Peace Project Water Use Plan

GMSMON#18 WLL Dust Control Monitoring

Implementation Year 10

Reference: GMSMON#18

BC Hydro Williston Reservoir Air Monitoring 2016 Annual Report

Study Period: 2017/01/01 – 2017/12/31

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GMSMON#18 WLL Dust Control Monitoring

BC Hydro Williston Reservoir Air Monitoring 2017

Annual Report

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Prepared By: Chu Cho Environmental LLP

Study Period: 2018/01/01 – 2018/12/31

Tsay Keh Dene, BC, V0J 3N0

GMSMON#18 WLL DUST CONTROL MONITORING

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Executive Summary:

Chu Cho Environmental began operating and maintaining the GMSMON#18 Williston Reservoir regional air quality monitoring network in March of 2014 (year 7 of the project) and continued work through 2015, 2016 and 2017 (years 8, 9, and 10). GMSMON#18 is a 10-year air quality monitoring program that is designed to assess the impact of dust mitigation treatments on Aeolian dust emissions from the Finlay Reach of the Williston Reservoir. The program was expanded in year 4 to include the development of baseline ambient air quality data in the villages of Tsay Keh Dene and Kwadacha. Year-4 also included a significant change in instrumentation and the development of additional monitoring sites.

Following the rationale of the monitoring program Terms of Reference - Addendum 3, Chu Cho Environmental revised the network design in 2014 to increase the spatial and temporal resolution of the data. This allowed for a better evaluation of the impact of dust mitigation treatments on fugitive emissions from the reservoir beaches. The system design implemented in 2017 (Year 6) of the program was superior to those implemented in previous years, however 3 of the last 4 years of monitoring were not dusty leaving only 1 year with sufficient "dust" data.

Chu Cho Environmental views GMSMON#18 as having two distinct network components, each of which addresses a different question posed in the GMSMON#18 Addendum 3 document:

1. The **Regional Monitoring Network** comprises between 16 and 18 E-Samplers and 8 Meteorology Monitoring sites. This network is designed to assess the impact of dust mitigation treatments on Aeolian dust emissions from the Finlay Reach of the Williston Reservoir.
2. The **Reference Monitoring Network** comprises 2 TEOM Monitoring stations and 2 Meteorology Monitoring stations. This network is used to evaluate the regional ambient air quality within the context of the guidelines and standards developed by the BC MoE and the CCME.

The analysis for each of these network components has been separated into two sections for this report. The intended use and Data Quality Objectives (DQOs) for each network component are stated at the beginning of each section.

The GMSMON#18 air quality monitoring project exists as a response measure designed to analyze the fugitive dust emissions created by annual reservoir operations that results in the exposure of large expanses of loose sediment with little vegetative cover or other protection from wind erosion. These sediments are primarily a loosely packed glacial till consisting of gravel, sand, silt and clay with minimal organic content. At full-pool, or 672m above sea level (asl), these sediments are covered by 5 – 15 metres of water and are not exposed to wind erosion. In November each year, the reservoir freezes and the water inputs are less than the output at the dam, resulting in continued drawdown and lowering the water level of the reservoir. The minimum water level varies from year to year, depending on power demand and precipitation, but cannot currently be drawn-down below 654.41 m asl). Following spring thaw and melting of the ice, the expanses of sediment are exposed for several months before the reservoir is recharged. During these months the prevailing winds and seasonally changing weather patterns result in periods of wind erosion. The wind erosion results in dust storms that develop locally, and if winds are sustained, will migrate, eventually filling the valley with airborne sediment. It is during the erosive spring months that dust mitigation techniques are

applied to the reservoir sediment expanses in order to slow or stop the erosion. The mitigation program is called the Williston Dust Mitigation Program (WDMP) and is administered by Tsay Keh Dene Nation in collaboration with Chu Cho Industries LP. The primary goal of GMSMON#18 is to evaluate the impact of these mitigation techniques at both a local and regional scale through the monitoring of suspended sediment in the air.

Utilizing the Regional Monitoring Network, Chu Cho Environmental has developed and will continue to refine analysis techniques that provide new insight into the development, evolution and migration of dust storms in the Finlay Valley. We have incorporated spatial techniques such as heatmap analysis and linked this with time-lapse imagery and video editing software to create strong visual tools. This allowed us to observe dust storms and the associated particulate matter data values. This analysis has been completed but certain refinements for presentation in this document as well as an animation are time intensive and will be included in the 10-year synthesis report.

This report demonstrates the direction and approach that Chu Cho Environmental has implemented over the past four years for the investigation of the data captured by the monitoring equipment. For year-4 of Chu Cho Environmental operation, our project team focused streamlining the analysis techniques and building the required models to address the management question, while simultaneously increasing the security and reliability of the data sources. These advances will be detailed in this report.

More data collection is required before strong conclusions can be reached. Chu Cho Environmental is proposing that GMSMON#18 be continued for two more monitoring seasons in order to collect an adequate number of years of data in order to constrain the dataset across the full spectrum of dust and weather events. Although the GMSMON#18 program was a 10-year project, the data collected during the first 6 years did not sufficiently address the key management question. This could be due to the scale of the problem and a program designed with too few instruments, collecting data at too slow a time interval. Chu Cho Environmental remedied these issues in 2014 by deploying a dense monitoring network of 18 samplers collecting data a 5-minute interval. However, this means that there are only 4 years of data and of those 4 years only 1 year, 2015, was a typically "dusty" year. The other 3 years were not dusty due to high reservoir levels and high precipitation levels, so the dataset is not well constrained. Given the lack of good "dust" data Chu Cho Environmental suggests this program should continue for 2 more years. BC Hydro's current Williston Reservoir drawdown models are indicating that the reservoir will be approximately 3 metres lower in elevation than 2016 and 2017. The 2018 dust season has the potential to be a good year for data collection.

Data Summary:

In general, the spatial and temporal variability between sites is large. We have defined a dust event as exceeding the threshold of 0.1 mg/m^3 total suspended particulate (TSP) over a 5-minute period. The rationale behind this definition is expanded upon in Section 2. It should be noted that this is not a regulatory threshold this is merely an internally consistent threshold that is representative of significant airborne dust in the Finlay Valley. E-samplers are not a regulatory instrument and the data collected by the Regional Monitoring Network should not be interpreted as such. E-Samplers are intended for inter-comparison studies because they are internally consistent; these types of studies are often called "Fence Line Studies". One sampling station recorded 84 dust events over the 2017 dust season, whereas another site recorded only 1 event. The average was 25 dust events. Some events are short lived and highly localized to an individual beach or group of beaches, while others fill large sections the valley. Overall, 2017 was a low dust year as there were only 6 small scale, short-lived events lasting between 6 and 18 hours, and no moderate scale events lasting more than 18 hours.

The Regional Monitoring Network allows our team to observe dust events that begin in one location and then migrate in response to sustained wind events. The distributed network of sample stations has allowed our team to evaluate the relative contribution of local area sources to the overall quantity of airborne sediment in the valley.

In 2014 and 2015, our team attempted to evaluate the before and after effects of applying tillage to beaches on the reservoir as a mitigation technique. There are significant data limitations preventing conclusive analysis of this point, however, in general there was limited evidence to suggest that applying tillage to a given beach will result in a reduction in airborne dust over time. So far, the test cases have presented statistically significant but confounding results, in some cases tillage appears to reduce dust emissions after its application and in others it appears to significantly increase emissions after its application. **Many of these results are linked to multiple confounding variables such as precipitation and wind speed and it has been difficult to unpack and evaluate the results by controlling for these environmental variables.** These analyses direction have not been included in this report because the current analysis procedure is not satisfactorily rigorous enough to adequately deal with these variables, therefore Chu Cho Environmental does not feel comfortable discussing the results. Much work is required in this direction before conclusive results may be discussed. With two years of continued monitoring, Chu Cho Environmental is committed to expanding this analysis and driving towards useful results.

Chu Cho Environmental have attempted to manage the Reference Monitoring Network to the standards of the CCME and will provide a basic analysis of these data following the CCME guidelines. However it should be noted that the TEOMs in Tsay Keh Dene and Kwadacha were not designated as a US EPA Federal Equivalence Method (FEM) for $PM_{2.5}$ and PM_{10} monitoring, which are used for CCME and BC MoE guidelines for CAAQS and AQO, respectively[1]. It is not known if this issue was an oversight when the previous contractor acquired the equipment in 2011. Despite this fact we still operated the TEOM units under the same guidelines and strict standards of the CCME. The TEOM in Tsay Keh Dene recorded excellent data, though it should also be noted that repeated equipment issues with the TEOM in Kwadacha resulted in no useable data for 2017.

The 2017 dust season was lighter to what might be referred to as an average dust season in the Finlay Valley. There were a few short-lived but intense events along with two long duration large events. In Tsay Keh Dene, there was one 24-hour exceedance of the provincial PM_{10} AQO and one 24-hour exceedance of the

[1] Upon contacting the TEOM distributor for Canada, CD Nova, it was learned that Thermo Fisher, the manufacturer of the TEOM 1405-D, the models installed for the Reference Monitoring Network, likely did not have that specific model tested for FEM designation. Therefore we cannot definitively say that the $PM_{2.5}$ and PM_{10} data collected can be used for federal CAAQS ($PM_{2.5}$) or provincial AQO (PM_{10}) determination calculations.

federal $PM_{2.5}$ CAAQS between April and June. It should be noted that the data collected by the Reference Monitoring Network are not used to directly address the key management question posed in the Terms of Reference for GMSMON#18, but are used to characterize the long term regional ambient air quality in Tsay Keh Dene. These data are also not meant to be input into the Canadian Ambient Air Quality Standards (CAAQS) objective determination calculation. The data from this network have provided provide valuable insight into the long-term air quality trends within the region.

In addition to managing the air quality monitoring networks there were two other additional program components identified in the Addendum 3 document, these include:

1. Mentorship and Capacity Building Objectives, and
2. Community Engagement.

2014 was "Year-1" of Chu Cho Environmental's control over GMSMON#18 included many successes and learning opportunities. Year-2 included early deployment (April 7th, 2015), procedural refinement and the development of numerous processing algorithms to help improve the project. Our project team found many efficiencies and opportunities to improve the program. 2016 (Year-3) was successfully implemented by avoiding all of the shortcomings of the previous two years. And 2017 (Year-4) began with a successful deployment of the regional network but saw an increased level of equipment fatigue, particularly from some of the deep-cycle batteries that needed to be swapped out of some sites early in the season. Careful review of the raw data indicates that very good data was collected during the 2017 season.

Chu Cho Environmental has been honoured to work on the GMSMON#18 program over the previous four years to document the fugitive dust within the Williston Reservoir airshed through improved data collection procedures, analysis techniques and the application of advanced statistical analysis techniques.

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1.0 Project Proponents and Partnerships

1.1 Finlay Valley Airshed

The Finlay Valley extends from the Peace Arm of the Williston Reservoir north towards Tsay Keh Dene and Kwadacha villages.

The Finlay Valley is part of the northern Rocky Mountain Trench, residing between the Rocky Mountains to the east and the Omineca Mountains to the west. The Rocky Mountain Trench formed shortly after the end of the Laramide Orogeny and the formation of the Rocky Mountains when the land was rebounding after the tectonic pressure was relieved and before the development of the Omineca Mountains (Canning et al., 1999).

The region has experienced many glaciations over the previous 200 million years, the last of which ended approximately 9000 years ago. Successive glaciations deposited large volumes of sediment through various lacustrine and fluvial processes leaving the Finlay Valley and Rocky Mountain Trench with an extensive layer of glacial overburden that comprises massive sand and gravel benches interlaced by fine lacustrine unconformities (Rutter, 1977). The Williston Reservoir now sits in the northern Rocky Mountain Trench having flooded over 1,775 km^2 of valley bottom. Annual operation of the W.A.C. Bennett dam can change the reservoir surface elevation from 655m to 672m above sea level, leaving beaches, cutbanks and gravel outcrops exposed for several months during the spring freshet period.

Successive glaciations and river incision have created a valley that is broad and U-shaped, but is also deeply incised by the Finlay and Parsnip rivers. Given the shape of the valley, the annual fluctuation in reservoir level has the potential to expose large expanses (~20,000 Ha) of loose erodible sediment during the spring months before the reservoir is recharged following spring freshet. While the water is low, the exposed beaches, which are composed of mixed sand, silt, clay, and gravel beds tend to erode during spring wind events resulting in the emission of large amounts of fugitive dust.

Winds in the northern Rocky Mountain trench tend to follow the orientation of the valley, flowing either Northwest or Southeast. There are many arms along the reservoir which generate valley cross winds at different times of the year. Generally, the ground level winds in this area are steered by the orientation of the valley. This means that southerly winds drive the airborne fugitive dust from the reservoir beaches directly along the Rocky Mountain Trench northward where they pass through Tsay Keh Dene and Kwadacha.

The airborne dust arriving in Tsay Keh Dene and Kwadacha is a nuisance and poses a potential health issue when concentrations exceed Canadian Ambient Air Quality Standards (CAAQS).

1.2 Management Summary: GMSMON#18 Management Questions and Program Components

The dust control management plan (DCMP) under Section 5.1 of the Peace River Water Use Plan (WUP) was implemented with the expressed goal of reducing the duration and magnitude of the dust storms that affect the quality of life for people living adjacent to the reservoir (BC Hydro, 2007). The DCMP consists of three major components: dust source surveys, erosion control trials and Air Quality (AQ) monitoring.

The AQ monitoring component of the DCMP is the result of a 10-year commitment (2008 to 2018) by BC Hydro to measure fugitive dust emissions that result from the annual operations of Gordon M. Schrum Hydro Power Facility and the Williston Reservoir. The purpose of the AQ monitoring program is to quantify the levels of Particulate Matter (PM) in the air shed surrounding the reservoir. The results of the AQ monitoring program are integral in formalized dust control audit procedures for testing the overall effectiveness of the erosion control methods employed by the WDMP. Theoretically, a successful erosion control program will result in diminished PM emissions observed by the AQ monitoring network. The key management question for this program as defined in the GMSMON#18 ToR document is:

What is the impact of dust mitigation treatments on Aeolian dust emissions from the Finlay Reach of the Williston Reservoir?

The results of this AQ monitoring program will provide input into adaptive management of dust mitigation plans for the Williston Reservoir. Ultimately, some of the analysis avenues investigated in this annual report may be changed as required in favour of more concise analyses that become available once we have amassed sufficient data. Other avenues included in this analysis may be foundational and will be the building blocks of what is to come in future iterations of this report. Note that throughout this report we will refer to the scale of the dust events, in some cases events are small and localized and in other cases they are broad and widespread. We apply technical definition to these terms in Section 2.

The following table provides a summary of the various program components that pertain to year-10 of GMSMON#18 and the status of those components:

Table 1: Management Summary - Status of GMSMON#18 Program Components

Program Component	Management Question	Management Hypothesis (Null)	Status
Regional Monitoring Network	Do the dust mitigation activities result in decreased regional or local dust emissions?	Dust mitigation activities do not result in a reduction of dust emissions when evaluated at either a regional or local scale.	17 E-Samplers and 8 Meteorology sites were deployed in 2017 to address this question. The samplers collected data at 5-minute intervals from April to October. Statistical analysis of data indicated that mitigation activities have minimal effect on reducing local/regional fugitive emissions. Currently it is not possible to delineate mitigation treatment effects from the numerous confounding variables such as rainfall, relatively humidity and reservoir rise.
Reference Monitoring Network	Are the long-term ambient air quality values for PM_{10} and $PM_{2.5}$ in Tsay Keh Dene and Kwadacha within the provincial Air Quality Objectives (AQOs) and Federal Standards (CAAQS)?	The ambient air quality values for PM_{10} and $PM_{2.5}$ in Tsay Keh Dene and Kwadacha do not meet the provincial AQOs or the CAAQS.	During the 2017 dust season, there was 1 exceedance of the provincial AQO for PM_{10} and 2 exceedances of the federal CAAQS for $PM_{2.5}$. The weather in 2017 followed typical patterns giving rise to a few large wind events. In this report we have also provided additional analysis of the TEOM data by examining the 10-minute average maximum daily values. Please note that we are not comparing these data to a 24 hour standard. This is in no way meant as a surrogate to the Federal or Provincial standards but speaks to the highly variable event driven nature of the dust events in Tsay Keh Dene.

Program Component	Management Question	Management Hypothesis (Null)	Status
Mentorship and Community Engagement	n/a	n/a	Chu Cho Environmental employees who reside in Tsay Keh Dene are steadily taking on more responsibilities across the company, which required the hiring of an additional crewmember for AQ monitoring. Our Tsay Keh Dene crewmembers were responsible for weekly monthly instrument maintenance and data management for the regional monitoring network. These employees were also trained on management of the TEOM Reference Monitoring System.
Enhanced Data Security, Transparency and Access	n/a	n/a	Chu Cho Environmental enlisted third party applications for hosting data online. A remote log in system that allowed remote access to the instrumentation. An email list serve from the Tsay Keh Dene Reference station was available to anyone who wanted to receive a .csv file summarizing the previous 12 hours of data. Regional data were synced after field downloads via Dropbox and reviewed shortly after for completeness.

1.2.1 Updates to Monitoring Network

Chu Cho Environmental did not implement any major changes to either of the monitoring networks for the 2017 dust season. Efforts to continue operating the monitoring networks into 2018 and beyond are currently being discussed.

Only 2 minor changes were made to the Regional Monitoring Network in order to deal with loss of site access and wildlife interactions, these include:

1. 25Km (aka Chunamon) was replaced by Bob Fry South:
    a. Forestry operations over the winter of 2016 decommissioned the bridge that was required to access 25Km (aka Chunamon). As a result a new site was chosen on a beach south of the Bob Fry River.
2. E-Sampler at Shovel was removed due to ongoing wildlife (bear) incidents.
    a. Based on instances of interference with the equipment at Shovel in 2016 and two consecutive instances of interference and damage in May 2017, the E-Sampler was removed from the site and not relocated.

1.3 Data Summary

The following tables provide a detailed summary of all of the components involved in this program and the rate at which each component is collecting data:

Table 2: Summary of Air Quality Response Measures Monitored

	Response Measures		
	Total Suspended Particle Concentration	Particulate Matter Concentration	
	TSP	$PM_{2.5}$	PM_{10}
Variable ID	001 - 030	pm25	pm10
Sampling Year(s)	2014-2017	2011-2017	2011-2017
Sampling Frequency	5 min (April-Jun)	10 min (January to December)	10 min (January to December)
Measurement Units	mg/m^3	$\mu g/m^3$	$\mu g/m^3$
N	(17)	2	2
Data type	measured	measured	measured
Equipment	E-sampler	TEOM 1405-D	TEOM 1405-D

Table 3: Summary of Meteorological Equipment Used in GMSMON#18

	Meteorology Monitoring										
	Wind Speed		Wind Direction		Relative Humidity		Rainfall		Air Temperature		Air Pressure
Variable ID	ws	ws	wd	wd	rh	rh	prcp	prcp	temp	temp	press
Sampling Year(s)	2014 - 2017	2011 - 2017	2014 - 2017	2011 - 2017	2014 - 2017	2011 - 2017	2014 - 2017	2011 - 2017	2014 - 2017	2011 - 2017	2011 - 2017
Sampling Frequency	5 min (Apr-Sept)	10 min (Jan-Dec)	5 min (Apr-Sept)	10 min (Jan-Dec)	5 min (Apr-Sept)	10 min (Jan-Dec)	5 min (Apr-Sept)	10 min (Jan-Dec)	5 min (Apr-Sept)	10 min (Jan-Dec)	10 min (Jan-Dec)
Measure ment Units	m/s	m/s	degrees	degrees	%	%	mm	mm	degrees Celcius	degrees Celcius	kPa
N	8	2	8	2	8	2	8	2	8	2	2
Data type	measured	measured	measured	measured	measured	measured	measured	measured	measured	measured	measured
Equip.	Met Station	TEOM 1405-D	Met Station	TEOM 1405-D	Met Station	TEOM 1405-D	Met Station	TEOM 1405-D	Met Station	TEOM 1405-D	TEOM 1405-D

NETWORK COMPONENT I: REGIONAL MONITORING NETWORK

2.0 Regional Monitoring Network

2.1 Network Characterization

The Regional Monitoring Network was designed to assess the impact of dust mitigation treatments on Aeolian emissions from the Finlay Reach of the Williston Reservoir. This network was not altered significantly for 2017; minor changes were identified above in Section 1.2.1. The Regional Monitoring Network initially consisted of 17 Met One E-Samplers (reduced to 16 on May 16th) and 8 meteorology monitoring stations. The 17 E-Samplers were dispersed across the many cutbanks, points, beaches and gravel bars in the reservoir's Finlay Arm.

Some locations such as Bob Fry South, Chowika, Ingenika, and Rat Lake are situated on large gravel bars or rock out crops that do not produce dust. The dust recorded at these locations came from elsewhere further upwind within the reservoir basin. Other sites such as Middle Creek North and Shovel are situated directly on or very near to beaches that are known high dust emitters. Samplers located on or near beaches are generally good indicators of the local dust conditions. The number of samplers deployed was limited to site accessibility and the number of available instruments.

E-Samplers are designed to measure continuous air quality data at 1 Hz and can record that data at various averaging intervals. Since 2014, we have been using the 5-minute averaged data option, which allows the units to function autonomously for up to 15 days before the on-board memory is full and requires downloading. E-Samplers are designed to measure either Total Suspended Particulate (TSP), PM_{10}, or $PM_{2.5}$ but they cannot measure all three simultaneously. Through joint planning and consultation, it was determined that measuring TSP was the priority for the Regional Monitoring Network. TSP includes all size fractions of fugitive particulate that may be ejected into the air from reservoir beaches by wind erosion.

Alongside the 17 E-Sampler sites there were 8 meteorological monitoring stations. These stations were placed in the same locations as 2016. Each meteorology station was outfitted with a rain gauge, temperature probe, relative humidity sensor, wind vane, and anemometer. The data were logged using a CR1000 datalogger.

Ultimately, the location of the 17 sample sites was determined by accessibility and the characteristics of the site that adequately represent the airshed in that local zone. The Regional Monitoring Network is designed so that when examined as a group of E-Samplers working together, each site provides an important component for understanding the regional air quality and the overall effect of the WDMP activities. By developing a monitoring network with increased spatial distribution and sampling frequency Chu Cho Environmental has created more opportunities to probe and use the data to address the key management question and to provide insight into the effectiveness of WDMP operations.

Figure 1 shows the location of the 17 dust monitoring and 8 meteorology monitoring stations within the Finlay Arm of the Williston Reservoir.

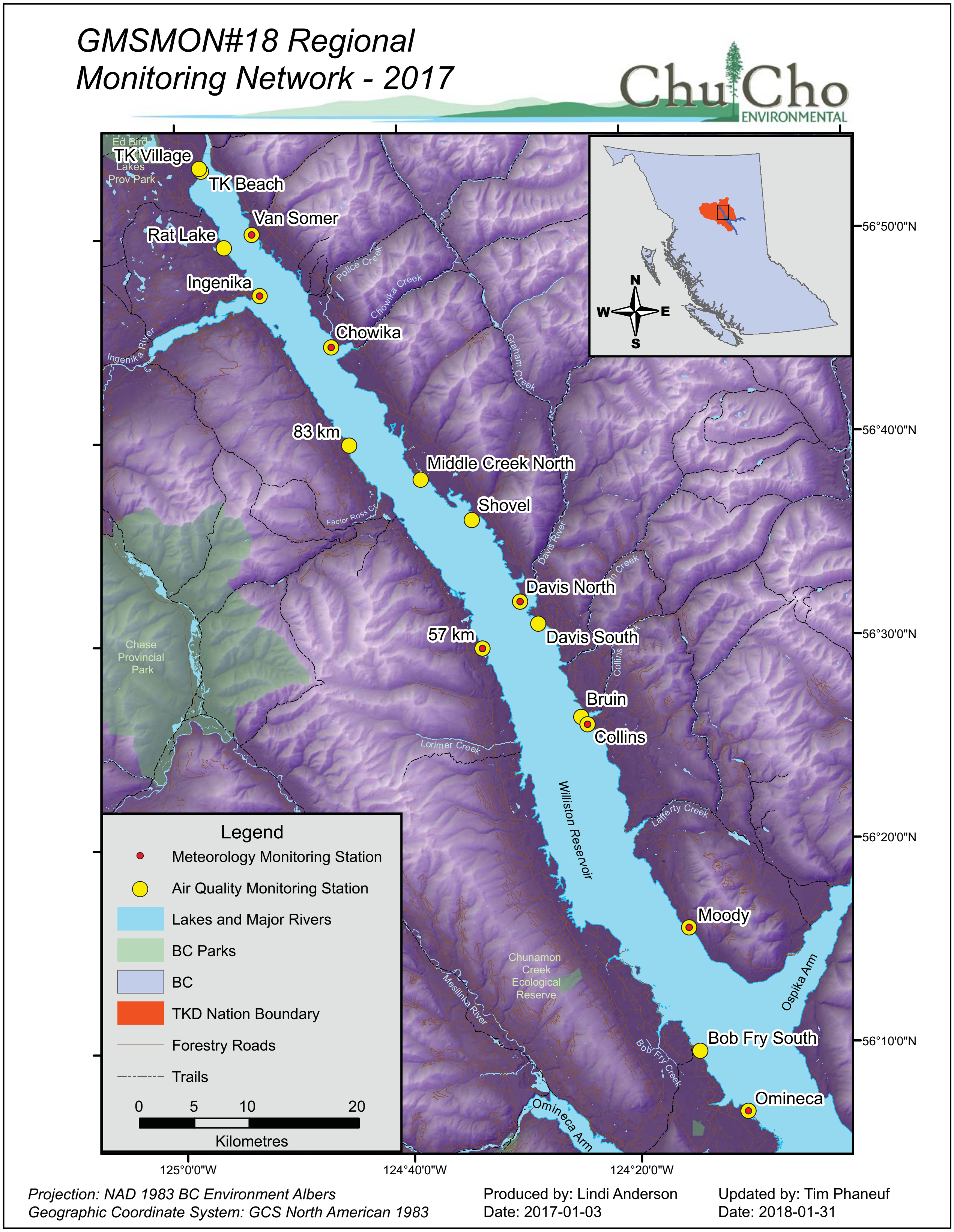

Figure 1: Map of Regional Monitoring Network Sampling Locations

2.1.1 Detailed Site Descriptions

Table 4 provides a detailed overview of the monitoring station site locations, the instrumentation included and the type of airshed representation that the site provides:

Table 4: Regional Monitoring Network Site Descriptions and Locations

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instrumentation
Tsay Keh Village	56.892	-124.964	Tsay Keh Village	The E-Sampler in Tsay Keh Dene is located on top of the TEOM Monitoring Station and is meant to collect data that is to be compared to the TEOM 1405-D. In 2015, we added an additional E-Sampler in TKD that is located adjacent to Tsay Keh Beach, which is a known high emitter.	Regional	E-Sampler
Van Somer	56.837	-124.886	Van Somer	Van Somer point is primarily comprised of Sandy Loam type sediment and is a known high emitter beach. This beach holds tillage quite well because the increased clay content tends to hold moisture. The sample site is located on a gravel bar above the beach that is well exposed to southerly and northwesterly winds. The sampling equipment is well positioned to capture some local dust but also much of the regional dust passing through the area.	Regional & Local Dust	E-Sampler, Met Station

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instru-menta-tion
Tsay Keh Beach	56.888	-124.96	Tsay Keh Village	Tsay Keh Beach is located at the northern tip of the Finlay Arm where the Finlay River meets the Williston Reservoir and has excellent exposure to southeasterly winds. The beach is composed of highly mobile sediments and is considered a beach with high emission potential (Nickling et al. 2013). An E-Sampler has been placed in the foreshore zone of this beach since 2015 in order to capture the emissions from Tsay Keh Beach prior to entering the village.	Local Dust	E-Sampler
Chowika	56.743	-124.769	Chowika	The Chowika monitoring station rests on a large gravel bar that extends far into the reservoir. This site is very well exposed to northwest-erly and southerly winds and captures much of the fugitive dust from southern beaches that migrates towards TK village. This site produces no local dust emissions.	Regional Dust	E-Sampler, Met Station

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instrumentation
Middle Creek North (MCN)	56.634	-124.640	Chowika	MCN Beach is an exposed sand sheet and a high elevation beach with excellent wind exposure from the southeast and northwest. This beach is usually the first to be exposed in the spring and the last one to be covered up by the reservoir. Large depositional and erosional sand features form on this highly mobile beach. This beach is considered a high emissions beach. This site has excellent exposure to southeasterly winds and moderate exposure to northwesterly winds. In 2017, this beach was not tilled but was irrigated. Access to the beach is limited by a temporary bridge, which in 2017, became overtopped with a reservoir elevation of 667.75 m (± 0.2 m).	Local Dust	E-Sampler
Shovel (Discontinued May 16, 2017)	56.599	-124.563	Davis	Shovel beach is a mixed sand/silt/clay type beach that is regarded as a high emitter with many local hot spots. The mixed sediments on this beach tend to create clusters of sparse vegetation. There are numerous anecdotal accounts indicating that this beach regularly emits high amounts of fugitive dust. This site has excellent exposure to southeasterly winds and moderate exposure to northwesterly winds.	Local Dust	E-Sampler

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instru-mentation
Davis North	56.535	-124.497	Davis North	Davis North Beach is a massive mixed sediment type beach that is considered a high fugitive dust emitter. The sampling equipment is well exposed to both northwesterly and southerly winds.	Local Dust	E-Sampler, Met Station
Davis South	56.514	-124.469	Davis	Davis South Beach is a mixed sediment type beach that is known to emit large volumes of fugitive dust. Very large wet areas make fording and tilling the beach difficult. The sampling equipment is located in a clearing above a gravel bar that is above the reservoir full-pool level. This site is well exposed to southerly winds and is not exposed to northerly winds.	Regional & Local Dust	E-Sampler
Bruin Beach	56.437	-124.411	Collins	Bruin beach is primarily composed of mixed sand and gravel and is considered a moderate emitter. The E-Sampler is located on a gravel point that is exceptionally well exposed to southerly, southeasterly and northwesterly winds. This site is well positioned to provide a regional representation of this area. Evidence of tillage from 2017 was present on the beach southwest of the E-Sampler.	Regional Dust	E-Sampler

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instru-menta-tion
Collins Beach	56.427	-124.393	Collins	Collins beach is a mixed gravel/sand/silt beach that extends from Collins Bay to Lafferty. This beach has limited vegetation at higher elevations and is a known high emitter. The sampling equipment is located on a gravel bar approximately 500 m south of the beach access point from Camp Collins. The equipment is well exposed to southeasterly winds and is moderately exposed to northerly winds.	Local Dust	E-Sampler, Met Station
Moody	56.263	-124.255	Moody	The E-Sampler at Moody sits on a high gravel bar above the beach. The beach itself is comprised of mixed sands and silt. This site is exceptionally well exposed to southerly winds and captures early season dust storms from the low elevation Ospika Island Beach that is covered by the reservoir early in the season.	Regional Dust	E-Sampler, Met Station
Rat Lake	56.827	-124.928	Ingenika Point	The E-Sampler is located on a high reservoir cutbank approximately 20 metres above reservoir full-pool level. This site is exceptionally well exposed to southeasterly winds and moderately exposed to northerly winds. No dust is generated locally and this site provides adequate regional representation.	Regional Dust	E-Sampler

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instru-menta-tion
Ingenika Point	56.700	-124.800	Ingenika Point	The sampling equipment is located on a rock outcrop on the northwestern corner where the Ingenika Arm and Finlay Arms intersect. This site is exceptionally well exposed to southeasterly, northwesterly and westerly winds and provides a regional representation of dust events that arrive at the old village location. No dust is produced locally here.	Regional Dust	E-Sampler, Met Station
83km	56.662	-124.746	Ingenika Point	The E-Sampler is located on a high reservoir cut bank approximately 20 metres above the reservoir full-pool level. The equipment is located on an old road adjacent to the reservoir. In 2009, the road was relocated to the west away from the reservoir and this site is located on what remains of the old road. This site is well exposed to Southeasterly winds and provides adequate regional representation. No dust is generated locally at this site.	Regional Dust	E-Sampler

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instru-menta-tion
57km	56.494	-124.552	57km	This site is named after the road kilometer where the access point is located. This site is located approximately 3 km north of the Ole Creek beach and is not included as part of the mitigation program due to its small size. The beach is comprised of highly mobile sand/silt sediments and is a moderate emitter of fugitive dust. The site is well exposed to northerly and southeasterly winds and captures much of the sediment laden air plumes that drift north from the coreless Coreless complex.	Regional & Local Dust	E-Sampler, Met Station
Bob Fry South	56.162	-124.243	Omineca	This site replaced the site further north at 25 km (Chunamon) and is located about 4.5 km southeast of Bob Fry River. The site consists of mainly gravel to very small pebbles. The site has moderate exposure to northerly winds and excellent exposure to southeasterly winds. Much of the fugitive dust emitted from Omineca Beach would pass by this site and therefore an excellent representative of regional dust. Due to the coarse beach sediment, this site produces no local dust emissions.	Regional Dust	E-Sampler

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instru-menta-tion
Omineca	56.105	-124.160	Omineca	This sample site is located near the center of Omineca Beach and is exceptionally well exposed to both northerly and southeasterly winds. Omineca beach is a mixed sand/silt/clay beach and is known a high emitter of fugitive dust. Mixed sparse vegetation tends to grow in the vicinity of the sampling equipment.	Local Dust	E-Sampler, Met Station

The following group of images shows each sample location from two perspectives:

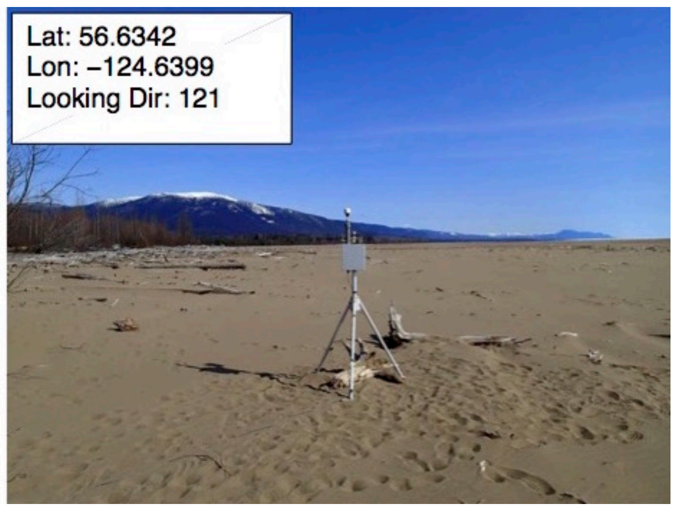

Figure 2: Middle Creek North Regional Monitoring Network.

Figure 3: Chowika Regional Monitoring Network.

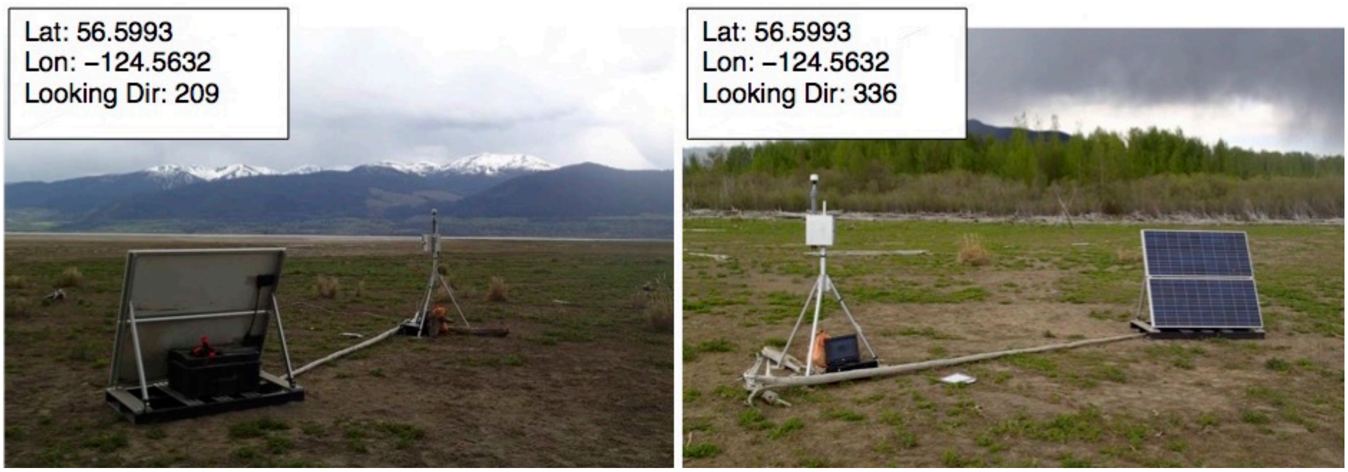

Figure 4: Shovel Regional Monitoring Network (Discontinued May 16, 2017).

Figure 5: Bruin Regional Monitoring Network.

Figure 6: Moody Regional Monitoring Network.

Figure 7: 83Km Regional Monitoring Network.

Figure 8: Davis North Regional Monitoring Network. Looking south in left image, roughly north in right image.

Figure 9: Rat Lake Regional Monitoring Network. Looking west in left image, south in right image.

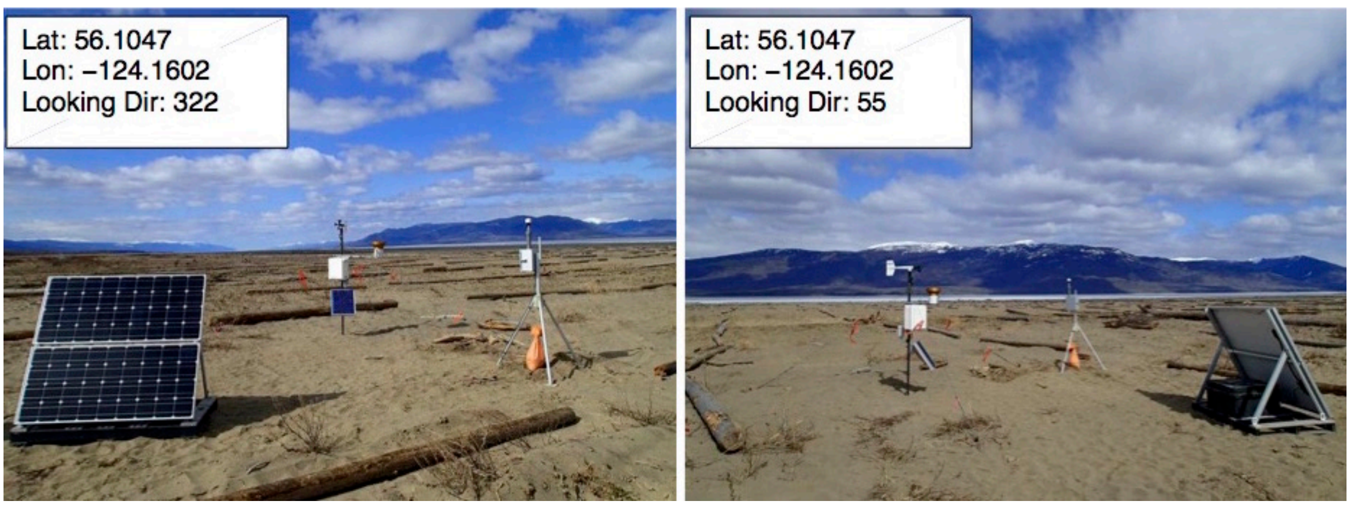

Figure 10: Omineca Regional Monitoring Network.

Figure 11: Davis South Regional Monitoring Network. Looking south in left image, roughly northwest in right image.

Figure 12: Tsay Keh Dene Regional Monitoring Network and Reference Station – E-Sampler is on top of enclosure.

Figure 13: 57Km Regional Monitoring Network.

Figure 14: Collins Beach Regional Monitoring Network. Looking southeast in left image, north in right image.

Figure 15: Ingenika Point Regional Monitoring Network.

Figure 16: Bob Fry South Regional Monitoring Network. Looking southeast in left image, northeast in right image.

The remainder of Section 2.0 provides detailed information on the instrumentation, the analyses and the results obtained from the regional monitoring network.

2.1.2 INSTRUMENTATION

The Met One E-Sampler is a nephelometer that functions according to a unique operating principle that employs forward laser light scattering to estimate the concentration of airborne particulate. Air is drawn into the unit at a constant flow rate of 2.0 L/min. The air enters a chamber, or laser optical module, where a laser diode emits a visible light (670 nm) laser beam directed through the sample air stream. The particulates in the air stream scatter the laser light, via reflection and refraction, in proportion to the amount of particulate in the air. The laser light not scattered continues forward into a laser trap and the scattered light is collected and focused by lenses onto a special light sensor. This sensor measures the intensity of the focused laser light which results in a proportioned particulate matter count within the air. No laser light detected by the sensor indicates that there is no light scatter and therefore no detectable particulates in the air.

The laser scatter method does not hold a Federal Reference Method (FRM) or Federal Equivalent Method (FEM) designation but has been approved for fence-line type inter-comparison studies by the U.S. forest service. This means that E-Sampler data are not directly comparable to that collected by an FRM or FEM machine and cannot be used to evaluate CAAQS exceedances or non-compliance. However, they are very useful for dispersion modeling and for observing source/sink locations around the reservoir.

There is no standard protocol or US National Institute of Standards and Technology (NIST) traceable method for calibrating and maintaining the E-Sampler since it does not carry FRM nor FEM designation. However, Chu Cho Environmental does employ a U.S. EPA quality program for monitoring and maintaining the function of the E-Sampler. This includes monthly flow calibration, leak check, filter cleaning and data validation.

2.2 Regional Monitoring Network Data Overview

E-Sampler light detecting sensor operates at 40 Hz; these measurements are internally averaged and temperature compensated into 1-second samples and are then recorded at 5-minute average intervals. Data are collected from 17 instruments for the entire snow-free period (approximately May to October) in the Finlay Valley. During the 2017 sampling season the reservoir reached it's maximum elevation for the year on July 30th at approximately 671 m. Prior to this many E-Samplers were removed from mid-June to mid-July due to site access issues (Middle Creek North) or reservoir inundation. The E-Sampler at Shovel was removed May 16, 2017, due to ongoing wildlife interactions that knocked the unit offline and eventually damaged the equipment. There were also multiple accounts of wildlife activity near the site. Remaining E-Samplers were retrieved at the end of September/beginning of October. There were 8 complete meteorology stations located at a subset of the 17 E-Sampler sites (Refer to Table 1 for the E-Sampler/Meteorology Combination list). These stations read the instrumentation at 1 Hz and recorded 5-minute averaged data for relative humidity, rainfall rate, air temperature, wind speed and wind direction. The regional monitoring network amassed an enormous volume of data very quickly and required an aggregation of complex computer programming to handle and process. Data were managed primarily through Dropbox syncing and Matlab scripting.

This distributed network of continuously monitoring E-Samplers and weather stations has allowed us to probe dust events (some through avenues which have not been investigated) and also allowed our team to create visuals that provide un-paralleled insight into the development, evolution and termination of dust events.

The analyses discussed in this report represent Chu Cho Environmental's perspective and current understanding of the air quality issues within the Finlay Valley. Following the presentation of our results, a preliminary data review will be performed to uncover potential limitations of using the data, to reveal outliers and explore the basic structure of the data. This review will begin with an exploration of the quality of the data through a basic statistical examination followed by an advanced statistical assessment using analysis of variance and regression.

2.2.1 Data Quality Objectives

For air monitoring networks, Data Quality Objectives (DQOs) are statements that document and specify the data quality criteria that must be satisfied in order to have adequate confidence in the conclusions of studies (CCME, 2011). Ultimately the DQOs are a series of statements that relate the quality of the measurements to the level of uncertainty that we were willing to accept for results derived from this data.

DQOs must have attributes that are both qualitative and quantitative and are generally defined as those measureable attributes of the monitoring data that allow program objectives and measurement objectives to be met.

As is typical for most air quality monitoring networks, even those of a non-regulatory nature, we will adopt the following DQO attributes:

- Accuracy:
  - E-Samplers must be calibrated and maintained to sustain an accuracy of greater than +/- 20%. The project samplers were sent to Met One Instruments for calibration every 18 months.
- Precision:
  - E-Samplers must be calibrated and maintained to sustain a precision that deviates less than 10% from a zero standard. This was done through an internal automated process within the E-Sampler and any errors detected were recorded and delivered to the user. This calibration process was completed with every field visit (minimum twice per month).
- Completeness:
  - In order to be considered a valid data reading the E-Sampler must record data for greater than 75% of the available minutes within an hour. This means that in order to be considered a valid hour of data there must be at least 45 minutes of data recorded.
- Averaging Period:
  - E-Sampler data are collected at 1 Hz and are recorded as 5-minute averages to the on-board memory. These data are downloaded and verified once or twice per month.
- Measurement Cycle:

  - E-Sampler data was collected from the end of April until the beginning of October. Data analysis focused on the period from April to June or what is typically called the dust season.

- Spatial Representativeness:

  - The samplers were located in areas where they would not be influenced by external factors that may have caused sample bias. This included the following specifications:

    - Sampler intake height is more than 2 metres above the earth's surface.

    - Sampler is located a sufficient distance away from roadways and other sources of external contamination such as incinerators or factories.

    - Sampler intake is located a sufficient distance away from airflow restrictions through 360 degrees of rotation and must be located at a distance away from an object that is at least 3 times the height of that object.

    - Sampler intake is located greater than 20 metres away from trees.

Chu Cho Environmental ensured that suitable technical procedures were in place to record and catalogue the processes that lead to successful achievement of the DQOs.

As E-Samplers do not carry a Federal Reference Method designation, we did not adhere to a national or international traceable standard (e.g. NIST) for auditing procedures. However, we utilized a TSI flow meter and record keeping standards that are of NIST quality to ensure that our network data was internally comparable.

2.2.2 Time Series Analysis

Data collected by the Regional Monitoring Network may show a variety of dust event types throughout the typical April – June dust season ranging in magnitude from small scale isolated occurrences that last less than 30 minutes to extreme valley wide events that may last more than 36 hours. The technical definition for each dust event scale is provided in Table 5 below. In 2017, the Regional Monitoring Network recorded numerous short lived but intense events and a couple of widespread events. The following sections will probe the data captured by the regional monitoring network in order to evaluate and quantify the frequency and magnitude of each dust event. Table 5 provides a description for the internally developed dust event scale classification level. These event scale classifications are used to describe dust events throughout the following sections.

Table 5: Dust Event Definitions

Dust Event Scale	Technical Definition
Small	Less than 6 hours in duration with a TSP concentration above 0.1 mg/m^3
Moderate	Between 6 and 18 hours with a TSP concentration above 0.1 mg/m^3
Large	Longer than 18 hours with a TSP concentration above 0.1 mg/m^3
Extreme	Longer than 36 hours with a TSP concentration above 0.1 mg/m^3

Figure 17 contains a time series depiction of the E-Sampler data collected at four locations in the Regional Monitoring Network. The remaining 13 E-Sampler time series graphs are located in Appendix A. Each of the plots in Figure 17 features the time series TSP data measured by each instrument. ***The data shown on these charts are unprocessed raw data that represent the 5-minute average TSP concentrations recorded by the instrument***. Viewing the raw data through this lens is highly useful as it demonstrates the variability in the data and the frequency of events both large and small.

Figure 17 demonstrates that there were several relatively high (>0.1 mg/m^3) magnitude but short duration TSP peaks throughout the dust season. It is interesting to note that Moody (non-beach site), at the southeastern portion of the Finley Reach experienced considerably fewer dust events with very little background ambient particulate matter than other sites (beach and non-beach).

A large amount of processing is performed on the raw data presented in Figure 17; anomalous values were removed and the data subjected to intensive statistical analysis probing for maximums, averages, variances and other relationships between samplers and locations.

2.2.2.1 Threshold and Event Scale

Over the years much of the discussion surrounding dust events in the Finlay Valley has focused on threshold wind speeds for initiating sediment movement. The high temporal resolution of the E-Samplers means that we were able to capture more events of varying magnitude at relatively high frequency, however not all the activity recorded by an E-Sampler should be considered a dust event

Since E-Samplers are not FRM/FEM certified instruments there is no numerical standard by which to define a dust event. Previously for this project, we developed a subjective means for defining a dust event using images captured by a network of time-lapse cameras. The threshold value was determined by comparing images captured during dust-free periods to those captured during periods of increasing dust where the relative ocular obscurity was proportional to the volume of dust in the air. By repeating this exercise for numerous dust events across numerous sites we were able to arrive at a value that our project team felt was a reasonable approximation for a threshold dust value. We used a number of replicate sites for the exercise (Middle Creek North, Shovel Creek, Van Somer, 35km, Ingenika and Davis North) and arrived at a value of 0.1 mg/m^3 TSP (per average 5-minute period) as the E-Sampler threshold for dust events. Obviously there is a great deal of subjectivity in this reading but our project team felt that it was important that very small non-representative readings were not included in the analysis. Dust events are categorized by the number of instances where one or more consecutive 5-minute records are >0.1 mg/m^3.

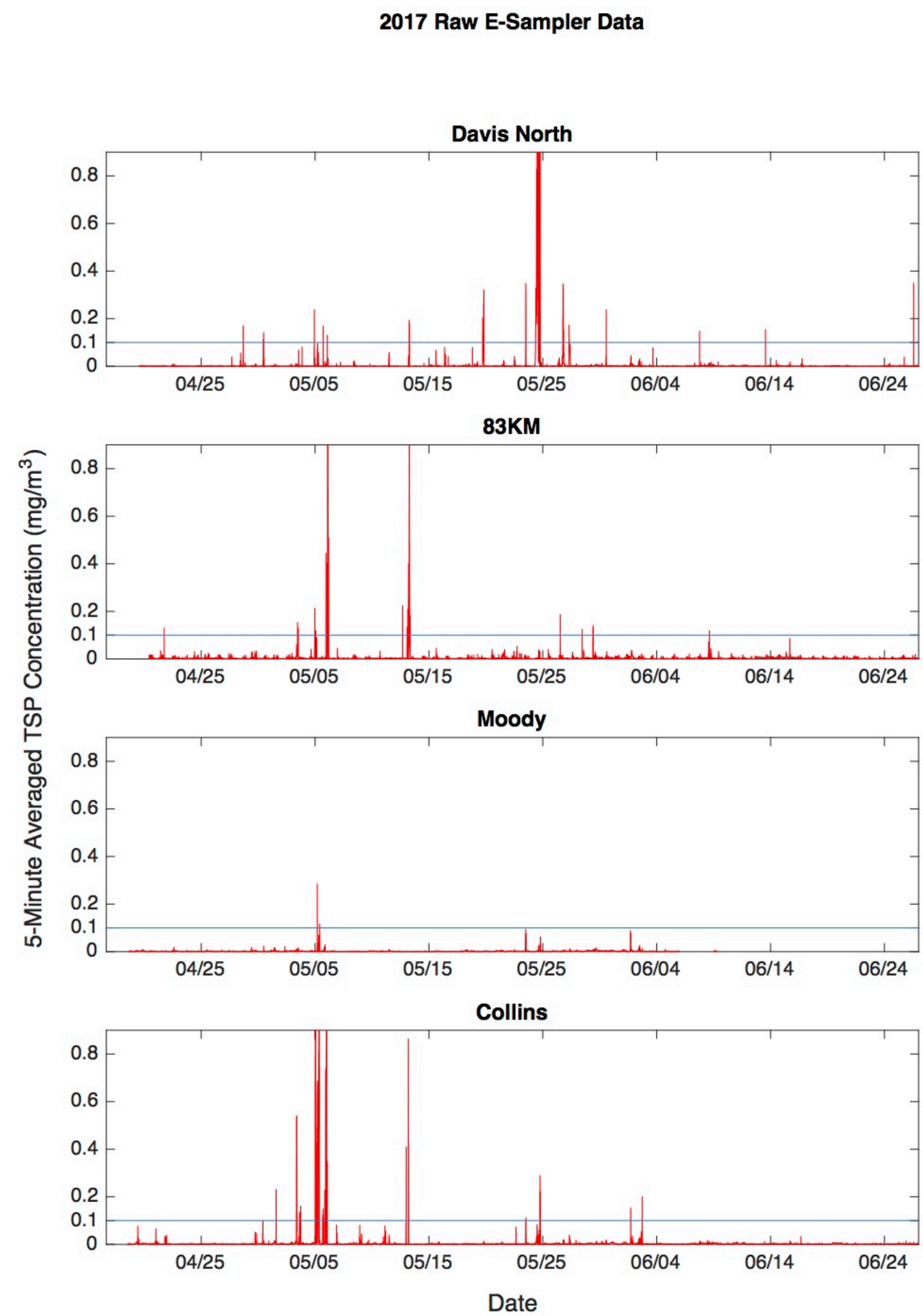

Figure 17: Sample of Regional E-Sampler Data from 4 Locations – Showing 5-minute average TSP concentration data. The horizontal blue line represents the 0.1 mg/m^3 TSP concentration across the chart.

2.2.3 Statistical Analysis

Basic descriptive parameters were extracted from the time series data collected at each location over the duration of the dust season. These data are described in the next three sections and summarized in Table 6 on the following page. The 2017 dust season was 72 days long from April 16th until June 27th, 2017.

2.2.3.1 Dust Events and Total Suspended Particulate

There were an average of 25 dust events recorded across all samplers during the 2017 dust season. This value compares well with 2016 and 2014, which averaged 19 and 29 dust events, respectively, but less than half as many than in 2015, which averaged 56 dust events. The percentage of time with dust was measured at 0.45%. This number is less than the 0.63% reported in 2016, up from 0.1% measured in 2015, and less than half from the 2014 season at 1.05%. Middle Creek North (MCN) had the most recorded dust events with 84 and an average TSP concentration during those dust events of 0.23 mg/m^3. The average wind speed during these events (at MCN) was 4.7 m/s. Omineca had the second most dust events with 58. The average TSP concentration during those events was a little lower than MCN at 0.20 mg/m^3 with the average wind speed during these events being 7.2 m/s.

During dust events, the average dust concentrations were largest at Collins Beach (0.47 mg/m^3), Tsay Keh Village (0.47 mg/m^3), and Davis North (0.51 mg/m^3). Middle Creek North, by quite a wide margin reported the highest percent of time with dust at 2.61%, the next highest beach was Davis North at 0.77%. Middle Creek North has consistently been one of the highest recorded dust emitters since monitoring began here in 2014. It should be noted that the E-Sampler at MCN had to be removed on June 13, ahead of other sites, because the bridge accessing the site (at an elevation ≈667.75 ±0.2 m) had been overtopped by rising reservoir water level. Even with the reservoir at that elevation there was still a large area of the beach exposed with dust events being recorded just prior to the E-Sampler being removed. Whereas most other stations had much fewer dust events in June.

In nearly all cases where threshold events were recorded in 2017 the wind was arriving from a southerly direction (between 91 to 269º). Exceptions to this observation include Moody and Bruin. Moody consistently records few dust events, and 2017 was no different with only 2 events recorded. There are no large beach complexes to the southeast or northwest of Moody, so the dust may have been local. The two events were recorded early on in the season, when the reservoir would have been low and more sediments above the water. Also the shoreline has a slight bowl shape to it with the northern part reaching further into the reservoir so with the right southeasterly wind it is possible that a local eddy current might have setup directing any airborne dust to curve back into the sampler from the northwest. In contrast, Bruin is located at the south end of a large Beach complex, so it is reasonable to understand that a northwesterly wind would produce dust and blow it past the Bruin sampler.

It should be noted that there were a few issues at some sites that could not be rectified before the end of the dust season in June. There were repeated power issues with the E-Sampler at 57 km, first from the batteries, then the charge controllers. Prior to issues with wildlife at Shovel, which resulted in the removal of the E-Sampler from the site, batteries were not able to charge effectively from the solar panels during the day to power the sampler overnight. Access to this site was very limited which made any exchange of batteries extremely difficult. Aside from battery issues, the E-sampler placed at Rat Lake began failing its self-check and calibration routine, which is performed hourly. Due to a lack of operational E-Samplers, a non-operational unit was made operational in Tsay Keh and replaced, which lasted for two weeks before failing its self-check routine. Another unit was brought in after the middle of June.

The data presented below were extracted using the threshold criteria described above and are reported within the context of our definition of dust events. For example, the column marked "% Time with Dust Above Threshold" represents the percentage of the total time that the sampler was reading above the threshold value.

Table 6: 2017 Dust Season Dust Event Summary Statistics – Statistical data calculated using the 5-minute average data.

Site ID	# of Dust Events	Avg. TSP Conc. (mg/m^3) during events	% Time with Dust Above Thresh-old	Avg. Wind Speed (m/s)	Max Wind Speed (m/s)	Min Wind Speed (m/s)	Thresh-old Wind Speed (m/s)	Thresh-old Wind Spd. Std. Dev. (m/s)
Tsay Keh Village	6	0.47	0.16	0.3	3.3	0	1.3	1.2
Tsay Keh Beach	29	0.29	0.37	1.3	7.2	0	1.9	1.9
Van Somer	32	0.20	0.34	4.4	11.6	0	5	3.1
Chowika	25	0.28	0.31	2.7	15.4	0	2.5	3.0
MCN	84	0.23	2.61	4.7	11.9	0.2	3.9	2.4
Shovel	10	0.19	0.14	5.8	8.7	3.4	5.8	1.3
Davis North	27	0.51	0.77	7.5	12.6	0.2	5.1	3.0
Davis South	17	0.25	0.26	4.5	12.6	0	6.7	4.5
Bruin	17	0.34	0.33	6.6	10.7	1.6	6	2.3
Collins	31	0.47	0.60	3.2	10.7	0.1	3.8	3.4
Moody	2	0.18	0.02	1.2	3.4	0.3	2	2
Rat Lake	**1**	**0.34**	**0.01**	**1.7**	**1.8**	**1.7**	**1.7**	**0**
Ingenika	27	0.21	0.39	2.0	4.6	0.2	1.9	1

Site ID	# of Dust Events	Avg. TSP Conc. (mg/m³) during events	% Time with Dust Above Thresh-old	Avg. Wind Speed (m/s)	Max Wind Speed (m/s)	Min Wind Speed (m/s)	Thresh-old Wind Speed (m/s)	Thresh-old Wind Spd. Std. Dev. (m/s)
83 km	27	0.28	0.35	2.5	9.7	0	2.8	2.4
57 km	10	0.23	0.14	5.6	7.4	2.8	5.8	1.1
Bob Fry South	14	0.21	0.14	5.3	8.9	0.6	4.3	3.1
Omineca	58	0.20	0.65	7.2	9.2	1.6	6.7	1.6
Average:	25	0.29	0.45	3.9	8.8	0.7	4.0	2.2

2.2.3.2 Wind Speed and Wind Threshold

For the 2017 dust season, the average wind speed for all sites during dust events was 3.9 m/s (Table 6). This value is less than the average values for 2016 and 2014 (6.9 and 6.4 m/s, respectively), but higher than 2015 (3.1 m/s). Both Davis North and Omineca had the highest averaged wind speeds at 7.5 and 7.2 m/s, respectively). Other large wind speeds were recorded on beaches such as Bruin (6.6 m/s) and Shovel (5.8 m/s prior to removal). The greatest maximum wind speeds were all from the east side of the Finlay Reach (with the exception Moody and Shovel); those sites saw wind speeds above 10 m/s. Chowika reporting the highest speed at 15.4 m/s with Davis North, Davis South, Middle Creek North, and Van Somer rounding out the top five. All other sites in the regional network had maximum winds less than 10 m/s. High winds don't necessarily indicate that a beach would have a lot of dust storms or spend more time above the dust storm threshold. While some beaches like Davis North and Omineca reported high average wind speeds and a higher percentage of time in dust events than other sites, (0.77% and 0.65%, respectively), Middle Creek North was an anomaly. The average wind speed at Middle Creek North was 4.7 m/s just above the median value for all sites (4.4 m/s), but had the most dust events and, by far, spent the most amount of time with dusty conditions (2.61%). This continues a trend seen in previous years of observations that Middle Creek North is a very high emitter beach for relatively low to moderate wind speeds because of the loose and dry sediments which comprise the beach surface.

The locations that saw the fewest dust events were all non-erosive sites: Moody, Tsay Keh Village, and Bob Fry South The only site that had a northerly threshold wind direction was Moody, and as already mentioned, it only recorded two dust events. The threshold wind speed for those events were 2.0 m/s, with the average speed for the site also fairly low at 1.2 m/s.

Sites such as Ingenika, 83 km and Chowika are interesting because they represent distal location from dust sources. These three sites recorded dust events that were about average for all sites, Ingenika and 83 km with 27 events and Chowika with 25. The percentage of time these sites were under dusty conditions (time above event threshold) was less than the Finlay Reach average (0.45%), which indicates that these dust events moving northward up the valley were not the result of large sustained dust scale event. Compared to the other non-erosive sites, these sites spent a lot more time under dust conditions, showing that Ingenika, 83 km and Chowika are well suited to record dust events moving through the Finlay Reach.

The average threshold wind speed for dust events was calculated by extracting the wind speed data leading up to the point in time when the event threshold of 0.1 mg/m^3 TSP was surpassed and averaging the previous 30 minutes of data. The average wind speed threshold for all dust samplers was calculated at 5.9 m/s in 2014, 3.1 m/s in 2015, 6.6 m/s in 2016 and 4.0m/s in 2017.

2.2.3.3 Wind Direction

There was some degree of variability with the average threshold wind direction between many of the sample sites. The dominant threshold wind direction had a southwesterly component that varied to more westerly to more southerly, which was predominantly seen on the eastern shoreline of the Finlay Reach. Tsay Keh Beach and Tsay Keh Village sites along with most other sites on the western shore had a threshold wind direction from the southeast. Of course as previously mentioned both Bruin and Moody had northerly components to a more westerly wind. Given the orientation of the Finlay Valley (Rocky Mountain Trench), it would be expected the dominant wind directions in this part of the Finlay Valley would be northwest or southeast winds that have been identified by Nickling et al. (2013). To some extent the dominant wind direction reported in 2017 may have been influenced by some of the unavoidable compromises (such as site access) that must be made during site selection, even with efforts made to avoid placing sites where the influence of local geography and vegetation will affect wind readings.

2.2.4 Dust Event & Occurrence Type Heatmap Analysis

The images presented over the next several pages (Figures 18 - 21) were created using a heatmap interpolation analysis that was applied to the Regional Monitoring Network data. This process uses nearest neighbour triangulation to create a high density array of coloured triangles where the greatest “heat,” or in our case dust, is indicated by bright yellow, and the least dust is indicated by dark blue.

The heatmap interpolation is performed across the entire 17 E-Sampler/8 Met Station dataset for every 5-minute interval. The result is a time series of spatial data and images that show where the greatest concentration of dust is at any given 5-minute interval within the Finlay Valley. This perspective has truly revolutionized our thinking surrounding dust events in the reservoir. Namely, it was widely accepted that dust events occur at relatively infrequent intervals, usually on a large scale. Over the past four years, this analysis has shown us that there are, in some cases, hundreds of events on a single beach throughout the dust season. These dust events can range in size from small to large scale, and that some locations regularly emit much higher levels of dust than others. This conclusion, as reached through analysis of the heatmap data is consistent with the anecdotal observations provided by numerous people who have in some way worked on the dust mitigation project since 2008.

In order to fully appreciate this analysis we have created programming that enables us to observe these spatial heatmap images temporally by linking each image in time lapse. The result is a video, which can be sped-up or slowed down to view the initiation, development, evolution and dispersion of dust events in 5-minute time segments. The time-lapse videos are discussed in Section 2.2.5 Time-Lapse Analysis.

Firstly, we will examine 4 snapshots from the heatmap analysis for 3 different event types from the 2014 dust season and two event types recorded during the 2017 season. Our intention is to discuss the development of various dust events over time and it is apparent that the data collected in 2014 are well suited to this purpose. Figures 18 through 20 show three distinct types of dust event that were observed on several occasions throughout the 2014 dust season. Note that the arrows on the images point towards the direction winds are coming from and the length of the arrow is proportional to strength of the wind. All data shown below were calculated using the 5-minute average data recorded by the E-Samplers, therefore each image represents a 5-minute average data snapshot of the dust conditions surrounding the reservoir. We have also included a storm from 2017 (Figure 21) that are representative of the prevailing conditions during that dust season.

2.2.4.1 Example of a Large Scale Event

Figure 18 contains four images, which show the development of a valley wide dust event. Figure 18 (A) shows the storm beginning near MCN at 06:20 on May 22nd, 2014 with winds from the south. 5 hours later, Figure 18 (B) shows how the storm has grown to fill the southern section of the Finlay Valley. Figure 18 (C) shows that the storm took a brief hiatus near 16:00 (with the exception of the MCN area) but didn’t completely subside until after 10:30 on May 23rd, 2014.

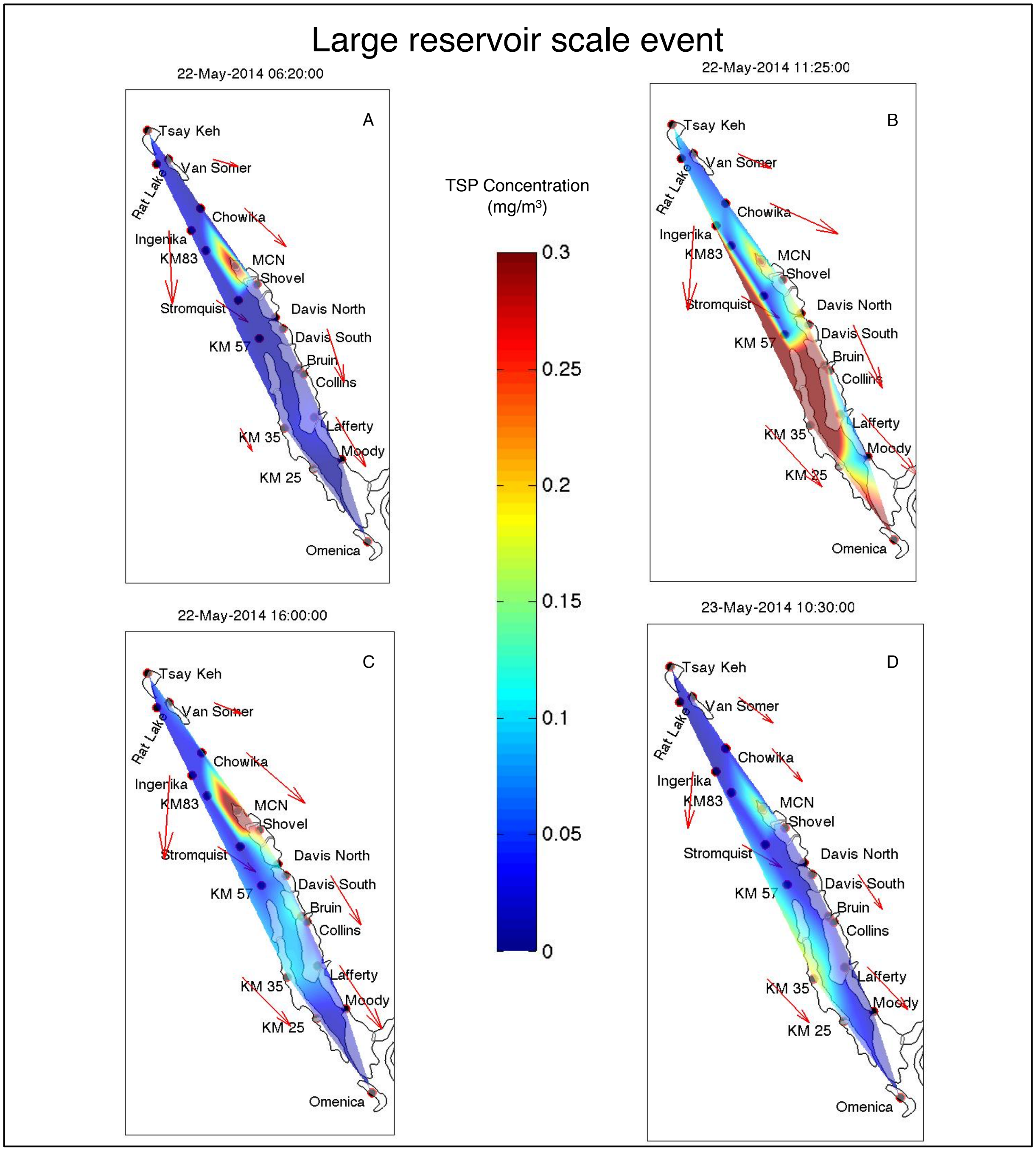

Figure 18: Heatmap Analysis - Large Scale Event – Each plots shows an instantaneous snapshot of the 5-minute average data.

2.2.4.2 Example of a Small Scale Occurrence

Figure 19 contains four images, which show the development of a small occurrence localized to a single beach. Figure 19 (A) shows the Finlay Valley under pristine air quality conditions at 06:45 on May 25th, 2014. Figure 19 (B) shows the development of a small microburst at 25 km and 35 km starting at 06:50. At 06:55, the microburst has blown up to a very high concentration localized dust occurrence (Figure 19 (C). Then at

07:00, Figure 19 (D) shows that the microburst dust occurrence has stopped and dissipated. This entire micro-occurrence took place over a 20-minute period and although this would not adversely affect the air quality in Tsay Keh Dene it is a prime example of the variability across the reservoir. This occurrence does not pass our threshold limit to be considered a dust event.

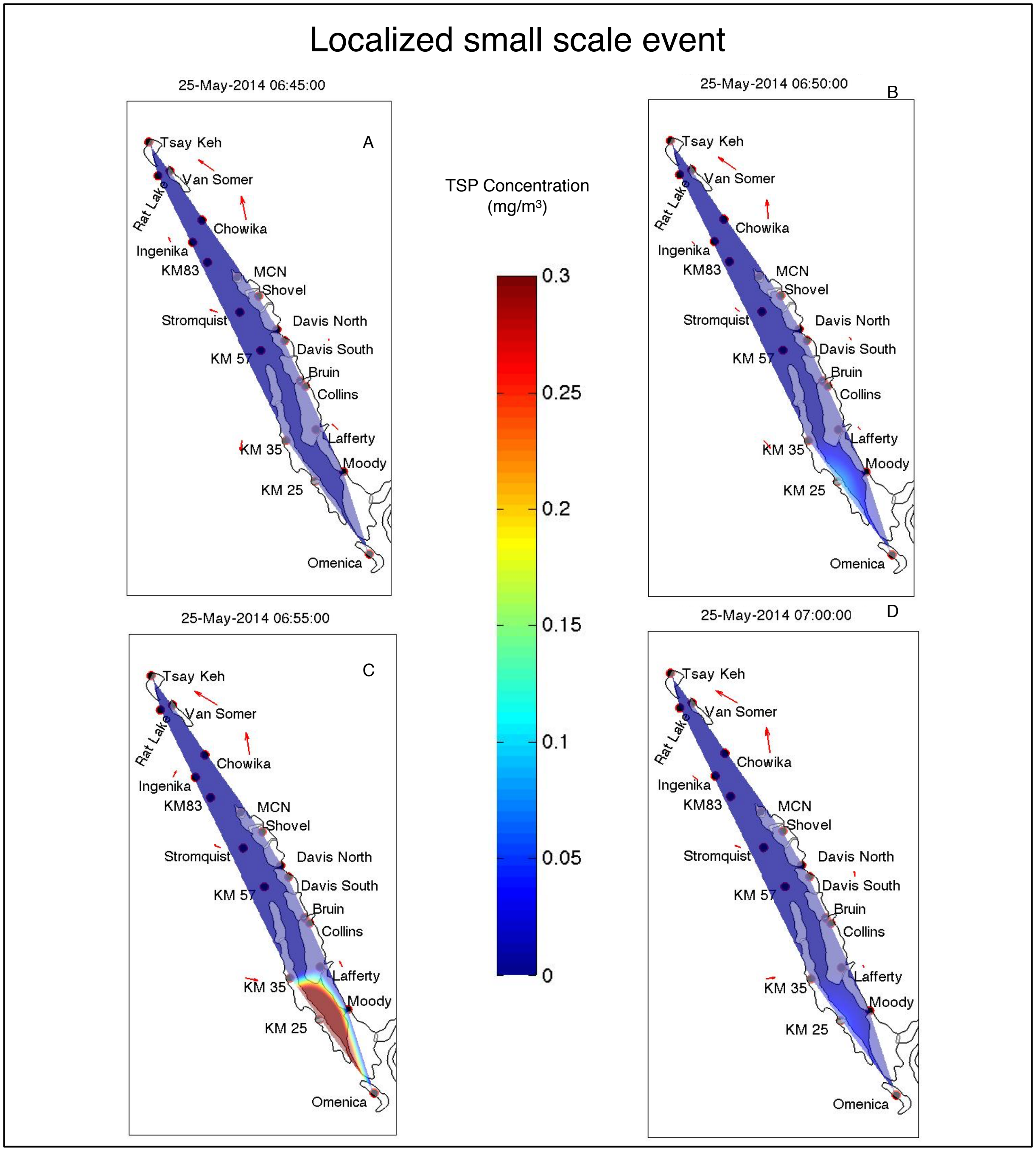

Figure 19: Heatmap Analysis - Localized Occurrence – Each plots shows an instantaneous snapshot of the 5-minute average data.

2.2.4.3 Example of a Migrating Event

Figure 20 contains four images, which show the development of a small but migrating dust event. This is perhaps the most interesting new observation that our distributed network of E-Samplers has allowed us to observe. Figure 20 (A) shows the start of a dust event at 19:35 on May 20th, 2014 on Collins Beach and Bruin Beach with winds from the south. Figure 20 (B) show the same event 10 minutes later arriving at Davis South and Davis North beaches. Figure 20 (C) shows this same event beginning to arrive at Shovel Creek at 19:55 and then 5 minutes later, Figure 20 (D) shows the event arriving at MCN. There are numerous short-lived events that begin in the southern regions of the Finlay Valley and migrate north like the example in Figure 20. We should note that on May 20th, 2014 this phenomenon had been happening all day, the example shown in Figure 20 was the 3rd such occurrence of the day.

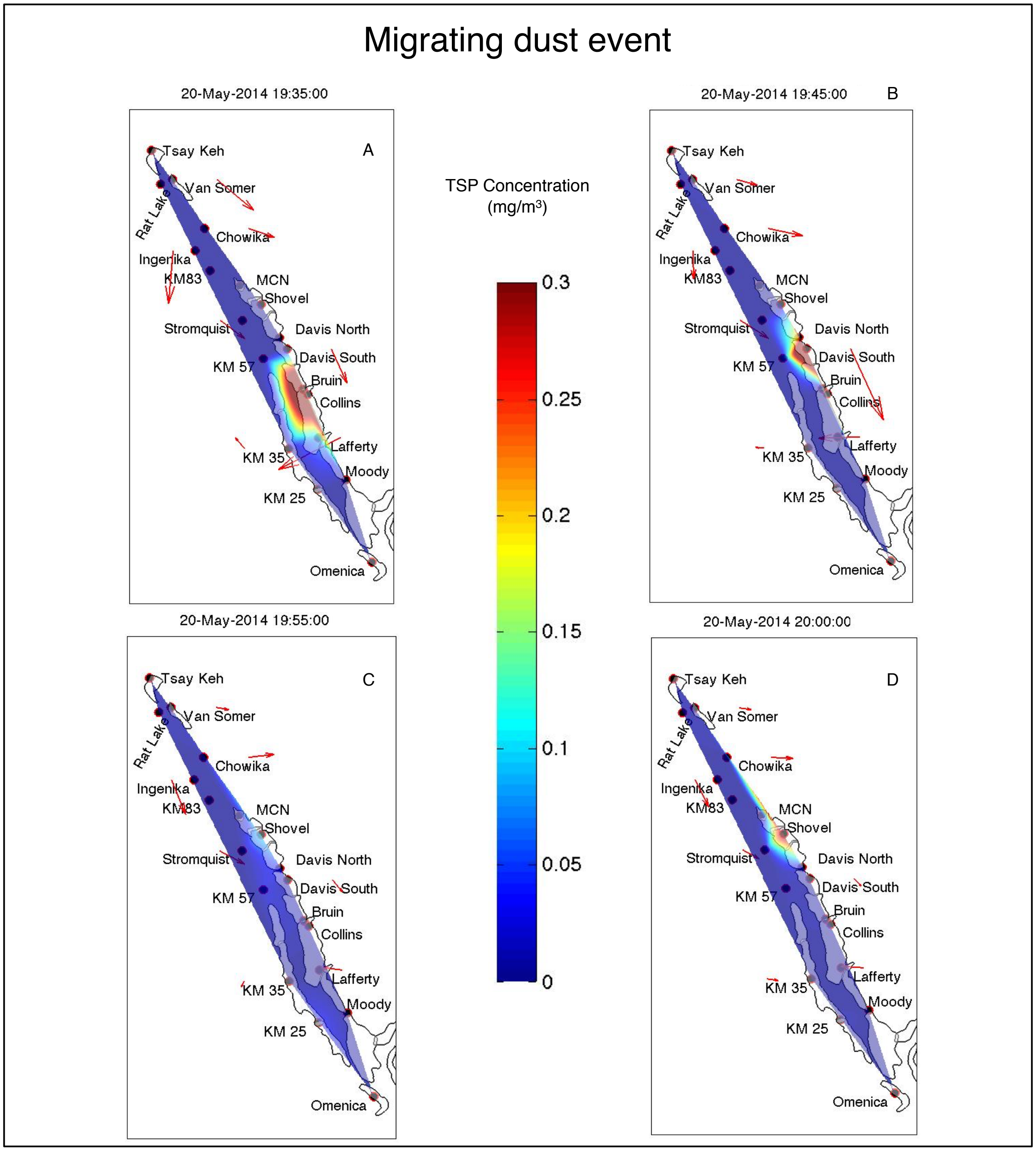

Figure 20: Heatmap Analysis - Migrating Dust Event – Each plots shows an instantaneous snapshot of the 5-minute average data.

2.2.4.4 May 2017 Event

Figure 21 shows a mid-season small dust event recorded in May 2017. The event started at approximately 5 pm on May 24th, 2017, as winds from the northwest were moving down the Finlay Reach a dust event was recorded at Van Somer. Although no event was recorded on Tsay Keh Beach, this event may have originated there due to the location of the E-Sampler on the Beach in Tsay Keh Dene and the beach being downwind of the E-Sampler during this event. Twenty minutes later, the cloud of dust had quickly moved to the southeast where the E-Sampler at Chowika recorded a lesser concentration of dust (Figure 21), but still higher than the 0.1 mg/m^3 5-minute average TSP concentration. It's possible that some of the heavier particles in the dust cloud simply dropped out of suspension while travelling to Chowika. Chowika is a gravel bar and therefore no new fugitive dust would have been kicked into the air. Further south, by 6 pm the Middle Creek North, Davis North, Davis South and Bruin are reading high concentrations of dust. Fifteen minutes later at 6:15, the most intense part of the storm is occurring, but the northwest winds are beginning to slow. At 7 pm, while there are still high levels of dust being recorded by the E-Samplers at Bruin and Collins, the dust event has ended for Middle Creek North and Davis North. One hour later at 8 pm, the event is over.

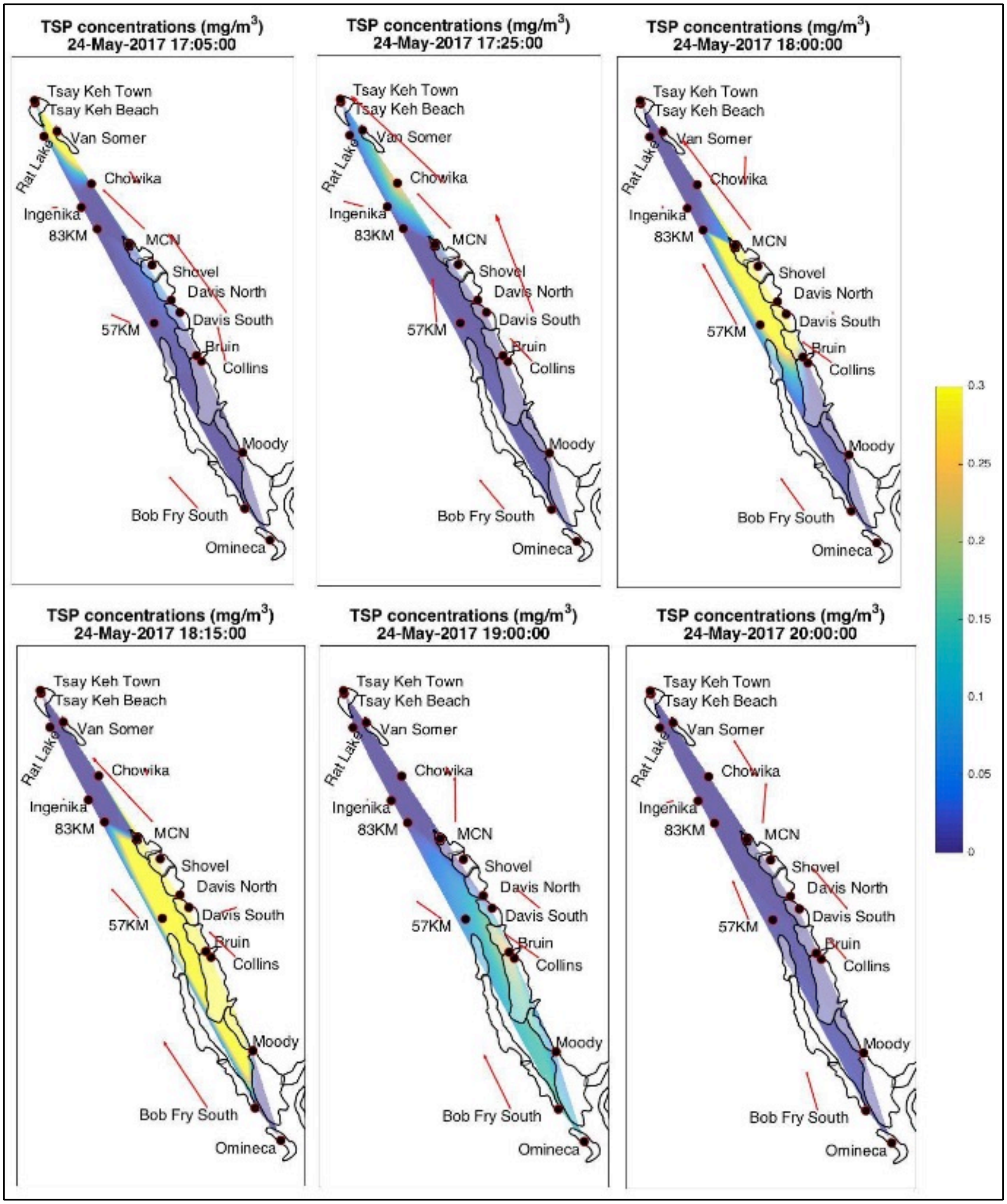

Figure 21: Very high intensity short-term dust event recorded on May 24th, 2017. Event – Each plots shows an instantaneous snapshot of the 5-minute average data.

2.2.5 Time-Lapse Analysis

Moultrie D-555i game cameras were deployed at selected regional monitoring sites. These cameras were set to record images at 5-minute intervals synced with the collection schedule of the nearby E-Sampler. Although the manufacturer specifications indicated that the Moultrie game cameras would be well suited to this application, in practice the cameras lacked the ability to auto-focus quickly and performed poorly in low light conditions. The cameras were also very inconsistent in power consumption patterns, some batteries lasting months while others would last only 2 weeks. Moving forward we will acquire cameras that represent the latest in affordable time lapse image capture technology for this project.

The primary use of the game cameras was to capture time-data synced images in order to provide a visual record of dust events along side the numerical value for the same event. In this way, the viewer of the video can associate the visual aspect of the dust events to the numerical data read by the E-Samplers. This exercise was completed for both the 2014 and 2015 dust seasons. We opted not to link the time-lapse images to the heatmap video for 2016 and 2017 but instead opted to upload a 7-minute and 14-minutes video, respectively, of the entire dust season. Viewing the dust season in this way provides the viewer with an intuitive and rapid method for constructing conclusions about the frequency and magnitude of dust events in 2017.

Videos from the 2014 dust season are posted here:

https://vimeo.com/118043075

https://vimeo.com/117007358

Videos from the 2015 dust season are posted here:

https://vimeo.com/152634706

https://vimeo.com/152631808

The Video from the 2016 dust season is posted here:

https://vimeo.com/202436881

When viewing these videos it may be useful to pause for certain frames in order to step through the frames one by one to observe the progression of the dust events.

We will continue analyzing the data in this way, using strong visuals and time-lapse images to provide greater insight into the dust events. Moving forward we will investigate new and advance analysis techniques that will enable us to extract more detailed information from each video.

2.3 Statistical Analysis and Mitigation Treatment Analysis

For this report Chu Cho Environmental will continue with a basic statistical approach to analyzing the Regional Monitoring Network E-Sampler data. As our project team gains experience working with the E-

Samplers and comes to know the full capabilities of the instrument and the network design, we will expand upon this analysis to further address the key management question central to this project.

2.3.1 Descriptive Statistics and Analysis of Variance

All descriptive statistics and ANOVA operations were performed on data that met the threshold criteria outlined above. It is not relevant to this discussion to analyze the non-threshold data. Therefore each data point used in the following analyses is above 0.1 mg/m^3 TSP and is representative of the station during a dust event.

For our analysis of variance we have selected a confidence interval of 99%, which means that our alpha value against which to test our p-value is 0.01.

2.3.1.1 Descriptive Statistics

Table 7 below provides basic descriptive statistics for each of the 17 E-Samplers across the Regional Monitoring Network. Table 8 provides an easy comparison for each of the 7 E-Samplers located on non-erosive sites, while Table 9 presents the 10 E-Samplers from moderate to highly erodible locations. As previously mentioned, data collected at Shovel (typically one of the highest fugitive dust locations) suffered from power issues, and bear encounters. During the first bear encounter, the site was knocked offline and remained that way for a few days before employees were able to set the equipment back up. On the next site visit, employees arrived at the site to find much more damage had been done, damage that would not allow the continued operation of the site. 57 km also suffered from long stretches of down time due to power issues that were first thought to be battery issues, but upon further investigation, were issues with the charge controllers.

For 2017, sites located near or on moderate to highly erodible locations had only a slightly greater overall average TSP concentration (0.292 mg/m^3) during dust events than those on non-erosive sites (0.283 mg/m^3). For the non-erosive sites, this was much higher than what was reported during the 2016 dust season.

The highest recorded 5-minute TSP concentration in 2017 was from Davis North at 4.864 mg/m^3, followed by Bruin at 3.107 mg/m^3. Over the past 4 years, Davis North and Bruin always seem to be amongst the top sites for maximum TSP recorded in the Regional Monitoring Network. For specifically non-erosive beaches, both Tsay Keh Village and Chowika reported the highest maximum TSP concentrations over a 5-minute average at 0.984 mg/m^3 and 0.969 mg/m^3, respectively.

Standard deviation and variance values during dust events at each site were quite large relative to the mean in many instances indicating that there is significant variability in the dataset. Both Davis North and Bruin locations, had very high standard deviation values and variance values; for those sites, standard deviations were greater than the mean.

Table 7: Basic Descriptive Statistics for TSP Concentration from all 17 Regional E-Sampler Monitoring Sites (All Units are mg/m³ and were calculated using the 5-minute average data recorded by the E-Sampler).

	MCN	Shovel	Chowika	Bob Fry	Collins	Moody	83 km	Davis North	TK Beach	Davis South	Van Somer	TK Village	57 km	Ingenika	Rat Lake	Omineca	Bruin
Mean	0.2346	0.19	0.2844	0.2074	0.4745	0.1795	0.2776	0.506	0.2902	0.251	0.1968	0.4684	0.2322	0.2129	0.3443	0.2005	0.3409
Min.	0.1	0.1	0.102	0.102	0.103	0.114	0.101	0.102	0.101	0.102	0.1	0.11	0.104	0.101	0.258	0.1	0.1
Max.	1.238	0.444	0.969	0.708	2.247	0.285	0.91	4.864	1.307	0.788	0.907	0.984	0.441	0.593	0.472	0.708	3.107
Std Dev.	0.1254	0.1061	0.1922	0.117	0.3515	0.0817	0.1938	0.6957	0.2514	0.1622	0.1491	0.2513	0.0854	0.1245	0.1128	0.1134	0.528
Var.	0.0157	0.0113	0.0369	0.0137	0.1236	0.0067	0.0376	0.484	0.0632	0.0263	0.0222	0.0632	0.0073	0.0155	0.0127	0.0129	0.2788

Table 8: Basic Descriptive Statistics for TSP Concentrations from 7 Non-Erosive Locations (All Units are mg/m³ and were calculated using the 5-minute average data recorded by the E-Sampler).

	Chowika	Bob Fry	Moody	83 km	TK Village	Ingenika	Rat Lake
Mean	0.2844	0.2074	0.1795	0.2776	0.4684	0.2129	0.3443
Minimum	0.102	0.102	0.114	0.101	0.11	0.101	0.258
Maximum	0.969	0.708	0.285	0.91	0.984	0.593	0.472
Standard Deviation	0.1922	0.117	0.0817	0.1938	0.2513	0.1245	0.1128
Variance	0.0369	0.0137	0.0067	0.0376	0.0632	0.0155	0.0127

Table 9: Basic Descriptive Statistics for TSP Concentrations from 10 Moderate to Highly Erodible Locations (All Units are mg/m³ and were calculated using the 5-minute average data recorded by the E-Sampler).

	MCN	Shovel	Collins	Davis North	TK Beach	Davis South	Van Somer	57 km	Omineca	Bruin
Mean	0.2346	0.19	0.4745	0.506	0.2902	0.251	0.1968	0.2322	0.2005	0.3409
Minimum	0.1	0.1	0.103	0.102	0.101	0.102	0.1	0.104	0.1	0.1
Maximum	1.238	0.444	2.247	4.864	1.307	0.788	0.907	0.441	0.708	3.107
Standard Deviation	0.1254	0.1061	0.3515	0.6957	0.2514	0.1622	0.1491	0.0854	0.1134	0.528
Variance	0.0157	0.0113	0.1236	0.484	0.0632	0.0263	0.0222	0.0073	0.0129	0.2788

2.3.1.2 ANOVA Between All E-Samplers

The following analysis is based on a one-way ANOVA used to examine the 17 E-Sampler datasets for significant differences in dust concentration data between site locations. This approach will allow us to examine the dataset to determine if there are sites within out monitoring network around the reservoir that exhibit significantly higher dust concentrations than others. The null hypothesis for this ANOVA is:

> **H_0:** There is no significant difference in the mean dust concentration between all 17 E-Sampler instrument locations.

Table 10: ANOVA Summary Table for All E-Sampler Data

Source	Sum Squares	Degrees Freedom	Mean Squares	F	p-value
Groups	17.538	16	1.09611	12.34	$3.83513e^{-31}$
Error	138.42	1558	0.08884		
Total	155.958	1574			

Since $p = 3.83513e^{-20} < 0.01$ we may reject the null hypothesis at a 99% confidence interval. Therefore the mean dust concentration between the E-Sampler monitoring sites is significantly different. This means that there are beaches within the dataset that contain mean dust concentrations that are significantly different that the rest. In order to evaluate which samplers are driving this significance we create a box and whisker plot of the ANOVA data, shown in Figure 22. It is clear that the significant difference is driven by the presence of strong outliers at Davis North, Collins Beach and Bruin Beach. In this case, this means that in 2017 these beaches had many instances where the dust concentrations were significantly higher than the surrounding beaches.

To some extent this is expected because of the morphological characteristics of the individual beaches on which the sampler is located. It is therefore appropriate to further resolve these data by creating groups of erosive beach-adjacent and non-erosive beach-adjacent sites and conduct the same analysis. This will provide two views on the data that the above aggregation of sites does not. 1) We are able to parse which locations around the reservoir regularly emit significantly higher volumes of dust and we are able to plan our mitigation strategy accordingly and 2) In the case of the non-erosive sites, we are able to see which sites regularly receive significantly higher volumes of dust from other sources so that we can identify up-wind areas that regularly contribute to poor air quality.

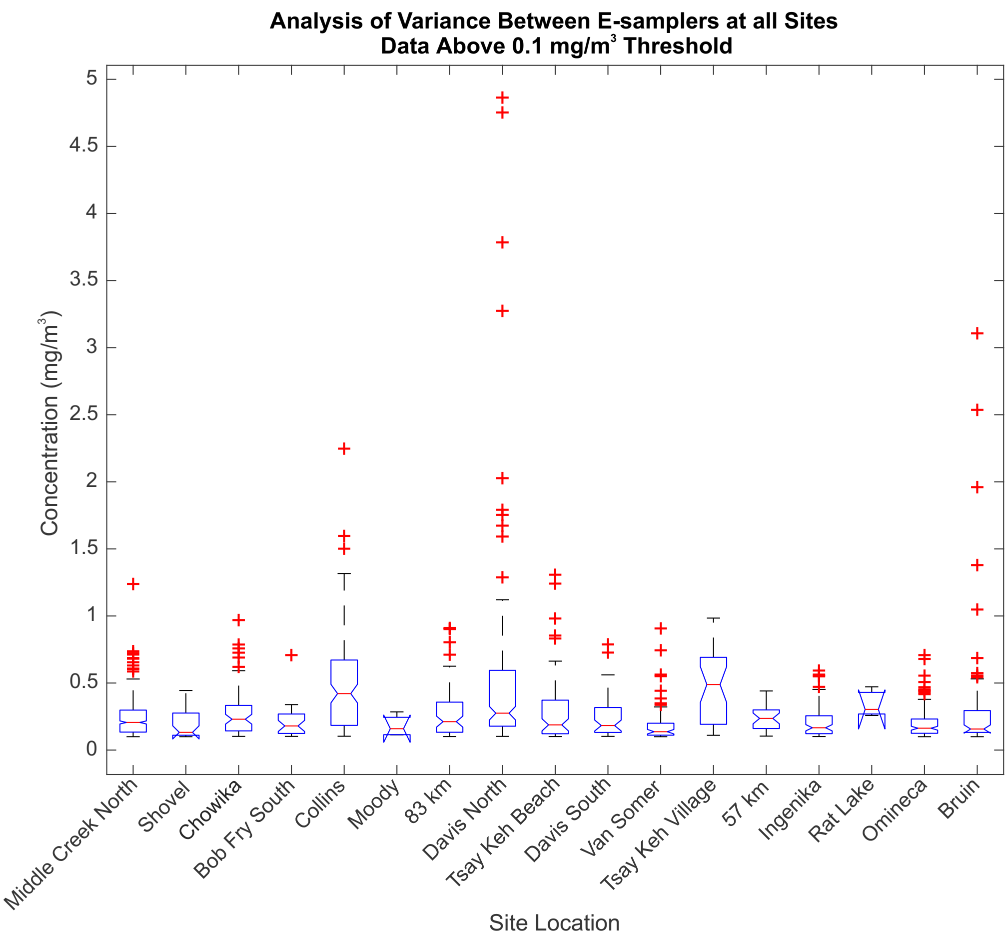

Figure 22: Results of ANOVA for entire 17 E-Sampler Dataset.

2.3.1.3 ANOVA Between E-Samplers Located in Non-Erosive Areas

Since significant differences in mean dust event concentrations were identified above in Section 2.3.1.2, it is relevant to parse the data into two groups, which broadly represent the different geophysical characteristics of the sites. Some sites are located in highly erosive areas while others are located on non-erosive gravel bars and outcrops. These data have divided the data into these two groups for the following ANOVA. The first group is the Non-Erosive group and the null hypothesis stated for the ANOVA is as follows:

> **H_0:** There is no significant difference in the mean dust concentration between E-Samplers that are located in non-erosive zones surrounding the reservoir.

Table 9: ANOVA Summary Table for E-Sampler Data from Non-Erosive Locations

Source	Sum Squares	Degrees Freedom	Mean Squares	F	Prob > F
Groups	1.7735	6	0.29559	9.45	$1.83651e^{-9}$
Error	8.8192	282	0.03127		
Total	10.5928	288			

Since $p = 1.83651e^{-9} < 0.01$ we may reject the null hypothesis at a 99% confidence interval. Therefore the mean dust concentration values between the E-Samplers located at non-erosive sites are significantly different at the 99% confidence interval. Figure 23 below shows the box and whisker plot for the ANOVA at non-erosive sites, which reveals that the Tsay Keh Village site recorded significantly higher dust concentrations than the other non-erosive sites. Rat Lake and Chowika, which are located further south of Tsay Keh Village recorded the next highest dust concentrations respectively. Rat Lake and Chowika are located several kilometers away from the nearest source locations, which suggests that under the right wind conditions there can be significant drift of air parcels containing dust. This has been shown regularly throughout the GMSMON#18 reports (e.g. Fryrear et al. 2011, Nickling et al 2012). Interestingly, the significantly higher concentration recorded at the Tsay Keh Village site suggests that there are inputs contributing to the readings located between Chowika/Rat Lake and the village. The two obvious potential locations are Van Somer and Tsay Keh Beach itself.

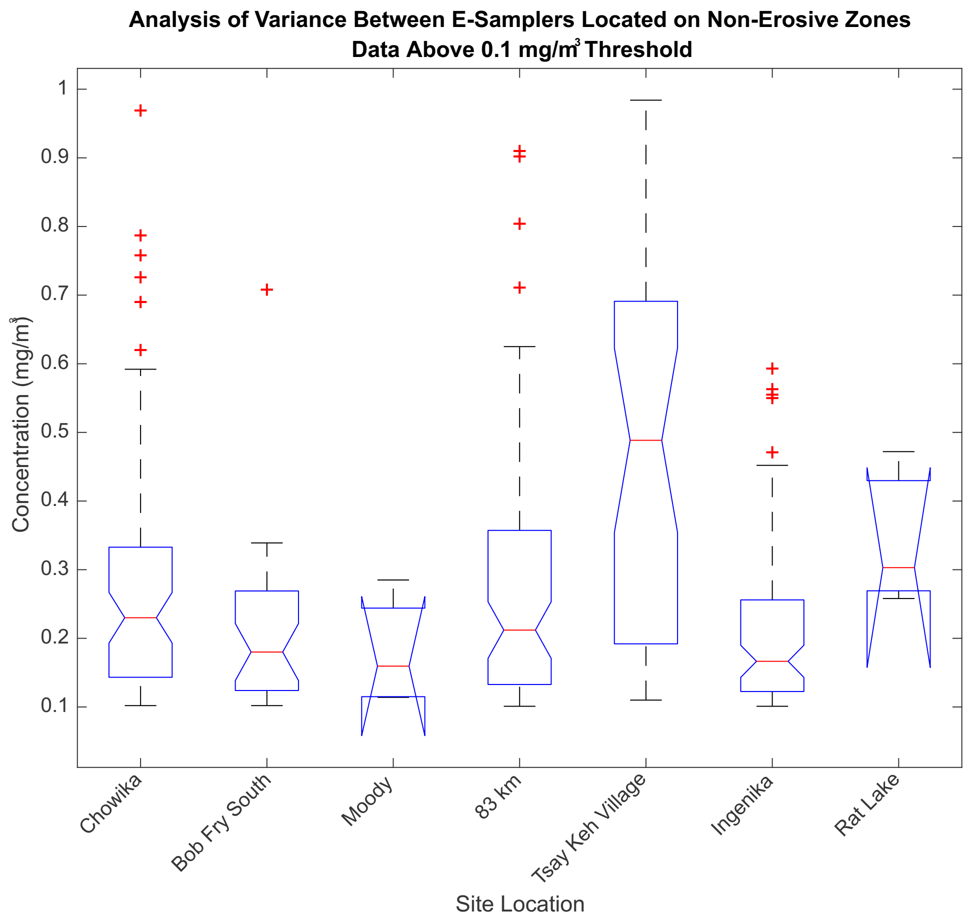

Figure 23: ANOVA Box and Whisker Plot for E-Sampler Data from Non-Erosive Sites

2.3.1.4 ANOVA Between E-Samplers Located in Erosive Areas

The second parsing of data represents the E-Samplers that are located in the moderate to highly erodible zones surrounding the reservoir. These include sites such as Middle Creek North and Davis North that are located very near to the erosive zones of the beaches. The null hypothesis for ANOVA of the erosive group of E-Samplers is as follows:

> **H_0:** There is no significant difference in the mean dust concentration between E-Samplers that are located in the moderate to highly erosive zones surrounding the reservoir.

Table 11: Summary Values for the ANOVA of E-Sampler Data Collected in Moderate to highly Erodible Zones

Source	Sun Squares	Degrees Freedom	Mean Squares	F	Prob > F
Groups	15.679	9	1.74212	17.15	$5.61032e^{-27}$
Error	129.601	1276	0.10157		
Total	145.28	1285			

Since p = $5.61032e^{-19} < 0.01$ we may reject the null hypothesis at a 99% confidence interval. Therefore there are significant differences in dust concentration values between E-Samplers located in moderate to highly erosive zones. Figure 24 below shows the box and whisker plot for the ANOVA at moderate to highly erodible sites. The highest dust readings were recorded at Davis North in 2017 and this value is significantly higher than many of the other erosive sites with this value being driven by the relatively high outlier values. Collins Beach and Bruin Beach were the locations that recorded the next highest averages and again several outliers with very high dust concentrations. Some of the sites, which regularly recorded high values in previous years did not record high dust concentrations in 2017, this includes Middle Creek North, Van Somer and Shovel. This likely arises from a combination of local weather events, reservoir rise and beach coverage as well as mitigation activities applied by the WDMP. In general, after 4 years of administering this program in this form we tend to see either a combination of highly localized events persisting in a relatively constrained area of the reservoir or in fewer instances we see very large wide-spread events that are recorded at all instruments in the valley. During years when the weather is wetter and the winds are less intense, the events tend to be localized with a few exceptions. During dry years with regular winds we tend to see fairly wide-spread events on a regular basis.

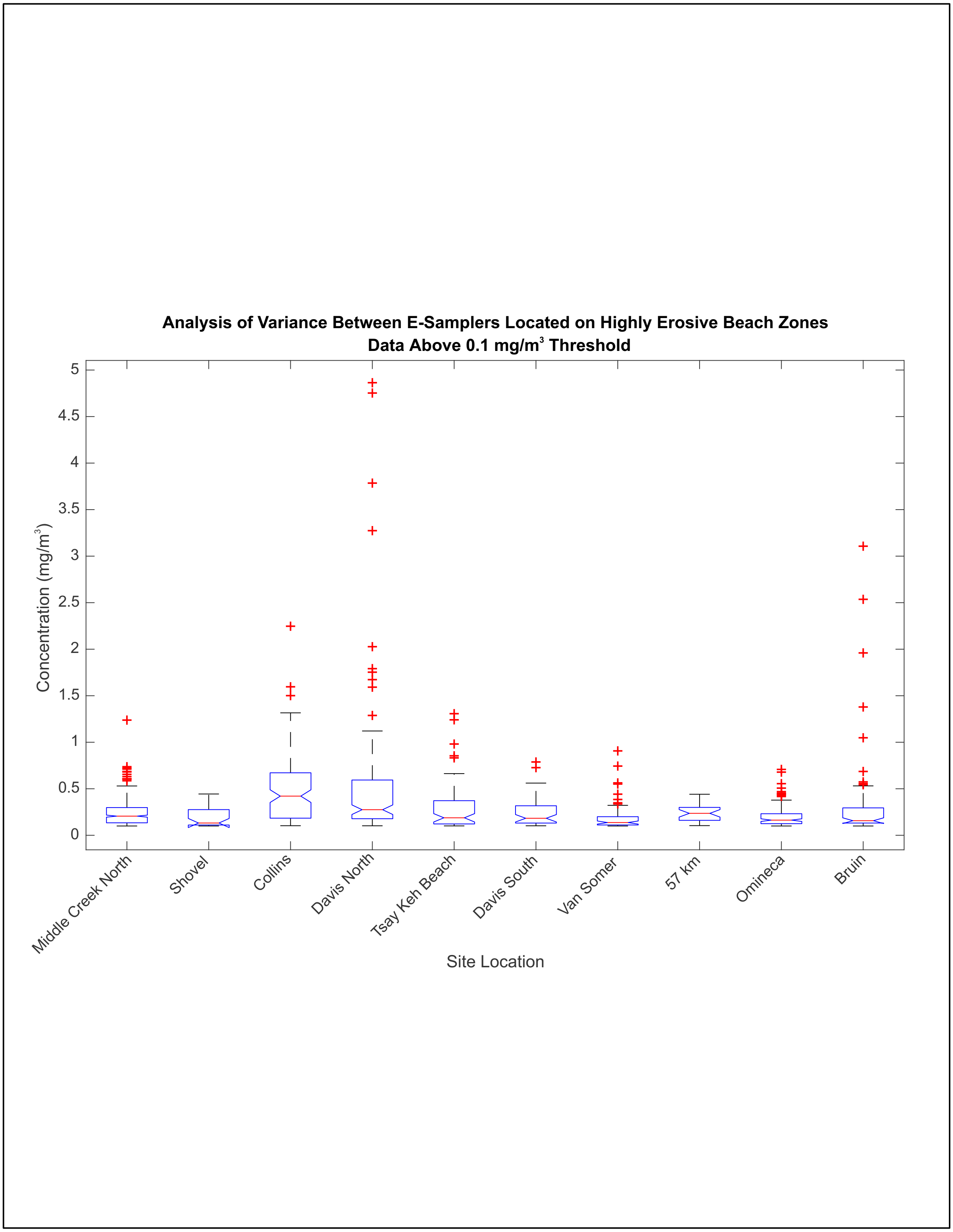

Figure 24: ANOVA Box and Whisker Plot for E-Sampler Data from Moderate to Highly Erodible Sites.

Network Component II: Reference Monitoring Network

3.0 Reference Monitoring Network

3.1 Network Characterization

Canadian Ambient Air Quality Standard (CAAQS) achievement determination requires that the Reporting Areas (RA) be based on the Census Metropolitan Areas (CMA) and census agglomerations (CA). Therefore, the distribution of CAAQS reporting stations is based on population numbers and urban density (CCME 2011). Generally, for CAAQS reporting there should be 1 particulate sampler for every 250,000 people and the sampler should be placed between 6 – 8 km apart or should have a distribution that is dependent on the distance between the CMA and the major source that may be affecting it (CCME, 2011).

The province of British Columbia uses a suite of ambient air quality criteria that have been developed provincially and nationally to inform the decisions on the management of air contaminants (BC MoE, 2016). The suite of criteria that are applicable to this report include the Provincial Ambient Air Quality Objectives (AQOs), the CAAQS and the Pollution Control Objectives (PCOs) of industry. The most recent revisions to the BC Ambient Air Quality Objectives were updated in December 2016. Those that are relevant to this project include:

Table 12: Air Quality Objectives and Standards Relevant to this Project

Contaminant	Average Period	Objective/Standard	Date Adopted	Source
$PM_{2.5}$	24 Hour	28 $\mu g/m^3$	2013	CAAQS
$PM_{2.5}$	Annual	10 $\mu g/m^3$	2013	CAAQS
PM_{10}	24 Hour	50 $\mu g/m^3$	2005	Provincial AQO

3.1.1 GMSMON#18 Air Monitoring Network Characterization

The reference monitoring network managed by Chu Cho Environmental in the Finlay Valley meets or exceeds the above criteria as it consists of two major monitoring stations located approximately 72km apart in villages with less than 400 people each. The monitoring station in Tsay Keh Dene is located approximately 450m away from the edge of the major source which affects the village (the reservoir) and is sited away from any structures or other impediments to air flow that might bias the sample. The monitoring station in Kwadacha is located approximately 75km away from the reservoir along the Rocky Mountain Trench and within the village is sited reasonably far away from structures and other impediments to airflow.

The spatial distribution of these samplers fits within the Regional Scale category for monitoring and since the populations of both Tsay Keh Dene and Kwadacha are less than 400 each, our Reference Monitoring Network technically do not meet the standards for CAAQS reporting as well as Special Studies (British Columbia Air Protection Section Environmental Quality Branch, 2006) because they are not US EPA FEM designated. It was not the intention of the project to use this monitoring network for a regulatory purpose, but we did aspire to the same standards set by the CCME for the CAAQS and BC MoE for the AQO. This network is intended to monitor the long-term trends in air quality for the region as it relates to reservoir dust and the mitigation activities conducted by the WDMP.

Figure 25 below, shows the location of each monitoring station within the Finlay Valley relative to the reservoir. The Finlay Valley tends to direct the wind flow either northwest or southeast; all recorded dust events are generated by southeasterly winds. The valley is approximately 10 km wide at Tsay Keh Dene and narrows to less than 4 km at Kwadacha. Figure 26 shows the Tsay Keh Dene monitoring station outfitted with an E-Sampler, 2 BGI PQ200s, relative humidity/temperature sensor, barometric pressure sensor, rain gauge, and a wind speed/direction monitor. Figure 27 shows the Kwadacha monitoring station outfitted with a relative humidity/temperature sensor, barometric pressure sensor, rain gauge, and a wind speed/direction monitor.

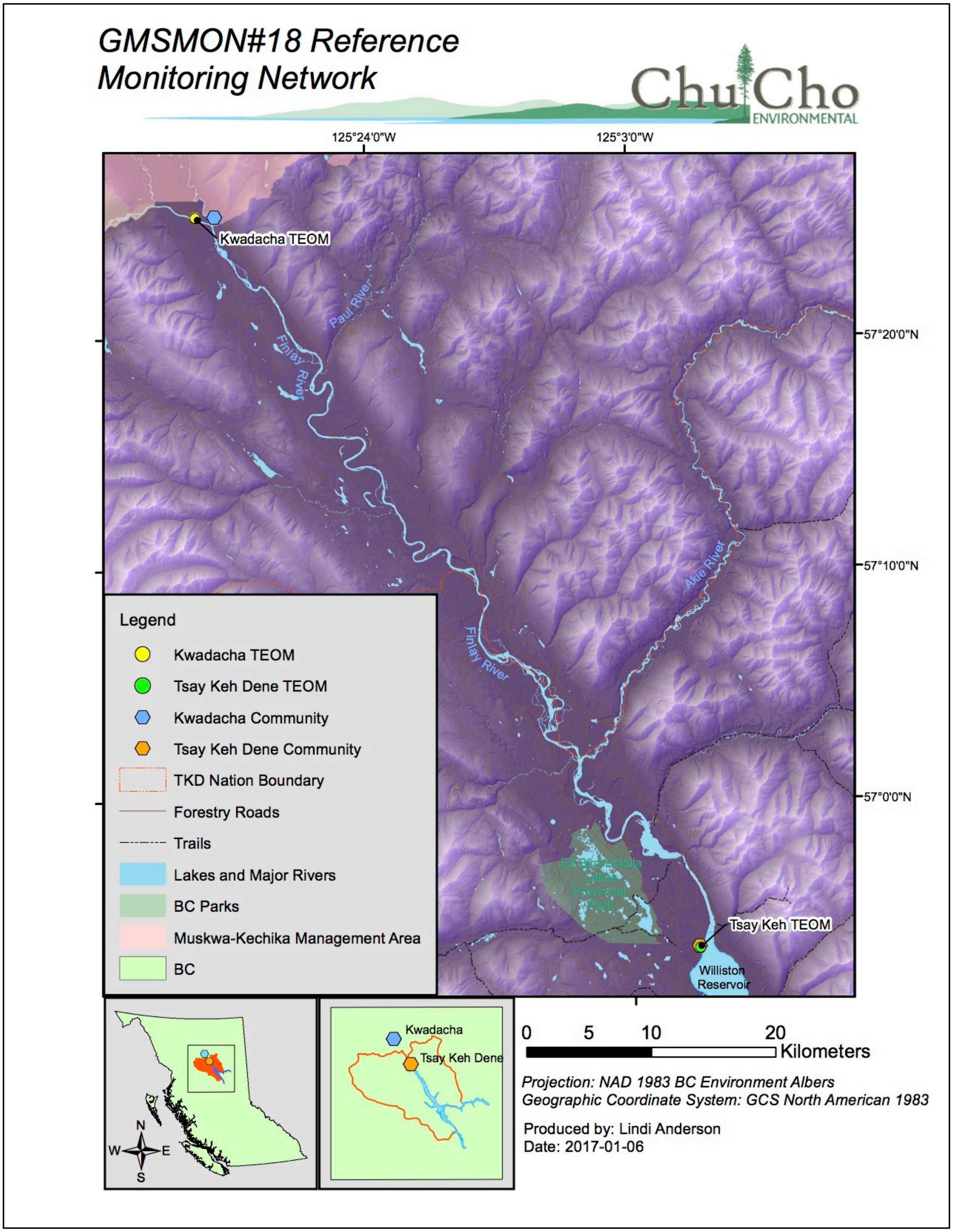

Figure 25: GMSMON#18 Reference Monitoring Network

Figure 26: Tsay Keh Dene Air Monitoring Station

Figure 27: Kwadacha Air Quality Monitoring Station

3.1.2 Instrumentation

The GMSMON#18 air quality monitoring project use Thermo-Fischer Scientific TEOM 1405-D Dichotomous Ambient Particulate Monitor.

- The TEOM (Tapered Element Oscillating Microbalance) measures the volume of particulate in the air by calculating the amount by which the oscillation of the microbalance is attenuated as particles land on the filter, which sits atop the microbalance. In order to perform this calculation the TEOM must maintain and record a steady airflow through the instrument.

- Instrument maintenance and calibration techniques are implemented to ensure that the microbalance oscillation and flow volumes through the instrument remain constant and do not drift.

- The TEOM 1405-D reads the oscillation at 1Hz and records the average particulate concentration over 10-minute, 8-Hour, and 24-Hour periods.

The TEOM units were installed in the fall of 2011 and became fully operational in January of 2012, thus 2014 represented the 3rd complete year of operation for the system. The CCME guidelines require three years of valid data in order to evaluate and validate the data against the CAAQS. However, the data collected from December 2012 to April 2014 are not of a known quality and Chu Cho Environmental has not been able to obtain records of maintenance or calibration performed during this time period. Chu Cho Environmental will use the unprocessed high frequency data that is stored on the TEOMs internal memory to verify as best as possible the data from this record but with no maintenance records the data will not be considered valid for use in CAAQS determination. Furthermore, TEOMs themselves are a notoriously unreliable instrument suffering frequent breakdowns that stop the collection of valid data. In 2015, the TEOM in Kwadacha suffered a circuit board failure. This TEOM was removed on July 7th, 2015, sent to the manufacturer for repair and wasn't returned until April 2016, at which point the drive pump suffered catastrophic failure. The Kwadacha TEOM was repaired and brought back online once again in July 2016. The TEOM functioned well until November 2016 when the pump suffered failure again. The system was brought back online again in February 2017, the pump failed yet again in July 2017. TEOMs are known to have a multitude of reliability issues hence the provincial decision to migrate to the Thermo Sharp 5030. The TEOM in Tsay Keh Dene performed well during 2014, 2015, 2016 and 2017 seasons, however Chu Cho Environmental did have to replace the flow controller circuit board in this TEOM as well as perform several maintenance procedures that resulted in some limited loss of data. Overall the Tsay Keh TEOM data are of good quality while the Kwadacha data are of poor quality.

We will however evaluate the data collected by these instruments within the context of the CAAQS and the Provincial AQOs by simply comparing the results of our analysis to the standards/guidelines provided by the Federal and Provincial governments. To be clear, the data presented in the following sections should not be considered valid for comparison to health standards or otherwise. We will use them here to provide insight into the air quality in Tsay Keh Dene and to work towards addressing the key management question.

Once we obtain proper service records and have created the algorithms required to process the high frequency TEOM data, it is our plan to include a CAAQS determination calculation for $PM_{2.5}$.

3.1.3 Reference Monitoring Network Data Quality Objectives

When assessing the data obtained from the Reference Monitoring Network for completeness and validity, Chu Cho Environmental utilizes the following DQOs:

- Accuracy:
  - The TEOM 1405-D units must be calibrated and maintained to sustain an accuracy of greater than +/- 10%.
- Precision:
  - The TEOM 1405-D units must be calibrated and maintained to sustain a precision that deviates less than 10% deviation from a zero standard. This is done through K_0 Verification, Leak Checking and Flow Auditing.
- Completeness:
  - In order to be considered a valid data reading the TEOM 1405-D must record data for greater than 75% of the available hours within a day. This means that in order to be considered a valid day of data there must be at least 18 hours of data recorded.
  - During the hours of data collection the TEOM 1405-D must be operating within the tolerances described above for accuracy and precision not only with respect to the oscillating microbalance but also for the flow controllers and auxiliary instrumentation.
  - In order to be considered a valid dataset the TEOM 1405-D must record at least 70% of the available hours within a year.
- Averaging Period:
  - TEOM 1405-D data are measured at 1Hz and are recorded at 10-minute averages to the on-board memory, the CR1000 datalogger and the backup computer system. These data are downloaded and verified once or twice per month.
- Measurement Cycle:
  - TEOM 1405-D data is collected from January until December of each year. Data analysis is focused on the Period from April to June or what is typically called the dust season.

- Spatial Representativeness:
  - The samplers are located in areas where they will not be influenced by external factors that may cause sample bias. This includes the following specifications:
    - Sampler intake height is 5 metres above the earth's surface.
    - Sampler is located sufficiently far away from roadways and other sources of external contamination such as incinerators or factories.
    - Sampler intake is located sufficiently far away from airflow restrictions through 360 degrees of rotation and must be located at a distance away from an object that is at least 3 times the height of that object.
    - Sampler intake is located greater than 20 metres away from trees.
- Data Verification:
  - Data verification is the process by which the data are assessed to ensure that the minimum criteria are met for completeness and comparability. This process is automated through computer scripting.
  - As the data are processed, invalid days or measurements that are suspect are flagged so that the technician performing the verification can then manually inspect the data for the issue. This two-step process is essential in ensuring that the data collected by our network are meeting the requirements of our DQO program.

Chu Cho Environmental ensures that suitable technical procedures are in place to record and catalogue the processes that lead to successful achievement of the DQOs.

3.1.4 Methodology

In order to ensure that the data collected by the baseline monitoring stations are of a known quality we have implemented a Quality Assurance/Quality Control (QA/QC) program that is built on the guiding principles of the provincial monitoring network (BC MoE, 2009). For this project, Chu Cho Environmental performs site visits, instrument calibrations and audits and data validation.

TEOM 1405-D air samplers require that the primary air filters be changed every 6 weeks or sooner as the filter loading approaches 90%. During each filter exchange members of our project team also perform the basic calibration and verification procedures to ensure that the TEOM and its meteorological equipment are functioning properly, these procedures include:

- K_0 spring constant verification of the oscillating TEOM components,
- Leak check verification to ensure that the TEOM is air tight,

- Inspection of numerical data recorded by the data loggers to ensure that all instruments are functioning properly and that the readings reflect a reasonable reality,
- A visual inspection of all meteorological and TEOM equipment,
- The TEOM enclosure is swept and all surfaces are cleaned with an ammonia based cleaning agent,
- The data system is inspected to ensure that all data are being recorded to the appropriate location and are being backed-up at regular intervals.

After every third filter exchange or sooner if necessary, members of our project team will perform the more advanced calibration and verification procedures that are required to ensure proper TEOM function, these include:

- The flow rates are audited and calibrated for each airflow channel: Bypass, $PM_{2.5}$, PM_{Coarse}
- The virtual impactor is dismantled and thoroughly cleaned using and ammonia based cleaner,
- All rubber gaskets are greased with vacuum seal silicon,
- All voltage points within the TEOM unit are checked to ensure that the numerous sensors are functioning properly,
- The additional TEOM sensors are calibrated, this includes the air pressure and temperature sensors.

In addition to the standard maintenance routines required to ensure data validity, there are several long-cycle routines associated with the physical TEOM components that suffer wear-and-tear. These items include the air pump (18 – 24 months) and several of the onboard sensors, which monitor airflow or temperature for example.

After each visit to the TEOM station our team technicians record their activities in a logbook that is kept inside the TEOM enclosure. This logbook is an important component of the QA/QC procedures.

By carefully crafting and implementing our QA/QC strategy we have managed to achieve a very high standard for data quality with only four data outages related to failing TEOM system components. Regular data outages are recorded when the technicians perform maintenance routines such as filter exchanges or K_0 verification but these are unavoidable. In order to be considered a valid data day the TEOM must record data for more than 75% of the available hours in a 24 hour period.

3.2 Reference Monitoring Network Data Overview

For this Year-10 final report we will analyze the 2017 datasets from the period covering January 2017 to December 2017, collected at Tsay Keh Dene.

3.2.1 Tsay Keh Dene Monitoring Station 24 Hour Average Air Quality and Meteorology Characterization

Figure 28 (a) through (d) shows plots of the 24-hour average meteorology and air quality data recorded at the Tsay Keh Dene monitoring station during between the period spanning January 2017 to December 2017.

3.2.1.1 Meteorology

In Tsay Keh Dene, the 2017 dust season was atypical as there were very little exceedances of either the BC Air Quality Objective (AQO) for PM_{10} or the federal CAAQS for $PM_{2.5}$ (Figure 28 a). Daily average wind speeds did not depart too much from the four previous years (2013-2016. During the dust season these daily average wind speed were right around 2.0 m/s and there were no days where the average wind speed exceeding 3.0 m/s (Figure 28 b). The dust season started off a little cooler than 2016 but by the middle of May the daily average temperature crept up to 10°C (Figure 28 c); for the remainder of the season, daily temperatures were roughly the same as they were in 2016. The dust season saw more rain in Tsay Keh Dene compared to the three previous years with some moderate to larger rain showers occurring in May (Figure 28 d), when more of the reservoir beaches are exposed (ie. June). It has been noted in the past that large dust events tend to be associated with rain events (Nickling et al 2013); this is because rain is associated with a drop in pressure and changes in pressure result in wind.

3.2.1.2 24-Hour Average Dust Concentrations

The 24-hour average PM concentrations for 2017 are shown in Figure 28 (a). The brown line represents PM_{10} and the green line represents $PM_{2.5}$, while the horizontal dashed lines across the plot represent the exceedance standards, that is an AQO of 50 $\mu g/m^3$ for PM_{10} (BC MoE, 2016) and 28 $\mu g/m^3$ for $PM_{2.5}$ for the CAAQS (CCME, 2012). Table 13 shows the 24-hour average value for days where the $PM_{2.5}$ value was greater than 28 $\mu g/m^3$ and the PM_{10} value was above 50 $\mu g/m^3$.

When averaged over 24-hours there were very few exdeedances of either the AQO or CAAQS. There was only one exceedance of the AQO for PM_{10} and only two exceedances of the CAAQS $PM_{2.5}$. Table 13 details these exceedances, showing that the only record of the AQOs being exceeded was during the dust season on May 3, 2017, and one of the only two CAAQS exceedances in 2017 was during the dust season on May 6. Exceedance values observed between the months of April and July are related to dust events. The other CAAQS exceedance was on December 16, 2017, which would have been related to wood smoke from home heating and a strong temperature inversion with no or very little wind that prevented the smoke from dissipating.

Table 13: 24-hour average 2017 PM_{10} and $PM_{2.5}$ values that were above the provincial AQOs and federal CAAQS.

Date	PM_{10} Value (µg/m^3)	Date	$PM_{2.5}$ Value (µg/m^3)
03-May-2017	59.0 (dust)	**06-May-2017**	40.4 (dust)
		16-Dec-2017	43.4 (smoke)

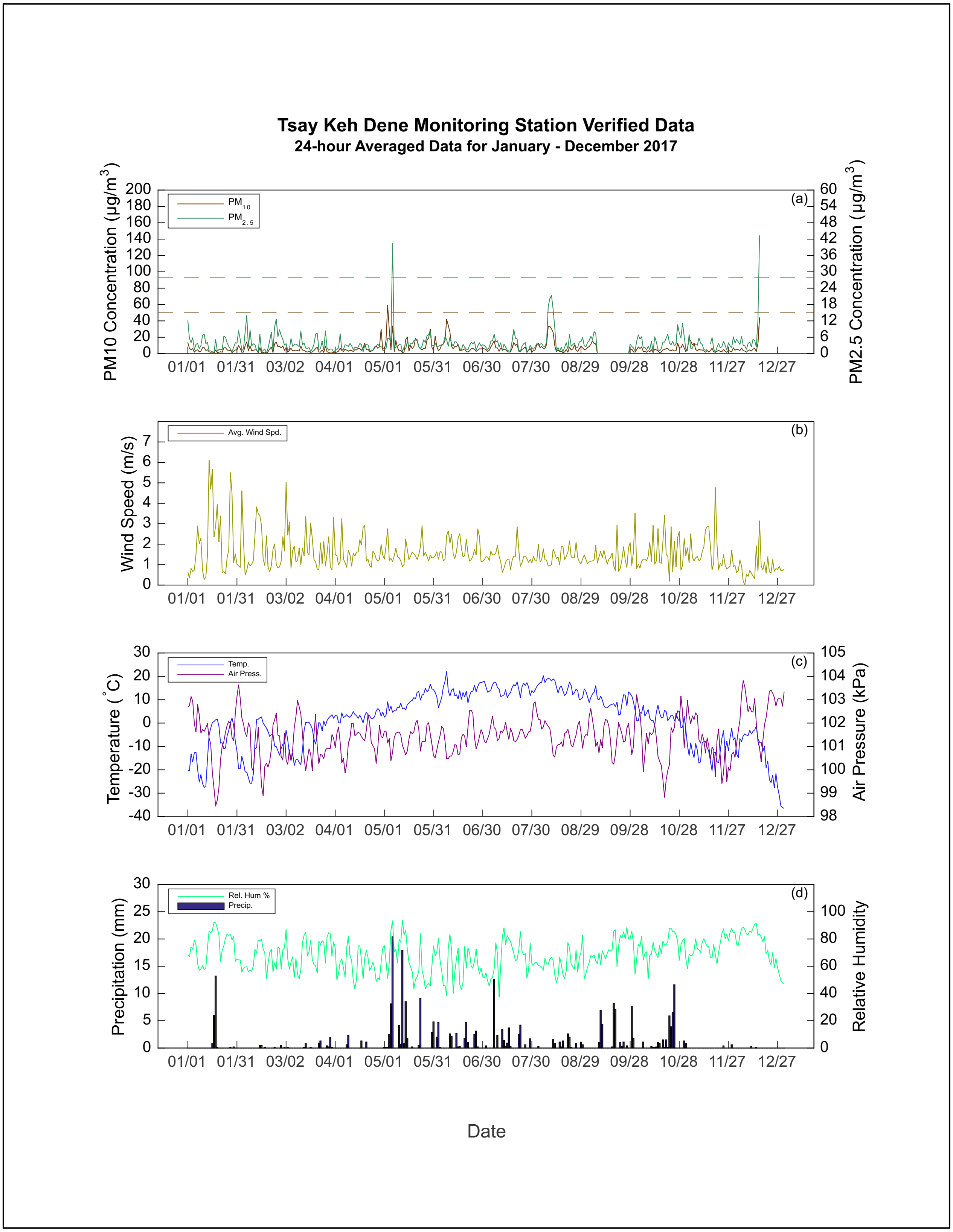

Figure 28: 2017 Tsay Keh Dene air quality monitoring station data – 24-hour average data. Exceedance standards in (a) are illustrated by the colour coded horizontal dashed lines.

3.2.2 Maximum Particulate Concentrations

Although there was only one PM_{10} and $PM_{2.5}$ exceedance events during the 2017 dust season (April 16th – June 27th), using the 24 hour metric for reporting air quality does not adequately represent the mode of air quality issues in Tsay Keh Dene because averaging tends to "smooth out" the extreme but short duration events that are typical of the air quality issues in Tsay Keh Dene.

All major dust activity in Tsay Keh Dene is derived from wind events that cause erosion on the beaches of the Williston Reservoir. These wind events are sporadic and vary greatly in magnitude, duration and frequency from one event to the next. As a result, these events may be highly localized and might persist for a short duration but the actual volume of dust emitted may be enormous. Under these conditions, calculation of a 24-hour average tends to minimize the actual impact of these acute dust events.

In this section we will evaluate the maximum value recorded for PM_{10} and $PM_{2.5}$ concentrations between April 16th, 2017 and June 27th, 2017. ***To be explicitly clear, the following analysis is in no way meant to be compared to the Federal and Provincial air quality standards or objectives and the reference values are merely presented on the following figures in order to provide relative context. This analysis also does not make any health or health-risk claims associated with the data presented below.***

Figure 29 shows the unfiltered 10-minute average PM_{10} and $PM_{2.5}$ data recorded by the Tsay Keh Dene TEOM 1405-D during the 2017 dust season. Note that 10-minute averaged data from the TEOM 1405-D is the smallest recordable increment the instrument outputs. The green dashed line in Figure 29 (a) represents an arbitrary reference value for $PM_{2.5}$ of 28 $\mu g/m^3$, while the brown dashed line in Figure 29 (b) represents an arbitrary reference value for for PM_{10} of 50 $\mu g/m^3$. These values are provided for reference only and are in no way meant to represent the provincial or federal air quality standards.

From April 10th to June 30th, 2017, there were a number of data spikes that represent large volumes of particulate entering the airspace around the TEOM 1405-D for a short period of time. The high intensity short duration data spikes are visible in Figure 29 (a) and (b), which contains the raw un-processed 10-minute average TEOM 1405-D PM_{10} and $PM_{2.5}$ data.

To demonstrate the high frequency, high intensity, short-duration events that impact Tsay Keh Dene, the daily maximum value has been extracted from the TEOM dataset for each day where one 10-minute average value was above the arbitrary reference values of 50 $\mu g/m^3$ for PM_{10} and 28 $\mu g/m^3$ for $PM_{2.5}$. These data are shown in Table 14.

Table 14: Maximum 10-minute average PM_{10} and $PM_{2.5}$ Values Recorded During the 2017 Dust Season in Tsay Keh Dene.

Date	PM_{10} Value (µg/m3)	Date	$PM_{2.5}$ Value (µg/m3)
18-Apr-17	54.91	**21-Apr-17**	31.19
29-Apr-17	121.6	**06-May-17**	214.5

Date	PM_{10} Value (µg/m3)	Date	$PM_{2.5}$ Value (µg/m3)
02-May-17	145.3		
03-May-17	465.1		
04-May-17	139.3		
06-May-17	194.8		
08-May-17	175.4		
14-May-17	80.4		
15-May-17	103.2		
17-May-17	65.67		
28-May-17	61.05		
29-May-17	89.3		
01-Jun-17	100.2		
06-Jun-17	80.2		
07-Jun-17	80.2		
08-Jun-17	296.5		
09-Jun-17	174.8		
10-Jun-17	107.4		
15-Jun-17	60.02		

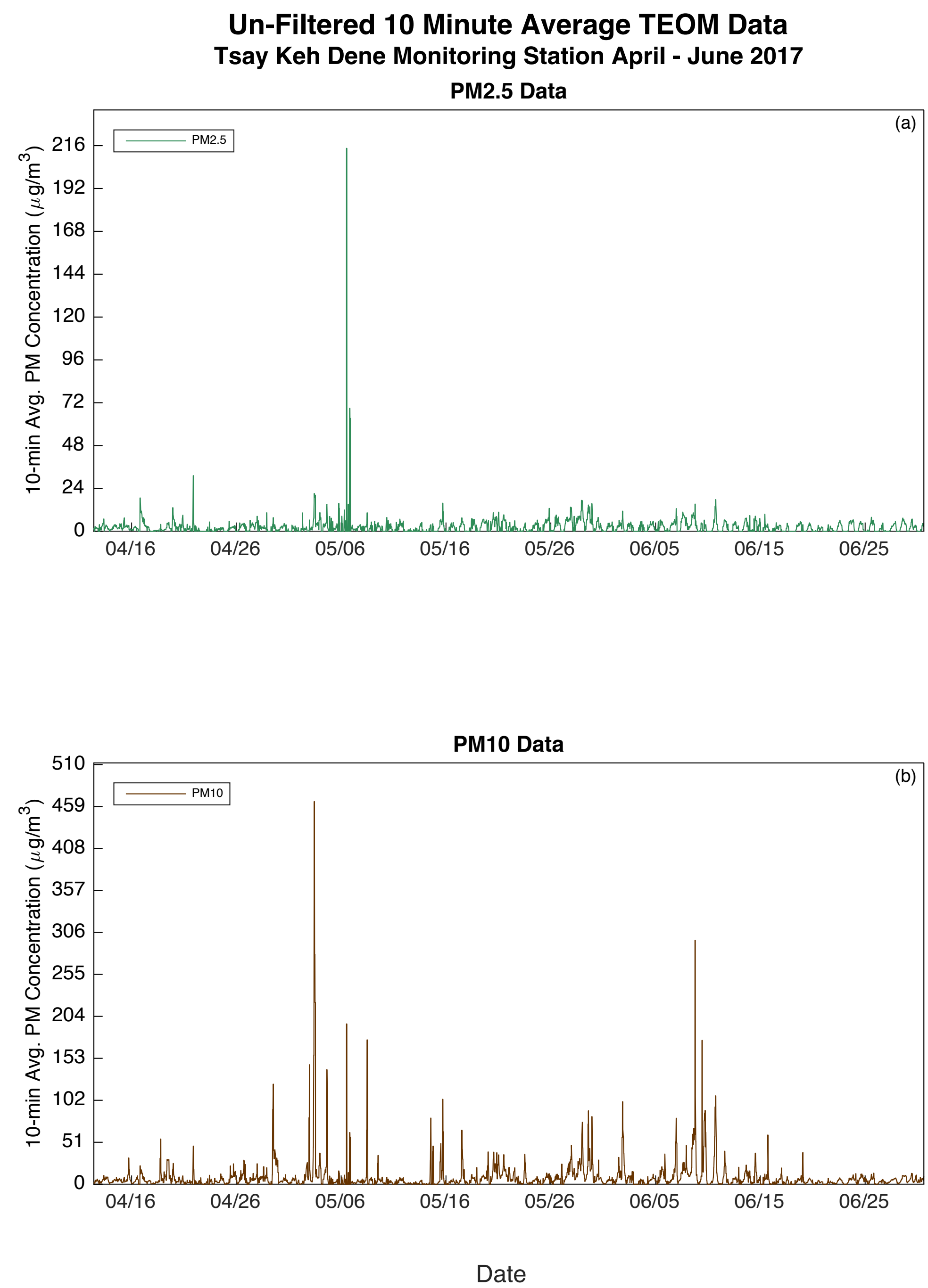

Figure 29: Raw 10-Minute Average TEOM data for the 2017 dust season. Horizontal dashed lines represent an arbitrary reference value.

3.3 Data System and Remote Access

Data from the TEOM units and associated meteorological equipment are accessed and displayed in several different ways. Our goal is to provide the highest level of data security and reliability by using multiple redundant systems that record, process, store and distribute the data. We are also looking at methods to continue to improve the ways in which people can view and interact with the data collected by the air quality monitoring network. To date, we have implemented the following system changes to improve connectivity, security and access:

Community Data Display:

Data are currently being streamed from the dataloggers using Campbell Scientific RF401 spread-spectrum 900 MHz radio transmitters and receivers. Campbell Scientific provides hardware and software that can be manipulated to display in real-time the data that are collected by the TEOM 1405-D and meteorological equipment. An omni-directional antenna that broadcasts the 900 MHz signal is mounted on the TEOM enclosure and is powered by the RF401. A second RF401 receiver unit equipped with a whip-antenna is attached to a laptop that is running Campbell Scientific's LoggerNet software. This computer is connected to a 32" TV that is wall-mounted in the Tsay Keh Dene band office and Kwadacha school. This system has proved extremely reliable, requiring only limited intervention to reset following system faults. We will continue to update the data display to keep it relevant and interesting.

Daily email:

Data from the CR1000 datalogger are downloaded over an RS-232 serial connection to a server computer located inside the TEOM enclosure. These data are processed into 10-minute averages and are then appended into 12-hour data files. After the processing is complete, the 12-hour data file is emailed to the project manager and field managers. Simultaneously the data are backed up to a system USB-key and are also uploaded the Chu Cho Environmental's ftp site. New for 2015 are a fourth and fifth layer of backup redundancy that includes a full system hard drive ghosting every 24 hours and a Dropbox backup of the key system and data files. If there is an issue with the data of if there is an issue with the TEOM of any of the meteorological instrumentation then a special email is sent out alerting the managers of the issue. This email provides a very quick way to check on the monitoring system to ensure that it is functioning properly.

www.logmein.com:

www.logmein.com provides remote desktop access to the server computers inside the TEOM enclosures. This is the most reliable method for creating remote access to these server machines that operate inside the VPN created by the Tsay Keh Dene IT group. This remote access allows us to reboot any component of the monitoring system and greatly improves our overall system reliability and up-time.

4.0 Ancillary Objectives

In addition to providing the management services required to operate the air quality monitoring systems, Chu Cho Environmental built a program centered on capacity building, knowledge transfer and community engagement. This program is focused on mentorship and skills development within Tsay Keh Dene band members and is also meant to provide a link between community members and the science of the Williston Dust Mitigation Program.

4.1 Mentorship Program

In our mentorship program we utilize a process of employee self evaluation and management evaluation of employees to monitor metrics in the form of Key Performance Indicators (KPIs) such that each employee can track their success and growth as an environmental monitor and in particular an air quality technician. The metrics that we use as guidelines include but are not limited to the following:

- Worker is able to fully download the data and recalibrate the instrument on their own.
- Worker is able to diagnose problems and develop, record and communicate a working solution in the field.
- Worker is able to make, record and communicate management decisions in the field.
- Worker is careful, thoughtful and thorough with regards to scientific issues.
- Worker is always safe.
- Worker always makes unbiased decisions with regards to the scientific process.
- Worker makes good field notes with clear observations and records that are both relevant and important.
- Worker is competent with a field computer for data capture and storage.
- Worker is developing a sense of confidence with regards to program tasks and knowledge about air quality.
- Worker is sensitive to QA/QC issues and takes great pride and care in ensuring that the instrumentation is always functioning properly and with proper calibration requirements.

We at Chu Cho Environmental recognize that it is our responsibility and commitment to provide an open and communicative work environment in order to cultivate success and growth within our employees. We also utilize a number of non-specific personality metrics in order to evaluate the overall confidence and aptitude growth of our employees. To date we achieved exceptional growth in knowledge and confidence within four of our employees and we expect continued growth through the future of this project.

Chu Cho Environmental now has full-time employees in Tsay Keh Dene who are able to autonomously manage the basic maintenance and operation of the Air Quality Monitoring Stations. These employees possesses a rudimentary understanding of how the instrument functions and what normal operation should entail. When a major issue is encountered, the employees alert the Chu Cho Environmental project manager immediately and the problem is rectified as soon as possible. Due to the remoteness of the TEOM monitoring stations and the difficulty in maintaining a reliable internet connection to the machine, it is imperative to have well trained local employees who can frequently visit the instrumentation to ensure proper operation. This has been one of the greatest improvements in our program and has contributed to our overall success in reducing instrument downtime.

4.2 Community Engagement

Chu Cho Environmental is a band owned company and regularly participates in community events such as open houses or village gatherings where the exchange of information is encouraged between community members and organizations. We do not present unverified air quality data at these events but instead provide visuals and information related to the project and what we are doing to monitor and help improve the air quality in Tsay Keh Dene.

Chu Cho Environmental also built community data displays that are presented on TVs that are wall-mounted in the Tsay Keh Dene band office and the Kwadacha school. The data are broadcast in real-time from the TEOM enclosure using an RF401 900 Mhz spread spectrum radio transmitter and are received on an RF 401 that is attached to a computer which runs the TV data display. Figures 35 through 37 show sample screen grabs of the data display, note that there is no live data shown in these images. These displays are meant to be easy to read at a glance and will continue to be updated and refined as Chu Cho Environmental continues to manage the project. The data area broadcast from the monitoring station at the same frequency as they are being recorded by the CR1000 data logging system, this means the weather data are updated every 10 seconds and the air quality data are updated every 10 minutes.

This method of displaying the data is quite reliable but ultimately depends on a PC laptop running Windows 7 and so suffers crashes related to operating system failure. Maintaining and rebooting this system has also been incorporated into the training of the technicians who maintain the TEOM monitoring stations.

The new data display system includes the following major updates:

- More intuitive screen widgets to display the data,
- A “Last Data Update” timestamp that shows when the data were received,
- High quality graphics and visuals that are nice to view, and
- High frequency and increased reliability link to the data source.

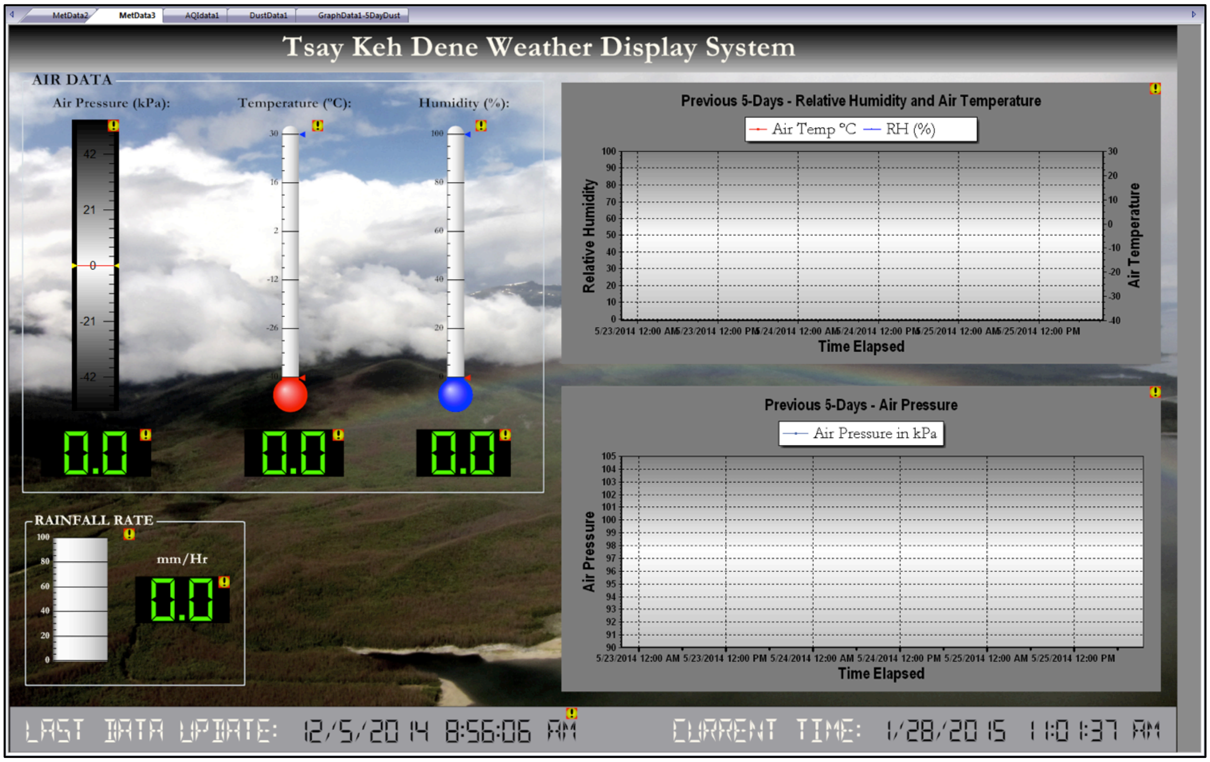

Figure 30: Data Display Air Parameters and 5-Day Charts

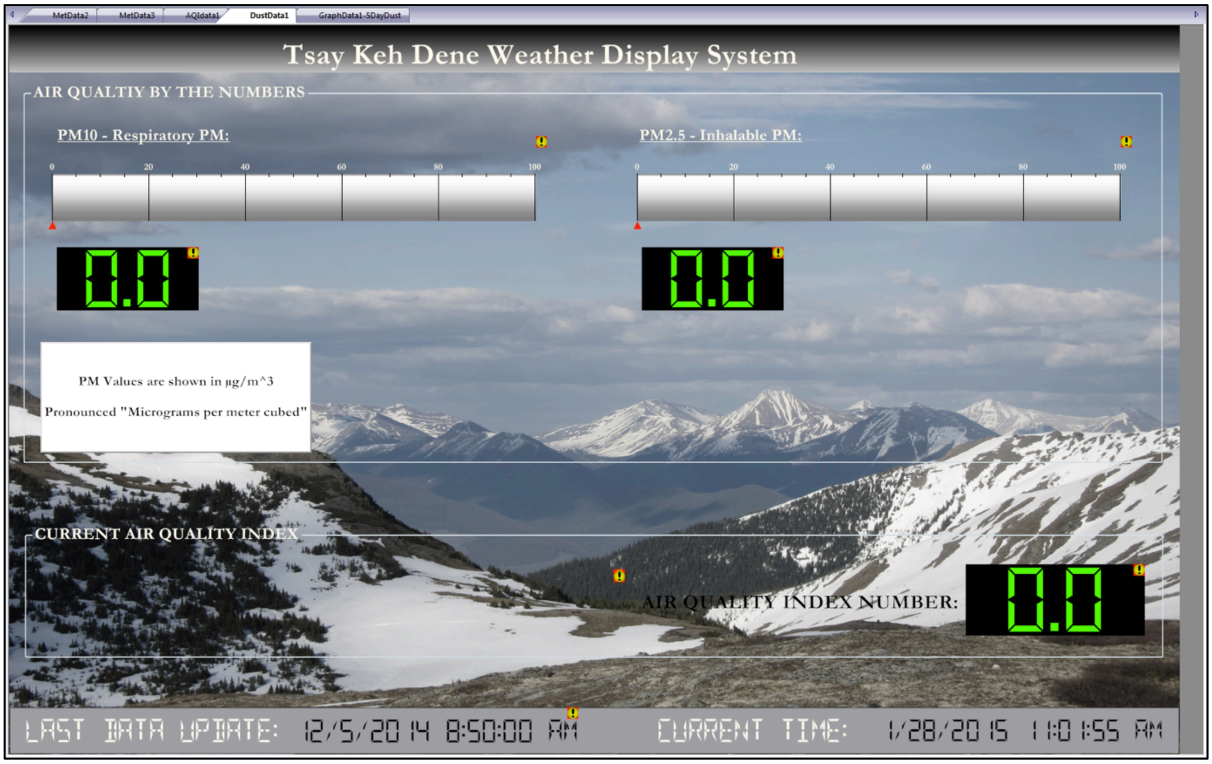

Figure 31: Data Display Air Quality Data and Air Quality Index

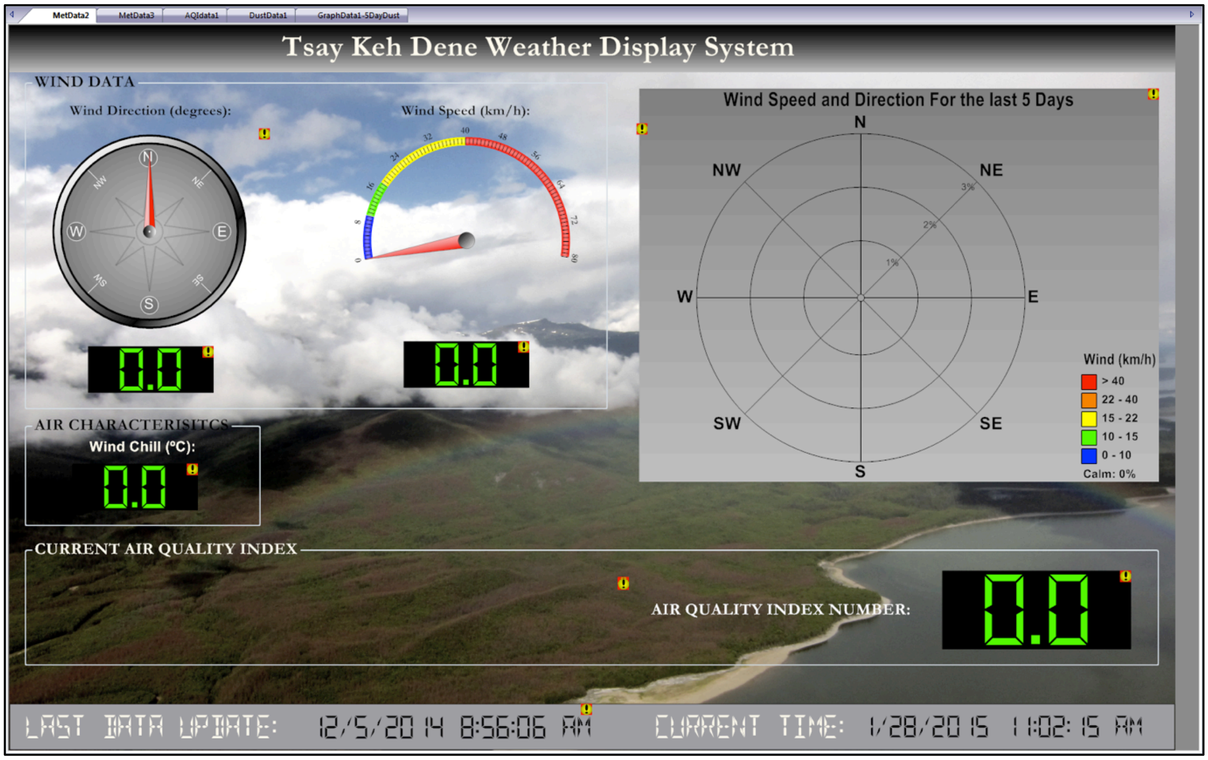

Figure 32: Data Display Wind Parameters and 5-Day Wind Rose

5.0 Discussion and Direction for 2018

5.1 Brief Summary for 2017

Through discussion with BC hydro representatives it was determined that Chu Cho Environmental would submit an annual report in January of each year. This report will be reviewed internally by BC Hydro and the edits will be delivered to Chu Cho Environmental by March of each year. Following this Chu Cho Environmental will update and revise the report and will issue a final version by April of each year.

Each of the annual reports prepared by Chu Cho Environmental should ultimately be considered individual annual building blocks that will lead up to a comprehensive 10-year analysis report that is being prepared.

Overall, we at Chu Cho Environmental consider 2017 a successful year for the GMSMON#18 project. Our team has continued to collect an enormous amount of data that industry and academic air quality experts (modellers' in particular) have deemed unparalleled and unique. The dust season for 2017, was similar to the previous two years years, however these years were not dusty years. Of course there were some disappointments in 2017, due to wildlife, power and ongoing equipment issues. Repeated bear sightings and damage to the equipment at Shovel required the E-Sampler be permanently pulled from that site. Repeated power issues with different pieces of equipment at 57 km meant that data was absent for many days at a time. Repeated and ongoing catastrophic issues with the TEOM in Kwadacha have been both frustrating and disappointing.

The primary finding presented somewhat repeatedly throughout this report note that dust storms are not discrete long duration events that always result in the exceedance of Provincial or Federal standards. Instead we must think of dust events as having dynamic impacts and a range of characteristics. Dust events can range in scale from short duration, isolated, microburst-type occurrences to extreme duration events, covering a very large area of the Finlay Reach of the Williston Reservoir.

There are several areas throughout the reservoir that show regular and repeated incidences of fugitive dust emissions, even during low-dust years. These locations are the so-called "hot spots" and are likely suitable candidates for erosion control measures.

Finally, we would like to remind the reader that the analysis and conclusions presented in this report represent a very preliminary approach to examining the enormous amount of that that was collected by the monitoring networks in 2017.

5.2 Direction for 2018

With the extension of the project for another two years, Chu Cho Environmental will be working to refine dust-monitoring program to be more effective and efficient. Part of this refinement process is removing sites from the monitoring networks:

- Sites that may be duplicating data from another nearby site,
- Sites that are not severely impacted by fugitive dust emissions from the reservoir, or

- Sites whose travel time, monitoring, and/or return on useful data makes their deployment cost prohibitive.

Thus far for the winter of 2017/2018, the Williston Reservoir elevation has been roughly 2-3 m below levels during the same time period one year earlier. This is an indication that 2018 may a dusty year along the Finlay Reach.

Chu Cho Environmental LLP and Chu Cho Industries LP are in the same family of companies and are working to developing a closer integration for the 2018 season. Chu Cho Industries has obtained new dust mitigation equipment for use in the 2018 dust season. Chu Chu Environmental will be deploying additional resources in order to evaluate the effectiveness of the new equipment.

6.0 REFERENCES

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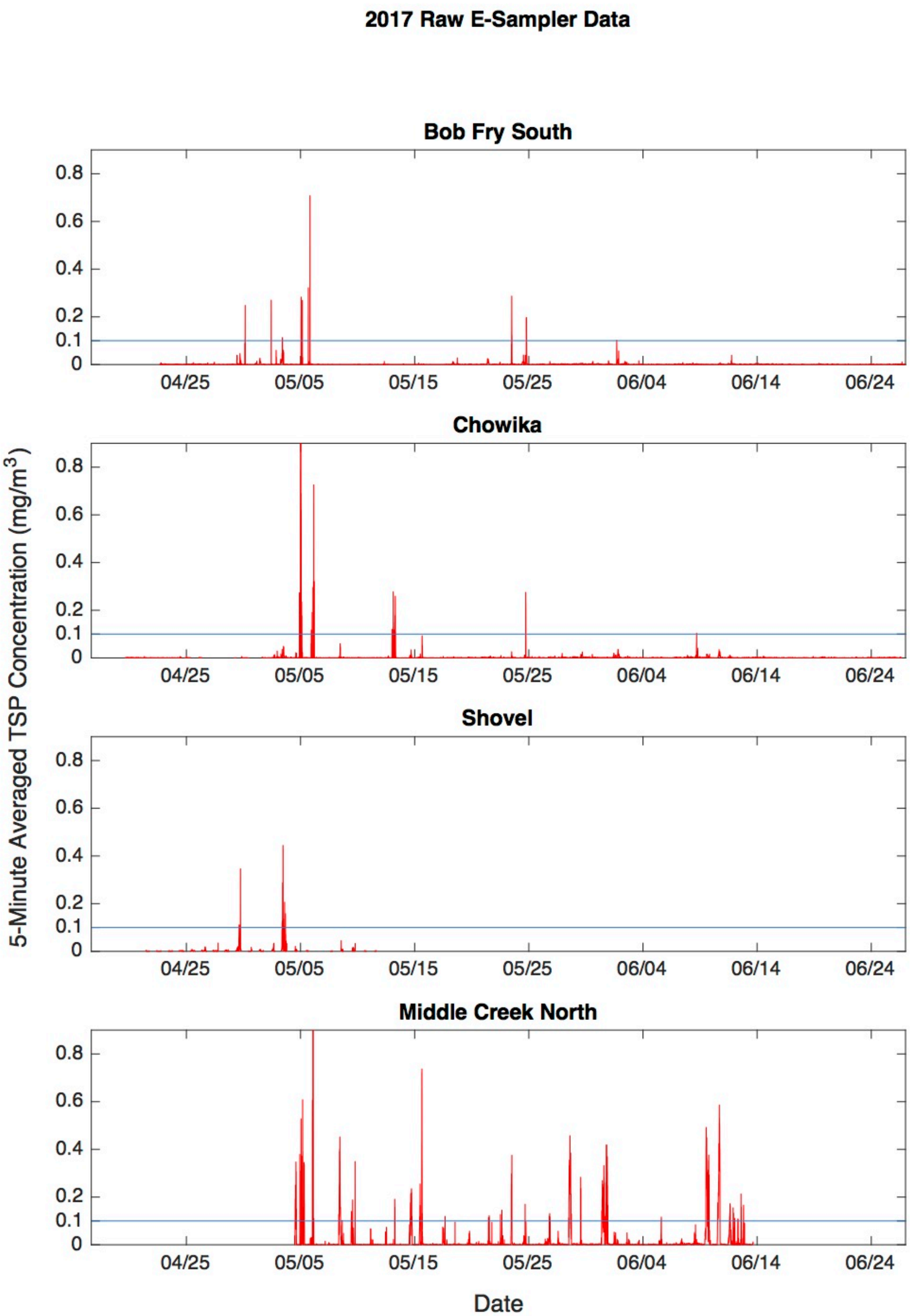
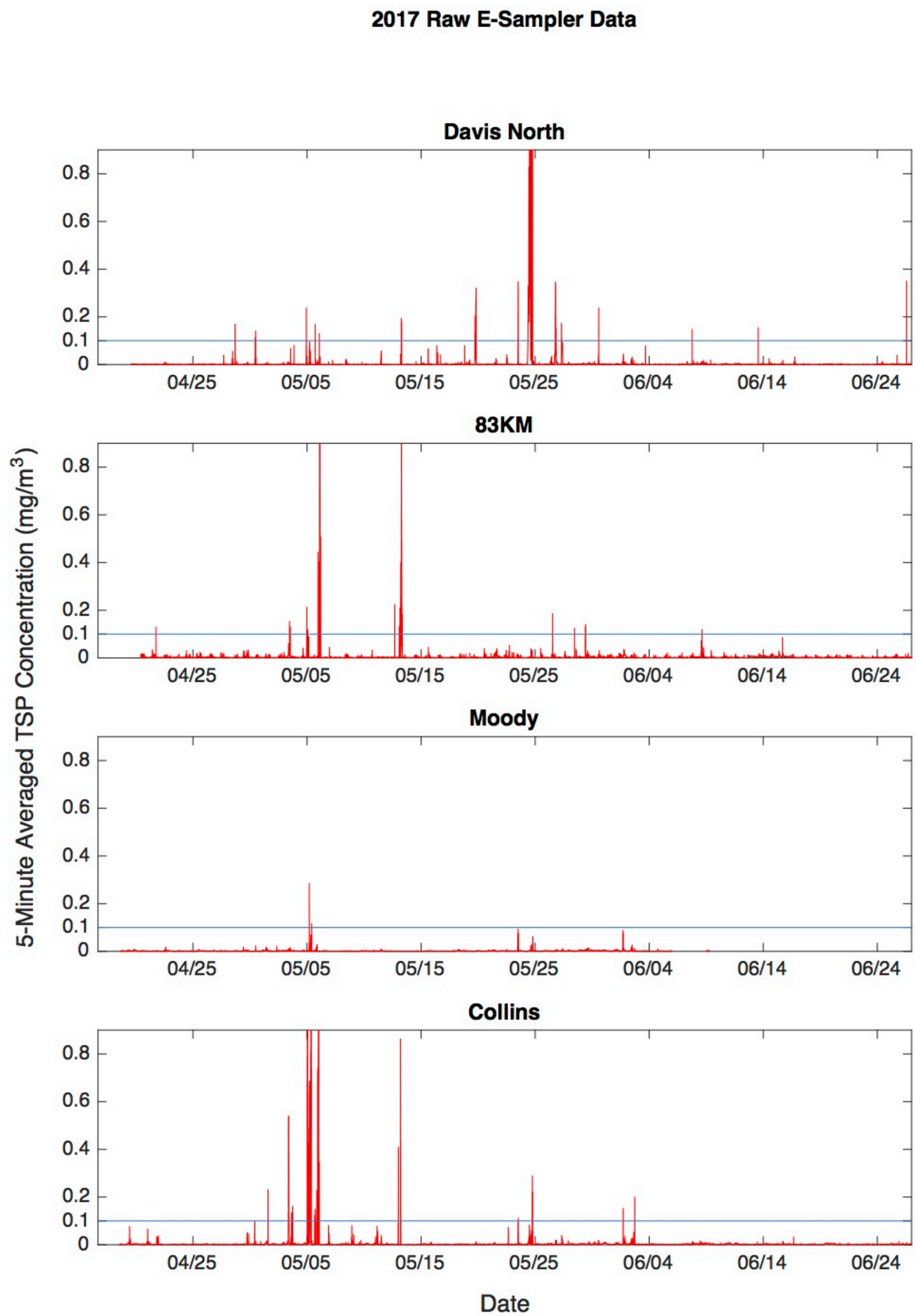
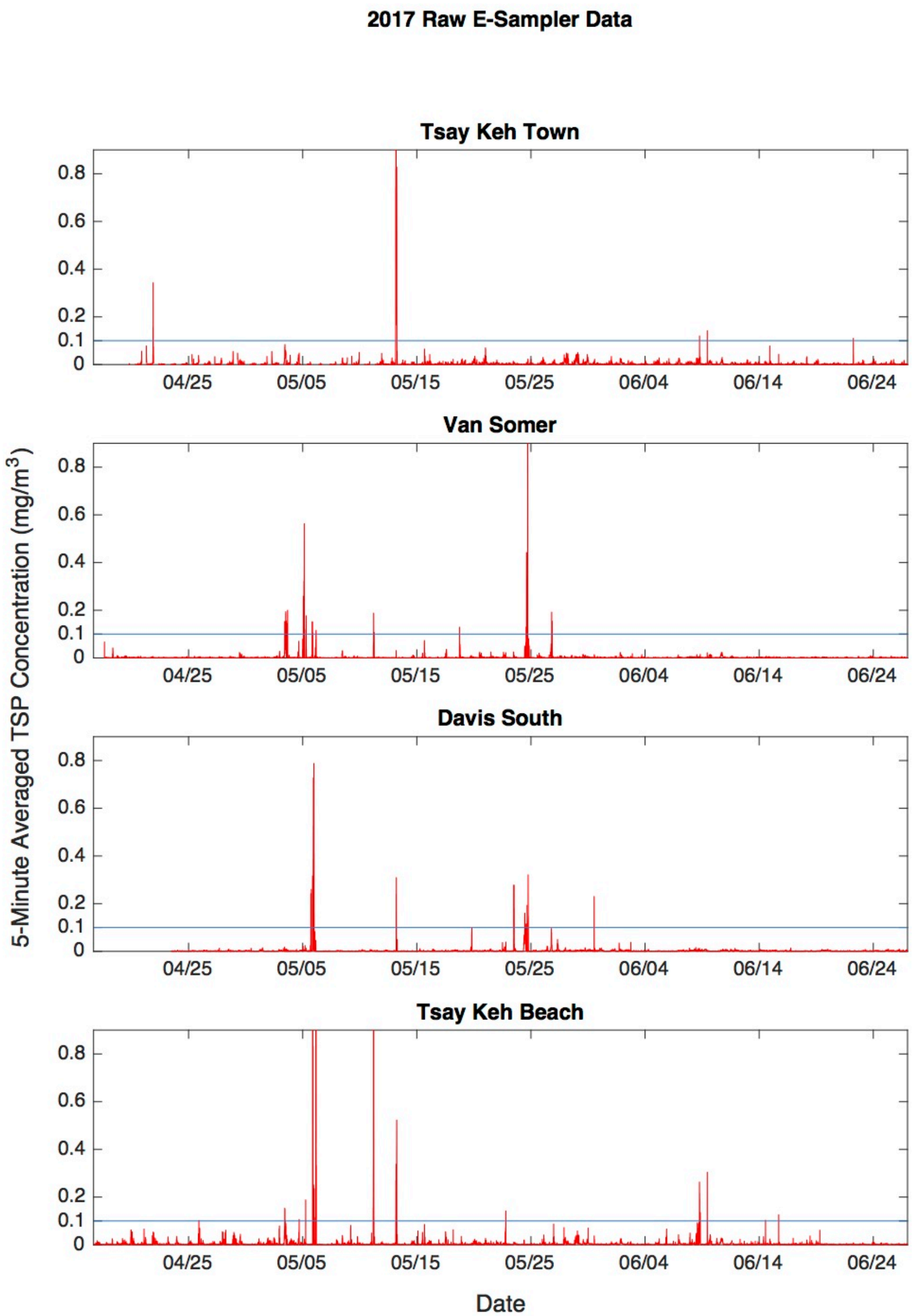
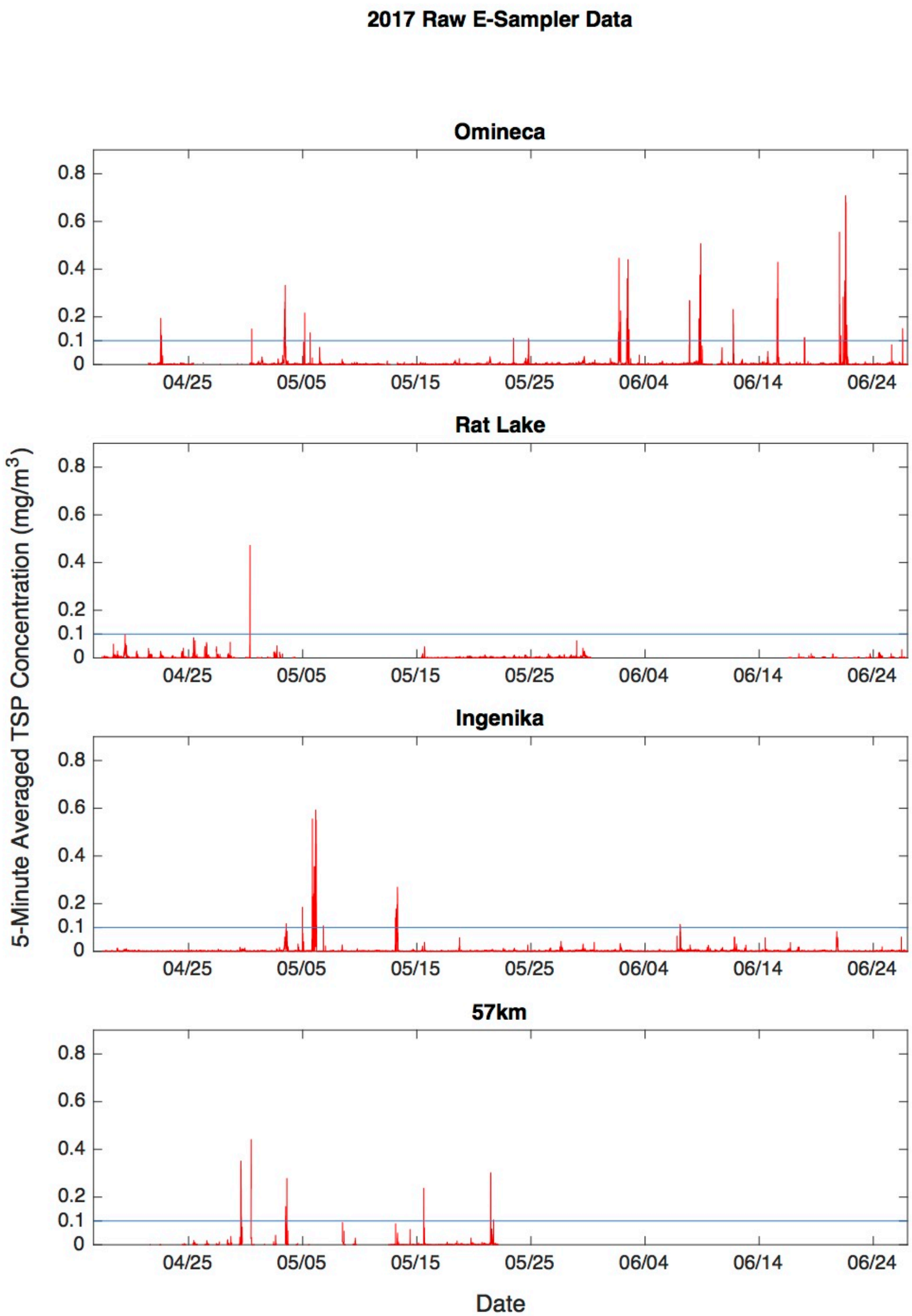
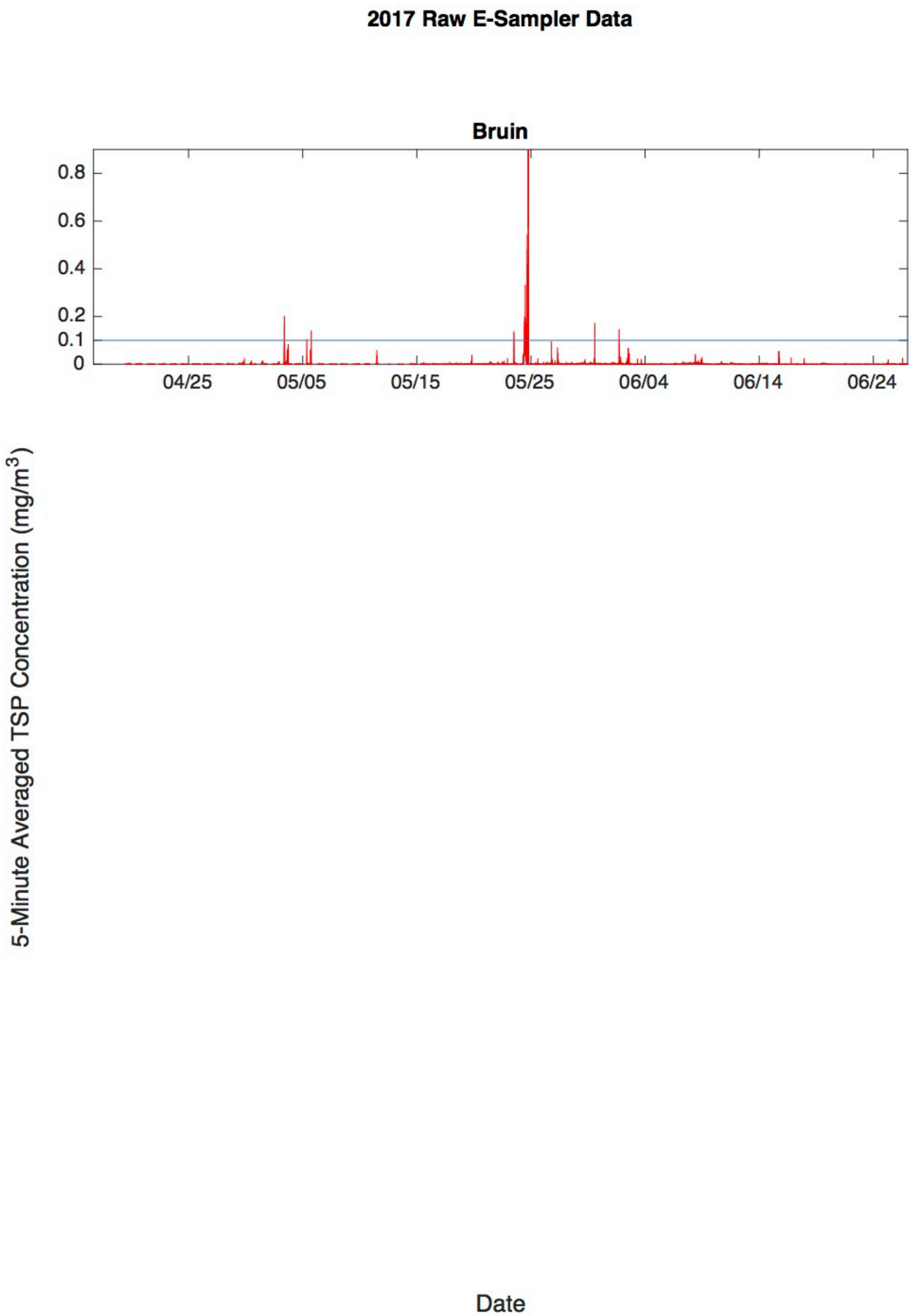
APPENDIX A E-SAMPLER TEMPORAL DATA


2017 Raw E-Sampler Data
Bob Fry South
Chowika
Shovel
Middle Creek North
5-Minute Averaged TSP Concentration (mg/m3)
0.8
0.6
0.4
0.2
0.1
0
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date

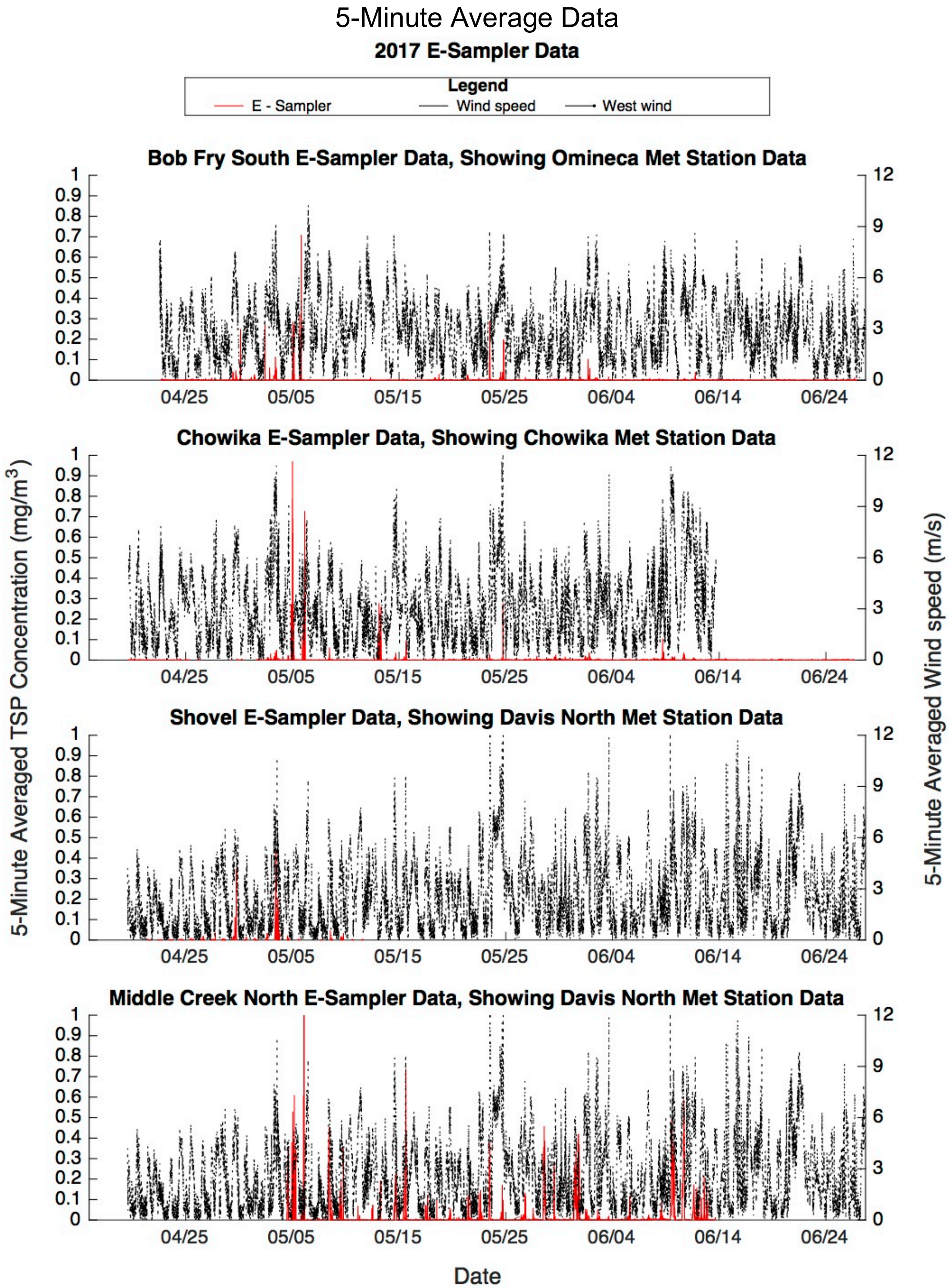

2017 Raw E-Sampler Data
Davis North
83KM
Moody
Collins
5-Minute Averaged TSP Concentration (mg/m3)
0
0.1
0.2
0.4
0.6
0.8
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date

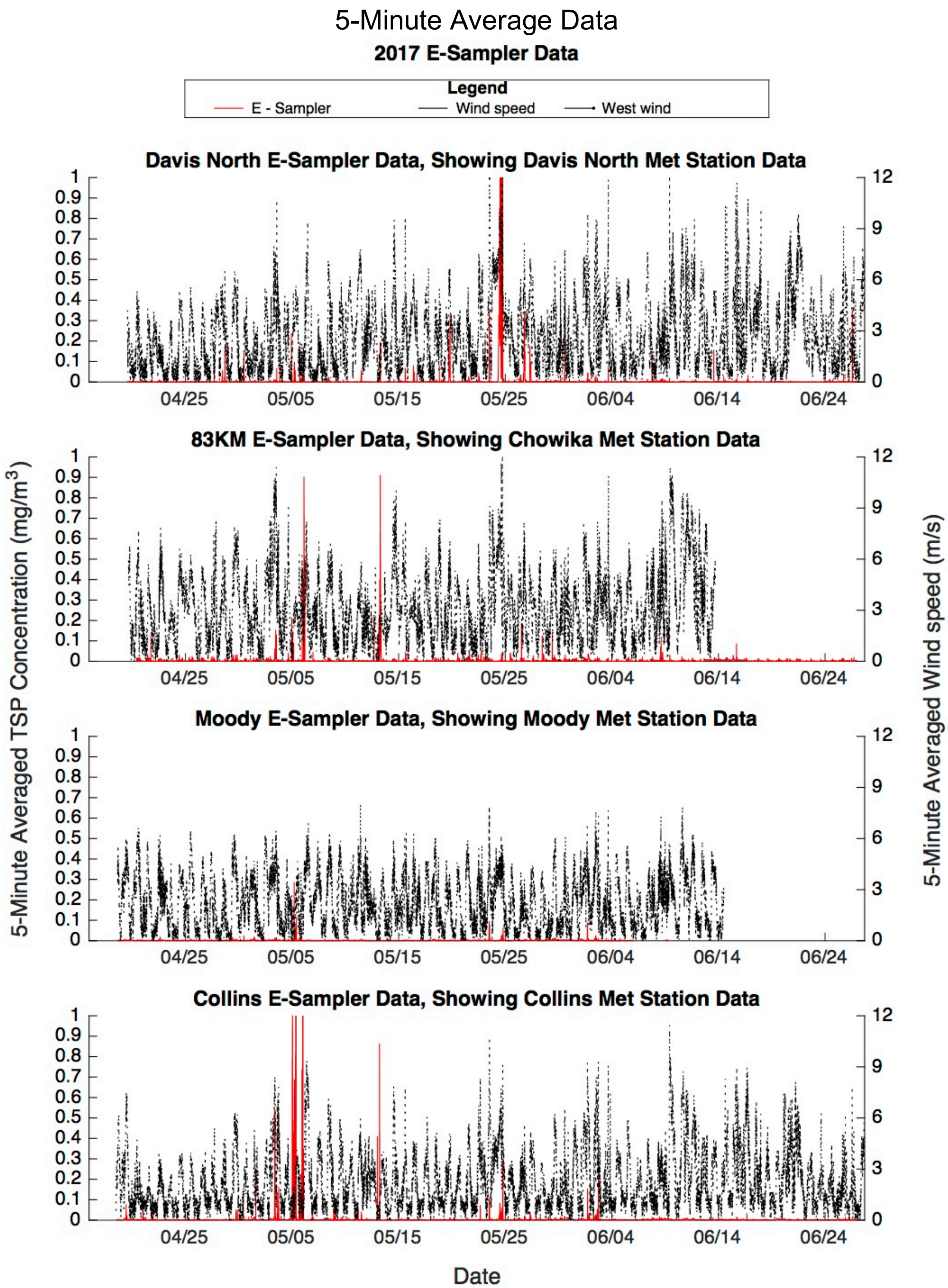

2017 Raw E-Sampler Data
Tsay Keh Town
Van Somer
Davis South
Tsay Keh Beach
5-Minute Averaged TSP Concentration (mg/m3)
0.8
0.6
0.4
0.2
0.1
0
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date

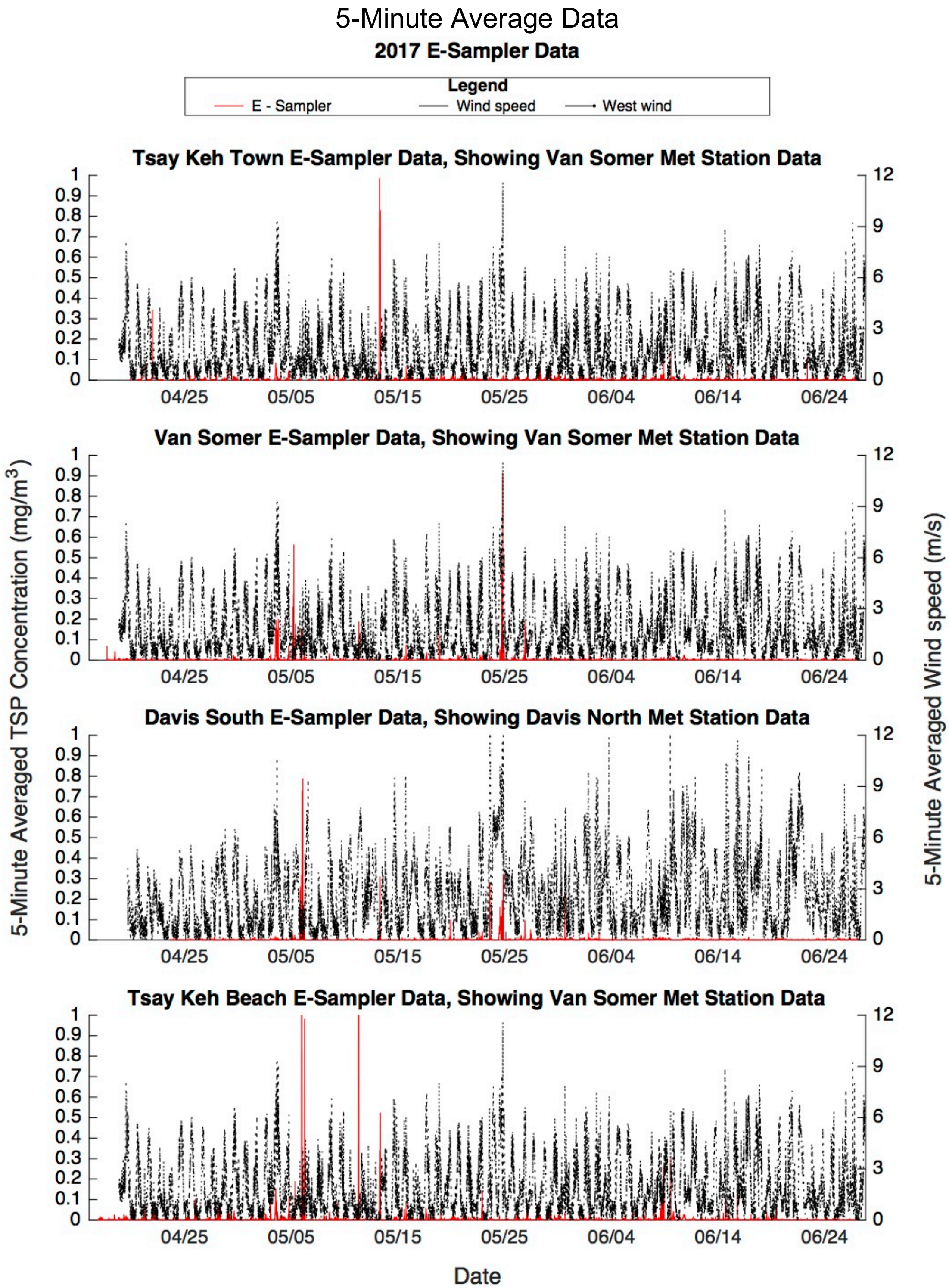

2017 Raw E-Sampler Data
Omineca
Rat Lake
Ingenika
57km
5-Minute Averaged TSP Concentration (mg/m3)
0
0.1
0.2
0.4
0.6
0.8
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date

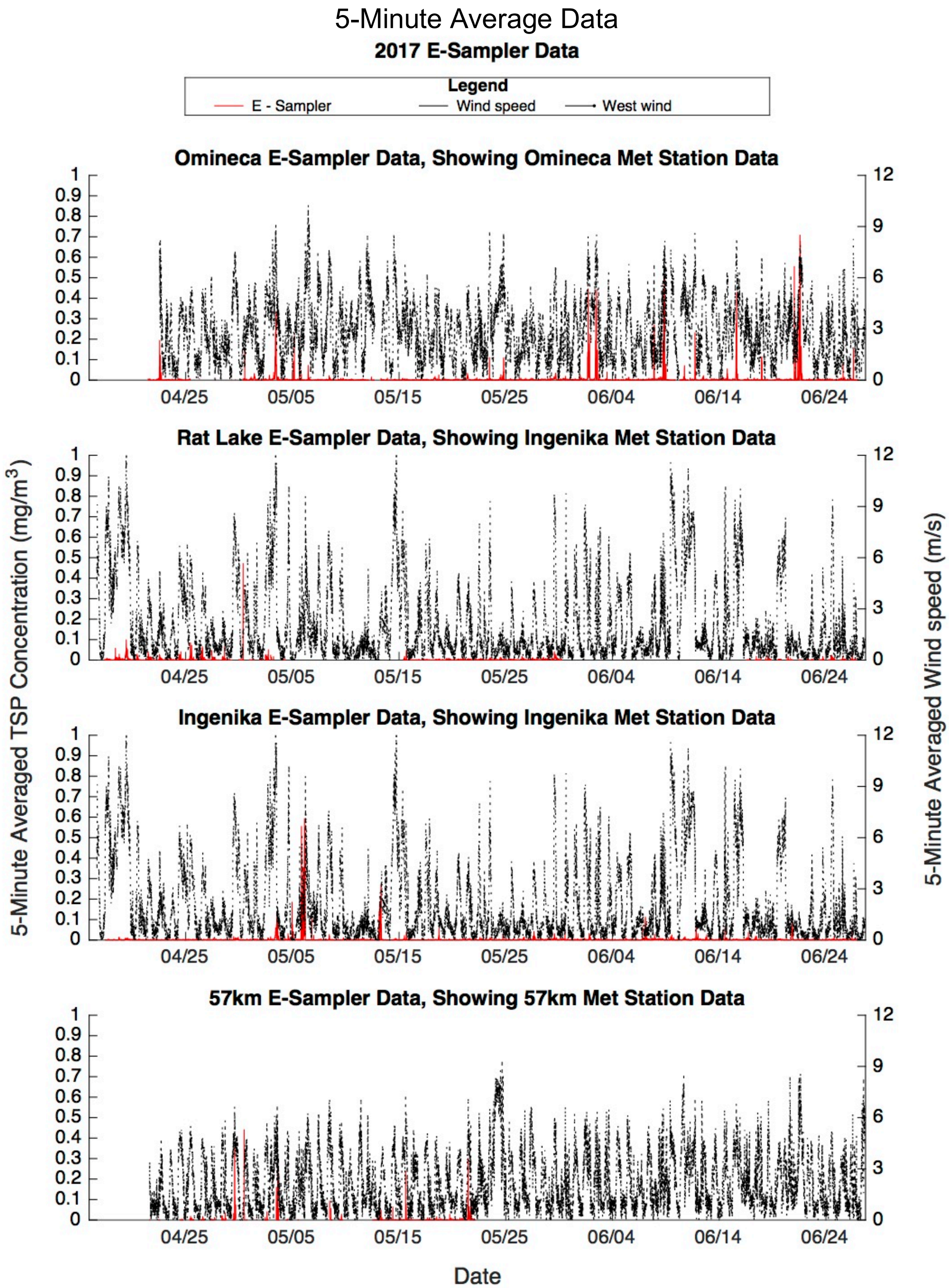

2017 Raw E-Sampler Data
Bruin
0.8
0.6
0.4
0.2
0.1
0
04/25
05/05
05/15
05/25
06/04
06/14
06/24
5-Minute Averaged TSP Concentration (mg/m3)
Date

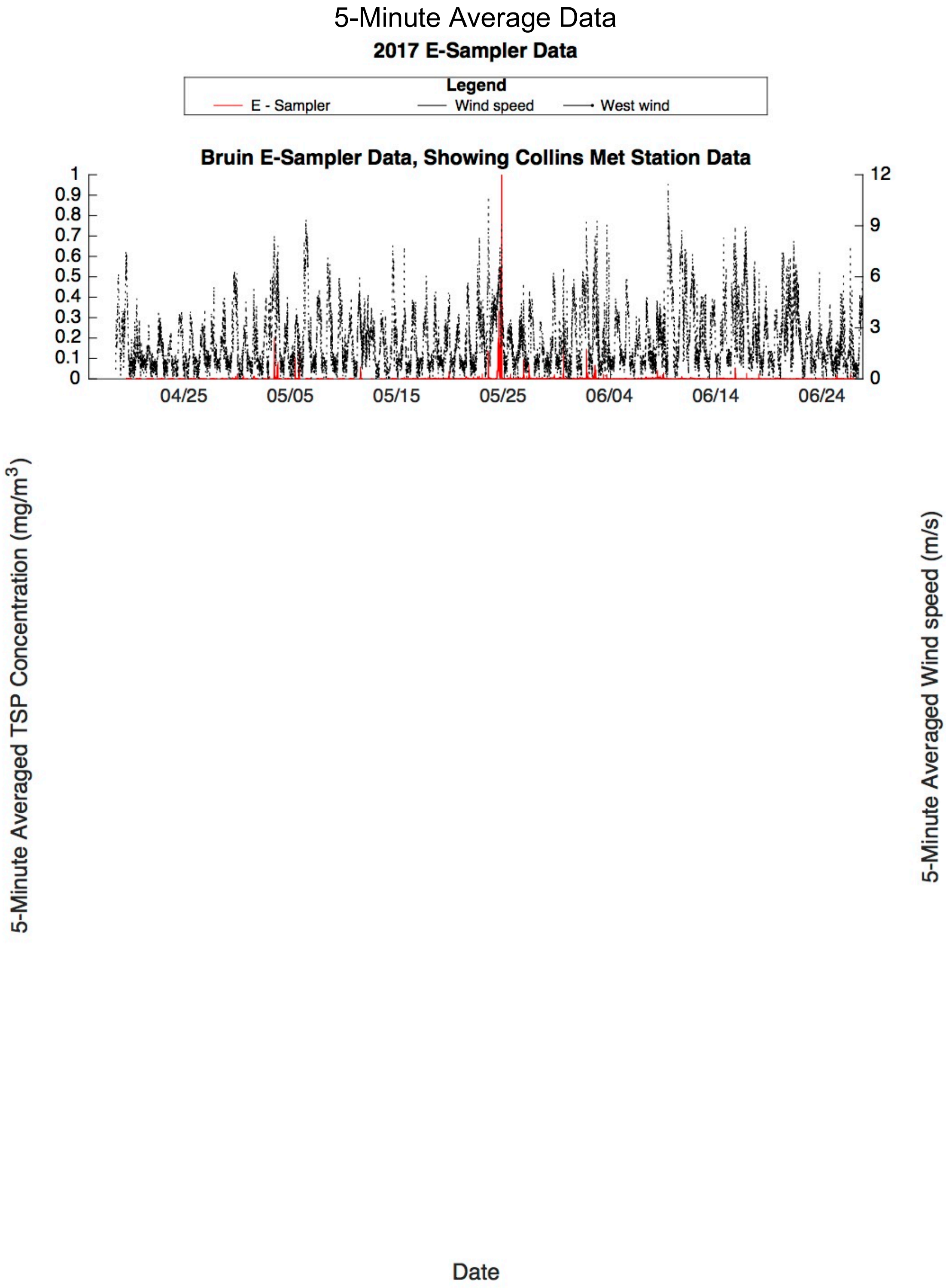
APPENDIX B E-SAMPLER DATA OVERLAYED WITH WIND SPEED


5-Minute Average Data
2017 E-Sampler Data
Legend
E - Sampler
Wind speed
West wind
Bob Fry South E-Sampler Data, Showing Omineca Met Station Data
Chowika E-Sampler Data, Showing Chowika Met Station Data
Shovel E-Sampler Data, Showing Davis North Met Station Data
Middle Creek North E-Sampler Data, Showing Davis North Met Station Data
5-Minute Averaged TSP Concentration (mg/m3)
5-Minute Averaged Wind speed (m/s)
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date


5-Minute Average Data
2017 E-Sampler Data
Legend
E - Sampler
Wind speed
West wind
Davis North E-Sampler Data, Showing Davis North Met Station Data
83KM E-Sampler Data, Showing Chowika Met Station Data
Moody E-Sampler Data, Showing Moody Met Station Data
Collins E-Sampler Data, Showing Collins Met Station Data
5-Minute Averaged TSP Concentration (mg/m3)
5-Minute Averaged Wind speed (m/s)
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date


5-Minute Average Data
2017 E-Sampler Data
Legend
E - Sampler
Wind speed
West wind
Tsay Keh Town E-Sampler Data, Showing Van Somer Met Station Data
Van Somer E-Sampler Data, Showing Van Somer Met Station Data
Davis South E-Sampler Data, Showing Davis North Met Station Data
Tsay Keh Beach E-Sampler Data, Showing Van Somer Met Station Data
5-Minute Averaged TSP Concentration (mg/m3)
5-Minute Averaged Wind speed (m/s)
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date


5-Minute Average Data
2017 E-Sampler Data
Legend
E - Sampler
Wind speed
West wind
Omineca E-Sampler Data, Showing Omineca Met Station Data
Rat Lake E-Sampler Data, Showing Ingenika Met Station Data
Ingenika E-Sampler Data, Showing Ingenika Met Station Data
57km E-Sampler Data, Showing 57km Met Station Data
5-Minute Averaged TSP Concentration (mg/m3)
5-Minute Averaged Wind speed (m/s)
04/25
05/05
05/15
05/25
06/04
06/14
06/24
Date


5-Minute Average Data
2017 E-Sampler Data
Legend
E - Sampler
Wind speed
West wind
Bruin E-Sampler Data, Showing Collins Met Station Data
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
12
9
6
3
0
04/25
05/05
05/15
05/25
06/04
06/14
06/24
5-Minute Averaged TSP Concentration (mg/m3)
5-Minute Averaged Wind speed (m/s)
Date