded.

Although beneficial from cost-efficiency and safety perspectives over conventional hand stream sediment sampling, a key question is whether the data gathered by the airborne technique are equivalent to the conventional technique. A comparison test to assess whether sampling biases exist and are significant to the geochemical outcome was performed in August of 2015, in the Kluane area of Yukon. Three samples were collected from each of 68 sites, one using the Aerochem technique and two using conventional hand-sampling.

A comparative analysis between Aerochem and the two hand samplers show variability between the three samples taken at the same sites with modestly higher variability between airborne and conventional techniques than the two samples collected with the conventional technique. The difference is not such that all datasets cannot be used effectively together. The airborne and conventional techniques are effective at identifying anomalous stream sediment geochemistry.

INTRODUCTION

This report examines the similarities and differences between conventional and helicopter (Aerochem) stream sediment sampling techniques. Sample material was collected and field observations documented at 68 sites in the study area by two hand samplers and Aerochem to compare the geochemical variance both between airborne and land-based samples, as well as between two independent ground samplers.

To acquire these data sets Aurora Geosciences and Capital Helicopters completed a test survey in the Kluane area of Yukon, west of Destruction Bay and Burwash Landing, between August 19 and 26, 2015 (Fig. 1). Three samples were collected at each station; two samples taken independently by samplers using the conventional ground method and a single sample collected using the airborne technique. The resulting geochemical data are analyzed to compare variance not only between the ground and airborne method, but also between both ground samples.

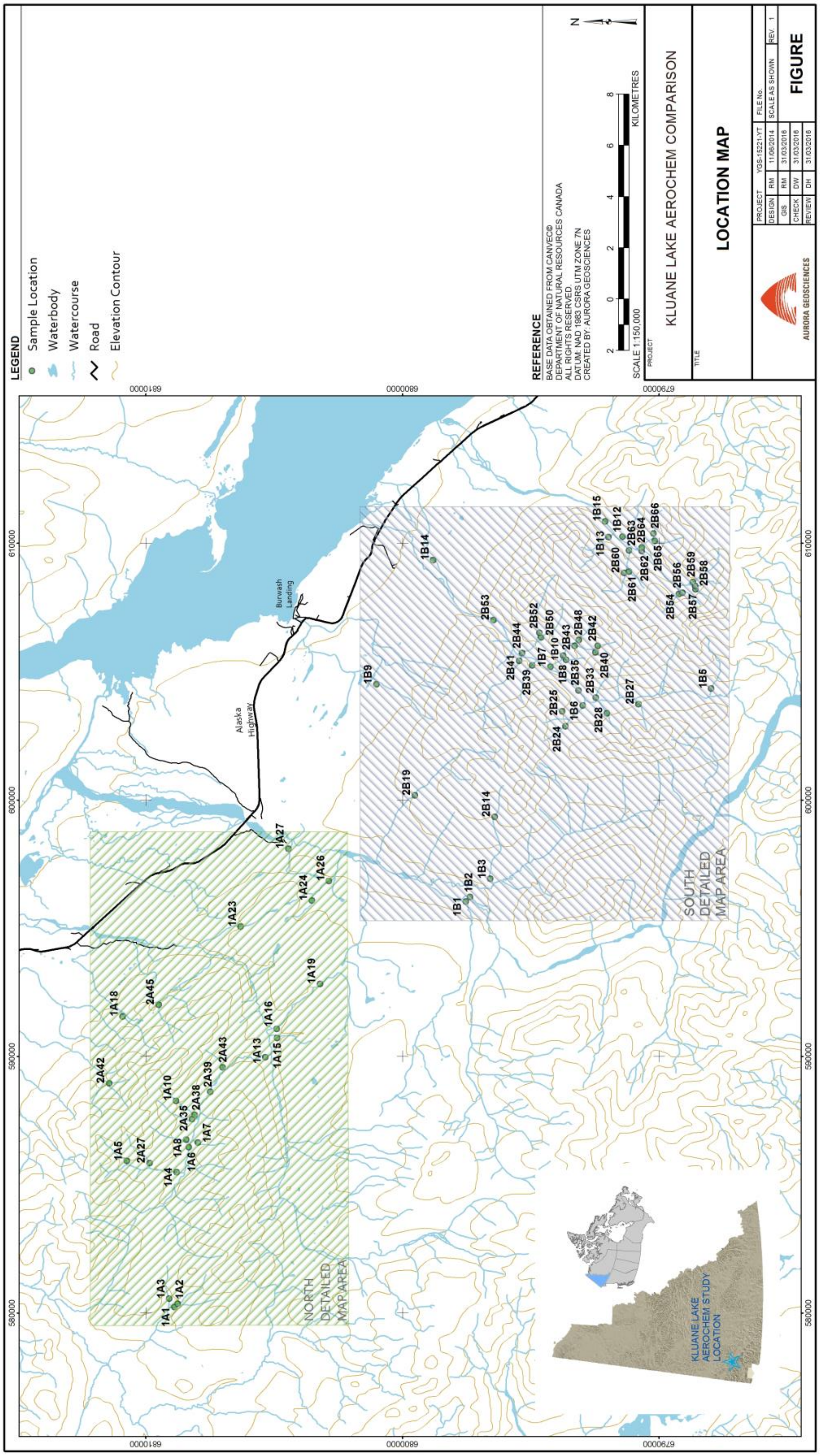

Figure 1. *Sample location map.*

CONTAMINATION TEST

To assess the extent of inter-sample contamination in the airborne sampling system, a cross-contamination experiment was performed. Sand from Grey Mountain Road (Whitehorse) was collected as a source of blank material. Material from a copper showing adjacent to the historic War Eagle mine in the Whitehorse Copper Belt was crushed (70% < 2 mm), pulverized (85% passing 75 microns or better) and then mixed by hand with blank material to produce a suitable volume of contaminated sample.

Three samples were taken from the blank material and two from the contaminated sample. A suite of 14 samples were then taken, alternating between the contaminated and blank sample bin. The samples were processed as per the field protocol, however, for cost purposes a forklift was used instead of a helicopter. All samples were coarse sieved to -12 mesh and then to -80 mesh at the sample prep lab. Only the blank samples in the alternating rotation of the contamination test are shown in Table 1; all contaminated samples are beyond the detection limit of 10 000 ppm.

Although the level of copper in the blank sample does increase, the test was designed to accentuate this. Sampling 3% copper stream sediment is not a realistic consideration in actual field deployment; however, the test shows that the cross-sample contamination level is very low at 0.04% and is therefore not a significant consideration.

Table 1. *Contamination test results.*

Blank material from Grey Mountain		Blank material contaminated with War Eagle mineralization		Alternate sampling - contaminated then blank	
	Cu ppm		Cu %		Cu ppm
Blank	12.07	War Eagle	3.05	Blank	19.53
Blank	12.26	War Eagle	2.84	Blank	29.39
Blank	11.28			Blank	23.22
				Blank	21.79
				Blank	19.47
				Blank	22.36
		Average	2.95	Blank	30.69
Average -ppm	**11.87**	**Average – ppm**	**29,450**	**Average -ppm**	**23.78**

Level of contamination-ppm (23.78 [avg of alternated blank] – 11.87 [avg of blank material] **11.91**

Level of contamination - % (11.91[ppm contamination] / 29,450 [contaminated sample]) * 100 **0.040**

SURVEY METHODOLOGY

Sample locations for the survey were located at the north end of Kluane Lake, Yukon, close to Burwash Landing, and to the south of the past-producing Wellgreen mine (Fig. 1). The terrain is generally very rugged. Approximately 90% of the samples were collected in the alpine.

At every station shown in Figure 1, three independent samples were collected; two were taken using two independent ground samplers by conventional hand sampling, and one using the Aerochem system. Some subsequent figures in this report highlight the northwest and southeast areas of Figure 1 individually.

Aerochem Sampling

The Aerochem system was created to address the high costs associated with regional stream sediment sampling. By operating in a small, low budget helicopter and requiring only two personnel at the central processing station, users can realize cost savings not possible through conventional methods. In addition, the technique offers safety benefits by mitigating several important hazards: injuries sustained while wading through steep, rugged creeks, encounters with wildlife, and the hazards of constantly entering/exiting helicopters often on precarious toe-in landings. Finally, Aerochem provides the ability to acquire geochemical data in areas that thus far remain unexplored due to conditions such as steep terrain or dense vegetation.

Aerochem is designed to operate within the limits of a Robinson R44, operated by Capital Helicopters (1995) Inc. The two-person ground crew sets up a mobile processing station near the center of the target area and all ground equipment and personnel can be mobilized in a single Robinson R44 load. The pilot collects a sample with the mechanically assisted airborne sampler and then flies back to this central processing station. The ground crew manually releases the sample on the wash station, transferring the sample into a holding bucket. To ensure samples are not cross-contaminated, one ground personnel thoroughly washes the sampling bucket using a methodology identical to that used in the contamination test (Section 0) before the pilot proceeds to the next sample station. Finally, the sample is sieved to -12 mesh and placed in a spun bond polyester sample (*Hubco*) bag.

Conventional Stream Sediment Sampling

Conventional stream sediment samples were collected using National Geochemical Reconnaissance (NGR) protocol.

- A 1 to 1.5 kilogram sample of silt/clay rich material (when possible) was collected either by hand or using a trowel.
- The target locations, when possible, were either at the ‘tail’ of a sandbar, active over bank deposit, or a quiet water zone – where there existed a relatively moderate to low energy transition within the stream.
- Material was collected from multiple sites along a 5-10 m length of the stream bed, approximately an inch below the surface.

- A photo was taken at each station, showing the sample bag with ID number in the foreground and the stream setting in the background.
- The material was placed in a spun bond polyester sample (*Hubco*) bag, which was then stored and dried in Whitehorse, before being delivered to Bureau Veritas Mineral Laboratories in Whitehorse.

Figure 2 shows the data collected at each NGR sample site. These data have been merged with the assay results and included with Appendix II of this report.

Job Number:		
Grid & Sampler Name:	**Grid:**	**Sampler:**
Sample Location:	**Line:**	**Station:**
Lab & Tag Number:	**Lab:**	
GPS Coordinates:	**E**	**N**
	Zone:	**NAD:**
Photo Number *(if appl.)*:		

Creek Composition (%)	Boulder	
	Cobble	
	Pebbles	
	Sand	
	Silt	
	Clay	
	Organics	

Stream Cut, Water Width, Incline	YES	
	NO	
	Water Width	
	Degrees	

Bank Collapse	YES	
	NO	

Vegetation Cover	Evergreen	
	Deciduous	
	Buck Brush	
	Alpine	
	Tundra	
	Marsh	

Dominate Creek Lithology

Valley Shape	U	
	V	
	canyon	
	plateau	
	marsh/ swamp	

Exposed Bedrock	YES	
	NO	

Comments

Figure 2. *Stream sediment sample data card.*

Geochemical analysis

Sample analysis follows protocols established by the Geological Survey of Canada (GSC) for their national Regional Geochemical Surveys (RGS) for stream sediments. In every batch of 20 sequential numbers, there are 18 field samples, a blind duplicate sample and a control reference sample. Field duplicates were not collected as the survey methodology already required two samples at each station. The blind duplicates were randomly selected and recorded at the lab from one of the 18 collected samples and inserted as the first sample in the batch (1001, 1021, 1041…). The standard or control reference alternated between Red Dog (obtained from Wayne Jackaman with *Noble Exploration Services*) and STSD1 (Canmet), inserted as the 15th sample of each sequence.

Samples were sent to Bureau Veritas Mineral Laboratories in Whitehorse, observing a chain of custody sufficient to meet regulatory reporting requirements. All samples are analyzed after a modified Aqua Regia digestion of a 15-gram sample of -80 mesh material split by ICP-MS using the ultra-trace detection limits. The package includes 53 elements. Analytical results were compiled with the site data (Appendix II). Upon completion of the analysis, sample pulps were returned to Whitehorse and weighed.

ANOMALOUS GEOCHEMISTRY

Figures 3, 4, 5 and 6 show plots of anomalous Ni and Ag for both hand and Aerochem sampling. These figures illustrate that in general, all samples - regardless of the technique – are consistent in whether a site is geochemically anomalous. Ag and Ni were chosen as example elements because both have greater spatial variability over the survey area and are generally of economic interest. From an exploration perspective, both techniques provide valuable grassroots data to assess the economic potential of a catchment basin.

Tables 2 and 3 list stations with anomalous nickel and silver. Both tables are based on one hand sampler where all stations that are two standard deviations above the mean (using robust estimators as described in Section 6.2) are listed. Highlighted stations in the Aerochem and second hand-sampler column indicate those below the two standard deviation threshold and the actual assayed value is shown as well as a measure of how anomalous the sample is expressed in standard deviations above the mean.

For nickel, although Aerochem stations 1A13 and 2B42 did not assay two standard deviations above the mean, they are both 1.6 standard deviations above the mean and are anomalous. Both second hand sample and Aerochem have site 1B7 similar to each other, lower than hand sampler 1. Site 1B10 is the only example where both hand samplers registered a highly anomalous value while the Aerochem sample was only slightly above the mean. Importantly, from a spatial examination of the nickel assay results in Figures 3 and 4, all three datasets point to the same basins as very anomalous in nickel.

Table 2. *List of Stations with Anomalous Ni.*

Aerochem			Ground 1	Ground 2		
Site	Ni (ppm)	SD from mean	Site	Site	Ni (ppm)	SD from mean
1A13	159.1	1.6	1A13	1A13		
1B5			1B5	1B5		
1B7	112.9	0.8	1B7	1B7	130.3	1.1
1B10	87.8	0.1	1B10	1B10		
2B33			2B33	2B33		
2B40			2B40	2B40		
2B42	158.3	1.6	2B42	2B42		
2B43			2B43	2B43		
2B61			2B61	2B61		
2B64			2B64	2B64		
2B66			2B66	2B66		

Similarly, Table 3 shows the anomalous results for silver. The only station where there are serious inconsistencies is 2A42. Closer examination of the photos from this site confirms that the hand samples and Aerochem sampled very different micro environments. As with nickel, a visual examination of Figures 5 and 6 confirm that all datasets point to the same basins as anomalous in silver.

Table 3. *List of Stations with Anomalous Ag.*

Aerochem			Ground 1	Ground 2		
Site	Ag (ppm)	SD from mean	Site	Site	Ag (ppm)	SD from mean
1A2	334.56	1.8	1A2	1A2		
2A27	207.59	0.7	2A27	2A27	281.44	1.4
2A42	81.32	-1.4	2A42	2A42		
2B57	287.34	1.5	2B57	2B57	303.08	1.6
2B58			2B58	2B58		
2B59	350.29	1.9	2B59	2B59		
2B60	312.92	1.7	2B60	2B60		
2B61	276.51	1.4	2B61	2B61	330.63	1.8
2B62			2B62	2B62		

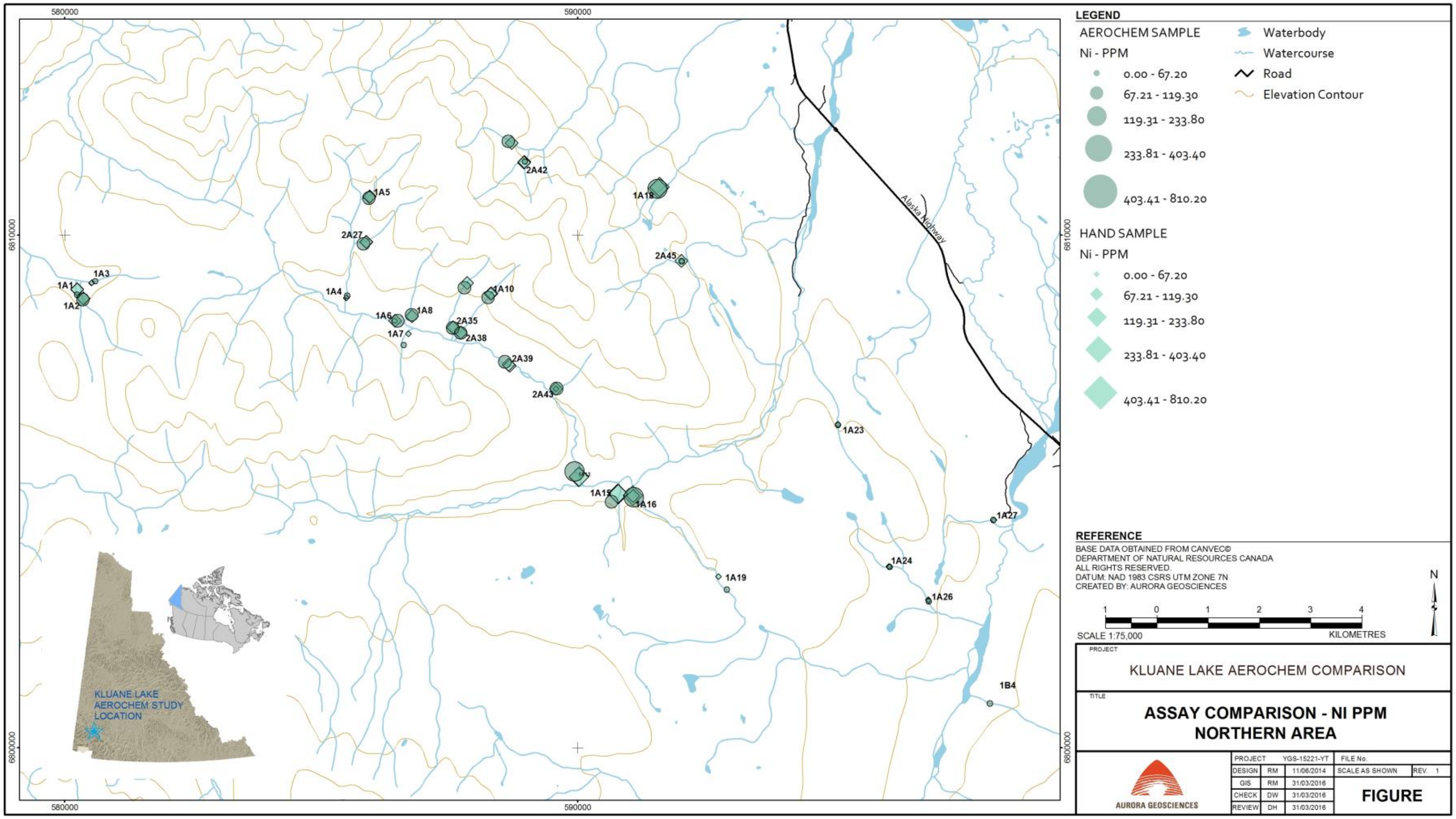

***Figure 3.** Assay comparison – Ni north area.*

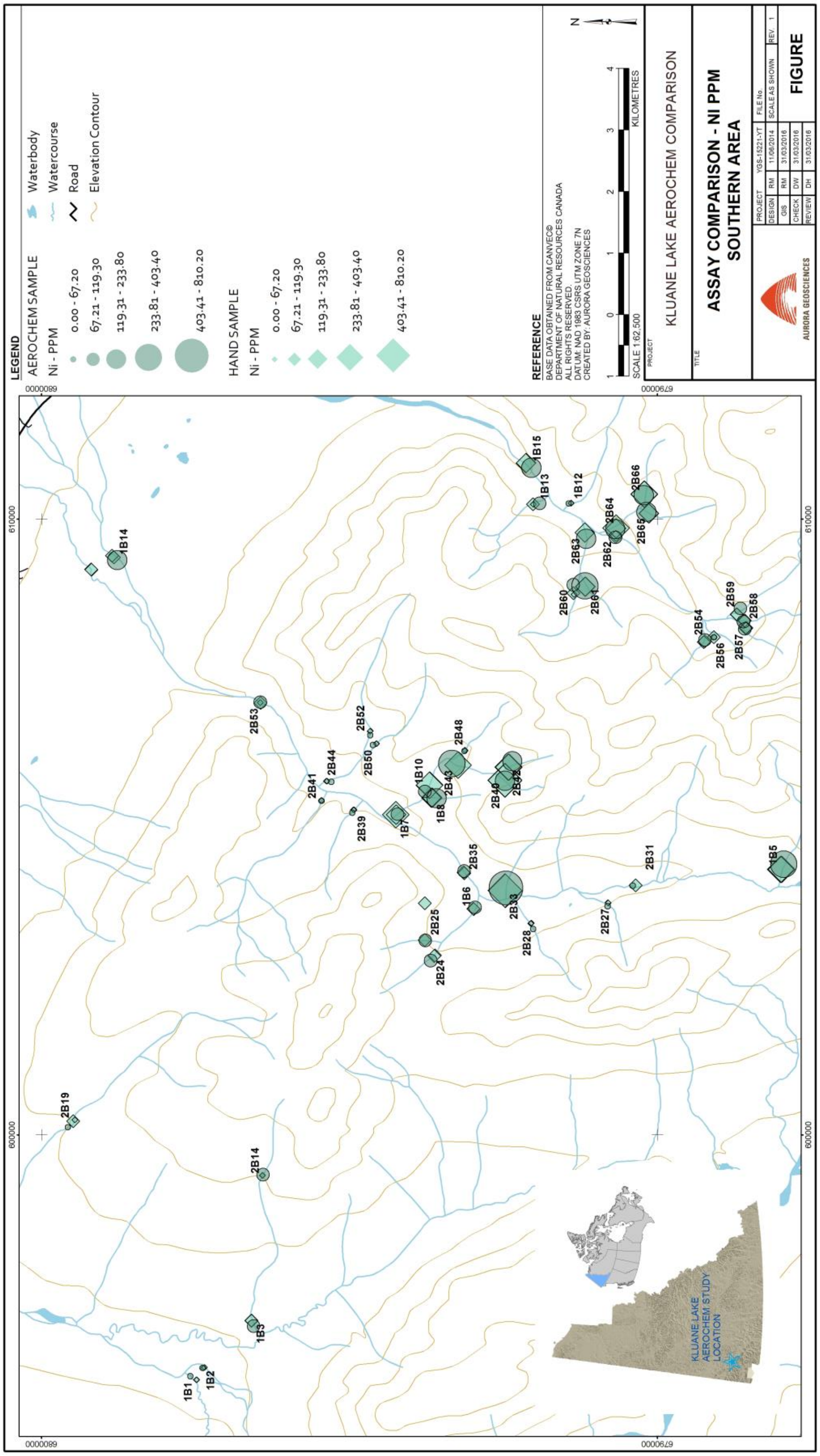

Figure 4. *Assay comparison – Ni south area.*

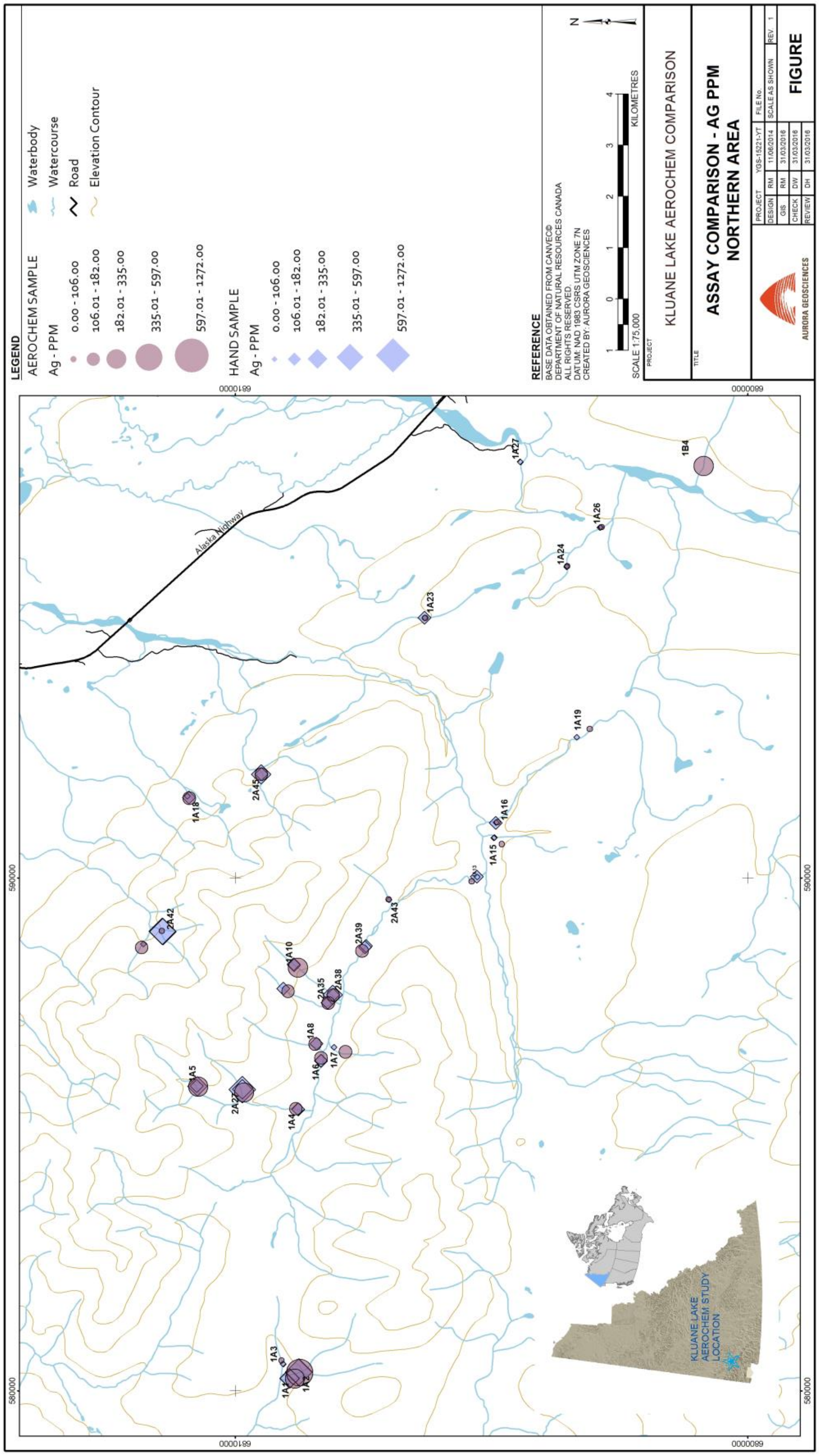

Figure 5. Assay comparison – Ag north area.

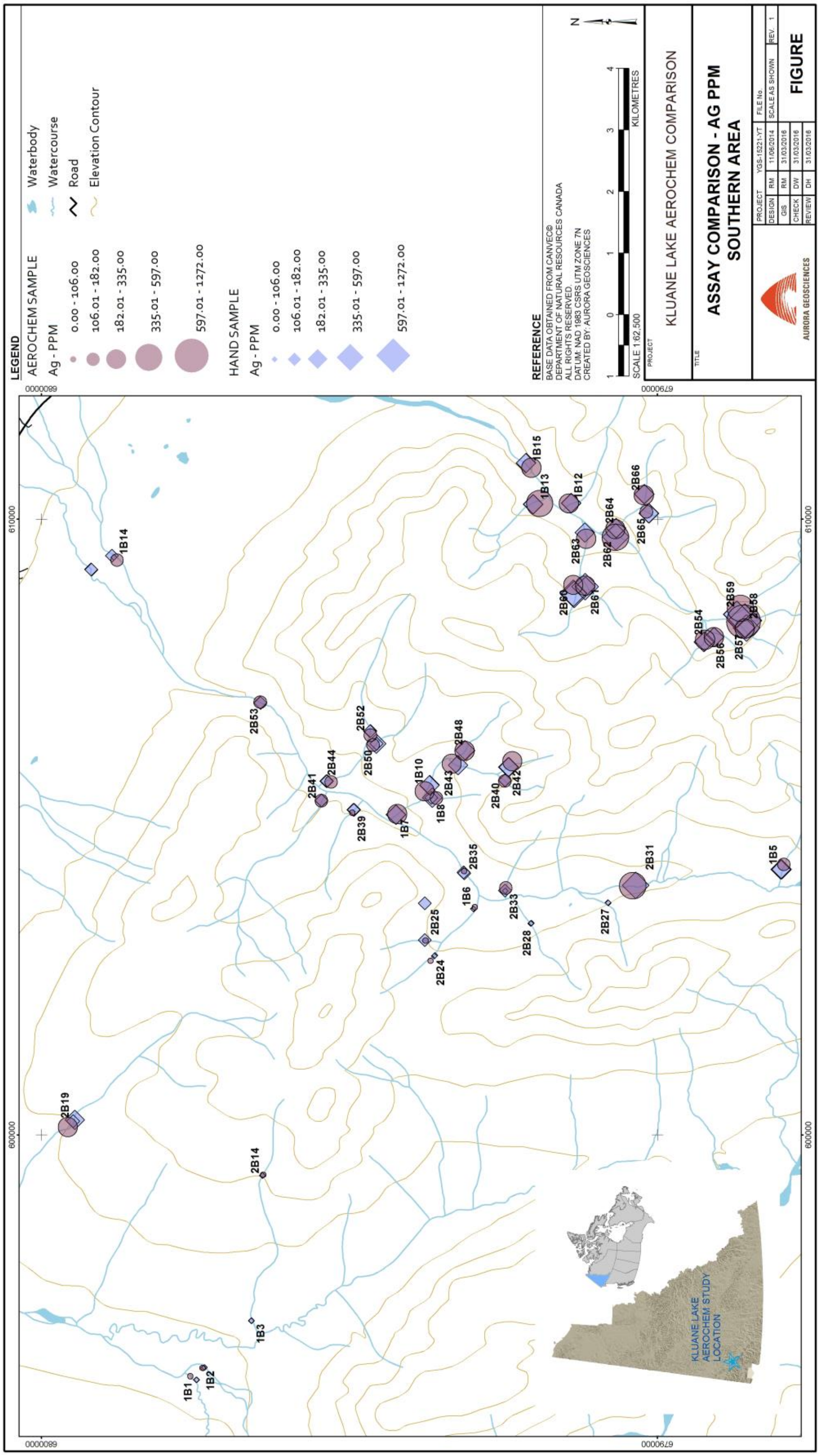

Figure 6. *Assay comparison – Ag south area.*

DATA ANALYSIS

Prior to the data analysis, sites that did not have a complete triplet of samples (two hand samplers and one airborne sample) were removed from the analysis.

Principle Component Analysis

As shown in Section 5, when elements are viewed individually, hand and airborne sampling produce consistent results. To capture the variability over the entire suite of analyzed elements, a principal component analysis is used.

A natural logarithmic transform is applied to all the geochemical data in order to approach a normal (Gaussian) distribution of each element prior to the principal component analysis; this converts the 52 (non-zero) elemental variables into 52 orthogonal components (eigenvectors). The complete definition of the principal components and the eigenvalues, which describe the contribution of each principal component to the total variability of the dataset, are in Appendix II. The first three principal components cumulatively account for greater than 55% of the dataset variability and each further component contributes 5% or less.

The data are sorted and binned into three datasets: hand sample 1, hand sample 2 and Aerochem sample. The purpose of the study is to critically examine the two sampling methods and whether they are compatible. To heighten the sensitivity of the analysis to variability between the datasets, the principal component factors are differenced and the absolute values of the difference are plotted in Appendix I. These plots reveal that the variability between hand and airborne sampling data are greater than the variability between that of the two hand samplers.

The variability can be quantified through a statistical analysis of the distribution of the principal component factor differences shown in Table 4. The median and mean are consistently lower for the differences between the hand samples than between hand and helicopter samples, as visually seen in the PCA plots of Appendix I. However the differences between the means of the datasets are all less than the standard deviation of the datasets, indicative of the large level of overlap between the populations. It should be noted that the distributions are non-Gaussian and therefore caution must be exercised when interpreting the standard deviation.

Table 4. *Distribution of principal component factor differences.*

F1	Hand1 - Aerochem	Hand2-Aerochem	Hand1-Hand2
Median	0.750	0.710	0.370
Mean	0.990	0.880	0.520
StdDev	0.808	0.741	0.534

F2	Hand1 - Aerochem	Hand2-Aerochem	Hand1-Hand2
Median	1.120	0.900	0.510
Mean	1.370	1.290	0.770
StdDev	1.178	1.518	0.801

F3	Hand1 - Aerochem	Hand2-Aerochem	Hand1-Hand2
Median	0.580	0.500	0.540
Mean	0.680	0.690	0.580
StdDev	0.585	0.750	0.410

Mean Normalized Difference

In addition to the principal component analysis, another method to contrast Aerochem and conventional sampling is the difference between normalized means. Robust estimators are calculated from a reduced dataset by trimming below the 10th and above the 90th percentiles of the natural log transformed dataset. A normalized dataset is produced by subtracting the robust mean from every element and dividing by the robust standard deviation.

Similarly, as for the PCA, differences are calculated at each station, however some elements are excluded from the analysis based on a large number of low-censored or nearly low-censored data. Elements W, S, Te, Ge, In, Re, Pd, Pt and Ta are excluded based on the visual assessment of histograms. Additionally, a ceiling of two standard deviations from the mean is imposed to prevent outliers from exerting undue influence on the result. The absolute value of the difference between the normalized values for each element is summed over all elements. A mean normalized difference is then calculated for each sample site and plotted in Appendix I. This gives a single estimator of the variability over all well-distributed elements. The average variability of the normalized mean over all stations is 0.46 and 0.48 for the difference between airborne and each hand sampler.

Expanding on the interpretation of this analysis, as the two datasets approach a single value at each site for each elemental analysis, the average of the normalized mean will approach zero. If the two datasets being compared differ for each element at identical stations by one standard deviation of that element (calculated from all stations) the average of the normalized mean will be 1. Therefore, the values of 0.46 and 0.48 represent significant differences between the airborne and hand sampled datasets.

Discussion

The average variability of the normalized mean at each station between the two hand samplers is 0.36, also showing significant differences between two instances of the same technique. The variability between the two different techniques is larger than the internal variability within a single technique, but only modestly so and is small enough that combining existing hand sampled stream geochemistry and Aerochem samples into a single analysis is a reasonable endeavor.

One reason for the greater variability between the techniques is a sampling bias and homogenization that is inherent to micro-site choice of each technique. Additionally although the sites are considered coincident in the analysis, in reality there is spatial variability between the three samples and a greater spatial distance between airborne sampler and hand sampler is expected than between hand samplers. However, this is accentuated by the design of the experiment which is a compromise between two truly independent hand-samplers and cost effectiveness. In order to maximize the number of samples collected for this study, the two hand samplers travelled together to reduce helicopter time. Although the samplers made efforts to act independently by the nature of their simultaneous exit from the aircraft, the spatial distribution of the two hand samples may be less than what it would have been if the hand-samples were truly independent.

SAMPLE VOLUME

A systematic difference between conventional and airborne sampling is the superior ability of the hand sampler to target fine material. This is mitigated to some degree by the increased volume of raw sample taken by the airborne system, but this larger volume of sample includes cobbles and boulders that are discarded in the preliminary processing.

The samples are sieved to -80 mesh at the sample prep lab followed by a 15 g split removed for analysis; the weight of the pulp that is returned therefore is a direct measurement of the amount of fines in the original sample. A larger sample is preferable, particularly for some elements (*e.g.*, Au) where a nugget effect is common.

Although the Aerochem sample was generally enough for an assay, there were four sites with insufficient material for a 15 g assay. In addition, as outlined in Figure 7 below, the remaining pulp from Aerochem, on average, is less than those of the hand samplers by approximately 15 g. A possible solution to the weight discrepancy between hand sampler and Aerochem could be addressed by a larger bucket.

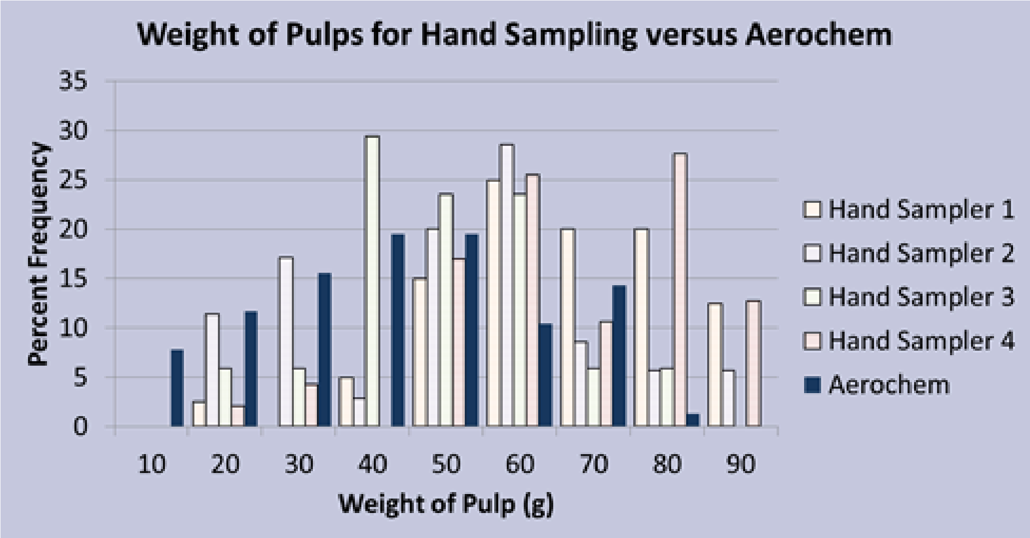

Figure 7. *Pulp **w**eight - **h**and **s**ampling vs **a**erochem**.***

CONCLUSIONS

Aerochem (patent pending) is a new airborne sediment sampling technique that offers safety and cost benefits over traditional hand sampling, particularly in difficult to reach areas such as rugged terrain or dense vegetation.

A comparative analysis between Aerochem and two hand samplers show significant variability between the three samples taken at the same sites with modestly higher variability (33%) between techniques than within a single technique. The difference is not such that the two cannot be used effectively together, as both techniques are effective at identifying anomalous stream sediment geochemistry.

In this test, the Aerochem system collected approximately 15 g less fine material than the hand samplers. As the mean mass of the fine fraction from the Aerochem technique is much greater than the 15 g required for assay, this is not considered to be a serious drawback of the system.

ACKNOWLEDGEMENTS

The authors would like to thank the following:
Yukon Geological Survey for supporting this research project;
Capital Helicopters (1995) Inc. for the joint venture in developing the Aerochem system;
Yukon Research Centre for their financial contributions in research and development; and
Wayne Jackaman with Noble Exploration Services for NGR RGS protocol and guidance.

Appendices are only available as digital files.

Appendix I

1:35 000 scale maps

Appendix I/Assay Comparison/Assay Comparison Ag.jpg
Appendix I/Assay Comparison/Assay Comparison Co.jpg
Appendix I/Assay Comparison/Assay Comparison Cu.jpg
Appendix I/Assay Comparison/Assay Comparison Ni.jpg
Appendix I/Results Comparison/PCA Comparison F1.jpg
Appendix I/Results Comparison/PCA Comparison F2.jpg
Appendix I/Results Comparison/PCA Comparison F3.jpg
Appendix I/Results Comparison/Normalized Mean Comparison.jpg

Appendix II

Principal Component Analysis

Appendix III

Stream Sediment Database Merged Assay Results

Appendix III/Stream Sediment Database Merged Assay Results.xls

Appendix IV

Certificate of Analysis

Appendix IV/Bureau Veritas Certificate of Analysis – 2015 Kluane Lake Aerochem Comparison.csv
Appendix IV/Bureau Veritas Certificate of Analysis – 2015 Kluane Lake Aerochem Comparison.pdf
Appendix IV/Bureau Veritas Certificate of Analysis – 2015 Kluane Lake Aerochem Comparison.xml

Appendix V

Project Log

Appendix VI

Aerochem Sample Silt Photos
Hand Sample Silt Photos