Peace Project Water Use Plan

GMSMON#18 WLL Dust Control Monitoring

Implementation Year 7

Reference: GMSMON#18

BC Hydro Williston Reservoir Air Monitoring 2014 Annual Report

Study Period: 2014/05/01 – 2014/12/31

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GMSMON#18 WLL Dust Control Monitoring

BC Hydro Williston Reservoir Air Monitoring 2014

Annual Report

Prepared For: BC Hydro and the Joint Planning Committee
Prepared By: Chu Cho Environmental
Study Period: 2014/05/01 – 2014/12/31

Tsay Keh Dene, BC, V0J 3N0

GMSMON#18 WLL DUST CONTROL MONITORING

PREPARED FOR:

BC HYDRO AND THE JOINT PLANNING COMMITTEE

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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 2014 (Year-7 of the project). GMSMON#18 is a 10-year air quality monitoring program 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 Federal Reference monitoring for the development of baseline ambient air quality data in the villages of Tsay Keh Dene and Kwadacha. The Federal Reference data will be used to contextualize the northern Finlay Valley region within the air quality standards developed by the BC Ministry of Environment (BC MoE) and the Canadian Council of Ministers of the Environment (CCME). 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 to increase the spatial and temporal data resolution. This has allowed for a better evaluation of the impact of dust mitigation treatments on fugitive emissions from the reservoir beaches.

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** is comprised of 19 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** is comprised of 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 of each network component are stated at the beginning of each section.

The GMSMON#18 air quality monitoring project exists because annual reservoir operations result in the exposure of large expanses of sediment with little vegetative cover or other protection from wind erosion. These sediments are primarily a loosely packed glacial till comprised of gravel, sand, silt and clay with minimal organic content. At full-pool, or 672m above sea level, these sediments are covered by 10 – 15 meters of water and are not exposed to wind erosion. In November the reservoir freezes and the water inputs are less than the output at the dam, resulting in continued drawdown until the reservoir water level reaches 655m above sea level (this varies from year to year depending on power demand and precipitation). Following spring thaw and the 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 changing weather patterns

result in periods of wind erosion. Like a push-broom on a driveway, the continued wind erosion results in dust storms that develop locally. If winds are sustained, the dust storms will migrate with the wind, 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 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 married this with time-lapse imagery and video editing software to create strong visual tools. This allows us to observe dust storms and the associated particulate matter data values. Chu Cho Environmental will continue to refine our analysis and data capture techniques to better address the key management question in years 8 through 10 of the program.

This report demonstrates the direction and approach that Chu Cho Environmental will use to investigate the data in the future. More data collection is required before strong conclusions can be reached. For year-1 of Chu Cho Environmental operation, our project team focused on building databases to house the data collected by each network, while simultaneously increasing the security and reliability of the data sources. These advances will be detailed in this report.

In general, the spatial and temporal variability between sites is large. A dust event is identified as exceeding the threshold of 0.1 mg/m^3 for more than 30 minutes. Some sampling stations had more than 100 dust events over the 6-week dust season, whereas other sites had as low as 5. The average was 29 dust events. Some events are short lived and highly localized to an individual beach or group of beaches, while others completely fill the valley. The development of this new monitoring network allows our team to observe dust events beginning in one location and then migrating in response to sustained wind events. The distributed network of sample stations has allowed us to evaluate the relative contribution of local areas to the overall quantity of airborne sediment in the valley. Our year-1 data indicates that the most frequent and highest concentrations of dust were recorded in the receiving environment in the vicinity of the beaches Bruin, Middle Creek North, Shovel, Davis North, Omenica and 35Km (Lorimer Area a.k.a. Coreless F).

We have also started to evaluate the before and after effects of applying tillage to beaches on the reservoir as a mitigation technique. There is limited evidence to suggest that applying tillage to a given beach will result in a direct reduction in airborne dust over time. In the four test cases analyzed in this report, the before/after comparison of mean dust concentrations showed significant but confounding results. In 2 cases the emissions decreased significantly but there was less than 1mm of rain before tillage and over 10 after tillage. In this case it was not possible to isolate tillage effects from rainfall. The remaining two cases showed significant increases in dust emissions following tillage but at these locations there was more rain prior to tillage and less rain following tillage. This is based on a one-year dataset of 19 E-Samplers collected over 6-weeks and is therefore not well constrained. Chu Cho Environmental does not believe that the analysis has been rigorous enough to provide conclusions with regards to these results. We will continue to add to this dataset moving forward in order to develop conclusive answers to this primary investigation.

Chu Cho Environmental has continued 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. The 2014 dust season was generally average showing two major 24-hour exceedences of the provincial objectives for PM_{10} and the Federal standards for $PM_{2.5}$ between April and June. There were a number of exceedences late in the summer resulting from nearby forest fires. 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 and Kwadacha. The data from this network has provided and will continue to provide valuable insight into the long-term air quality trends within the region.

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

1. Dustfall Monitoring,
2. Mentorship and Capacity Building Objectives, and
3. Community Engagement.

Year-1 of Chu Cho Environmental's control over GMSMON#18 included many successes and learning opportunities. Our project team found many efficiencies and opportunities to improve the program. Moving forward we have streamlined our data capture routines so they now require less driving and less intervention, which will result in efficient and timely collection and analysis.

It has been an overarching objective of Chu Cho Environmental to create methods and pathways that improve on the communication between the air quality monitoring program and the WDMP. For the 2015 season, we have developed the database and programming required to intake, process and report dust data shortly after each data collection period. This means that we will be able to provide near monthly summary tables and charts of unverified dust concentration and wind data. The WDMP will be able to use these data sooner to begin planning future mitigation tactics.

Chu Cho Environmental will continue to advance the GMSMON#18 program through improved data collection procedures, analysis techniques and the application of advanced statistical analysis techniques.

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1.0 Finlay Valley Airshed and Williston Dust Monitoring

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 Omenica 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 Omenica Mountains (Canning et al., 1999).

The region has seen many glaciations in the last 200 million years, the last of which left the area approximately 9000 years ago. Successive glaciations deposited large amounts of sediment through various lacustrine and fluvial processes leaving the Finlay Valley and Rocky Mountain Trench with an extensive layer of glacial overburden that is comprised of massive sand and gravel benches interlaced by fine lacustrine unconformities. The Williston Reservoir now sits in the northern Rocky Mountain Trench having flooded over 1,775 km^2 of forested valley. 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. The annual fluctuation in reservoir level has the potential to expose massive 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 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 threat when concentrations reach sufficiently high levels.

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 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 the 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 and will inform water use decisions as they pertain to dust control. Ultimately, some of the analysis avenues investigated in this first annual report may be abandoned 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.

The following table provides a summary of the various program components that pertain to year-7 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.	19 E-Samplers and 8 Meteorology sites were deployed in 2014 to address this question. The samplers are collecting data at 5 minute intervals from April to October. First year data indicate that mitigation activities are having minimal effect on reducing

			local/regional fugitive emissions but additional years of data are required to constrain the results. Currently it is not possible to delineate mitigation treatment effects from the numerous confounding variables such as rainfall, relatively humidity and reservoir rise. Generally the first year of the transition to CCE was a great success resulting in the capture of high quality data.
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 nor the CAAQS.	As has been found in most years prior to 2014, there were 1 or 2 exceedences of the provincial AQOs or Federal Standards during the dust season but that generally the air quality in Tsay Keh Dene and Kwadacha meet the guidelines. There were additional exceedences in the 2014 summer months due to ash from nearby forest fires. When compared to the provincial AQOs and Federal CAAQS the air in the Williston Reservoir area of the Finlay Valley is of good quality. However, as noted in this report, the AQOs and CAAQS tend to dilute the wind-driven air quality issues present in Tsay Keh Dene and Kwadacha.
Dustfall Monitoring Network	Are the baseline dustfall values within the bounds of the provincial Air Quality Objectives?	Dustfall values recorded in Tsay Keh Dene are not above the provincial AQOs for monthly dustfall.	Dustfall monitoring was implemented in 2014 and was conducted from May to October. A number of exceedences were found over the dust season and later in the year as a result of nearby forest fires. Dustfall monitoring will continue in 2015.
Mentorship and Community Engagement	n/a	n/a	Chu Cho Environmental employees who reside in Tsay Keh Dene or Kwadacha are steadily taking on more responsibilities for AQ monitoring. We suspect that following the 2015 field season

			that we will have 3 employees fully trained to autonomously manage the monitoring equipment. Chu Cho Environmental has participated in various community events and open houses to promote the AQ monitoring program.
Enhanced Data Security, Transparency and Access	n/a	n/a	New computer systems have been installed to improve network security and reliability. We have enlisted third party applications for hosting data online and have implemented a remote log in system to allow remote access to the instrumentation. Currently anyone who wishes could be added to an email list serve and could receive a .csv file summarizing the previous 12 hours of data.

1.2.1 Updates to Monitoring Network

With Chu Cho Environmental taking over the responsibility of managing the AQ program it was our vision to develop a simple, cost effective, unique and engaging program. This would be built on the successes of the past and the collaborative strength of the Chu Cho Environmental team members and subcontractors. Our project team implemented a scientifically rigorous program using modern technologies and methodologies to improve the overall outcomes. There were several key changes we made to the existing system in order to achieve this vision, these include:

- Adoption of an E-Sampler based regional monitoring program to avoid the use of costly filter-based analysis and to improve the spatial and temporal resolution of the data that are collected.
    - This is perhaps the most profound change to the monitoring network for 2014. We believe that this is the first regional monitoring network established on the reservoir that is capable of collecting data that can be used to truly address the key management question. Prior to the adoption of this monitoring network the temporal and spatial resolution of the data was low, making it very difficult to draw any reasonable conclusions. Moving forward Chu Cho Environmental will demonstrate that the data obtained from this new monitoring network will address

the key management question through rigorous statistical analysis and verification. The primary endeavors into this exercise include:

- Reference Monitoring Network data management system overhaul including adoption of MATLAB to process and manage web interaction.
- Adoption of new data display system in Tsay Keh Dene and Kwadacha using a VHF radio network and Campbell Scientific datalogger. This system is far more reliable than a web-based system in these remote villages.
- Integrated Dropbox Based data backup system to ensure that we are able to achieve zero lost data.
- 2015 early season deployment: Some equipment was staged in the fall to make a late winter setup possible. We deployed all 19 E-Samplers and 8 Meteorological Stations by April 7th, 2015.

1.3 Data Summary

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

2.0 Regional Monitoring Network

2.1 Network Characterization

For 2014, the regional monitoring network was altered significantly to provide higher temporal and spatial data resolution and to reduce the overall operating costs. The previous network utilized the BGI PQ200 reference sampler to collect 24-hour average regional air quality data once every six days, also known as 1-in-6 day sampling. Although scientifically rigorous and NIST traceable, the PQ200s are limited to 24 hour averaged filter data and incur significant labour and analysis costs for their operation. There is also a significant time lag between the sampling date, analysis date and reporting date. Previous to 2014 there were 8 regional monitoring sites that collected PM_{10} and $PM_{2.5}$ data.

Our project team developed an entirely new network based on continuous air quality samplers that we believe are better suited to address the key management question posed in the GMSMON#18 objectives. These samplers are developed by MetOne Instruments and are known as E-Samplers. For the 2014 season we were able to deploy 19 E-Samplers across the reservoir's many beaches, points and cutbanks in the Finlay Arm. Some locations such as Chowika, Ingenika, and Lafferty are situated on large gravel bars or rock out crops that do not produce dust. The dust recorded at these locations is coming from elsewhere further upwind within the reservoir basin. Other sites such as Middle Creek North, Shovel and Lorimer are situated directly on or very near to beaches that are known high dust emitters. These samplers 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. For the 2015 season there will be 20 E-Samplers deployed.

E-Samplers are designed to measure continuous air quality data at 1Hz and can record that data at various averaging intervals. We are currently using the 5-minute averaged data option, which allows the units to function autonomously for up to 30 days before the on-board memory is full and requires downloading. It was also agreed through joint planning that measuring PM_{10} and $PM_{2.5}$ is an unnecessary step in addressing the key management question and that doing so may cause some limited biasing of the results. For this reason, the E-Samplers were outfitted with a TSP cuthead, which allows the E-Sampler to capture Total Suspended Particulate (TSP). TSP includes all size fractions of fugitive particulate that may be ejected into the air from reservoir beaches by wind erosion.

Along with the 19 E-Sampler sites there are 8 meteorology monitoring stations. With the exception of one site, the meteorology monitoring stations were placed in the same location as years previous in order to maintain continuity for these monitoring sites. The meteorology station that was located at Rat Lake was moved to 35Km (Lorimer a.k.a. Coreless F).

Ultimately, the location of the 19 sample sites was determined by availability access and the ability of the characteristics of the site to adequately represent the airshed in that local zone. Our 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 19 dust monitoring and 8 meteorology monitoring stations within the Finlay Arm of the Williston Reservoir.

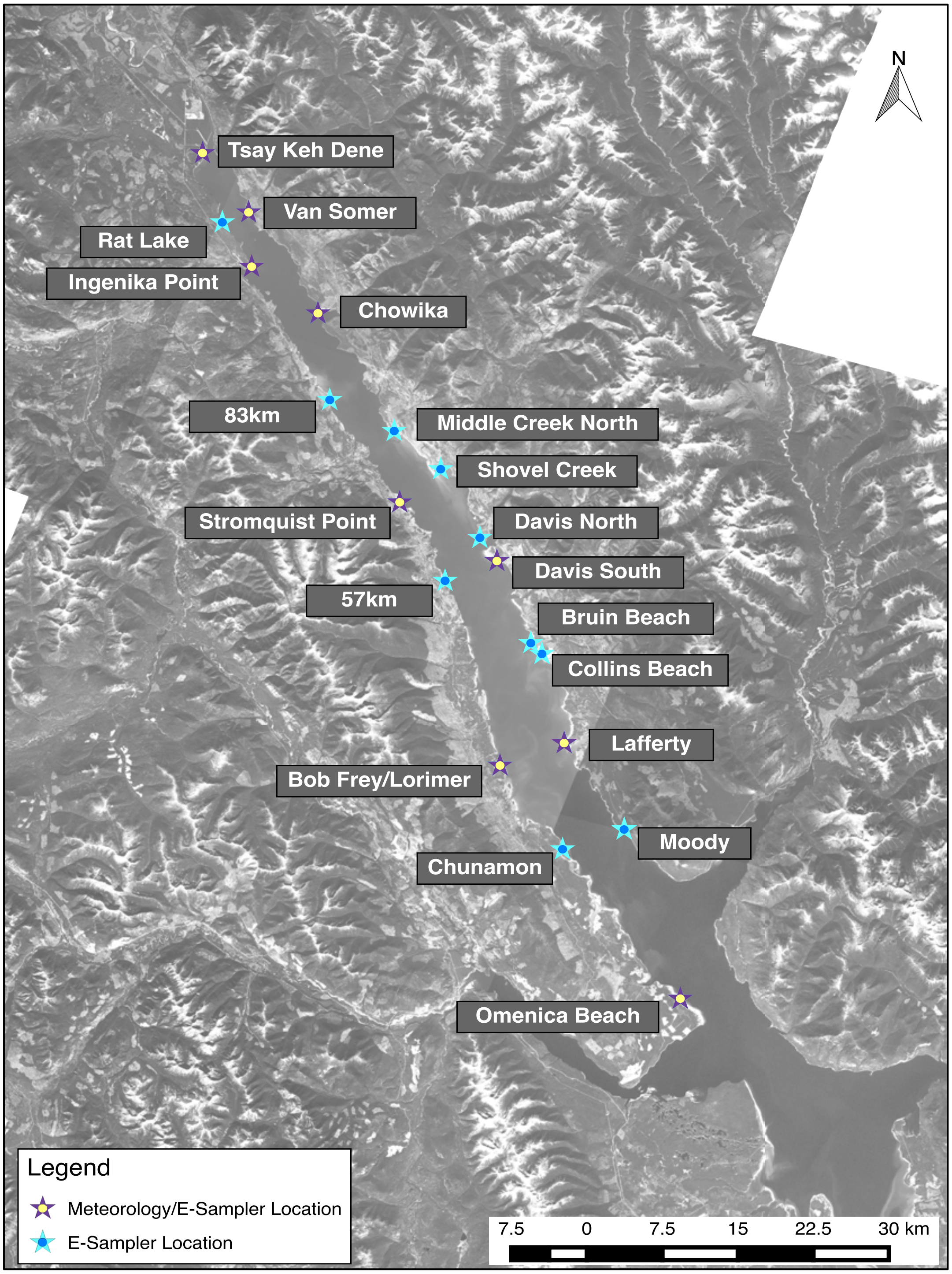

Figure 1: Map of Regional Monitoring Network Sampling Locations

2.1.1 Detailed Site Descriptions

Table 1 provides a detailed overview of the monitoring station site locations, the instrumentation included and the type of airshed representation that the site provides:

Table 2: Regional Monitoring Network Site Descriptions and Locations

Site Name	Lat	Lon	Met Station	Site Description	Airshed Representation	Instrumentation
Tsay Keh	56.892	-124.964	Tsay Keh	The E-Sampler is 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. For 2015, we have added an additional E-Sampler in TKD that is located adjacent to the Tsay Keh Beach, which is a known high emitter.	Regional	E-Sampler, Met Station
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 tends to hold 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 northerly winds. The sampling equipment is well positioned to capture some local dust but also much of the regional dust passing by the area.	Regional /Local Dust	E-Sampler, Met Station
Chowika	56.743	-124.769	Chowika	The Chowika monitoring station rests on a large gravel bar that extends far into the reservoir. This is very exposed to northerly and southerly winds and captures much of the fugitive dust from southern beaches that migrates towards TK village. This site produces no local dust emission.	Regional Dust	E-Sampler, Met Station
Middle Creek	56.634	-124.640	Chowika	MCN Beach is an exposed sand sheet and a high elevation beach.	Local Dust	E-Sampler

North (MCN)				This beach is usually 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 southerly winds and moderate exposure to northerly winds.		
Shovel	56.599	-124.563	Davis South	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 southerly winds and moderate exposure to northerly winds.	Local Dust	E-Sampler
Davis North	56.535	-124.497	Davis South	Davis North Beach is a massive mixed sediment type beach that is considered a very fugitive dust emitter. The sampling equipment is well exposed to both northerly and southerly winds.	Local Dust	E-Sampler
Davis South	56.514	-124.469	Davis South	Davis South Beach is a mixed sediment type beach that is known to emit large amounts of fugitive dust. Very large wet areas make travel and tillage difficult on this beach. 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, Met Station
Bruin Beach	56.437	-124.411	Collins	Bruin beach is primarily composed of mixed sand and gravel and is not considered a high emitter. The E-Sampler is located on a gravel point that is exceptionally well exposed to	Regional	E-Sampler

				Southerly and Northerly winds. This site is well positioned to provide a regional scope on the reservoir dust. This site recorded a number of large dust events that likely originated on Collins Beach to the south.		
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 some vegetation growth at higher elevations and is a known high emitter. The sampling equipment is located on a gravel bar approximately 500m south of the beach access point from Camp Collins. The equipment is well exposed to southerly winds and is moderately exposed to northerly winds.	Local	E-Sampler, Met Station
Lafferty	56.344	-124.354	Lafferty	The sampling equipment at Lafferty sits on a large gravel bar that divides the very low elevation sections of the beach from the higher embayments. Some of the higher beach zones will generate vegetative growth while the lower sections are quickly covered up by reservoir water. The northern part of this beach is also called Collins South and known to be extremely wet and full of root wads, stumps and deadheads. This site is exceptionally well exposed to northerly and southerly winds.	Regional Dust	E-Sampler, Met Station
Moody	56.263	-124.255	Lafferty	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

Rat Lake	56.827	-124.928	Ingenika	The E-Sampler is located on a high reservoir cutbank approximately 60 feet above the full-pool level. This site is exceptionally well exposed to southerly winds and moderately exposed to northerly winds. No dust is generated locally and this site provides adequate regional representation.	Regional Dust	E-Sampler
Ingenika Point	56.700	-124.800	Ingenika	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 southerly 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	Stromquist	The E-Sampler is located on a high reservoir cut bank approximately 40 feet above the full-pool watermark. The equipment is located on an old reservoir adjacent road. In 2009 the road was pushed back into the woods and this site is located on what remains of the old road. This site is well exposed to Southerly winds and provides regional representation. No dust is generated locally and this site provides adequate regional representation.	Regional	E-Sampler
Stromquist	56.567	-124.628	Stromquist	For 2014 this site was located slightly north of Stromquist Point in a somewhat sheltered embayment. Chu Cho Environmental feels that this site is not adequately representative of the regional air quality and so has been moved for the 2015 season.	Regional	E-Sampler, Met Station
57km	56.494	-124.552	Lorimer	This site is named after the road kilometer where the access point is	Regional /Local	E-Sampler

				located. This is located approximately 3km 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 southerly winds and likely captures much of the sediment laden air plumes that drift north from the coreless complex.	Dust	
Lorimer (35km)	56.321	-124.457	Lorimer	This site is located adjacent to Lorimer Creek and near Pete Toy Creek and is situated on the beach known as Coreless F. The beach is comprised of very fine mostly silt based sediments and is a very high emitter. The sampling equipment is well exposed to both southerly and northerly winds. No vegetation was found on this beach.	Local Dust	E-Sampler, Met Station
Chunamon (25km)	56.244	-124.353	Omenica	This site is located on the north shore of the Chunamon Creek embayment. In the area local to the E-Sampler there are mobile sediments but this site is generally marked with large amounts of vegetation. This site is well exposed to both northerly and southerly winds.	Local/Regional Dust	E-Sampler
Omenica	56.105	-124.160	Omenica	This sample site is located near the center of Omenica Beach and is exceptionally well exposed to both northerly and southerly winds. Omenica 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 and provides the Lat/Lon coordinates and the looking direction:

Figure 2: Middle Creek North Regional Monitoring Network

Figure 3: Chowika Regional Monitoring Network

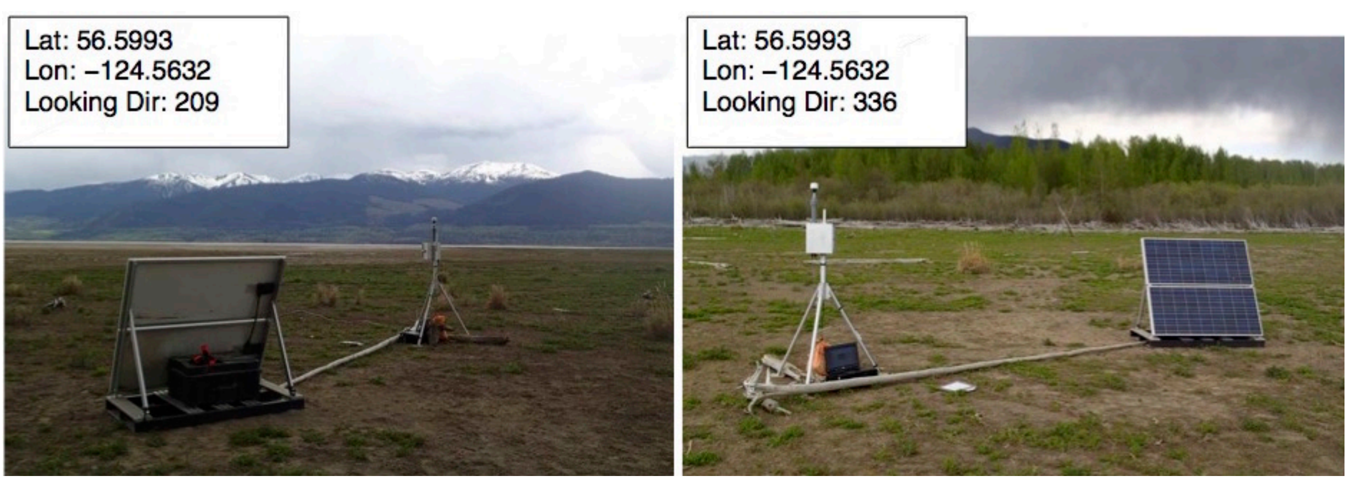

Figure 4: Shovel Regional Monitoring Network

Figure 5: 25Km Regional Monitoring Network

Figure 6: Bruin Regional Monitoring Network

Figure 7: Stromquist Regional Monitoring Network

Figure 8: Moody Regional Monitoring Network

Figure 9: 83Km Regional Monitoring Network

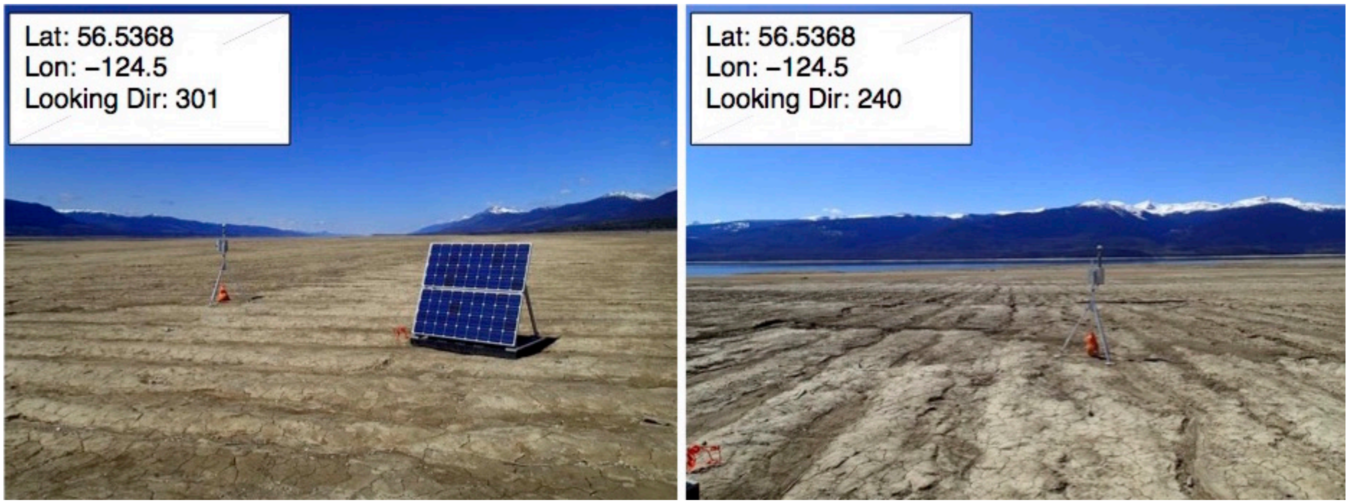

Figure 10: Davis North Regional Monitoring Network

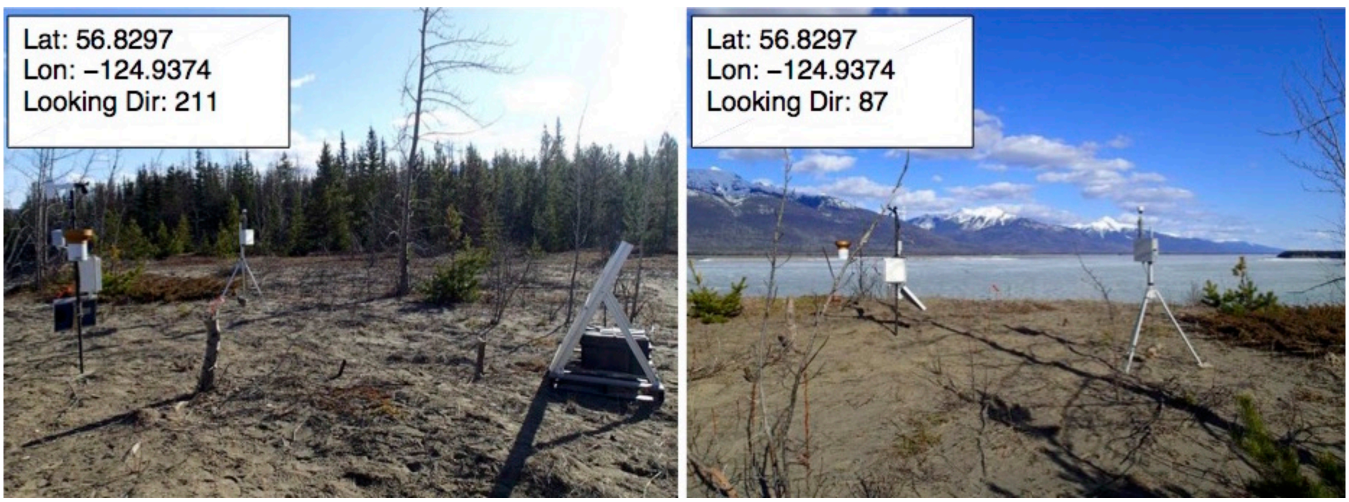

Figure 11: Rat Lake Regional Monitoring Network

Figure 12: Omenica Regional Monitoring Network

Figure 13: Davis South Regional Monitoring Network

Figure 14: Tsay Keh Dene Regional Monitoring Network and Reference Station

Figure 15: 57Km Regional Monitoring Network

Figure 16: Ingenika Point Regional Monitoring Network

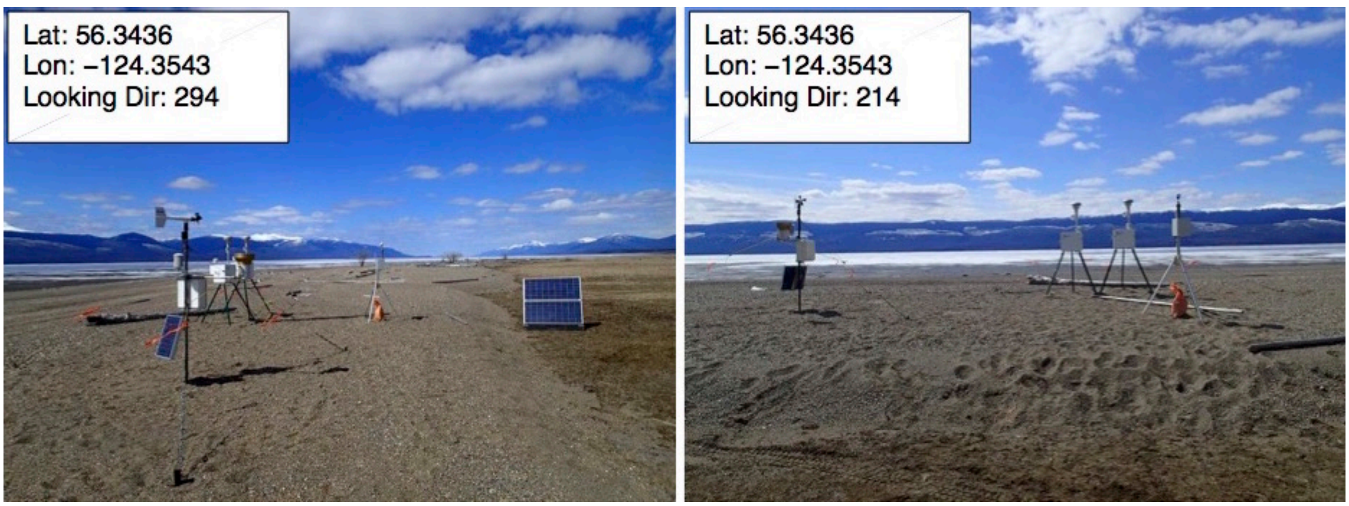

Figure 17: Lafferty Regional Monitoring Network

Figure 18: Lorimer (35Km) Regional Monitoring Network

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

MetOne E-Samplers function according to a unique operating principle that employs laser backscatter to estimate the concentration of particulate in air. Air is drawn into the E-Sampler at a constant velocity where it travels through a defined flow path and chamber. A 690nm laser is shone across the flow chamber, through the particulate laden air where it is received by a light sensor on the opposite side of the chamber. When there are zero particles in the air stream, there is zero scatter of the laser beam and the light sensor responds accordingly. Where there are a number of particles in the air stream, there will be some scatter of the laser beam and the light sensor will record a reduced signal. The sensor therefore responds to the amount of light, which passes through the flow and the response is inversely proportional to the amount of particulate in the air stream.

The laser scatter method does not carry 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 exceedences 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 NIST traceable method for calibrating and maintaining the E-Sampler since it does 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 data are read at 1Hz and are recorded at 5-minute average intervals. Data are collected from 19 instruments for the entire snow-free period (approximately May to October) in the Finlay Valley. There are 8 complete meteorology stations that are located at a subset of the 19 E-Sampler sites. These stations read the instrumentation at 1Hz and record 5-minute average data for relative humidity, rainfall rate, air temperature, wind speed and wind direction. The regional monitoring network amasses an enormous amount of data very quickly and requires an aggregation of complex computer programming to handle and process.

This distributed network of continuously monitoring E-Samplers and weather stations allows us to probe dust events through avenues, which have not yet been investigated and also allows 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 initial 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 generally to 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 are 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 will 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%.
- Precision:
  - E-Samplers must be calibrated and maintained to sustain a precision that deviates less than 10% from a zero standard. This is done through an internal automated process within the E-Sampler and any errors that are detected are recorded and delivered to the user.
- 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.
- Comparability:
  - We maintain a small subset of filter based monitoring instruments that are used to collect samples at random times for comparison to E-Sampler data. These data are used to provide assurance that the E-Samplers are maintaining function through time.
- Averaging Period:

- E-Sampler data are collected at 60Hz 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 is collected from April until October 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 more than 2 meters 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 meters away from trees.

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

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

2.2.2 Time Series Analysis

Generally, the data collected by the E-Samplers show a lot of dust activity throughout the typical dust season ranging in magnitude from small scale isolated events that last only 30 minutes to large scale valley wide events that can last more than 24 hours.

Figure 19 contains 4 plots, each of which represent a different E-Sampler from the Regional Monitoring Network, the samplers included in this plot are 25Km (Chunamon), Shovel Creek, Chowika and Middle Creek North. Each of the plots features the time-series TSP data (Red line), wind speed data (Black Line) and wind direction data (Barbs across the top). We understand that some of the barbs are difficult to see due to the quantity of data on the graph, this will be refined in the future. The data shown in Figure 19 include the entire 48 day 2014 dust season. Note that the wind data are missing from the 25Km plot due a faulty CR1000 lithium-ion battery.

Figure 19 provides an example of the frequency and magnitude with which E-Samplers respond to airborne dust. The plots in Figure 19 indicate that there are nearly daily responses to airborne dust at these locations and that in some cases these events are very large. The remaining 15 E-Sampler plots are included in Appendix A.

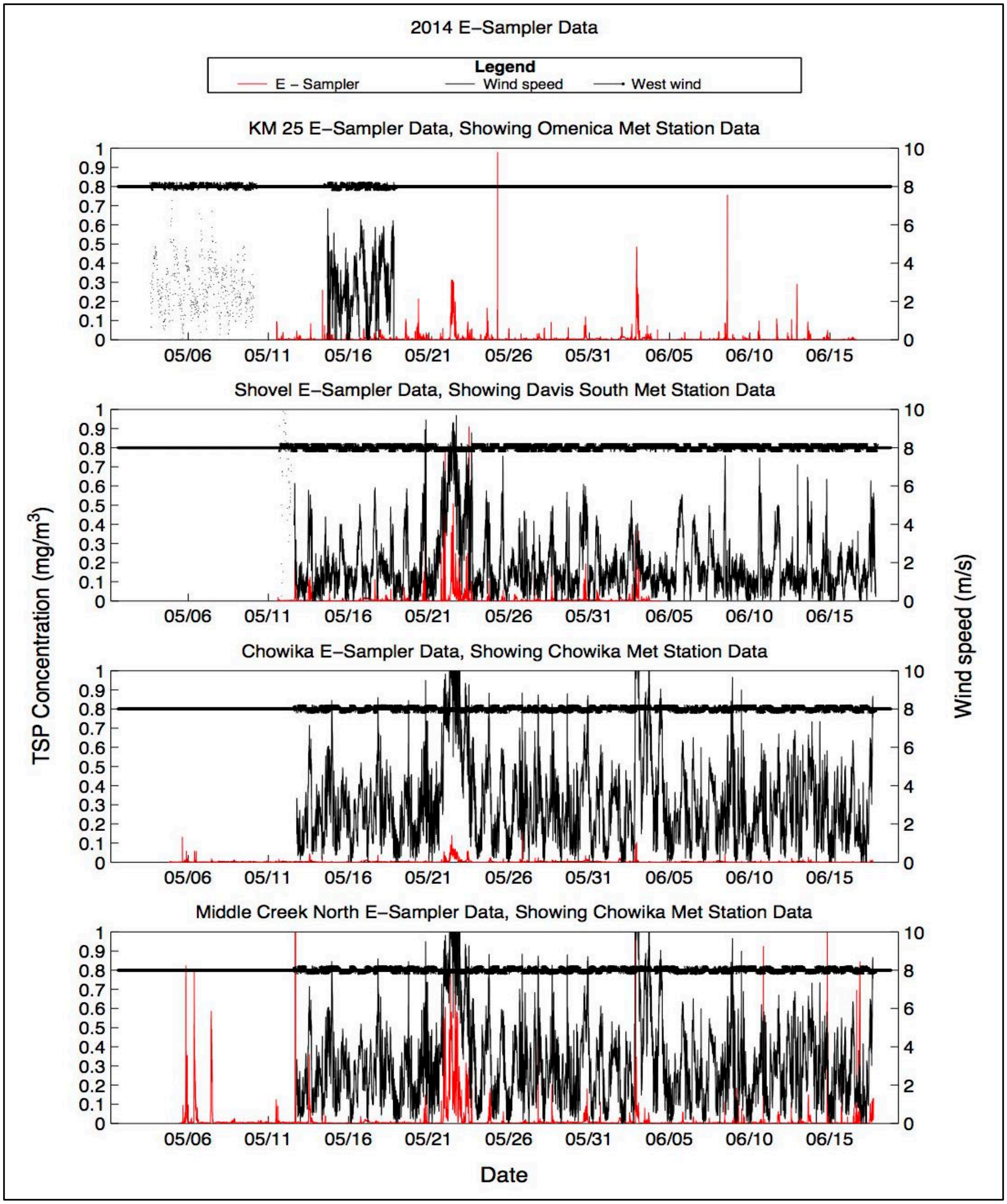

Figure 19: Sample of Regional E-Sampler Data from 4 Locations

Threshold:

Over the years much of the discussion surrounding dust events in the Finlay Valley has focused on the threshold wind speeds for initiating sediment movement. The high temporal resolution of the E-Samplers means that we are 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. There are microbursts and convective air movements, which could cause the E-Sampler to register particulate matter. These are not the event types we wish to analyze. We have decided that in order to qualify as a dust event, the E-Sampler must register an average value that is above the threshold for at least 30 minutes.

The threshold value is determined by comparing E-Sampler data to the time-lapse visual record of events and determining at what reading there is visual dust in the air surrounding the E-Sampler. We used a number of replicate sites for this exercise (Middle Creek North, Shovel Creek, Van Somer, Lorimer and Davis North) and arrived at a value of 0.1 mg/m^3 for the E-Sampler threshold for dust events. In order to be considered a dust event the average reading must exceed 0.1 mg/m^3 for 30 minutes or more. A drop in the average reading below the threshold for 20 minutes or more signals the end of a dust event. Note that this is a conservative value for the dust event threshold. In the following section, each reference to a dust event or a number of dust events indicates that the data have met the above criteria.

Statistical Analysis:

Basic descriptive parameters were extracted from the time series data collected at each location over the duration of the 48-day dust season. These data are summarized in Table 3 on the following page.

These data were extracted using the threshold criteria described above and are reported within the context of dust events. For example, the average TSP concentration at Middle Creek North (MCN) was 0.31 mg/m^3 during the 73 events recorded at that site. Similarly, the average TSP concentration at Chowika was 0.14 mg/m^3 during the 6 events recorded at that site.

Chowika is not located near any source beaches and will capture regional air parcels as they drift by, whereas the MCN sampler is located very near to a source beach. The effect of this difference in site characteristics and location can be observed through the average wind speed and threshold wind speed for these sites, which are substantially larger for Chowika at 9.7 m/s for both parameters versus 7.5 m/s and 6.1 m/s for MCN. This indicates that the overall wind speed in the valley must maintain a higher velocity in order for Chowika to register a dust event, while MCN will register a dust event at much lower speeds.

The following sections will examine these effects in detail.

Table 3: Regional Monitoring Network Data Characterization Summary

Site ID	# of Dust Events	TSP Conc. (mg/m³)	% Time With Dust	Avg. Wind Speed (m/s)	Max Wind Speed (m/s)	Min Wind Speed (m/s)	Threshold Wind Speed (m/s)	Threshold Wind Spd. Std. Dev. (m/s)	Avg. Wind Dir (deg)	Std Dev. Wind Dir (deg)
MCN	73	0.31	3.53	7.5	13.4	0.3	6.1	2.6	171	76
Chowika	6	0.14	0.04	9.7	13	4.6	9.7	3.2	188	147
Shovel	48	0.21	1.03	5.5	9.3	0.5	4.6	2	171	59
25Km	25	0.21	0.91	3	3.4	2.8	3.1	0.4	128	165
Bruin	49	0.30	1.85	8.4	13	1	7.2	2.4	242	88
Stromquist	11	0.18	0.31	2.1	6.3	0.6	2.1	2	191	71
Moody	5	0.14	0.12	11.4	12.7	9.3	10.2	0.5	330	6
83Km	14	0.25	0.25	2	4.3	0.3	2	1.4	200	78
Davis North	33	0.44	1.78	3.5	14.1	0.6	4	3.4	124	100
Rat Lake	15	0.31	0.31	7.6	11.1	0.9	7.3	3.1	174	57
Omenica	28	0.30	1.27	3.3	5.2	0.8	2.6	1.5	115	103
Davis South	23	0.22	0.81	4.7	9.7	1.1	5.7	3.1	121	86
Van Somer	23	0.19	0.31	7.7	11.3	2.5	6.7	2.9	226	89
Tsay Keh	23	0.15	0.59	9.3	11.5	2.3	8.6	2	128	17
57Km	41	0.26	1.66	5.8	9.8	0.6	4.3	2.1	251	134
Ingenika	7	0.13	0.08	4.6	10.9	0.3	5.6	4.8	205	68
Lafferty	14	0.22	0.88	9.5	12.7	2.7	8.2	2.2	206	81
35Km	108	0.59	4.23	6.5	11.6	0.9	4.7	1.8	199	125
Collins	5	0.13	0.04	9	10.3	5.9	8.7	1.7	170	39
Average	**29**	**0.25**	**1.05**	**6.4**	**10.2**	**2.0**	**5.9**	**2.3**	**186**	**84**

Number of Dust Events:

Samplers on Middle Creek North and Shovel Creek receive very large quantities of fugitive dust due the high wind exposure and proximity to mobile sediments. Using our estimated threshold of 0.1 mg/m^3 for TSP, the E-Samplers at Middle Creek North and Shovel responded to 73 and 48 dust events during the 48-day season. This means that there are multiple periods within a single day that fit the criteria for being classified as a dust event. Chowika on the other hand responded to only 6 events but is located far away from any dust source on a gravel bar that extends into the reservoir. 35Km (Lorimer) responded to 108 dust events, this is likely the result of highly localized wind activity and the presence of highly mobile silt and clay at the sample site.

Viewing the data through this lens allows us to examine our dataset for localized "hotspot" zones such as Middle Creek North, and then evaluate the downwind effects of hotspots on more remote sites such as Chowika. We utilize this approach to determine to what extent the "hotspot" beaches are contributing to downwind dust concentrations and under what environmental conditions they proliferate.

The average number of dust events as defined above across all sample locations throughout the dust season was 29, which is equivalent to approximately 1.05% of the total time that the instruments were recording. Middle Creek North and 35Km had the highest percentage of time with dust at 3.53% and 4.23% respectively. This indicates that in 2014 these sites are located in the highest emissions zones in the Finlay Arm of the reservoir.

Wind Speed and Wind Threshold:

The average wind speed during dust events was calculated as 6.4 m/s where the minimum was 2.0 m/s and the maximum was 10.2 m/s. There were a number of locations where *low* localized wind speeds were associated with dust events, these include: Middle Creek North, Shovel Creek, Stromquist, 83Km, Davis North, 57Km, Ingenika Point, and 35Km. These sites represent the full range of site types from gravel bars and wetted zones to highly emissive sand sheets. This is a clear indication that TSP will travel from the source beach to other areas of the reservoir. The migration of dust from source locations throughout the reservoir is discussed in detail in Section 2.2.4 Dust Event Type Heatmap Analysis.

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 threshold of 0.1 mg/m^3 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, which is approximately equivalent to the value of 6.0 m/s that was estimated through the PI-SWERL erosion study in GMSWORKS#20 (Nickling et al., 2011). Some sites such as 35Km show lower threshold values because the local beach sediments are highly erodible and therefore emit dust at lower wind speeds. Other sample sites such as 83Km and Ingenika point show lower than average dust event threshold wind speed as well, even though the sites are located where no dust is produced. The dust usually arrives at these sites within a few hours following an event at one of the more emissive sites further upwind. This reaffirms our observation that TSP tends to drift very long distances from source areas to samplers located in non-producing areas.

Wind Direction:

There is a great deal of variability within the average wind direction between many of the sample sites, however the dominant wind direction typically contains a southerly component but might vary from Southwest to Southeast. Many of the sites will generally respond to either Northwest or Southeast winds, which have been identified as the dominant wind directions in this part of the Finlay Valley (Nickling et al. 2013). To some extent the dominant wind direction value is influenced by some of the unavoidable compromises (such as site access) that must be made during our site selection. We do strive to avoid placing sites where the influence of local geography and vegetation will affect the wind readings.

2.2.3 BGI Filter Data Analysis

Chu Cho Environmental maintained a small subset of the BGI PQ200 Reference Monitoring units from the previous AQ monitoring network. It was decided that maintaining these instruments is very costly given the volume of usable data that are returned. Initially we had planned to use the data collected by these instruments to provide an independent verification for the co-located E-Sampler. However, the BGI PQ200s are built to collect PM_{10} and $PM_{2.5}$ sized particles while the E-Samplers were setup to collect TSP. These measurement values are fundamentally different and are not directly comparable.

Ultimately, the BGI PQ200s are an excellent instrument but their use in the regional monitoring network is not well founded. The purpose of the regional monitoring network is to address the GMSMON#18 key management question. By sampling on either a random or a 1-in-6-day schedule the BGI PQ200s are bound to miss dust events and therefore are unable to address the key management question. The BGI PQ200s are a reference monitor and if used at regular intervals over a long enough time period can begin to provide insight into baseline air quality issues. This is the primary use of the instrument.

Therefore, in this report we are presenting the BGI PQ200 data for reference but have decided to make no strong conclusion towards the GMSMON#18 key management question based on the results. We will report these data within the context of the CAAQS and the Provincial AQOs.

On the days that the BGI PQ200s were engaged and sampling, there were no exceedences of the Federal CAAQS or Provincial AQOs. The PM_{10} and $PM_{2.5}$ data are summarized in the following two tables. That is, all PM_{10} data were below the 24-hour average AQO of 50 mg/m^3 and all $PM_{2.5}$ date were below the 24-hour CAAQS of 28 mg/m^3. A summary table outlining the provincial AQOs and the Federal CAAQS is provided in Section 3.0 Reference Monitoring Network.

Moving forward, we have removed these instruments from the Regional Monitoring Network but will maintain operation of the 2 units located in Tsay Keh Dene to provide reference for the TEOM 1405-D monitoring unit.

Table 4: BGI PQ200 PM10 and PM2.5 Filter Based Air Quality Data

Site Name	Filter ID	Cass ID	PM_{10} Mass on Filter (µg)	PM_{10} Concentration (µg/ m³)	$PM_{2.5}$ Mass on Filter (µg)	$PM_{2.5}$ Concentration (µg/ m³)	Sample Date
Rat Lake	v-4475	20784	490	**20.42**	171	**7.13**	07-May-14
Ingenika	v-4474	20819	227	**9.46**	148	**6.17**	07-May-14
Lafferty	V-4470	27623	163	**6.79**	131	**5.46**	07-May-14
Van Somer	v-4472	24565	857	**35.71**	137	**5.71**	07-May-14
Tsay Keh	v-4480	20832	373	**15.54**	526	**21.92**	07-May-14
Stromquist	v-4464	27072	280	**11.67**	79	**3.29**	24-May-14
Ingenika	v-4463	23022	309	**12.88**	90	**3.75**	24-May-14
Lafferty	v-4467	27684	343	**14.29**	100	**4.17**	24-May-14
VanSomer	v-4469	29511	351	**14.63**	102	**4.25**	24-May-14
TsayKeh	v-4461	20882	186	**7.75**	80	**3.33**	24-May-14
Stromquist	v-4515	26230	237	**9.88**	110	**4.58**	18-Jun-14
Ingenika	v-4519	28919	178	**7.42**	157	**6.54**	18-Jun-14
VanSomer	v-4517	18526	177	**7.38**	173	**7.21**	18-Jun-14
Stromquist	v-4511	19276	415	**17.29**	136	**5.67**	04-Jul-14
Ingenika	v-4506	19385	195	**8.13**	128	**5.33**	04-Jul-14
VanSomer	v-4513	26552	209	**8.71**	119	**4.96**	04-Jul-14
TsayKeh	v-4508	17533	506	**21.08**	119	**4.96**	04-Jul-14
Stromquist	v-4498	24119	489	**20.38**	363	**15.13**	07-Aug-14
Ingenika	v-4504	27633	567	**23.63**	414	**17.25**	07-Aug-14
VanSomer	v-4499	27145	368	**15.33**	290	**12.08**	07-Aug-14
TsayKeh	v-4502	26204	526	**21.92**	319	**13.29**	07-Aug-14
Stromquist	v-4489	26451	117	**4.88**	98	**4.08**	10-Sep-14
Ingenika	v-4495	26563	184	**7.67**	153	**6.38**	10-Sep-14
VanSomer	v-4493	18839	113	**4.71**	106	**4.42**	10-Sep-14
TsayKeh	v-4491	24598	58	**2.42**	103	**4.29**	10-Sep-14

2.2.4 Dust Event Type Heatmap Analysis

The images presented in the next 3 pages (Figures 20 - 22) were created using an analysis called heatmap interpolation of the regional monitoring network data. This process uses nearest neighbor triangulation to create a high density array of coloured triangles where the greatest "heat," or in our case dust, is indicated by deep red, and the least dust is indicated by dark blue.

The heatmap interpolation is performed across the entire 19 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. 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 range in size from small to large scale, and that some locations regularly emit much higher levels of dust than others.

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.

In this section we will examine 4 snapshots from the heatmap analysis for 3 different event types. Our intention is to discuss the development of various dust events over time. Figures 20 through 22 show three distinct types of dust event that were observed on several occasions throughout the 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.

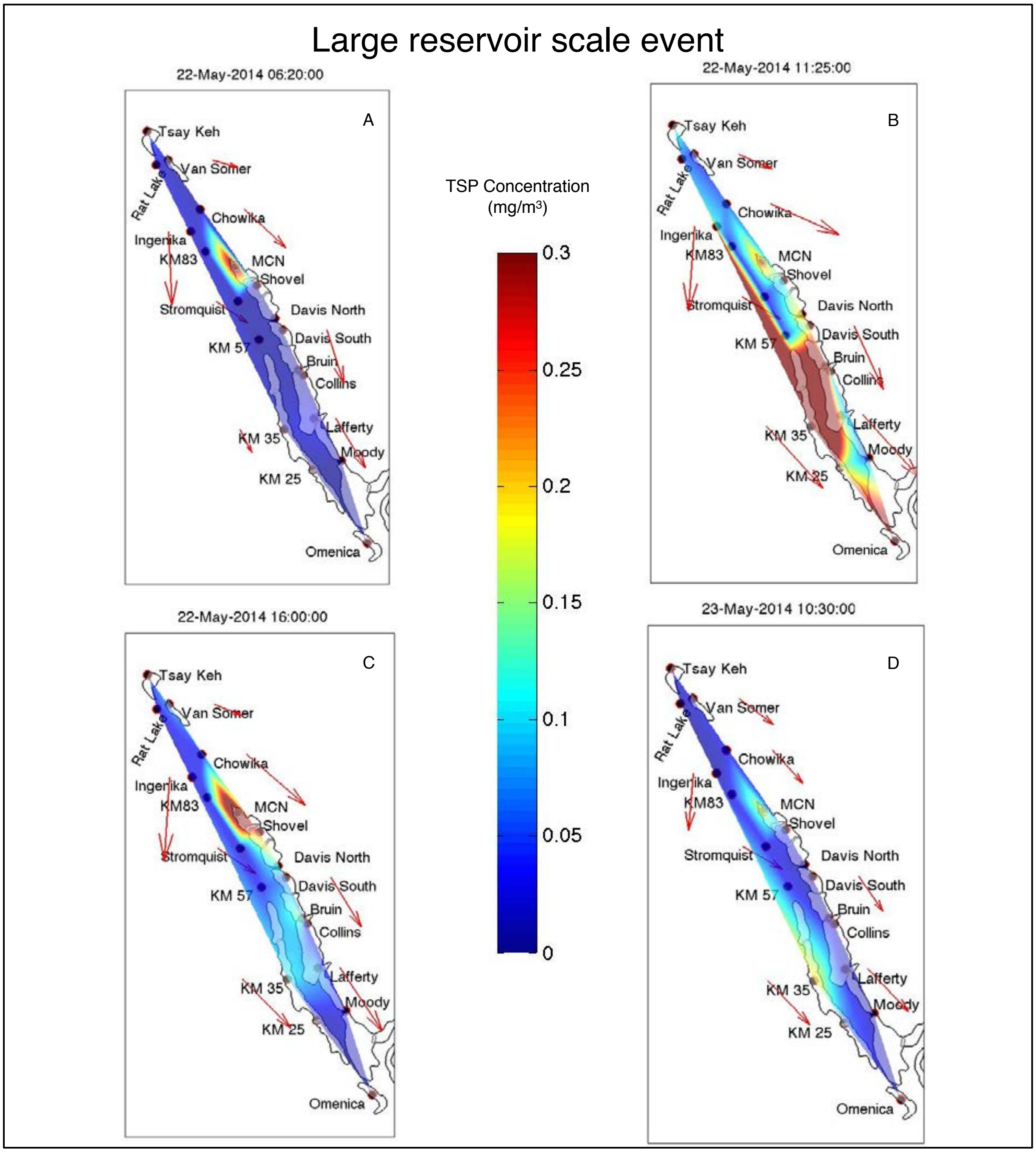

Figure 20: Heatmap Analysis - Large Scale Event

Large Scale Event:

Figure 20 contains four images, which show the development of a very large valley wide dust event. Figure 20 (A) shows the storm beginning near MCN at 06:20 on May 22nd, 2014 with winds from the south. 5 hours later, Figure 20 (B) shows how the storm has grown to fill the southern section of the Finlay Valley. Figure 20 (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.

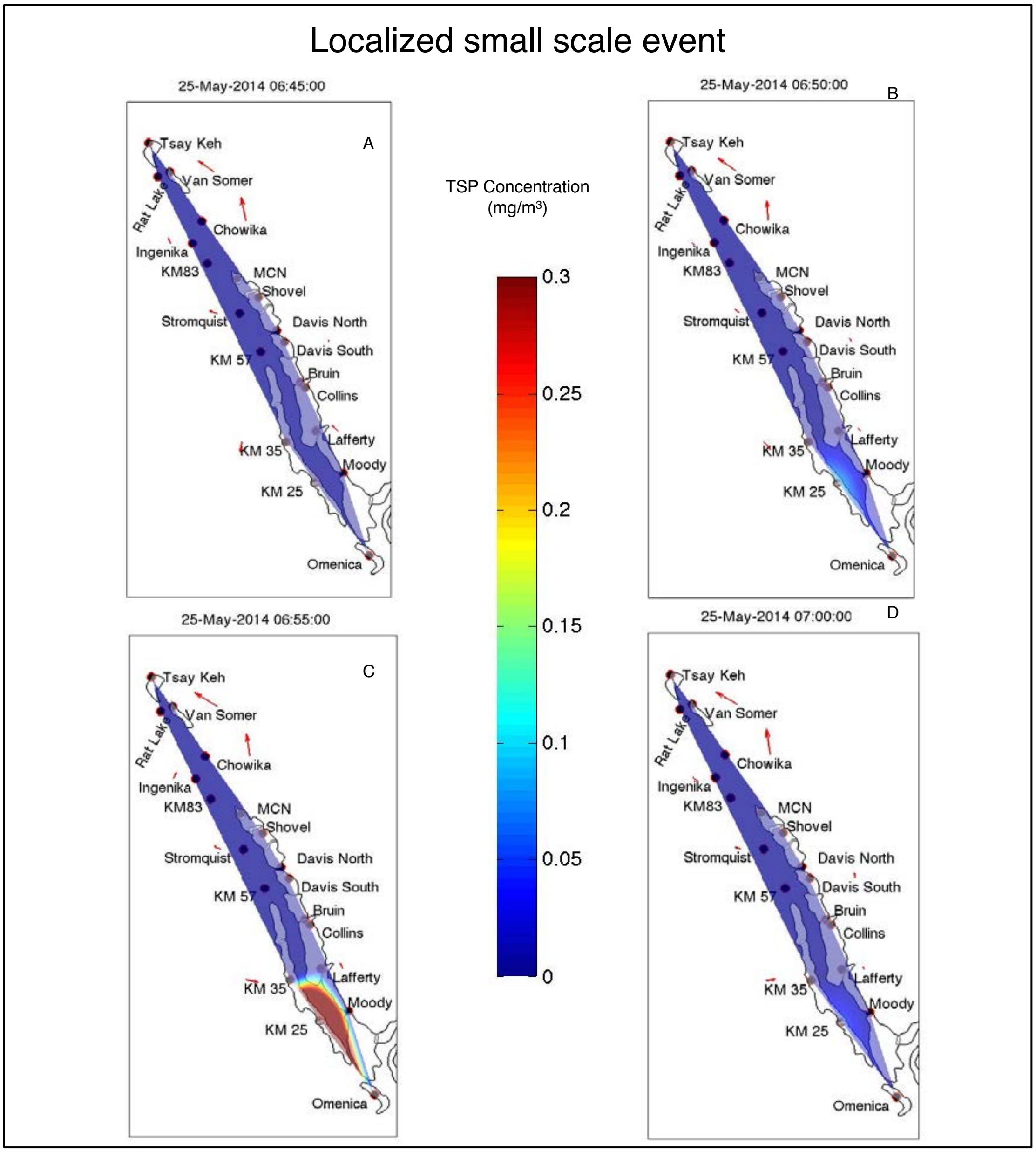

Figure 21: Heatmap Analysis - Localized Event

Small Scale Event:

Figure 21 contains four images, which show the development of a small event localized to a single beach. Figure 21 (A) shows the Finlay Valley under pristine air quality conditions at 06:45 on May 25th, 2014. Figure 21 (B) shows the development of a small microburst at 25Km and 35Km starting at 06:50. At 06:55, the microburst has blown up to a very high concentration localized dust event (Figure 21 (C). Then at 07:00, Figure 21 (D) shows that the microburst dust event has stopped and dissipated. This entire micro-event took place over a 20-minute period and although this event would not adversely affect the air quality in Tsay Keh Dene it is a prime example of the variability across the reservoir. This event does not pass our threshold limit to be considered a dust event.

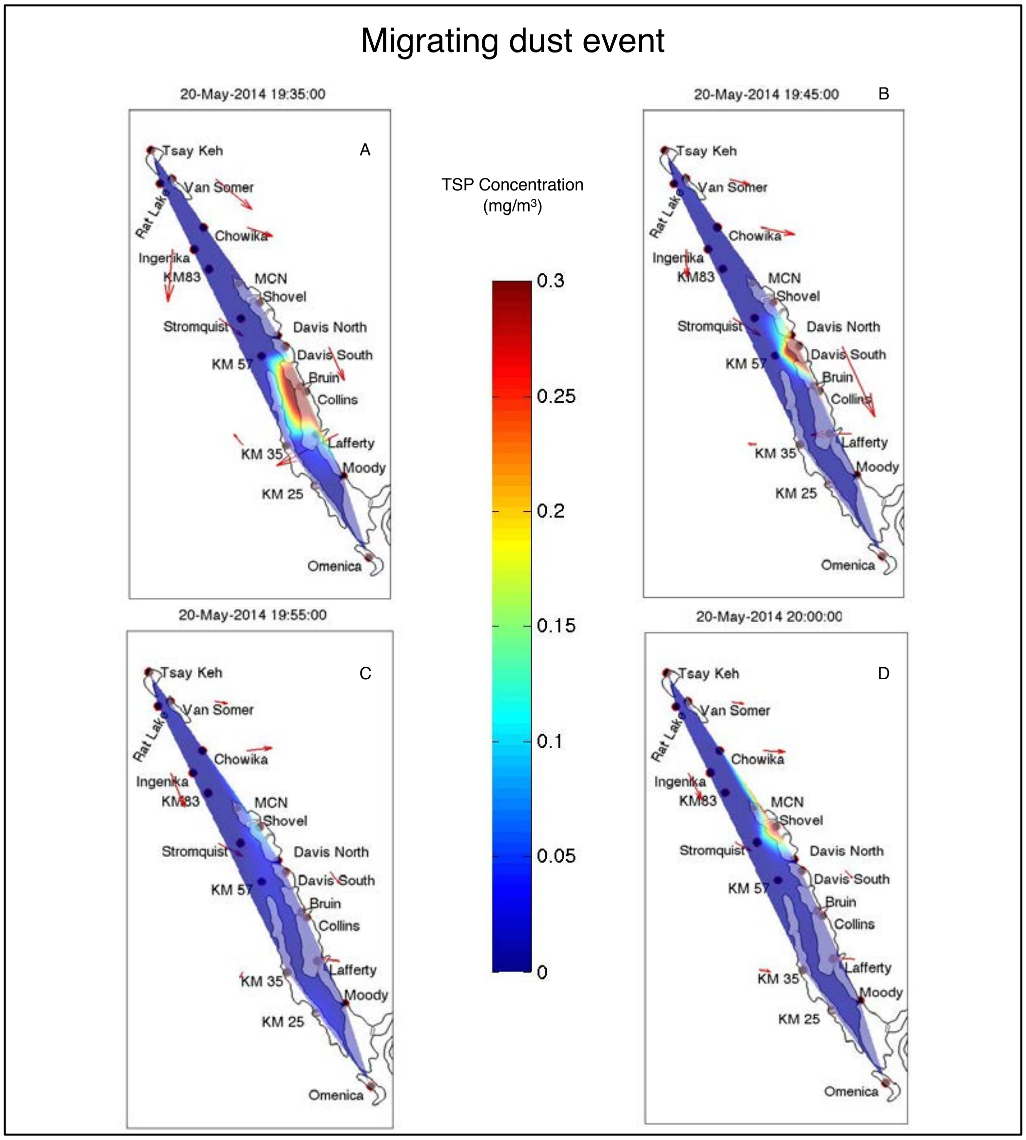

Figure 22: Heatmap Analysis - Migrating Dust Event

Migrating Event:

Figure 22 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 22 (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 22 (B) show the same event 10 minutes later arriving at Davis South and Davis North beaches. Figure 22 (C) shows this same event beginning to arrive at Shovel Creek at 19:55 and then 5 minutes later, Figure 22 (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 22. We should note that on May 20th, 2014 this phenomenon had been happening all day, the example shown in Figure 22 was the 3rd such occurrence of the day.

2.2.5 Time-Lapse Analysis

8 Moultrie D-555i game cameras were deployed at selected regional monitoring sites. These cameras were set to record images at 10-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 have isolated the cameras that function poorly and have removed them from the 2015 program.

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.

We have posted two of the videos online here at:

https://vimeo.com/118043075

https://vimeo.com/117007358

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 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 initiate 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 meet 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 and represents a portion of a developing 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

The following table provides basic descriptive statistics for each of the 19 E-Samplers included in the Regional Monitoring Network.

Table 5: Basic Descriptive Statistics for the 19 Regional E-Sampler Monitoring Sites (All Units are mg/m³)

	MCN	Chowika	Shovel	25Km	Bruin	Stromquist	Moody
Mean	0.3067	0.14	0.2073	0.2059	0.3014	0.1848	0.1355
Minimum	0.1	0.103	0.1	0.102	0.1	0.101	0.102
Maximum	2.163	0.198	0.909	0.978	2.191	0.389	0.179
Standard Deviation	0.2417	0.0359	0.1277	0.1156	0.3019	0.0677	0.023
Variance	0.0584	0.0013	0.0163	0.0134	0.0911	0.0046	0.0005
	83Km	**Davis North**	**Rat Lake**	**Omenica**	**Davis South**	**Van Somer**	
Mean	0.2476	0.4373	0.3118	0.2967	0.2249	0.188	
Minimum	0.105	0.102	0.102	0.1	0.1	0.1	
Maximum	0.525	3.1	1.934	2.453	0.706	0.437	
Standard Deviation	0.1296	0.5287	0.4204	0.3099	0.1231	0.0859	
Variance	0.0168	0.2795	0.1768	0.0961	0.0152	0.0074	
	Tsay Keh	**57Km**	**Ingenika**	**Lafferty**	**35Km**	**Collins**	
Mean	0.152	0.2571	0.1279	0.2246	0.5922	0.127	
Minimum	0.101	0.1	0.101	0.101	0.1	0.1	
Maximum	0.418	1.042	0.184	0.723	5.98	0.163	
Standard Deviation	0.0514	0.1806	0.0287	0.103	0.7676	0.0289	
Variance	0.0026	0.0326	0.0008	0.0106	0.5891	0.0008	

Generally most sites have mean values of similar magnitude (0.15 – 0.25 mg/m^3). There are several notable sites with values ranging from 0.3 to 0.6 mg/m^3. These include Middle Creek North, Bruin, Davis North, Omenica, and 35Km (a.k.a. Lorimer). There were several maximum values in the 2.0 mg/m^3 range, but the maximum value at 35Km was more than double the next nearest value at 5.98 mg/m^3. Anecdotal evidence would suggest that the sediments at 35Km are very fine and highly mobile. Not surprisingly, the data from 35Km show the highest standard deviation and variance at 0.77 and 0.59 mg/m^3. Davis North and Omenica show the next highest standard deviation for samplers located on a beach, at 0.52 and 0.31 mg/m^3, respectively. Interestingly, the data from Rat Lake has a standard deviation of 0.42 mg/m^3, indicating that there is large variability in the values surrounding the relatively small mean. The descriptive statistics shown in Table 5 are a good preliminary examination of the data and indicator of site conditions. Moving forward it will be very important to evaluate these data within the context of the many confounding variables that may affect the result. These variables may include: Precipitation, Relative humidity, Wind Speed/Direction and the daily reservoir level.

2.3.1.2 ANOVA Between All E-Samplers

We utilize a one-way ANOVA to examine the entire 19-instrument E-Sampler dataset 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 around the reservoir with 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 19 E-Sampler instrument locations.

Table 6: ANOVA Summary Table for All E-Sampler Data

Source	Sun Squares	Degrees Freedom	Mean Squares	F	p-value
Groups	57.573	18	3.1985	17.49	$7.5397e^{-53}$
Error	508.261	2779	0.18289		
Total	565.834	2979			

Since $p = 7.5397e^{-53} < 0.01$ 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.

The following table provides a Site Name/Boxplot Key to reference the groups shown in Figure 23.

Table 7: Boxplot Site Key

Site Name	Boxplot Key	Site Name	Boxplot Key	Site Name	Boxplot Key	Site Name	Boxplot Key
Middle Creek North	1	Stromquist	6	Omenica	11	Ingenika	16
Chowika	2	Moody	7	Davis South	12	Lafferty	17
Shovel	3	83Km	8	Van Somer	13	35Km	18
25Km	4	Davis North	9	Tsay Keh Dene	14	Collins	
Bruin	5	Rat Lake	10	57Km	15		

Figure 23 is a box and whisker plot showing the results of the ANOVA. Groups 18, 9 and 5, which correspond to 35Km, Davis North and Bruin contain a significant number of outliers within their respective datasets. These three sites are driving the significance within this analysis. Group 11, also known as Omenica also exhibited a large number of outliers. The red "+" symbol indicates that the data point is an outlier. There are a number of sites that contain very high outlier values.

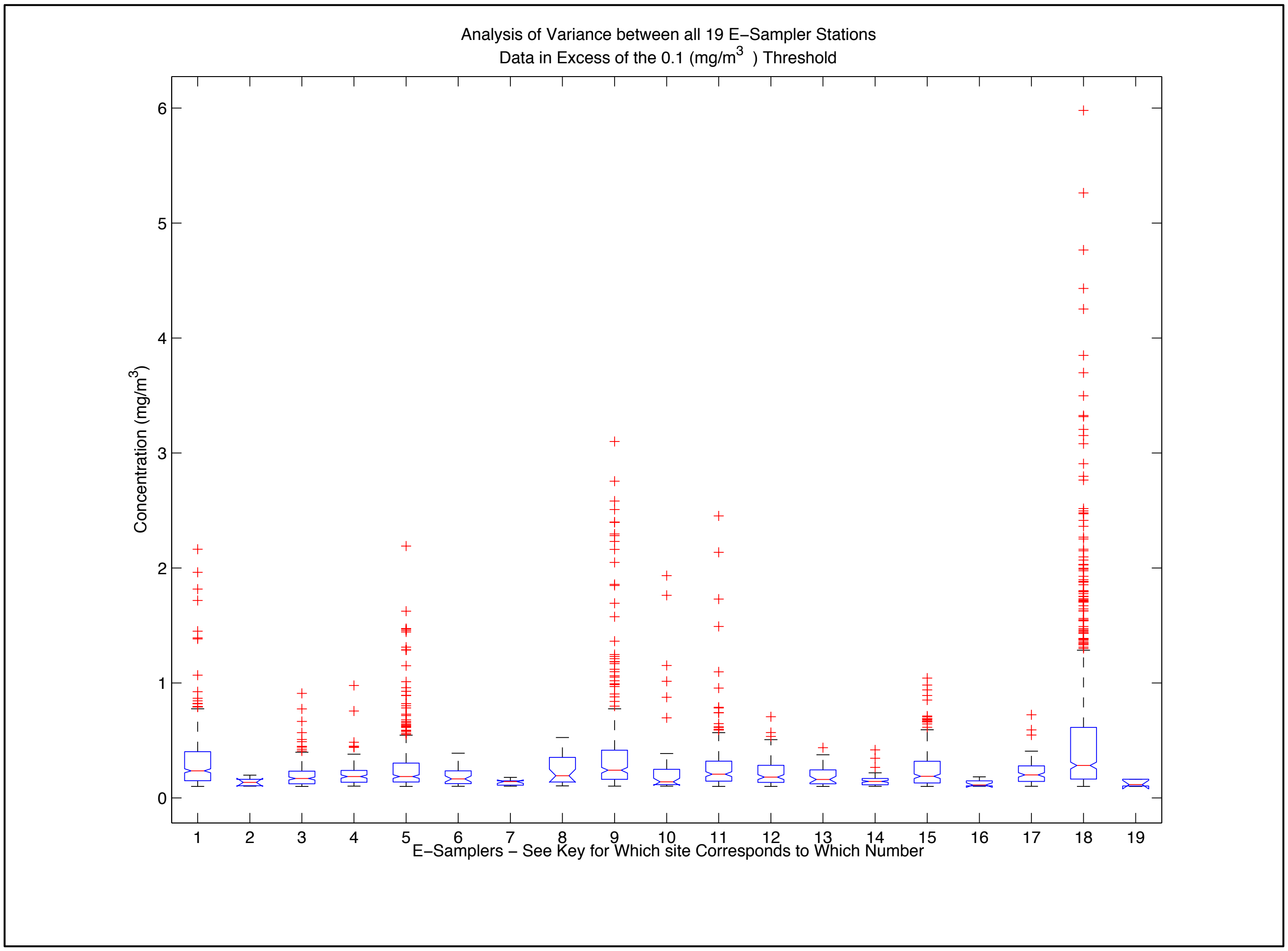

Figure 23: Results of ANOVA for Entire 19 E-Sampler Dataset

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

Since significant differences in mean dust event concentrations were identified above, 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. We 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 8: ANOVA Summary Table for E-Sampler Data from Non-Erosive Locations

Source	Sun Squares	Degrees Freedom	Mean Squares	F	Prob > F
Groups	1.0944	8	0.13679	5.14	$4.3732e^{-6}$

Error	9.716	365	0.02662
Total	10.8103	373	

Since p = $4.3732e^{-6} < 0.01$ 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. Figure 24 below, is a box and whisker plot of the ANOVA analysis performed on these data. Group 6 – Ingenika, shows that there are many outliers in this dataset. In general differences in mean dust concentration recorded at these sites appears to be small but significant. Using a multiple comparisons, we can see that group 6 and group 1 drive the significant difference. Using our site Name/Boxplot Key, this translates to Ingenika and Chowika (See Table 9 below). These sites are located far from dust source locations and only receive particulate matter during sustained high wind events. Ultimately, this means that these sites, which are located further away from dust source locations than many of the other sites are collecting volumes of dust that are significantly greater than those instruments that are located in other locations. In other words, the strong winds that are characteristic of these sites (Table 3 above) are contributing to the significantly higher concentration of dust recorded at these locations.

Table 9: Boxplot Name Key for Non-Erosive Sites

Site Name	Boxplot Key	Site Name	Boxplot Key	Site Name	Boxplot Key
Chowika	1	83Km	4	Ingenika	7
Stromquist	2	Rat Lake	5	Lafferty	8
Moody	3	Tsay Keh	6	Collins	9

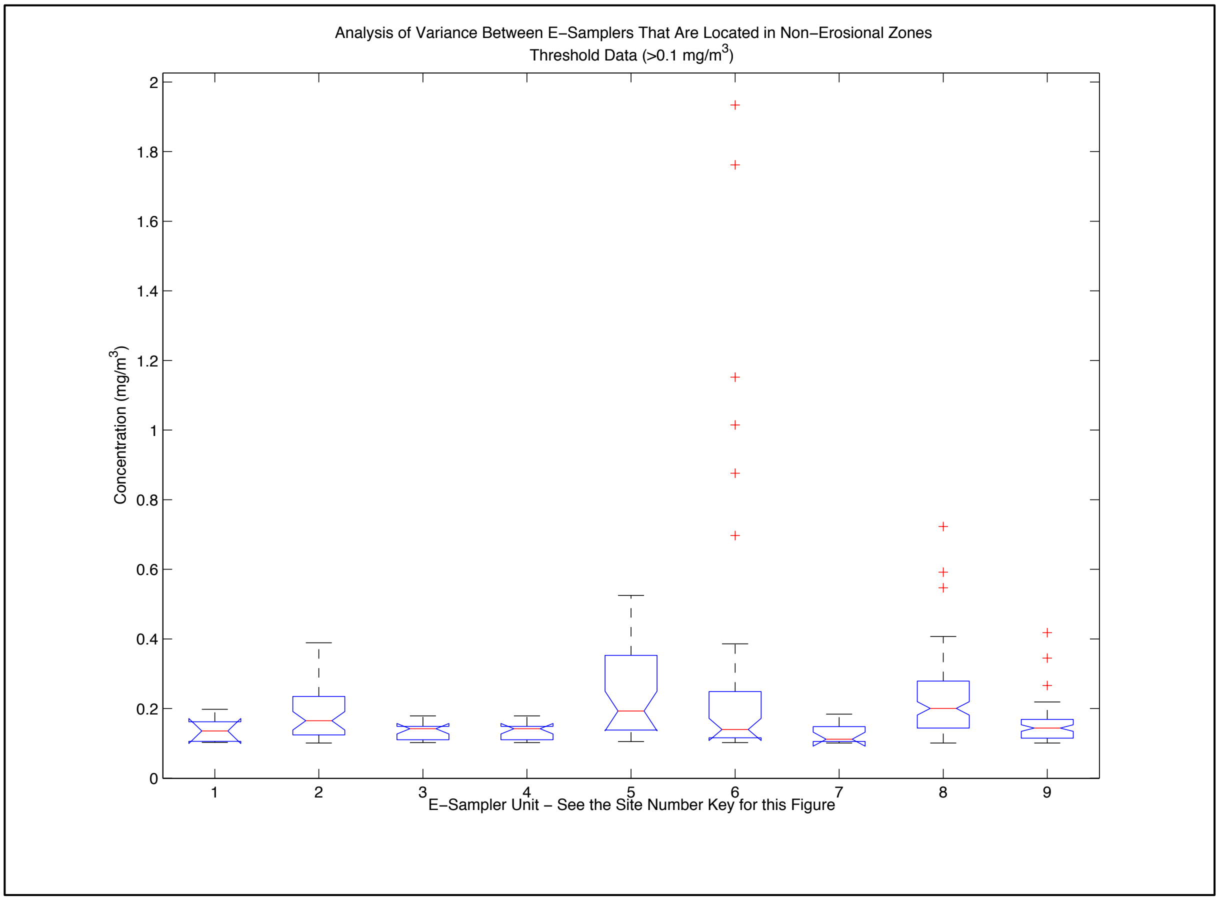

Figure 24: ANOVA Box and Whisker Plot for E-Sampler Data from Non-Erosional Sites

2.3.1.4 ANOVA Between E-Samplers Located in Erosive Areas

The second grouping of data represents the E-Samplers that are located in the moderate to highly erosive zones surrounding the reservoir. 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 10: 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	48.464	9	5.3848	26.18	$1.6885e^{-43}$
Error	498.548	2424	0.20567		
Total	547.012	2433			

Since $p = 1.6885e^{-43} < 0.01$ we may reject the null hypothesis at a 99% confidence interval. There are significant differences in dust concentration values between E-Samplers located in moderate to highly erodible zones. A multi-comparison analysis shows that the significance within this result is driven by Group 10 or 35Km and that to a lesser extent but still notable drivers of significance are Groups 1, 4, 6 in that order (Middle Creek North, Bruin and Omenica – See Table 11). This implies that the receiving environment in the vicinity of the 35Km E-Samplers collects significantly more fugitive dust than all other samplers followed closely by Middle Creek North, Bruin Beach and Omenica Beach. Figure 25 shows that there are numerous outliers in this dataset which may be driving the significance.

Table 11: Boxplot Reference Key for Figure 25

Site Name	Boxplot Key	Site Name	Boxplot Key
Middle Creek North	1	Omenica	6
25Km	2	Davis South	7
Shovel	3	Van Somer	8
Bruin	4	57Km	9
Davis North	5	35Km	10

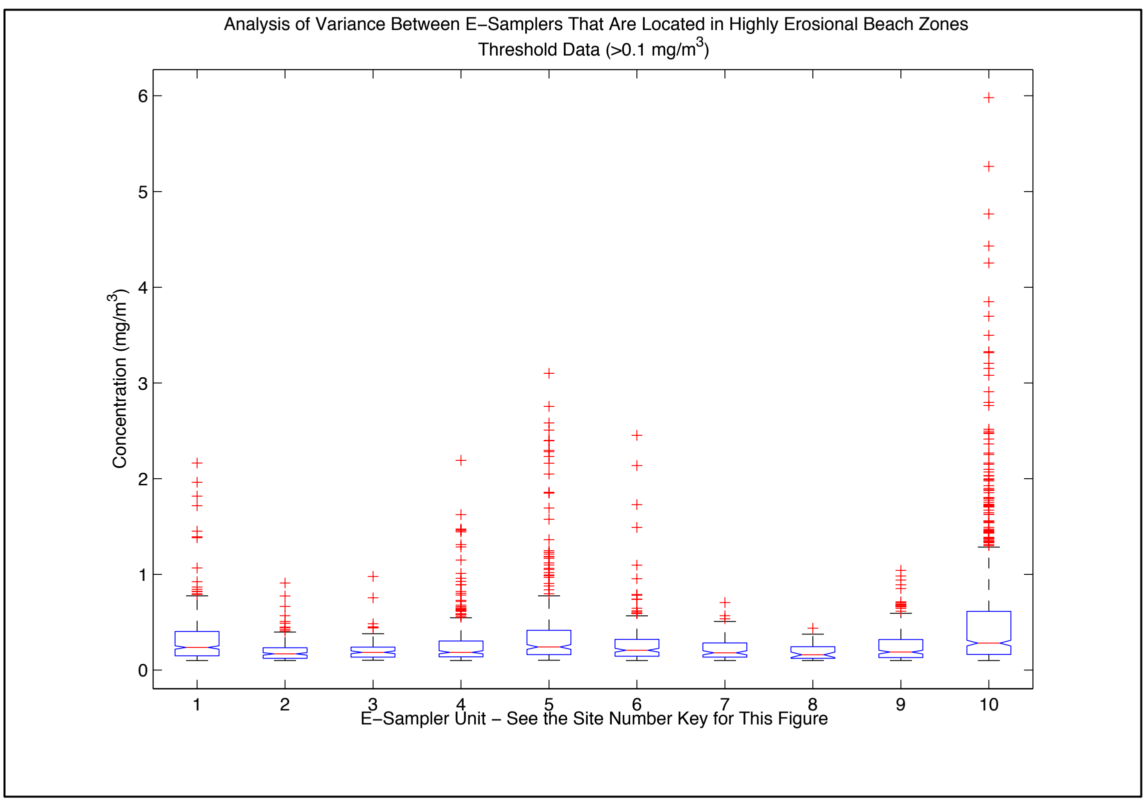

Figure 25: ANOVA Box and Whisker Plot for E-Sampler Data from Moderate to Highly Erosional Beach Sites.

2.3.2 Mitigation Treatment Analysis

In this section we will analyze the dust concentration recorded at E-Samplers from locations where the tillage date is known and in particular the highly erodible beach zones. More precisely, we will examine the basic statistics recorded before and after the implementation of the tillage and provide a T-Test comparison of means between these datasets.

The tillage tracks are recorded using Garmin 620 GPS units and the resulting track files are converted to *.kml files for import into Goggle Earth. The date that a particular tractor was in a particular location is recorded in the attribute file. Table 12 provides a summary of these data for the beaches that we have included in this analysis. Figure 26 shows a sample of the data collected from the Garmin 620 unit on the 35Km beach. Note that we do not have all of the data from all tractors, hence why there are gaps in the tracks shown in Figure 26.

There are an enormous number of variables external to tillage that may be controlling the fugitive dust emissions over time, these include: the number of wind and/or rain events, the daily relative humidity, and the reservoir elevation level. In order to minimize the temporal variability in this analysis we will examine data from 7 days before tillage application until 7 days after tillage application. In most cases the beaches were completely tilled within 2 days of tractors arriving. The dates quoted in Table 12 represent the last day of tillage on the given beach. This data analysis excludes data collected on days when the tillage was being applied to the given beach as we know that the tractors themselves generate some dust as they till the earth.

At the time of writing this the reservoir elevation data and erodible beach area data were not available. These parameters will be added in the next edition of this report in the fall of 2015.

Chu Cho Environmental would also like to note that this is the first time an approach through this lens to the air quality and tillage data has been attempted. Although our analysis here constitutes a small subset of the data we will be expanding this analysis in the future and will be gathering more data to better constrain the results. Currently, the data are not well constrained and so we would like to add the disclaimer that the result presented below represent the analysis for a single years data only and should not be considered conclusive.

Table 12: Summary of Beach Tilling Dates and the Before/After Data Collected by the Sampling Equipment.

Beach	Tillage Date	Before /After	Reservoir Level (m a.s.l.)	Avg. Wind Speed (m/s)	Total Precip. (mm)	Av. Rel. Hum. (%)	Avg. Conc (mg/m^3)	T-Test P-Value	Change in Beach Area
MCN	2014-06-03	BF		2.91	0.6	56.54	0.010	6.24e-7	
		AF		2.73	12	62.94	0.005		
Shovel	2014-06-02	BF		2.85	0.6	57.13	0.005	0.002	
		AF		3.30	13.4	65.37	0.003		
35Km	2014-06-02	BF		2.20	1.1	61.52	0.024	1.10e^{-12}	

		AF		2.73	3.5	63.50	0.083		
Van Somer	2014-05-19	BF		2.25	7.1	62.11	0.005	$4.55e^{-6}$	
		AF		2.24	3.5	60.52	0.008		

The data presented in Table 12 are both interesting and somewhat confounding. A T-test comparison of means was performed on the dust concentration data parsed out from before to after the application of tillage on a given beach. In all cases our T-test was designed to test the following null hypothesis at a 99% confidence level (alpha = 0.01):

> **H_0:** There is no significant difference in the mean dust concentration values from data collected 7 days before the application of tillage on a given beach to those collected the 7 days following the application of tillage.

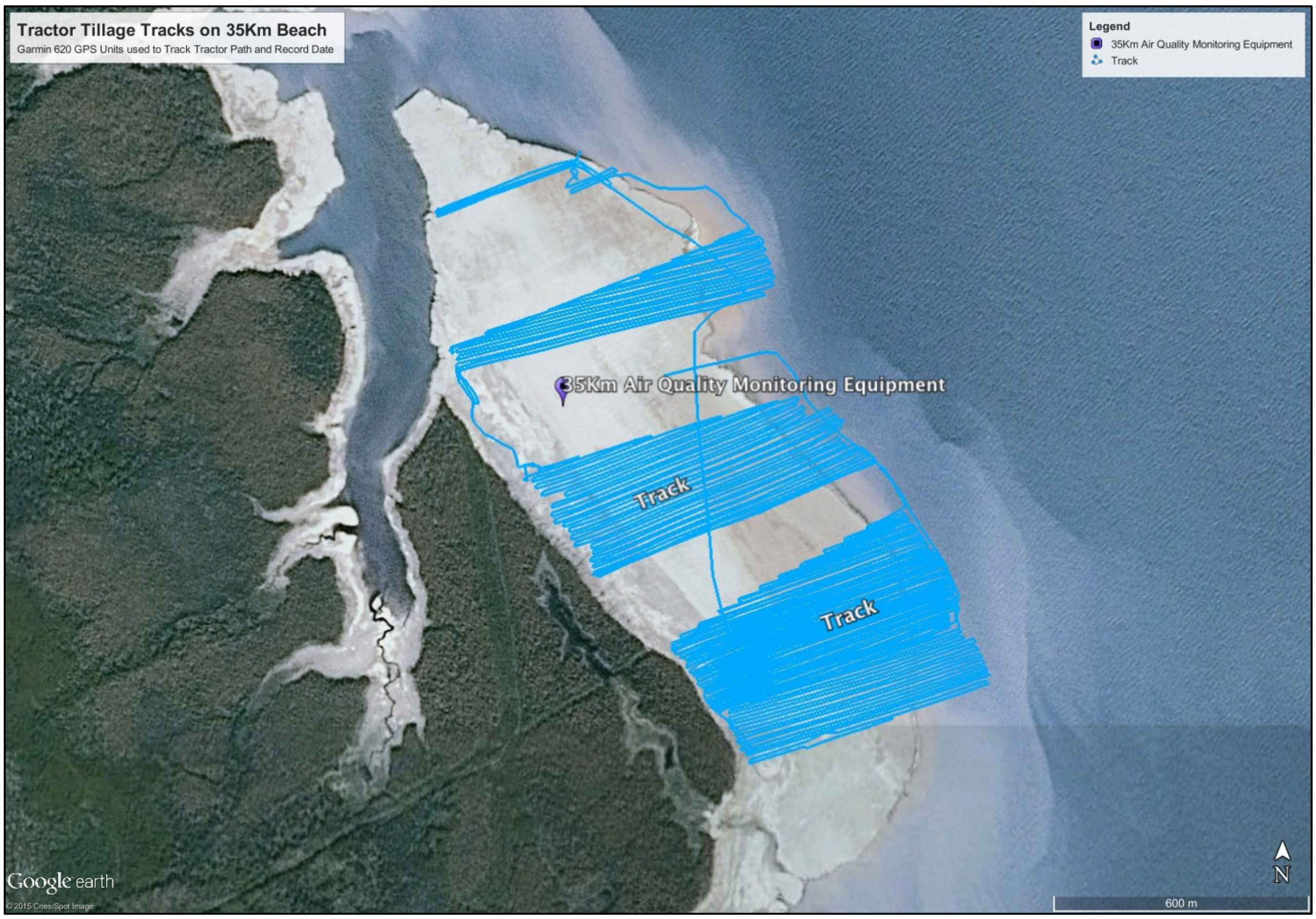

Figure 26: Garmin 620 GPS Tractor Tillage Tracks on 35Km Beach

In all cases the p-value was less than the alpha test values, therefore we can reject the null hypotheses and accept that there is a significant difference in the data from before and after the application of tillage on the given test beaches. However, the direction of the significance is not the same in all cases, two sites showed a decrease in dust readings while the remaining two showed an increase. Ultimately this means that our control and test variables are not well constrained. There are a host of other factors that are affecting these results.

At MCN and Shovel there was a significant decrease in fugitive dust emissions after the application of the tillage. However, at MCN in the 7 days leading up to the application of the tillage there was only 0.6 mm of rain while in the 7 days following the tillage there was 12 mm and at Shovel there was 0.6 mm before tillage and 13.4 after. The before/after wind speed and relative humidity are not strongly different in these cases. Ultimately, this means that we cannot completely attribute the decrease in dust emissions to the effect of the tillage, since there was so much rain in the days following the application of the tillage. More data is needed to constrain these results.

At 35Km there was a significant increase in fugitive dust emissions following the application of the tillage. The average wind speed was slightly higher and could explain some of the increased emissions recorded at the E-Sampler, but not completely. The total rainfall and average relative humidity were both higher as well but clearly not enough to slow down the dust emissions. Even though 35Km was tilled on the same day as MCN we know that weather around the reservoir can be highly localized and this is likely why we are seeing such high rainfall volumes at MCN and Shovel and minimal values at 35Km. In this case there is no reason to believe that tillage is effective here, in fact the data demonstrate the opposite, but as we said before, more data and analysis is required to constrain these results.

At Van Somer there was a significant increase in average fugitive dust emissions following the application of tillage. There was very little change in the average wind speed and a decrease in both rainfall amount and relative humidity. It would appear that as this site "dries out" following the application of tillage that the fugitive emissions begin to increase for the same given wind speed. Tillage begins to breakdown immediately following its application although some beach sediment types tend to hold it longer. Van Somer was part of a 2013 study and was shown to have very good prospects as a beach that would accept and maintain useful tillage for 10 – 14 days (Tilson et al. 2013). However, this is one beach and one sampler looking at a small subset of the data and as we've said above, more data is needed to constrain the results.

Simply looking at averages and drawing multiple and confounding conclusions is not our intention with presenting this avenue for analysis. Chu Cho Environmental has included this piece in the analysis to indicate where we are heading and what our future plans are for the enormous amount of data that is amassed by the regional monitoring network. We will be expanding this work through collaboration with industry modeling experts to create strong analysis approach following this lens.

For the 2015 season we have a better data capture and sharing plan in place with the WDMP so that we will know when a beach was tilled, how many hectares were completed, how many days it took, and what it cost. These multiple factors will be built into our analysis model for this approach along with all of the physical and meteorological data.

2.4 General Discussion

Chu Cho Environmental's updated continuous monitoring network has given us the ability to observe the small scale and migrating events that would otherwise be missed with periodic sampling. Examples such as those shown Figure 21 and 22 in Section 2.2.4 provide powerful examples of the type of analyses we are able to conduct with the data collected by the new Regional Monitoring Network. This will ultimately allow us to observe, on a much more detailed level, that impact that mitigation treatments are having on reservoir dust concentrations.

Although this report represents the start down many new analysis pathways, we would like to remind the reader that the results presented in this report are preliminary and that significant improvements will be made with each new iteration of this report.

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, 2013). The suite of criteria that are applicable to this report are 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 accepted in June 2013. Those that are relevant to this project include:

Table 13: Air Quality Objectives and Standards Relevant to this Project

Contaminant	Average Period	Objective/Standard	Date Adopted	Source
PM2.5	24 Hour	28 $\mu g/m^3$	2013	CAAQS
PM2.5	Annual	10 $\mu g/m^3$	2013	CAAQS
PM10	24 Hour	50 $\mu g/m^3$	2005	Provincial AQO
Dustfall	1 Month - Lower	1.7 $mg/(dm^2*day)$	1979	PCOs for Mining, Smelting and Related Industries
Dustfall	1 Month - Upper	2.9 $mg/(dm^2*day)$	1979	PCOs for Mining, Smelting and Related Industries

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. 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 is considered adequate to meet the standards for CAAQS reporting as well as Special Studies (British Columbia Air Protection Section Environmental Quality Branch, 2006).

Figure 27 below, shows the location of each monitoring station within the Finlay Valley and 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 10km wide at Tsay Keh Dene and narrows to less than 4km at Kwadacha. Figure 28 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 29 shows the Kwadacha monitoring station outfitted with a relative humidity/temperature sensor, barometric pressure sensor, rain gauge, and a wind speed/direction monitor.

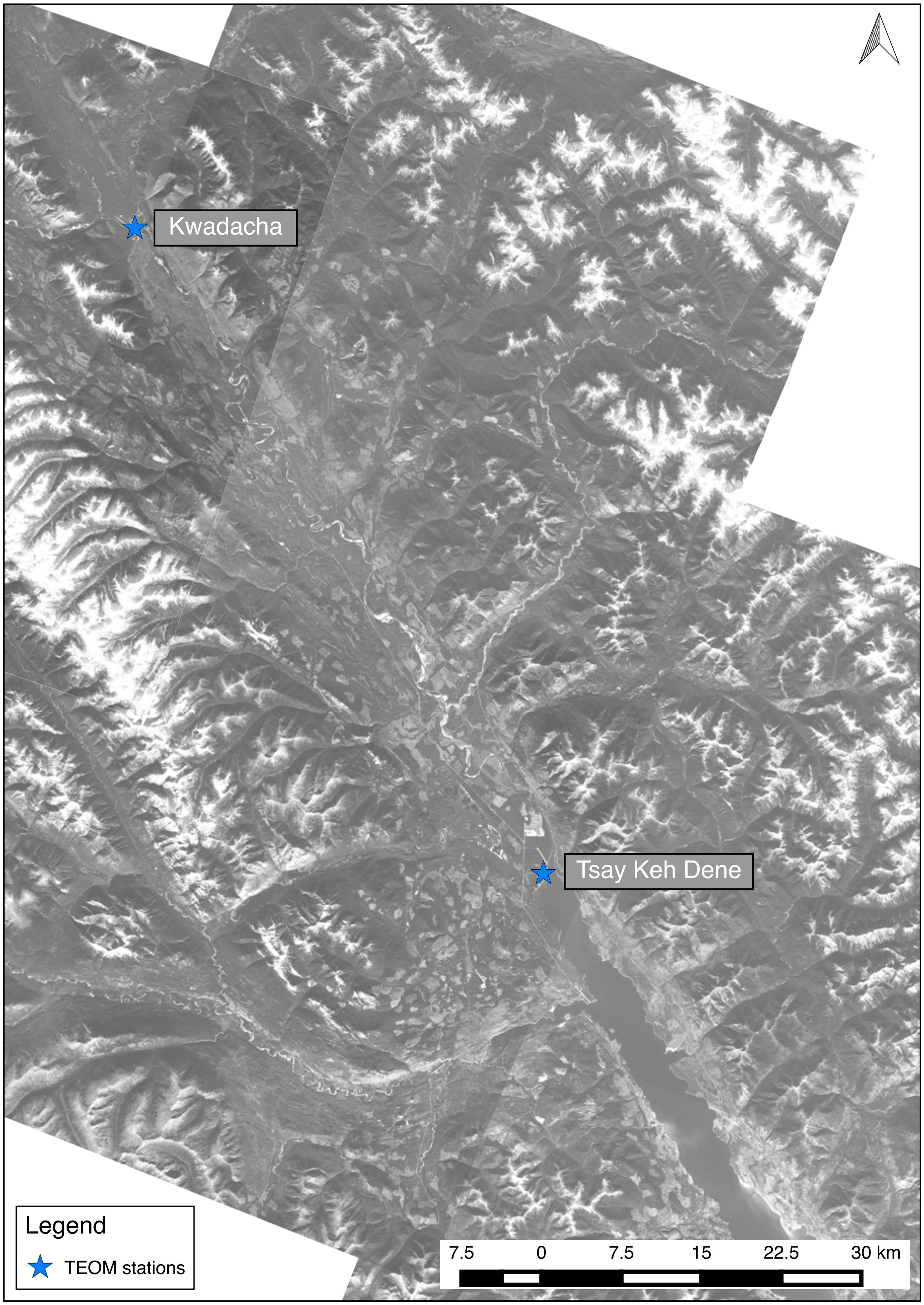

Figure 27: GMSMON#18 Reference Monitoring Network

Figure 28: Tsay Keh Dene Air Monitoring Station

Figure 29: Kwadacha Air Quality Monitoring Station

3.1.2 Instrumentation

The GMSMON#18 air quality monitoring project uses both Federal Reference Monitoring (FRM) and Federal Equivalent Monitoring (FEM) equipment for measuring and verifying air quality.

FEM:

- Thermo-Fischer Scientific TEOM 1405-D Dichotomous Ambient Particulate Monitor.
- U.S. EPA Designation EQPM-0609-182 for $PM_{2.5}$ (U.S. EPA 2012)
- U.S. EPA Designation EQPM-1090-079 for PM_{10} (U.S. EPA 2012)
- FEM instruments estimate mass concentration by using an active sensor to determine the particle concentration within a flow-controlled air stream where the sample is collected. The sensor responds to the presence of particles in the air stream and is designed to measure the mass concentration of particles in the air stream with a known precision and accuracy.
- 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 60Hz 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 represents 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 there are no records of maintenance of calibration performed during this time period. Chu Cho Environmental will use the raw 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. Since we do not have the maintenance records nor the properly validated data and performing the data verification procedures is very time consuming, Chu Cho Environmental will not include a CAAQS determination section in this report. Instead we will analyze data collected between April 2014 and August 2014 or what is typically called the dust season.

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

FRM:

- BGI PQ200 Ambient Particulate sampler.
- U.S. EPA designation RFPS-0498-116 for $PM_{2.5}$ (U.S. EPA 2012)
- U.S. EPA designation RFPS-1298-125 for PM_{10} (U.S. EPA 2012)
- BGI PQ200s are robust and easily configurable for $PM_{2.5}$ or PM_{10} applications.
- BGI PQ200s do not provide continuous PM monitoring and require significant labour costs and analysis costs for collecting air quality data.
- From 2012 – 2013 these were the primary instrument used to address the key management question posed by GMSMON#18 however, Chu Cho Environmental does not believe that these instruments are capable of doing this for two reasons:
    - These instruments can only record 24-hour average data and we know that reservoir dust storms may be short and sporadic in duration.
    - The labour costs in managing the instruments constrain the number of devices that can be deployed around the reservoir.
    - For these reasons the BGI PQ200 units are no longer being used to address the GMSMON#18 key management question.
- The BGI PQ200 units are used as independent verification tools for examining the validity of the TEOM 1405-D data.
- FRM Machines use a standard air filter that becomes loaded with particulate as air is pulled through the instrument. These filters are usually 47mm in diameter and must be placed in a sealed chamber across the flow path. Air is pulled though the instrument at 16.67 lpm for 24 hours. The filters are removed after 24 hours in the machine and are sent to a lab for gravimetric analysis to determine the mass of the particles that were deposited on the filter. Using the mass of particulate on the filter, the flow volume and the time that the filter was in the instrument the particulate concentration is calculated in $\mu g/m^3$.

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.
- Comparability:
    - We maintain a small subset of filter based monitoring instruments that are used to collect samples at random times for comparison to TEOM 1405-D data. These data are used to provide assurance that the TEOM 1405-D units are maintaining proper function through time.
- 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. For CAAQS determination the analysis is expanded to focus on the entire annual dataset and moving forward will incorporate the data collected since 2011.
- 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 meters 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 meters 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 and is completed 4 times annually.
    - 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 catalog the processes that lead to success 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 utilizes a strict schedule of sites 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 dataloggers 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. Data in this logbook are transcribed into a Word document a regular monthly intervals. 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. Since the TEOM units were re-installed on May 7th, 2015 by Chu Cho Environmental we have had four missed data days at each of the TEOM units.

3.2 Baseline Monitoring Network Data Overview

For this Year-7 final report we will analyze the 2014 datasets from the period covering April 2014 to August 2014, collected at both Tsay Keh Dene and Kwadacha.

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

Figure 30 (a) through (d) shows plots of the 24-hour average meteorology and air quality data recorded at the Tsay Keh Dene monitoring station during the months of April 2014 to August 2014.

Meteorology:

In general, the 2014 dust season was warner and dryer when compared to results of the 2011, 2012 and 2013 studies (Nickling et al. 2013), this resulted in an increase in the number of overall dust events as well as several wildfires in the area. Precipitation levels from May to August were very low when compared to previous years. This resulted in a slow reservoir rise, lower beach moisture, lower relative humidity and more mobile sediments in general on the reservoir beaches. Precipitation and relatively humidity are shown in Figure 30 (d) and air temperature and air pressure are shown in Figure 30 (c).

Winds are generally oriented along the Finlay Valley and so either come from the Northwest or Southeast. There were only two major sustained wind events during the typical dust season from May – June. The first event was on May 21st/22nd and consisted of powerful winds from the Southeast that resulted in a very large dust event in Tsay Keh Dene. On June 2nd/3rd there were very powerful winds from the Northwest that created a massive southerly migrating dust event. Wind speed and wind direction are shown in Figure 30 (b).

24-Hour Average Dust Concentrations:

24-hour average PM concentrations are shown in Figure 30 (a). The brown line represents PM_{10} and the green line represents $PM_{2.5}$. The colour coded dashed lines across the plot represent the exceedence standards, that is an Air Quality Objective (AQO) of 50 $\mu g/m^3$ for PM_{10} and 28 $\mu g/m^3$ for $PM_{2.5}$ (CCME, 2012).

We see that when averaged over 24 hours there were very few exceedences of the CWS or BC AQOs at the Tsay Keh Dene monitoring stations. There was only a single dust season exceedence for PM_{10} and zero exceedences for $PM_{2.5}$. Contrast this with the multiple days of exceedence during the woodsmoke events later in the summer. It is interesting to note that the dust season exceedence events are closely linked to the wind events shown in Figure 30 plot (b) while the late summer exceedences associated with woodsmoke are associated with very low winds. These also present an interesting link between rainfall and exceedence events. This is particularly evident on August 4th and 5th when the PM levels had been above the standard for several days and were rapidly extinguished by a rainfall event the following day.

The total exceedences recorded at the Tsay Keh Dene monitoring station are shown in Table 14. Over the period from May to August 2014 there were 10 total exceedence days for $PM_{2.5}$ none of which were during the dust season and 9 total exceedence days for PM_{10}; two of which were during the dust season. While there were relatively few exceedences of PM_{10} during the dust season it should be noted that the absolute value of the exceedence is more than 2.5 times that of the woodsmoke.

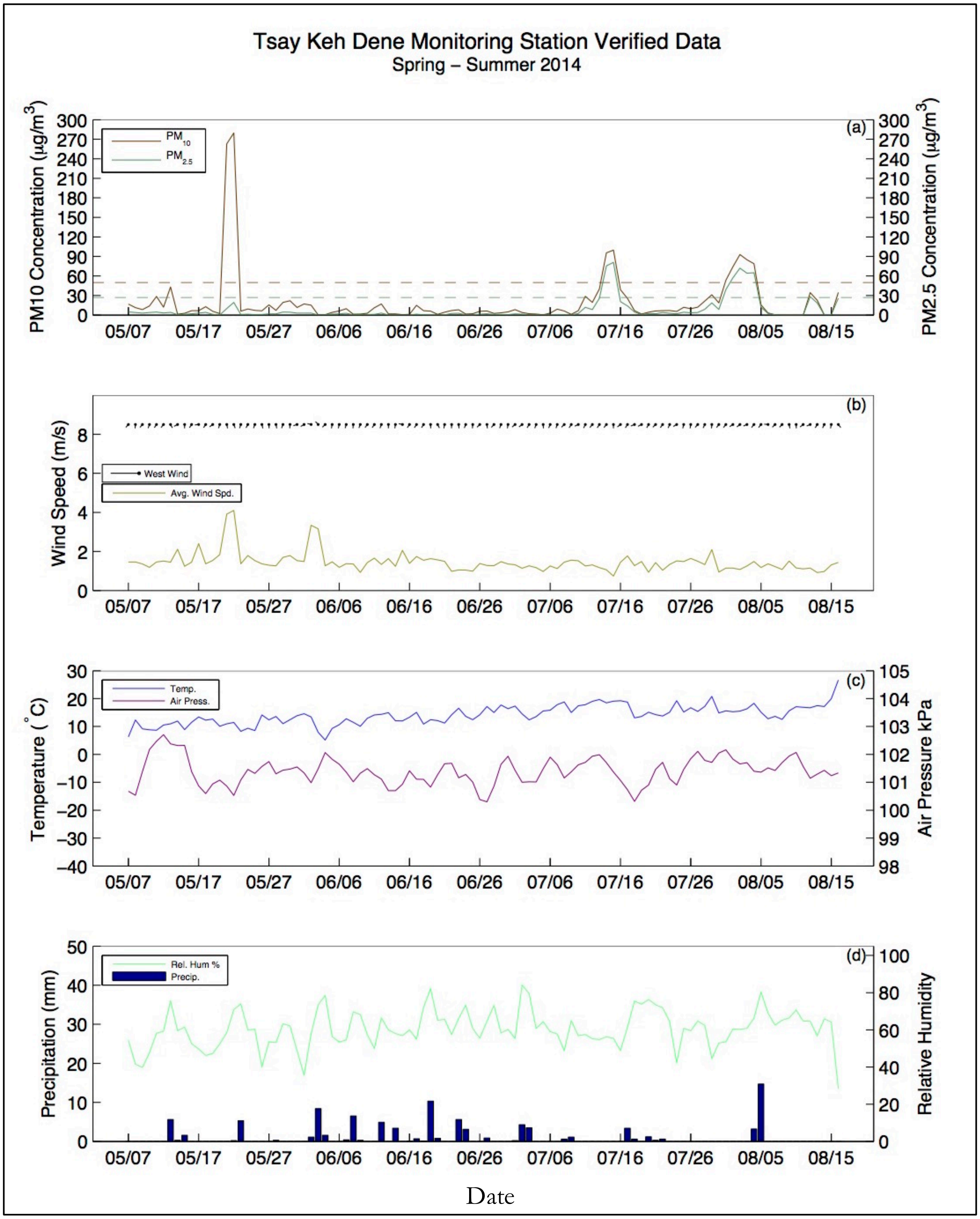

Figure 30: Tsay Keh Dene Ambient Air Quality Monitoring Station Data - April 2014 - August 2014

Table 14: PM10 and PM2.5 Exceedence Values and Dates

Date – $PM_{2.5}$	Value - $PM_{2.5}$	Date – PM_{10}	Value – PM_{10}
2014-07-13	25.725	2014-05-21	263.0028
2014-07-14	75.4573	2014-05-22	279.7088
2014-07-15	81.0185	2014-07-14	95.4813
2014-07-31	39.1481	2014-07-15	99.8261
2014-08-01	57.1504	2014-07-31	53.4068
2014-08-02	71.9915	2014-08-01	74.1305
2014-08-03	64.3648	2014-08-02	92.9017
2014-08-04	65.0269	2014-08-03	84.8325
2014-08-12	28.3535	2014-08-04	78.9315
2014-08-16	25.6092		

3.2.2 Total Hours of Exceedence

In the opinion of Chu Cho Environmental experts 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 very greatly in magnitude, duration and frequency from one event to the next. As a result, these events may be highly localized and might last only 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. Since the AQO, CWS and CAAQS are based on 24-hour averages, the air quality in Tsay Keh Dene generally meets these objectives. However, there may be several hours on any given day where the air quality is above the standards for PM. The impact of these hours is minimized when looking at the 24-hour average air quality data. Overall, this means that high frequency or high magnitude but short duration events are "smoothed" out.

In this section we will look at the dataset from May 2014 to August 2014 and will calculate the actual number of hours that the PM_{10} and $PM_{2.5}$ values were above the AQOs. Figure 31 shows the unfiltered and un-averaged PM_{10} and $PM_{2.5}$ data recorded by the Tsay Keh Dene TEOM 1405-D. The dashed lines are colour coded and represent the CAAQS or AQO for the given pollutant. In both charts (Figure 31 (a) and (b)) we can see that there are numerous and frequent exceedences of the CAAQS and AQOs. Some of these exceedences are very short-lived and as a result are not substantial enough to create an exceedence when averaged over a 24-hour period.

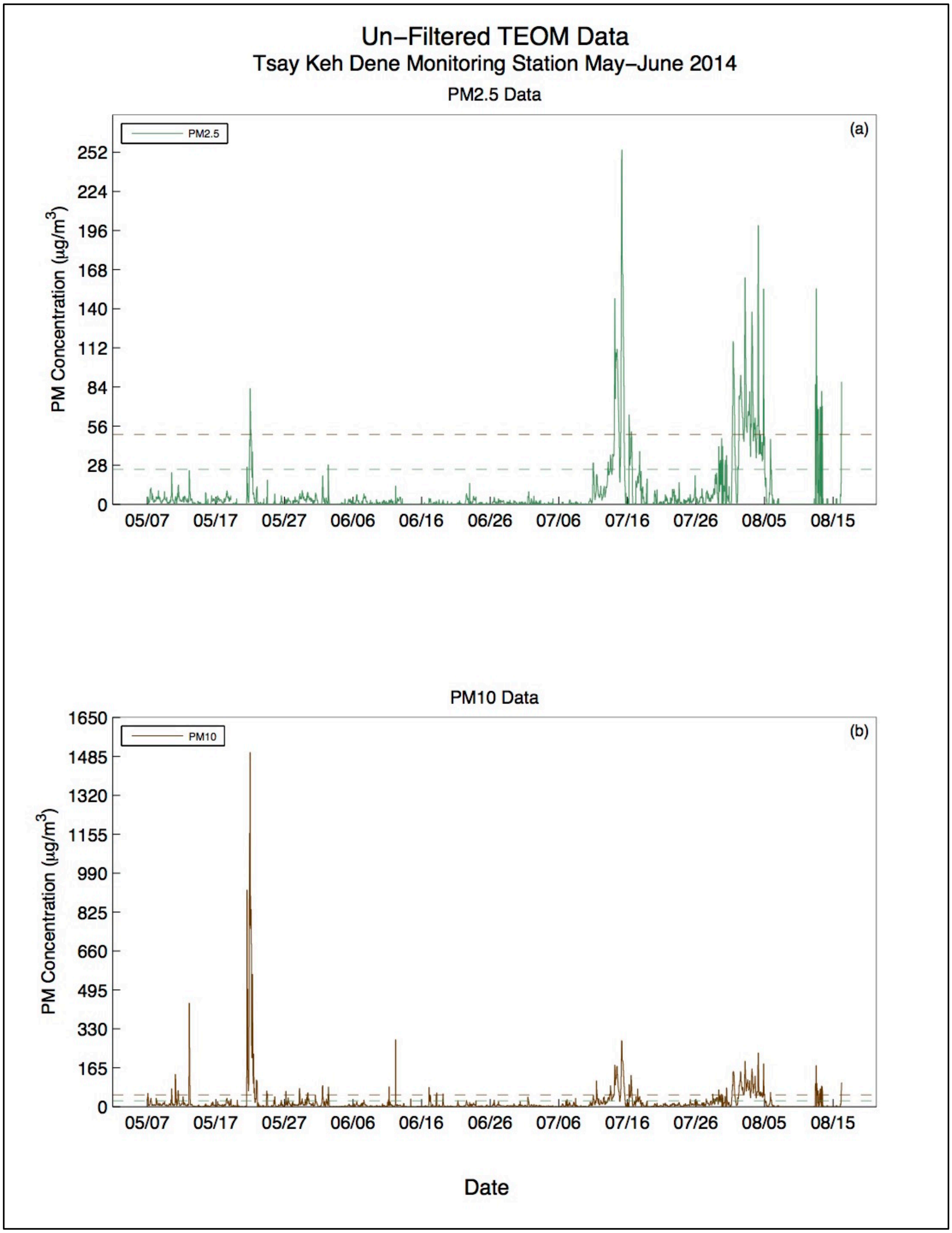

Figure 31: Un-Filtered and Un-Averaged Raw TEOM Data

Our project technicians extracted the total amount of time each day that the given parameter value was above the CAAQS or provincial AQO from the dataset. The total number of hours that each value was in exceedence of the standard was summed and the average value for the parameter was calculated during that time. These data are summarized in Table 15 for $PM_{2.5}$ and Table 16 for PM_{10}. There were a total of 179.5 hours of $PM_{2.5}$ exceedence and 368 hours of PM_{10} exceedence time, this equates to 7.5 days and 15.3 days respectively. Therefore using this method we calculated fewer $PM_{2.5}$ exceedences and more PM_{10} exceedences. In some cases there were less than 2 hours of exceedence in a given day.

For $PM_{2.5}$ this would imply that the exceedence values are derived from very high value but relatively short lived events. This means that the $PM_{2.5}$ content in the air spikes very high at time but then falls off quickly, however the spikes are large enough that overall average is pulled above the CAAQS exceedence standard.

PM_{10} on the other hand showed a dramatic increase in the number of exceedence days when calculated in this manner. This implies that PM_{10} values demonstrate both very high spikes that are short in duration and somewhat smaller value spikes that may last several hours. The latter, in which the spikes are relatively low but long in duration describes the situation in which the exceedence values are “smoothed out”, particularly in Tsay Keh Dene where the dust events are really storm events that tend to develop in the afternoons and subside as nightfall approaches. We will continue to investigate this avenue for analyzing these data because we feel that provides a useful perspective on the Tsay Keh Dene dust issue.

Table 15: Total Hours of PM2.5 Exceedence

Date	Value	Hours
22-May-14	63.4175	3.83333
14-Jul-14	104.9837	9.66667
15-Jul-14	124.0925	23.8333
16-Jul-14	61.69077	19
17-Jul-14	51.94	0.833333
31-Jul-14	93.97931	4.66667
01-Aug-14	79.70481	23.8333
02-Aug-14	78.49444	23.8333
03-Aug-14	77.17	23.8333
04-Aug-14	83.36795	18
05-Aug-14	107.3	2.83333
12-Aug-14	81.93636	1.66667
13-Aug-14	78.009	21.8333
16-Aug-14	69.185	1.83333
Tot. Days	**Avg. Val**	**Tot. Hrs**
7.4792	**82.5194**	**179.5**

Table 16: Total Hours of PM10 Exceedence

Date	Value	Hours
07-May-14	56.61	0.833333
11-May-14	92.89517	23.6667
12-May-14	56.33714	1
13-May-14	226.25	3.83333
21-May-14	124.6	0.666667
22-May-14	505.9196	23.8333
23-May-14	93.92304	12.5
24-May-14	61.06727	2.66667
25-May-14	54.74	0
27-May-14	65.39	0.833333
29-May-14	67.05667	2.83333
30-May-14	54.93667	2.83333
02-Jun-14	72.082	22.8333
11-Jun-14	84.2	0.833333
12-Jun-14	283.6	0.833333
17-Jun-14	66.215	1.83333
18-Jun-14	54.005	2.83333
19-Jun-14	54.34	0.833333
11-Jul-14	109.3	0.666667
12-Jul-14	66.02615	2
13-Jul-14	51.83818	2.66667
14-Jul-14	111.4638	23.8333
15-Jul-14	145.5061	23.8333
16-Jul-14	79.97033	23.8333
17-Jul-14	92.014	23.8333
18-Jul-14	75.23	0
28-Jul-14	53.27	0.833333
29-Jul-14	71.53	0.833333
30-Jul-14	68.68667	18.6667
31-Jul-14	114.6469	5.83333
01-Aug-14	100.3192	23.8333
02-Aug-14	95.04188	23.8333
03-Aug-14	94.19697	23.8333
04-Aug-14	89.96316	23.8333
05-Aug-14	97.38645	12
06-Aug-14	60.45	0.666667
12-Aug-14	85.52	2.83333
13-Aug-14	83.56455	22.8333
16-Aug-14	85.53385	2
Tot. Days	**Avg. Val**	**Tot. Hrs**
15.3333	**100.1443**	**368**

3.2.3 A Comparison of E-Sampler Data and TEOM Data

Since the E-Samplers do no carry a Federal Reference designation it is useful to provide a general comparison of E-Sampler and TEOM data in order to verify the abilities of the E-Sampler and to validate their use in this project. We will compare the data collected by the TEOM 1405-D to that collected by a co-located E-Sampler in Tsay Keh Dene over the same time period. The intake heads for both instruments are located at approximately 5 meters above the ground and are within 2 meters of each other.

Since the TEOM is recording PM_{10} and the E-Sampler is recording TSP it is not meaningful to perform a simple numerical comparison such as a regression between the values. However, we can draw a great deal of meaning from a visual comparison of the time series plots of these data.

Figure 32 contains two charts showing both TEOM data and E-Sampler data. Keep in mind that the vertical y-axis scales are not comparable since they are different quantities. The x-axis scales for each of the sub-figures (Figure 32 (a) and (b)) are identical and the temporal response times are striking similar. Both instruments respond quickly and with similar relative magnitude to both large and small dust events.

In general this comparison should allow us to feel confident that the MetOne E-Sampler provide excellent data quality and is well suited to our regional monitoring program.

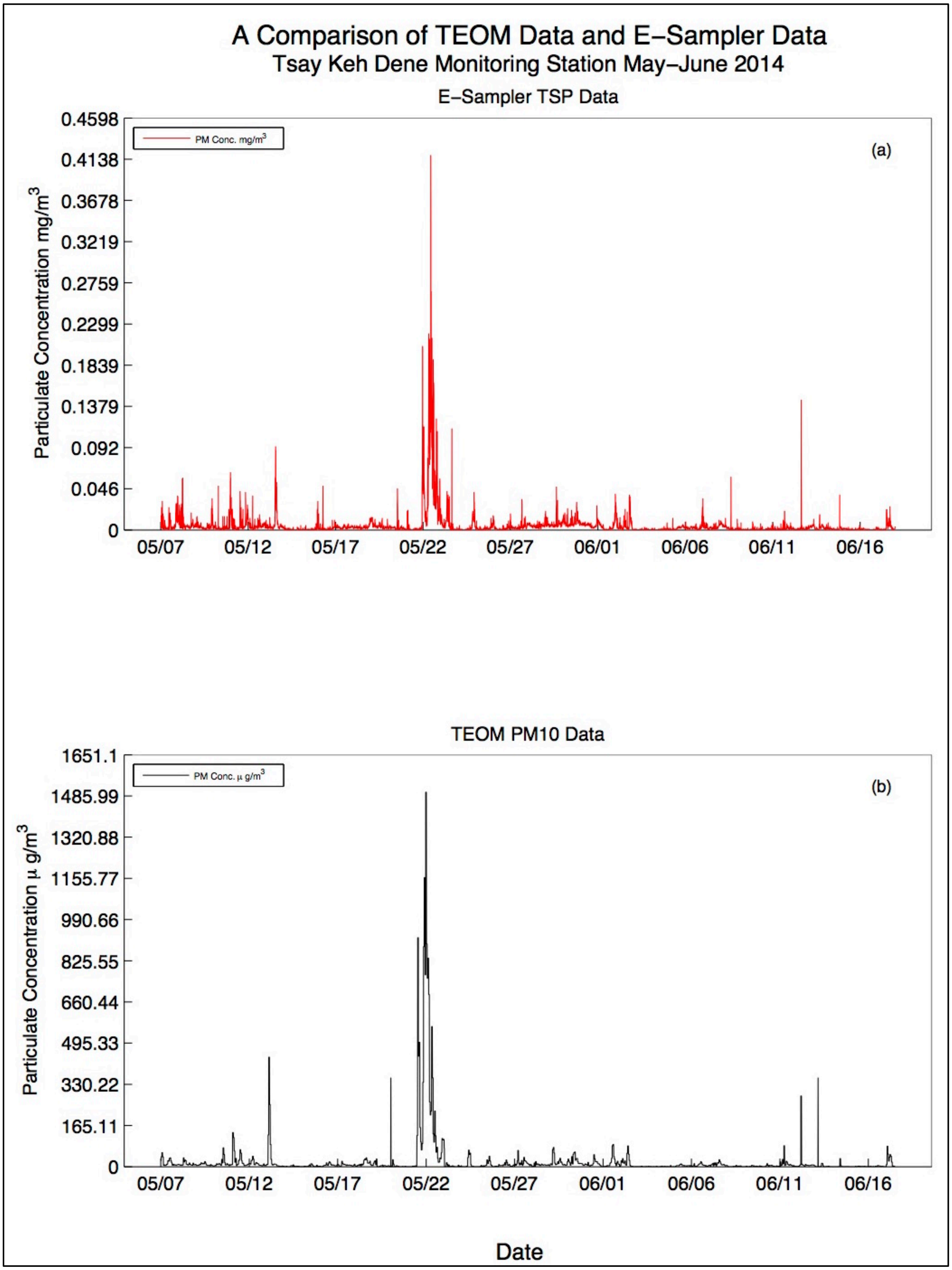

Figure 32: A Time Series Comparison of TEOM 1405-D Data and E-Sampler Data

3.2.4 Kwadacha Monitoring Station 24 Hour Average Air Quality and Meteorology Characterization

2014 data collected at the Kwadacha TEOM monitoring station are shown in Figure 33 (a) through (d). There were no exceedences of the Provincial AQO for PM_{10} and 4 exceedences of the Federal CAAQS for $PM_{2.5}$. The first two $PM_{2.5}$ exceedences were on May 20^{th} and 21^{st}, 2014 during a reservoir dust event and the remaining two events were in July during a woodsmoke event. The Kwadacha monitoring station is located over 70km away from the reservoir, which under most wind conditions is sufficiently far enough away that the larger particulate matter classes such as TSP and PM10 have fallen out of suspension. This is likely why there are no PM_{10} exceedences at Kwadacha but why there are $PM_{2.5}$ exceedences related to wind events further south on the reservoir. 2014 was a low precipitation year with very few large events above 10 mm in 24 hours. Relative humidity, temperature and air pressure demonstrated typical average values throughout the 2014 monitoring year.

As Chu Cho Environmental refines our data analysis and verification procedures we will provide more detailed analysis for the data obtained in Kwadacha.

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 was 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 band offices. 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.

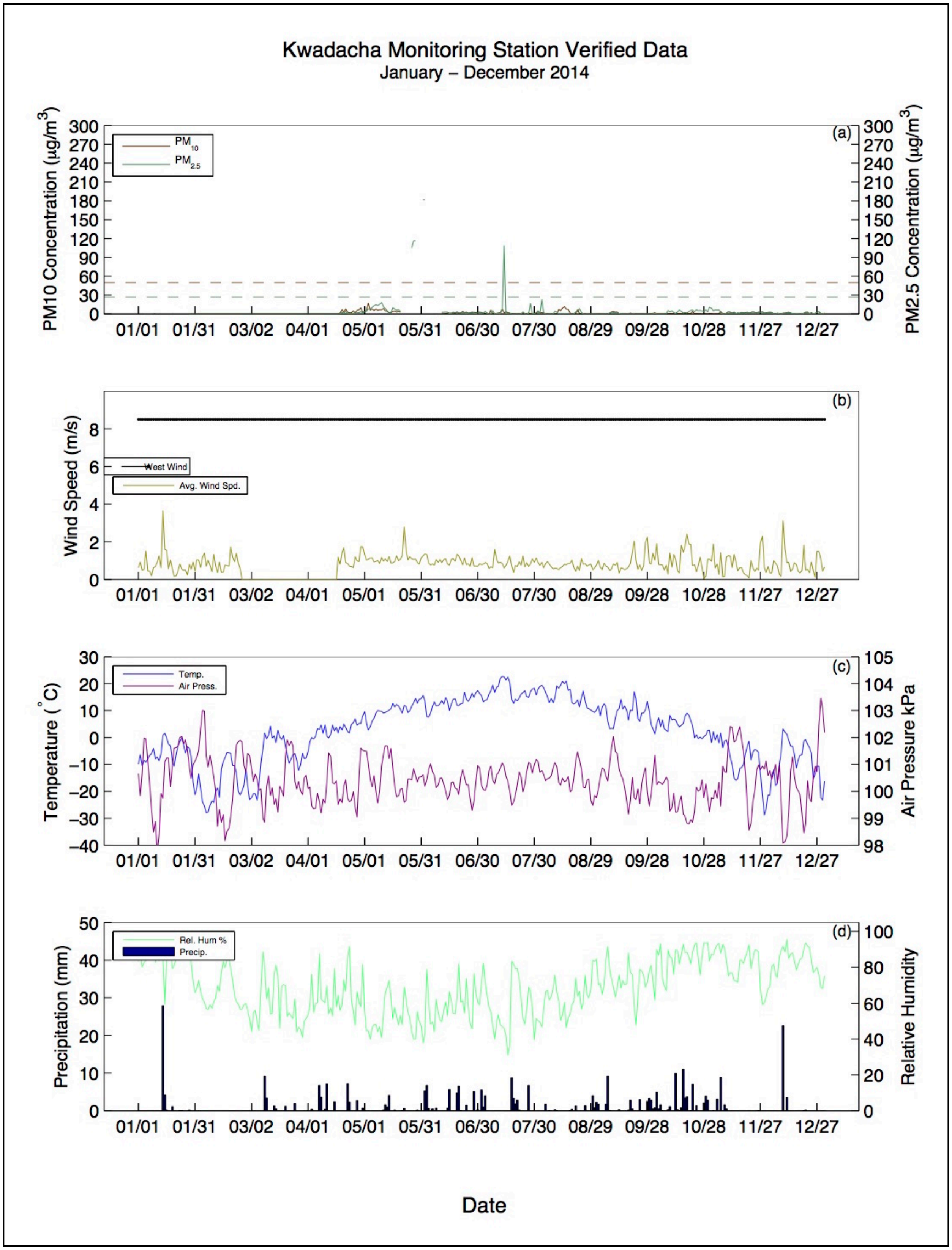

Figure 33: Kwadacha TEOM Monitoring Station 2014 Annual Data

Eagle.io:

All data are now available through a remote data access service called eagle.io. eagle.io is a web-based service that can access the data collected by the CR1000 datalogger through the Campbell Scientific NL200 Network Link Interface. Eagl.io queries the NL200 for data every 10-minutes, collects that data and then updates the database and the website. These data are available online at the refresh interval and can be viewed in several different ways including a list view, map view, or a dashboard view that contains small widgets to show the data.

Each page is available on eagle.io and can be shared and viewed by anyone who chooses to look. We will be updating our eagle.io profile in the coming months to take full advantage of the functions offered by eagle.io.

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 10minute 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. 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 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.

Looking ahead:

We will continue to look for ways to improve the overall reliability of the monitoring system and to create visuals that are more engaging and intuitive for people who are looking at and interpreting the data.

4.0 Dustfall Monitoring

Dustfall monitoring began in Spring 2014 in order to establish a baseline quantity for the volume of settleable particulate levels in the Tsay Keh Dene village area. Dustfall analysis will take place from May to October for each year of this project.

4.1 Equipment and Methodology

Dustfall sampling canisters prepared by ALS Environmental Laboratories were deployed at three locations in the vicinity of Tsay Keh Dene. The sample canister is a large 2 liter Nalgene bottle with a 4" diameter mouth that is open to the atmosphere. The sample canisters are opened, placed in a custom designed and built Dustfall stand and left alone to collect dust fallout for approximately 30 days.

Chu Cho Industries built the Dustfall stands according to design specifications supplied by EDI Environmental Dynamics Inc. Each Dustfall stand has a holder for the Nalgene canister that provides protection from cross winds and has vertical spikes welded on the rim of the wind guard to prevent birds from landing on the stand and contaminating the sample.

After approximately 30 days the sample canisters were removed, resealed and shipped to ALS Laboratories for gravimetric analysis. At this time, another canister is opened and placed in the Dustfall stand. The mouth of the sample canister is located as near as possible to 2 meters above the ground.

ALS Laboratories provides three values following the analysis: Fixed Dustfall, Volatile Dustfall and Total Dustfall. The volatile fraction are those particulates that are carbon based and therefore volatize when the sample is heated. Generally, for this project we are concerned with the Total and Fixed Dustall amounts since we know that the primary source of dust in TKD village is the reservoir beaches, which are comprised of silica based sands.

4.2 Network Characterization

Figure 34 shows the location of each sample site within Tsay Keh Dene village and relative to the reservoir. Table 17 provides a summary of the sampler ID, location and a site description. Each of the three samplers are shown in Figures 35 through 37.

Table 17: Summary of Dustfall Monitoring Stations

Sampler ID	Location	Site Description
DF-TK-01	Adjacent to TEOM Monitoring Station	This site is very open and free from the influence of trees, buildings or other impediments to flow. The sampler is located approximately 450m from the reservoir.
DF-TK-02	Southern end of Tsay Keh Airport adjacent to a Finlay River cutbank.	This sampler is adjacent to the reservoir atop a cutbank where the Finlay River meets the Williston Reservoir across from Ruby Red Beach. There are no nearby trees, buildings or other impediments to airflow that would influence the sampler.

DF-TK-03	Adjacent to a household in Tsay Keh village	This sampler is located in a sparsely wooded area adjacent to a household in Tsay Keh village. Airflow in the vicinity of the sampler is moderately influenced by the nearby woody vegetation but the sample canister does not collect pine needles or other falling organics.

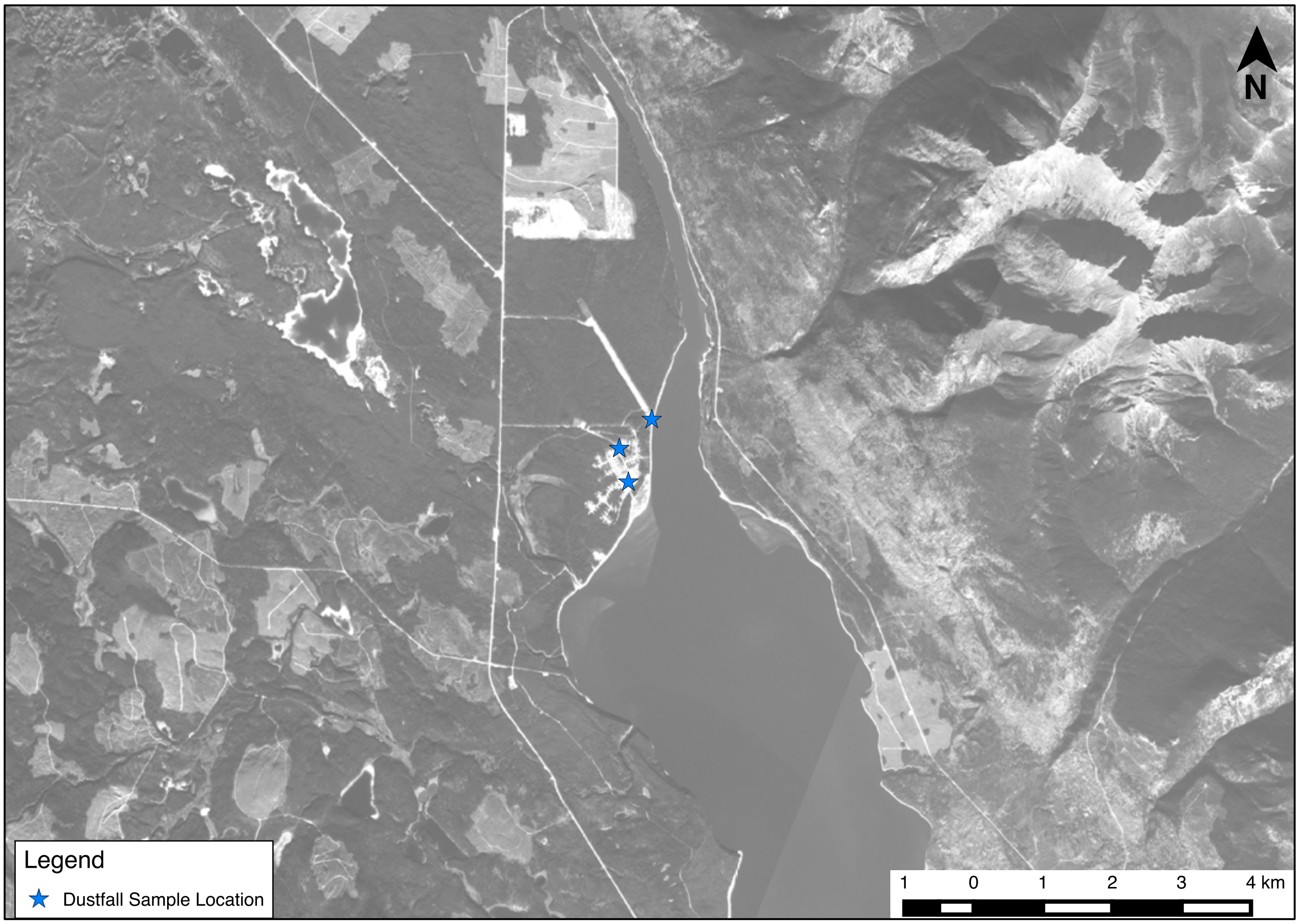

Figure 34: Tsay Keh Dene Dustfall Monitoring Network

Figure 35: DF-TK-01 Dustfall Sampler

Figure 36: DF-TK-02 Dustfall Sampler

Figure 37: DF-TK-03

4.3 Dustfall Analysis and Discussion

Dustfall samples were collected for 5 months including May, June, July, August and September (including approximately 10 days in October). The May/June Dustfall samples represent what is generally considered the Williston Reservoir's dust season. The July, August and September samples represent a time when the reservoir is typically at full-pool and in 2014 collected primarily ash fallout from the extensive forest fires in the area.

There were a number of months where the recorded Dustfall value was in exceedence of the lower Dustfall AQO of 1.7 $mg/dm^2 * day$ and only 2 true exceedences of the upper AQO of 2.9 $mg/dm^2 * day$ (BC MoE, 2013). There were a number of values that approached the upper limit but did not exceed it.

There are 2 anomalous values that are well in excess of the upper limit AQO both of which occurred at DF-TK-02. These values are over 12 times that upper limit value and are likely the result of external factors other than dust fallout. As a result, we will not include these results in the analysis for this report but should this trend continue at this site in the future and we have reason to believe that these numbers are representative of reality we will move to include them in this analysis.

Table 18 show the Fixed, Volatile, and Total Dustfall values for each of the three sites for each of the 5 sampling months. The detection limits and measurement units are also included in this table. Each of the true exceedence values in the table are highlighted in bold font.

The lower limit AQO was exceeded at each site during the month of may and only at DF-TK-02 during the month of June. The lower limit AQO was exceeded at all sites during the month of July including an upper limit exceedence at DF-TK-02. There was one lower limit exceedence at DF-TK-03 in August and only one upper limit exceedence at DF-TK-02 in September.

This preliminary analysis indicates that during the typical dust season, the dust fall out from dust events will likely exceed the provincial lower limit AQO for the month. Since the was above 668m for the month of July and August the Dustfall recorded during these month was not related to reservoir dust events but the result of ash fallout from forest fires burning in the adjacent valleys.

The Dustfall data are shown in Figures 38 through 40 on the following pages. Note that the scale on these charts has been standardized to accommodate the anomalously large values recorded at site DF-TK-02. There is no clear trend in the relationship between dust events, ash events and the proportion of Fixed Dustfall to Volatile Dustfall at this time. We will need to collect more samples before we can draw conclusions form these data.

Table 18: Dustfall Monitoring Network Summary Data

Site ID	Sample Date	Month	Fixed DF	Volatile DF	Total DF	Units	Det. Limits
DF-TK-01	2014-05-30	May	2.60	0.26	**2.85**	mg/dm^2*day	0.1
DF-TK-01	2014-06-30	June	0.45	0.51	0.96	mg/dm^2*day	0.1
DF-TK-01	2014-07-08	July	1.52	0.87	**2.40**	mg/dm^2*day	0.1
DF-TK-01	2014-09-10	August	0.60	0.75	1.35	mg/dm^2*day	0.1
DF-TK-01	2014-10-10	September	1.15	0.35	1.50	mg/dm^2*day	0.1
DF-TK-02	2014-05-30	May	34.3	1.17	35.4	mg/dm^2*day	0.1
DF-TK-02	2014-06-30	June	1.44	0.63	**2.06**	mg/dm^2*day	0.1
DF-TK-02	2014-07-08	July	1.95	2.28	**4.23**	mg/dm^2*day	0.1
DF-TK-02	2014-09-10	August	49.4	0.96	50.4	mg/dm^2*day	0.1
DF-TK-02	2014-10-10	September	4.74	0.56	**5.30**	mg/dm^2*day	0.1
DF-TK-03	2014-05-30	May	1.75	0.60	**2.35**	mg/dm^2*day	0.1
DF-TK-03	2014-06-30	June	0.63	1.03	1.66	mg/dm^2*day	0.1

DF-TK-03	2014-07-08	July	1.38	0.66	**2.04**	mg/dm²*day	0.1
DF-TK-03	2014-09-10	August	0.98	0.84	**1.82**	mg/dm²*day	0.1
DF-TK-03	2014-10-10	September	0.96	0.41	1.37	mg/dm²*day	0.1

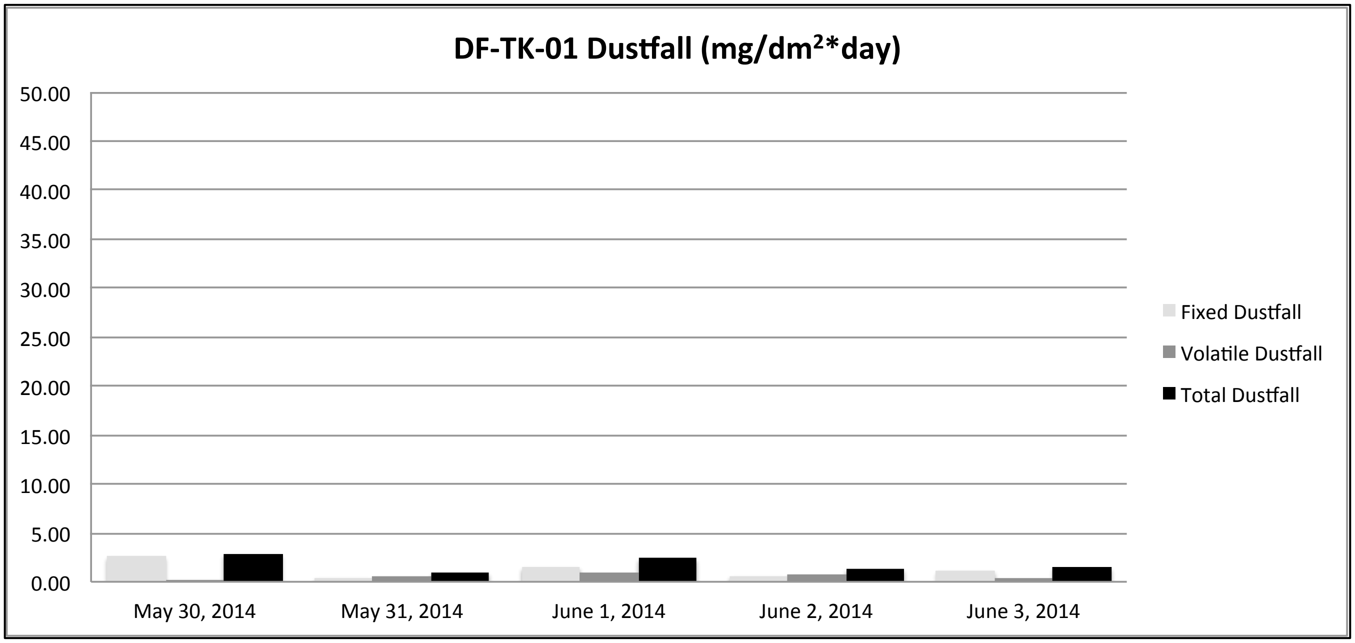

Figure 38: Dustfall Data for DF-TK-01

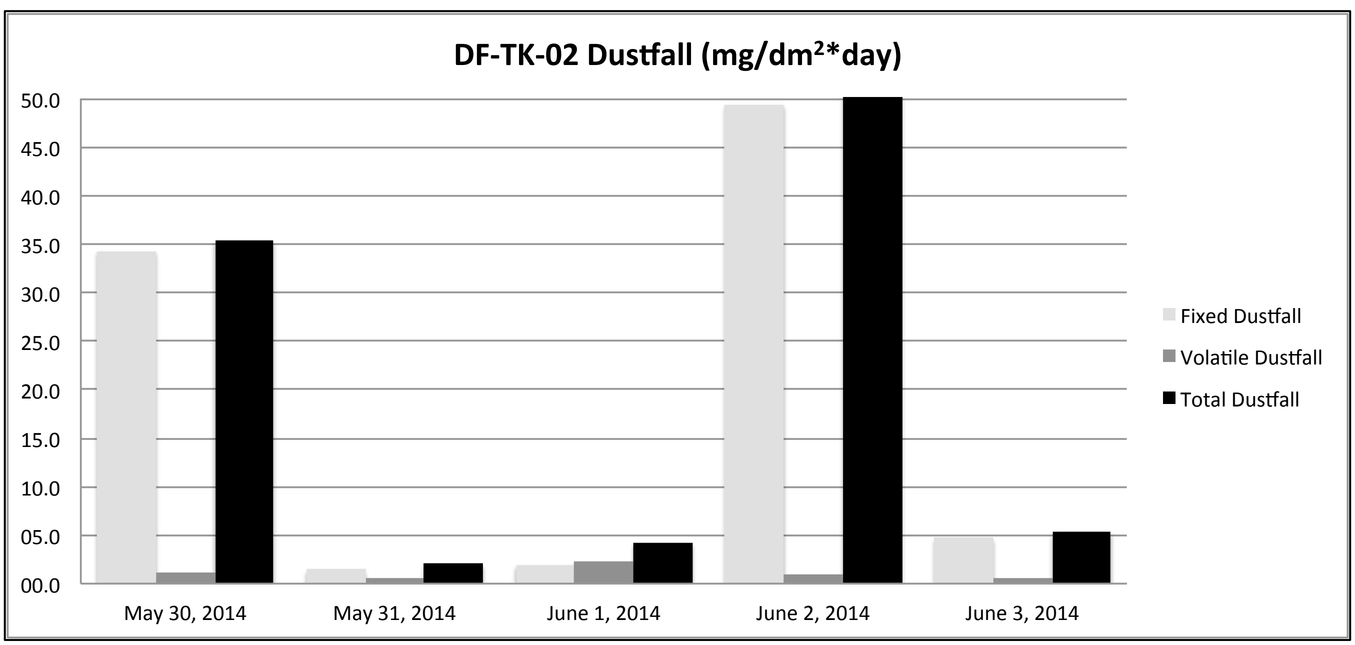

Figure 39: Dustfall Data for DF-TK-02

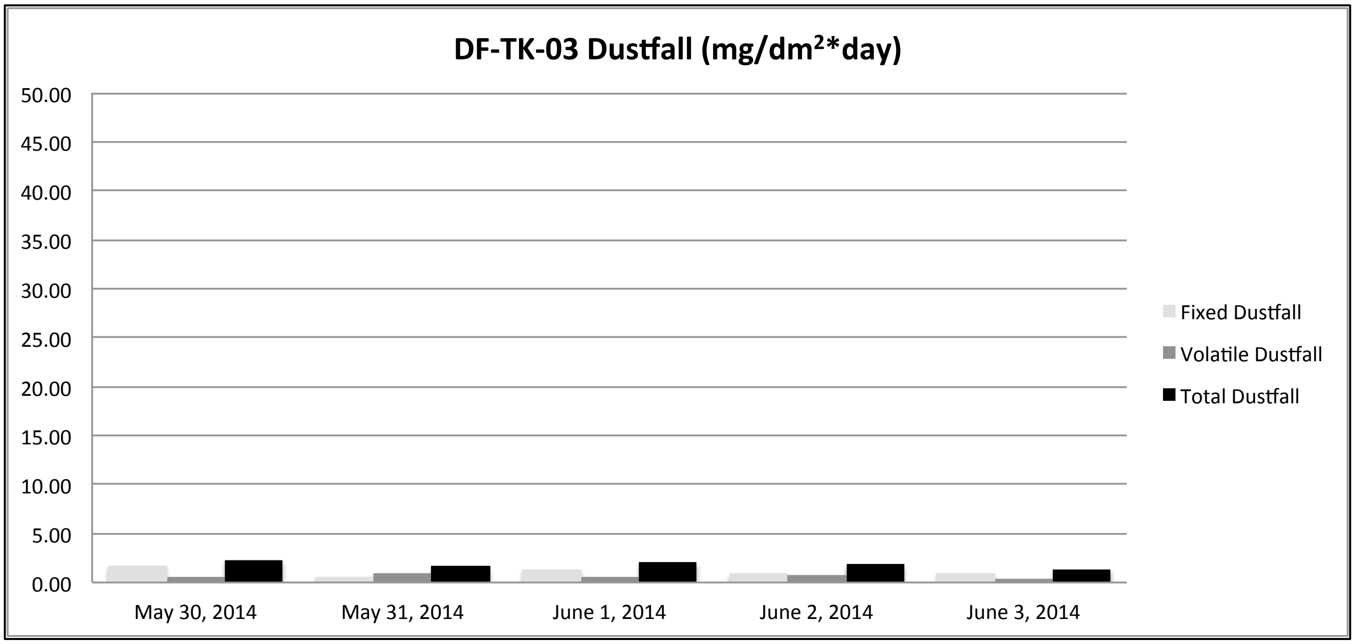

Figure 40: Dustfall Data for DF-TK-03

5.0 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.

5.1 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 a full-time employee in Kwadacha who is able to manage the basic maintenance and operation of the Kwadacha Air Quality Monitoring Station. This employee possesses a rudimentary understanding of how the instrument functions and what normal operation should entail. When our employee encounters an issue, they 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.

We expect that we will have 2 fully trained employees in Tsay Keh Dene who will be able to provide autonomous maintenance and management of the monitoring stations.

5.2 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 41 through 43 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.

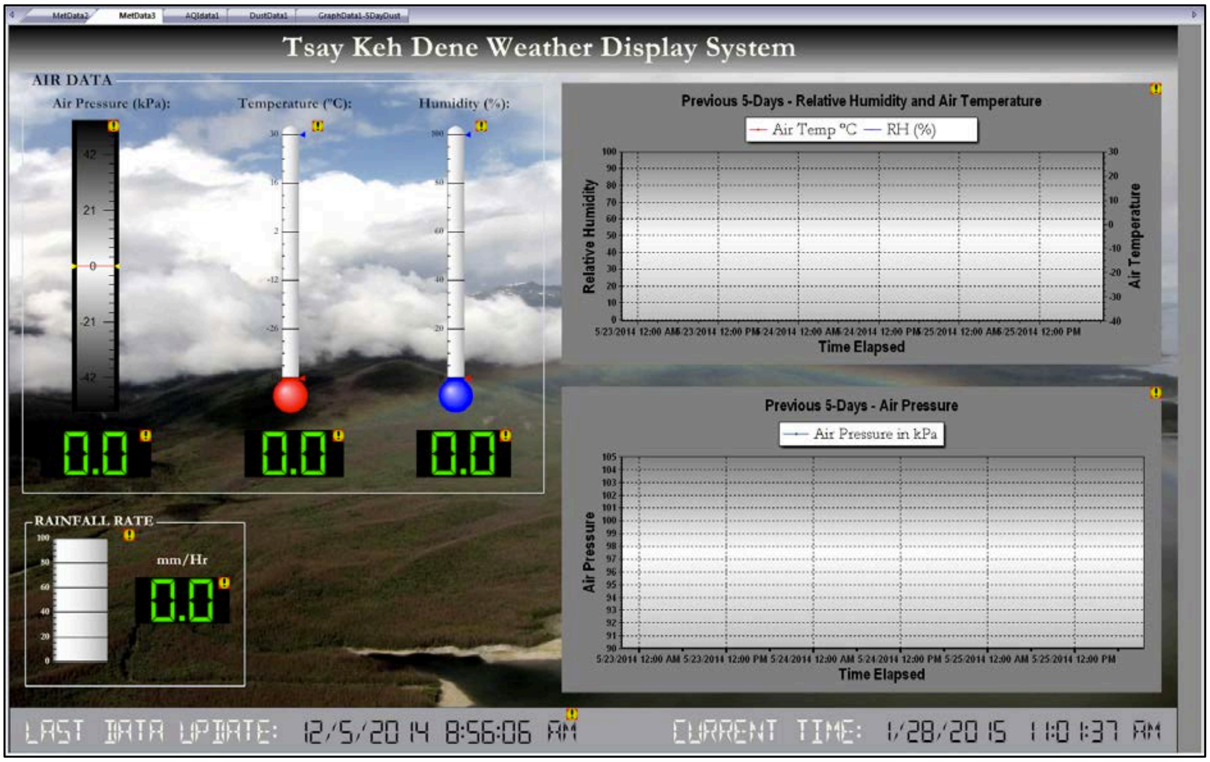

Figure 41: Data Display Air Parameters and 5-Day Charts

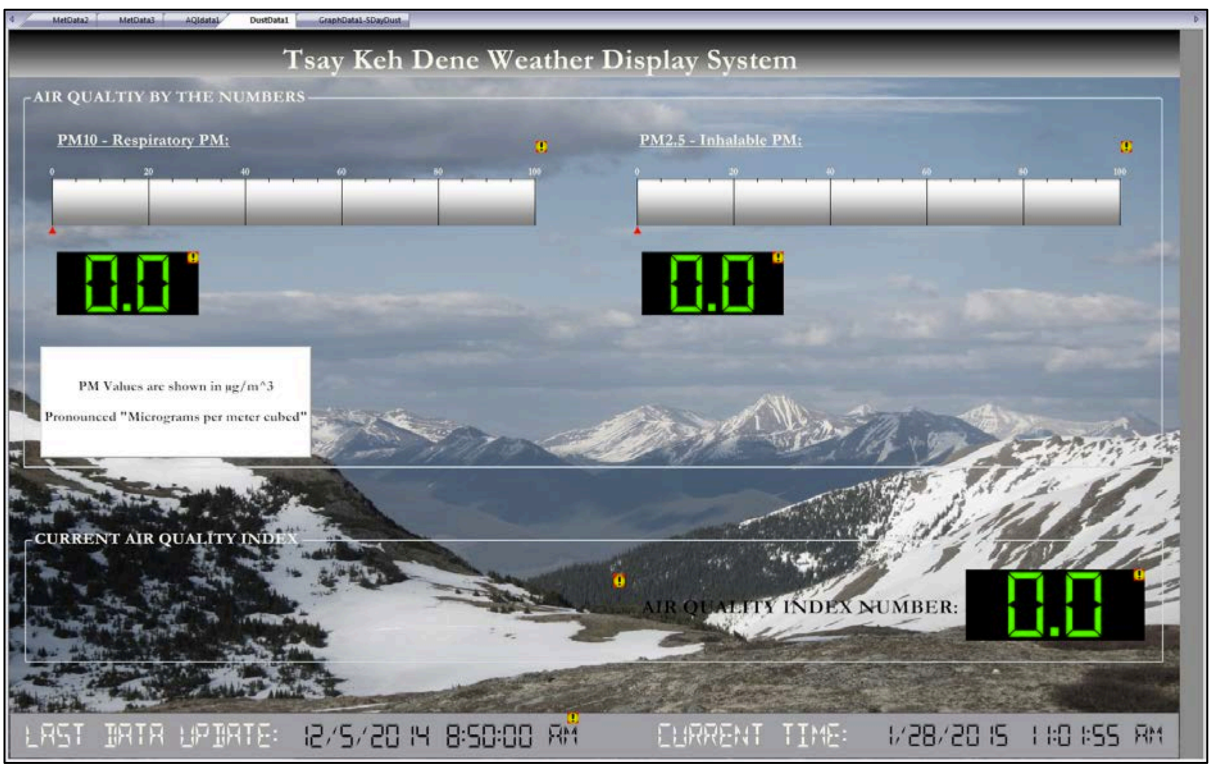

Figure 42: Data Display Air Quality Data and Air Quality Index

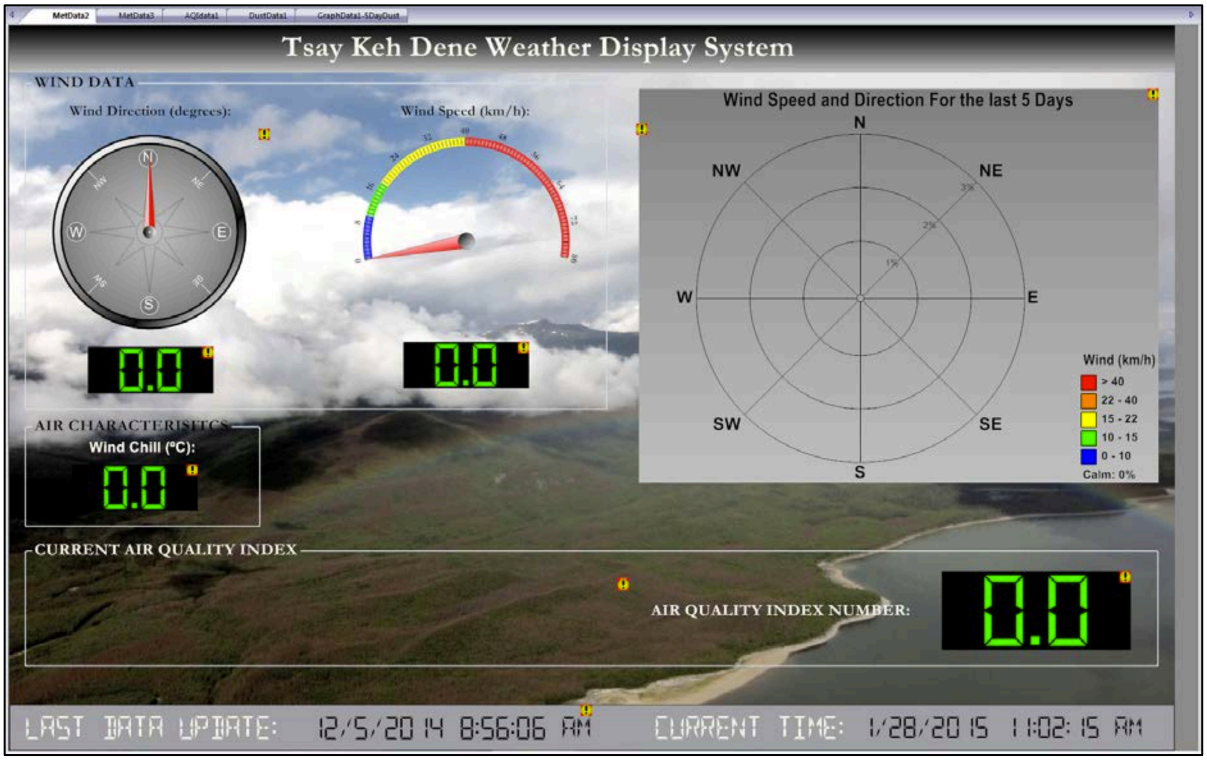

Figure 43: Data Display Wind Parameters and 5-Day Wind Rose

6.0 Discussion and Direction for 2015

6.1 Brief Summary for 2014

This report represents the second in a series of bi-annual reports that will be submitted to BC Hydro and the WDMP Joint Planning Committee. The results presented in this report shouldn't be considered conclusive but rather should be considered the building blocks that will ultimately allow us properly assess the mitigation efforts and provide answers to the key management question of GMSMON#18.

Overall, 2014 was a successful year for Chu Cho Environmental and the GMSMON#18 project. We collected a huge amount of data and have provided a very preliminary analysis of that data. Moving forward we have adopted several practices and procedures that will help hasten the pre-processing, analysis and delivery information from this project.

The primary finding presented somewhat repeatedly throughout this report is that dust storms are not discrete long duration events that always result in the exceedence of Federal and Provincial standards. Instead we must think of dust events as having very dynamic impacts and a range of characteristics. Dust events can range in scale from isolated very short duration microburst type events to very large very long mega events.

There are several areas throughout the reservoir that show regular and repeated incidences of fugitive dust emissions. These locations are the so-called "hot spots" and are likely good candidates for erosion control targeting. Chu Cho Environmental believes that by targeting the very worst areas contributing to fugitive dust that significant improvement to the overall ambient air quality in the Finlay Valley could be achieved.

Chu Cho Environmental 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 data collected by the monitoring networks. Following the 2015 dust season, we will begin to provide near real-time results of the response of the monitoring networks to mitigation efforts. Creating the database and algorithms required to perform these analyses is time consuming but well worth the effort.

The next iteration of this report will be released in Fall 2015 and will contain many of the updates outlined in the following section.

6.2 Direction for 2015

Chu Cho Environmental and Chu Cho Industries LP are in the same family of companies and are working on developing a close integration between the air monitoring program and the WDMP. Moving forward we will continue to improve upon this connection so that information can pass back and forth very quickly to help expedite the planning process in future years. The following summary topics comprise a list of tasks and analysis procedures that plan to incorporate into GMSMON#18 and future iterations of this report:

Winter 2015 Deployment:

In all previous monitoring seasons the air monitoring equipment was typically deployed during the first and second week of May. However, we know that there are early season dust events that occur prior to May when the beaches are exposed in April. The major impediment to setting equipment up earlier has always been snow cover and access to sites. For the 2015 season, Chu Cho Environmental rented two snowmobiles and a 6 seater Polaris Ranger on tracks, see Figure XX. This allowed us to access the sites earlier than ever before and successfully complete a full system setup by April 7th, 2015. The next time the sites are visited will be following the snowmelt; this early season setup is only made possible by the relatively high operating autonomy of the E-Samplers.

One additional E-Sampler was deployed at Tsay Keh Dene beach and one E-Sampler location was completely under reservoir water and so could not be deployed, thus there are 19 E-Samplers and 8 Meteorology Stations that began operation on April 7th, 2015.

Figure 44: 2015 Winter Setup Crew and Equipment

Future Data Analysis:

CAAQS and AQO Reporting:

- Our project team only just recently (April 16th, 2015) obtained the complete TEOM dataset dating back to January 2012 and so these data are not included in this report as the data could not be analyzed and verified in a timely manner.

- In all future iteration of this report we will have a fully developed CAAQS reporting system for $PM_{2.5}$ and an AQO reporting system for PM_{10}.

- It should be noted that the reporting of these data within this context will not provide any insight into addressing the key management question. The CCME provides numerous guidance documents for the analysis and reporting of AQ data and in every sense it is meant to represent the regional issues rather than an acute beach-by-beach account – this is why Chu Cho Environmental has designed the distributed network of E-Samplers.

- This reporting will be expanded to include the data obtained from the Kwadacha Monitoring station as well. There are several procedures that are currently under development to ensure that we will be able to include this analysis in future reports for GMSMON#18.

Event Magnitude and Response in TKD:

- In this report we began to extend the heatmapping analysis excise to evaluate the magnitude of dust events that migrate throughout the reservoir and the associated response of the TEOM in TKD. For example, it was demonstrated that the May 20th, 2015 storm arrived at our southernmost samplers several hours before arriving in TKD. We used this information to develop an understanding of the relationship between large migrating dust storms and the air quality in TKD.

- As we collect more dust storm data we will continue down this analysis pathway in order to develop a relationship between the scale and distribution of the events that occur on the reservoir beaches and the response of the TEOM in Tsay Keh Dene.

Dust Emissions Before and After Tillage:

- We have analyzed a single years data attempting to evaluate the response of the E-Samplers both before the application of tillage and following the application of tillage. Although our dataset is limited we have begun to see some emerging trends.

- We will continue to evaluate the E-Sampler data from this perspective to help constrain these data and provide a much needed more rigorous analysis here.

E-Sampler Flux Analysis:

- We will begin to evaluate the flux of sediment that passes the point of sampling for a given wind speed. This will provide us the ability to discuss dust concentrations in real terms so that we are able to estimate the approximately volume of dust that enters and exits a particular reservoir zone.

Isolating the impact of reservoir rise from mitigation efforts:

- We have begun to examine the rate of reservoir rise and the associated rate of beach inundation and how this relates to dust concentrations recorded by the regional monitoring network. We are currently working on a method to isolate the effect of mitigation treatments from the rate of beach inundation. Harry Brownlow of BC Hydro initiated this analysis in the Fall 2014.

- Currently, we know that on any given day the rate of beach inundation has the potential to exceed the rate of tillage application by approximately 4 to 10 times depending on the water elevation. Ultimately this means that the treatable area could disappear very quickly and that we should evaluate our mitigation strategies to ensure that we are meeting the highest possible efficacy over the long term.

Rigorous Statistical Analyses:

- As we continue to collect more data we will be able to begin to focus on the issues from a long-term trend and statistical perspective. Moving forward we will incorporate advanced regression and statistical models into our reporting.

7.0 References

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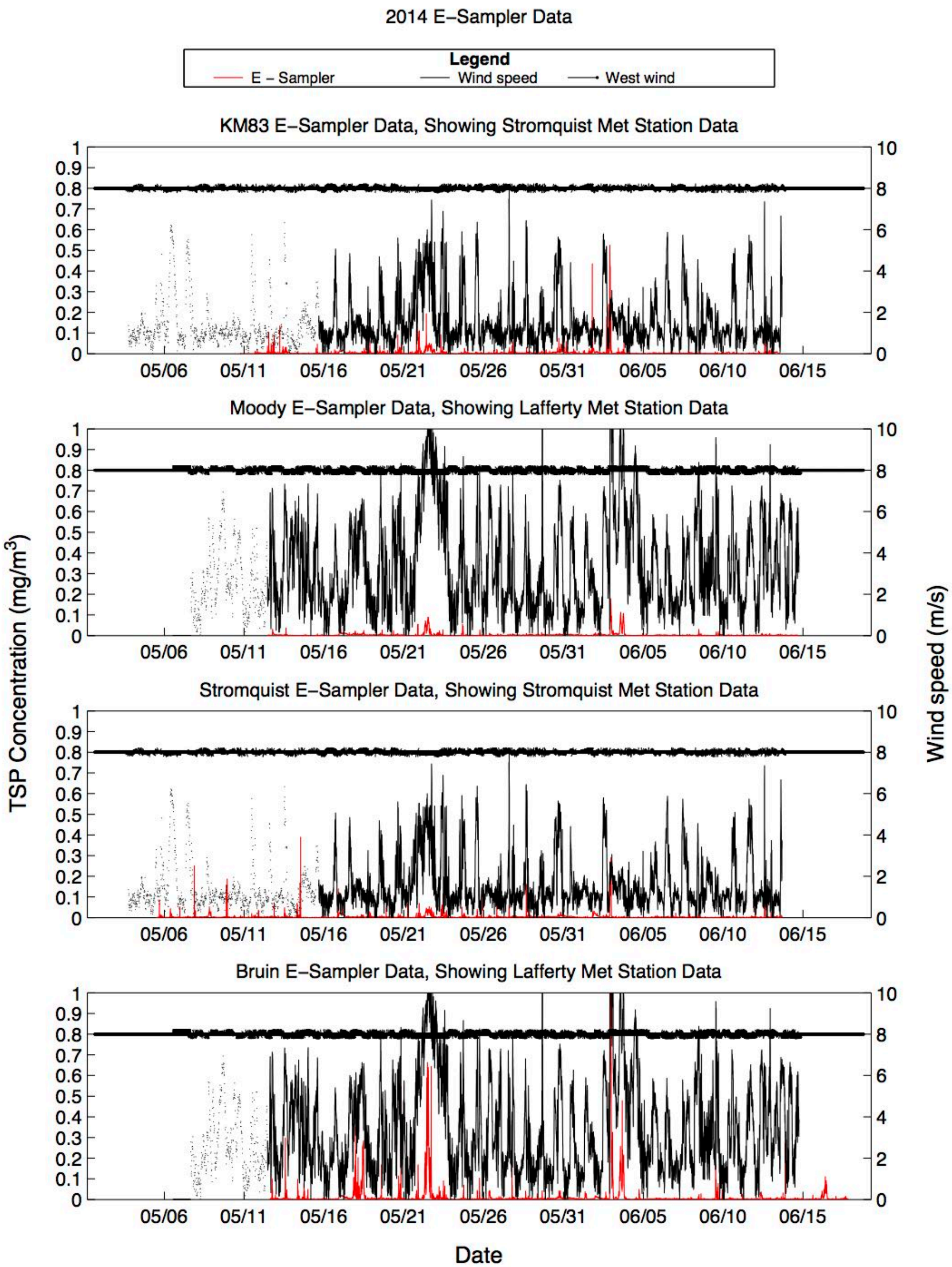
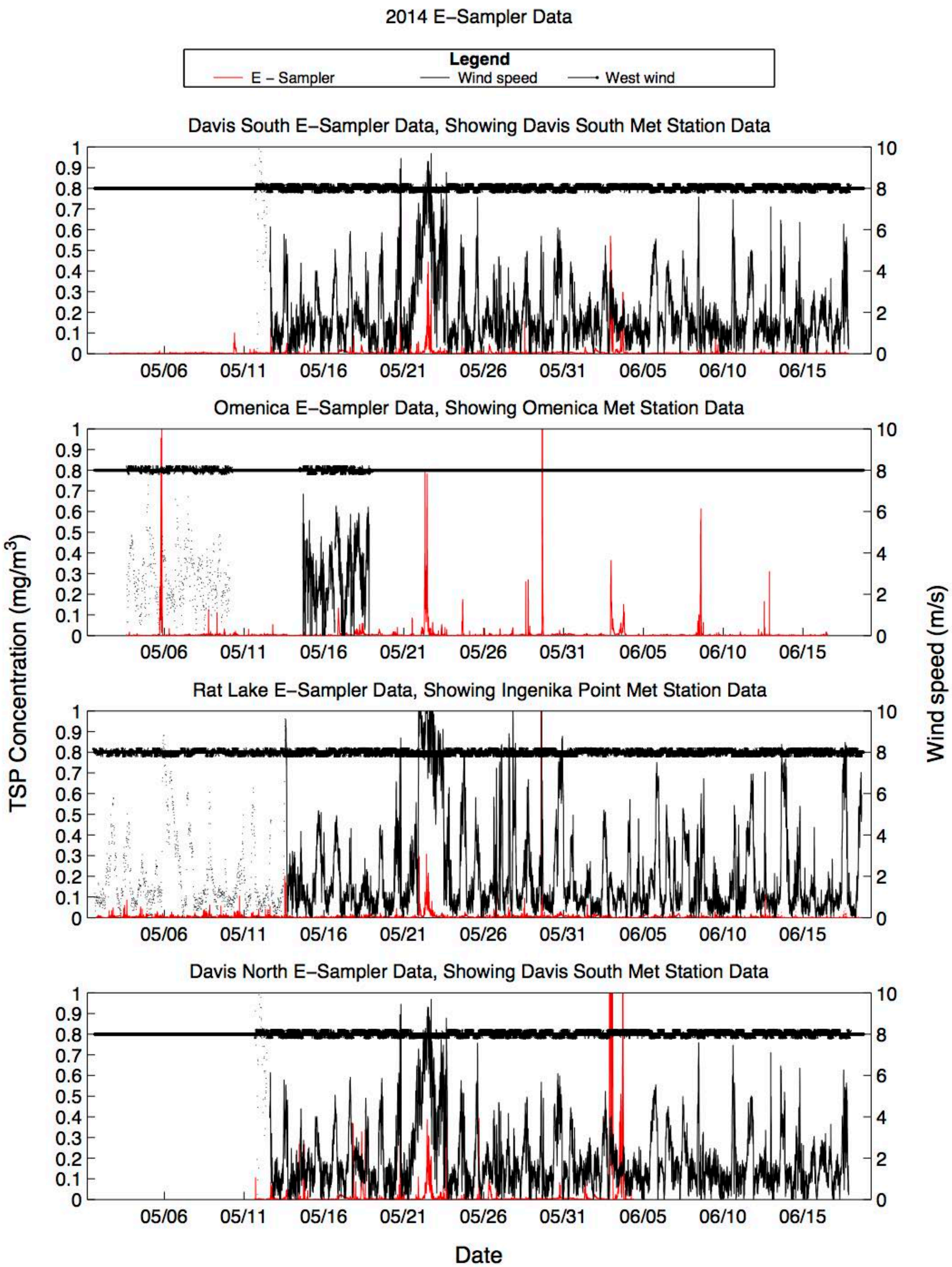
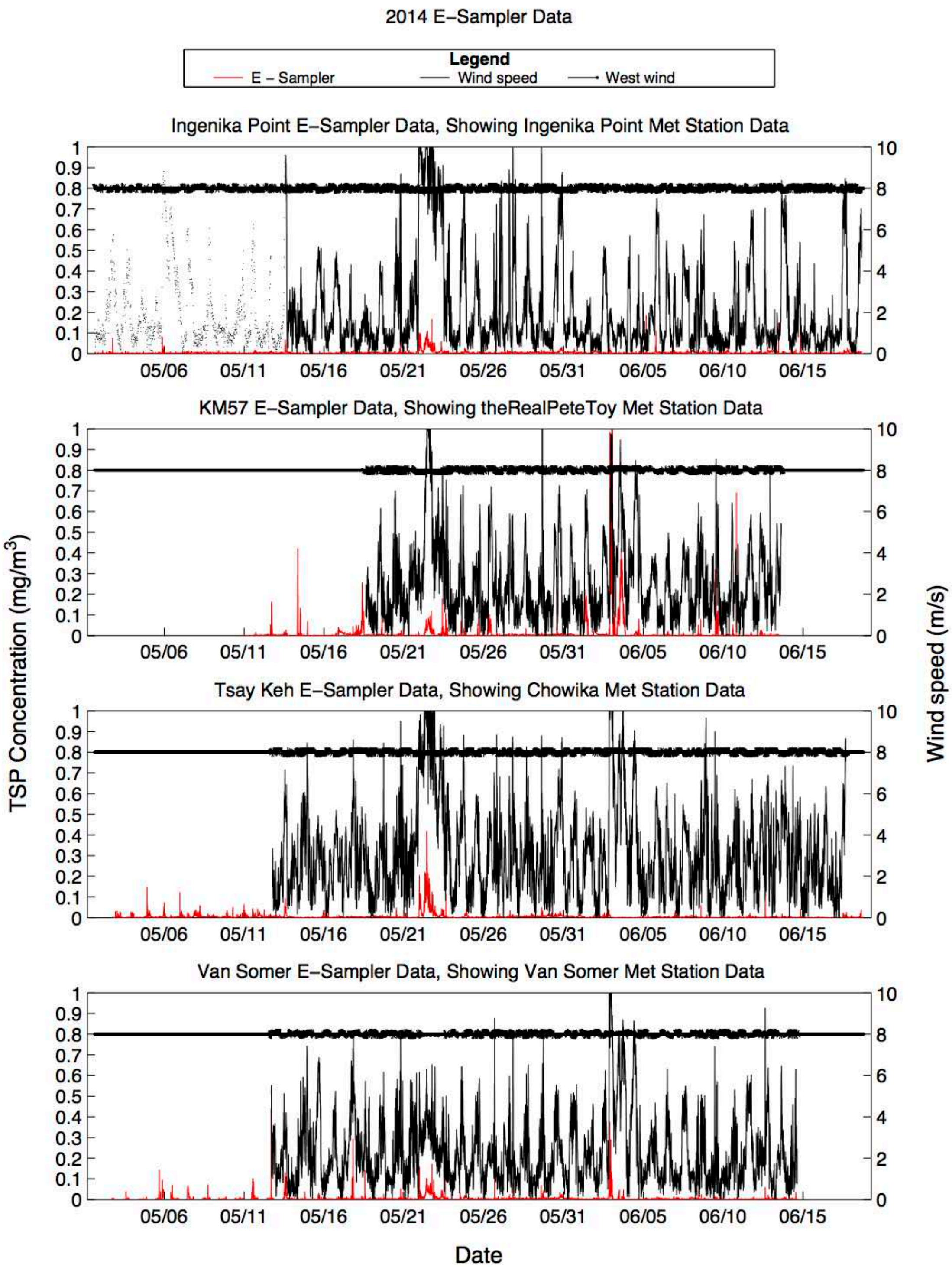
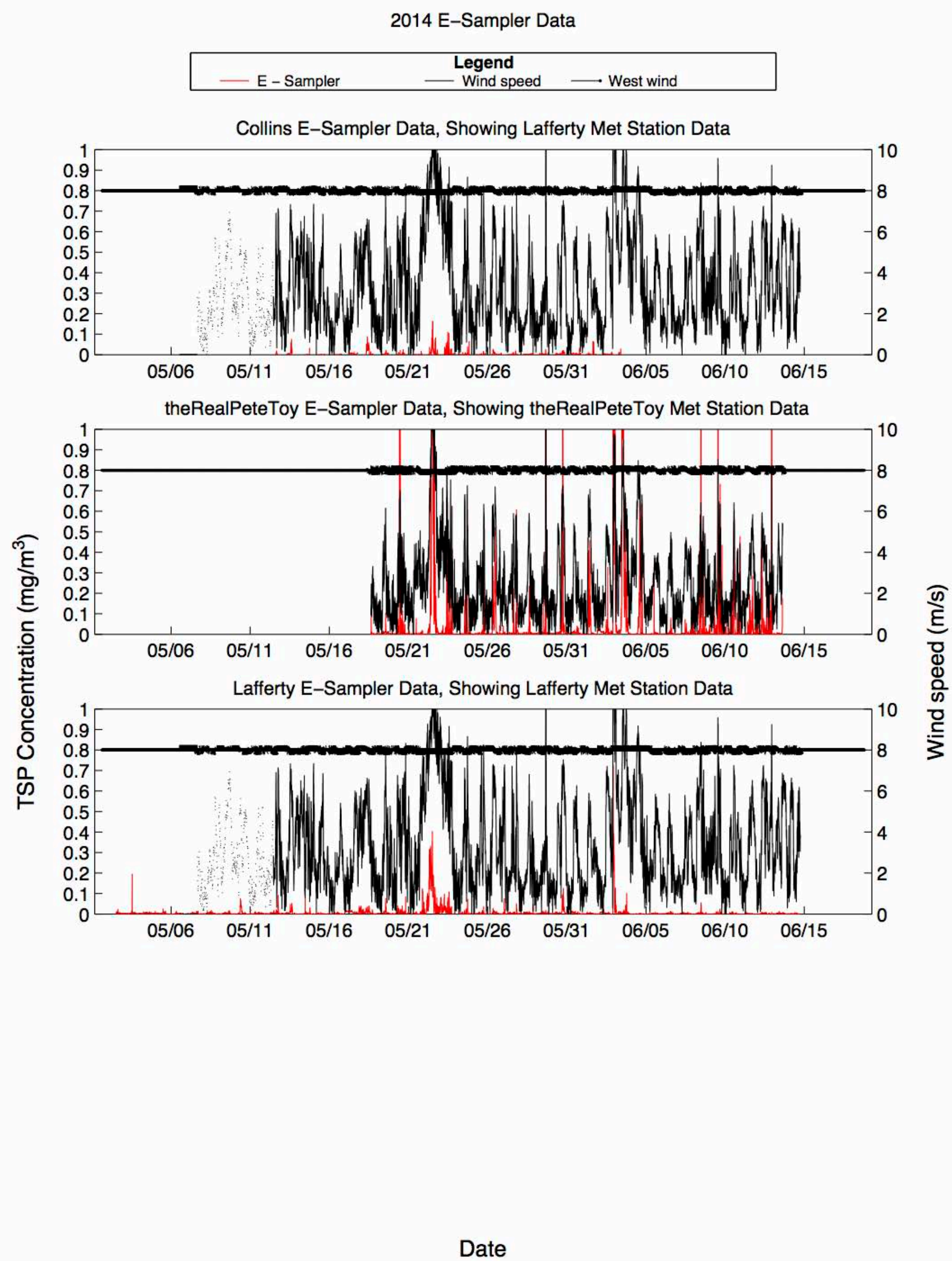
APPENDIX A E-SAMPLER TEMPORAL DATA


2014 E–Sampler Data
Legend
E – Sampler
Wind speed
West wind
KM83 E–Sampler Data, Showing Stromquist Met Station Data
Moody E–Sampler Data, Showing Lafferty Met Station Data
Stromquist E–Sampler Data, Showing Stromquist Met Station Data
Bruin E–Sampler Data, Showing Lafferty Met Station Data
TSP Concentration (mg/m3)
Wind speed (m/s)
05/06
05/11
05/16
05/21
05/26
05/31
06/05
06/10
06/15
Date


2014 E−Sampler Data
Legend
E − Sampler
Wind speed
West wind
Davis South E−Sampler Data, Showing Davis South Met Station Data
Omenica E−Sampler Data, Showing Omenica Met Station Data
Rat Lake E−Sampler Data, Showing Ingenika Point Met Station Data
Davis North E−Sampler Data, Showing Davis South Met Station Data
TSP Concentration (mg/m3)
Wind speed (m/s)
Date
05/06
05/11
05/16
05/21
05/26
05/31
06/05
06/10
06/15


2014 E−Sampler Data
Legend
E − Sampler
Wind speed
West wind
Ingenika Point E−Sampler Data, Showing Ingenika Point Met Station Data
KM57 E−Sampler Data, Showing theRealPeteToy Met Station Data
Tsay Keh E−Sampler Data, Showing Chowika Met Station Data
Van Somer E−Sampler Data, Showing Van Somer Met Station Data
TSP Concentration (mg/m³)
Wind speed (m/s)
05/06
05/11
05/16
05/21
05/26
05/31
06/05
06/10
06/15
Date


2014 E–Sampler Data
Legend
E – Sampler
Wind speed
West wind
Collins E–Sampler Data, Showing Lafferty Met Station Data
theRealPeteToy E–Sampler Data, Showing theRealPeteToy Met Station Data
Lafferty E–Sampler Data, Showing Lafferty Met Station Data
TSP Concentration (mg/m3)
Wind speed (m/s)
05/06
05/11
05/16
05/21
05/26
05/31
06/05
06/10
06/15
Date

APPENDIX B TEOM STATION 24-HOUR AVERAGE DATA

Table 19: 24-Hour Averaged Tsay Keh Dene TEOM Monitoring Station Data

Date	pm10	pm10_Max	pm25	pm25_Max	ws_Avg	ws_Max	WinDir	AirTemp	RH	Pressure	Rainfall
07-May-14	16.87075	56.61	4.85302	11.68	1.4637	6.958	221.2982	6.27081	54.3696	100.6799	0
08-May-14	11.28519	35.61	3.88496	9.75	1.4605	8.82	185.2871	12.3149	41.5839	100.5354	0
09-May-14	8.259604	20.34	3.04042	9.04	1.3605	6.762	220.0679	9.13572	39.7157	101.3854	0
10-May-14	13.86658	75.65	3.7669	22.71	1.1899	6.272	200.3192	8.79774	47.7183	102.1729	0
11-May-14	28.45558	136.9	4.58656	13.75	1.4603	10.78	213.7931	8.65614	58.1764	102.4729	0
12-May-14	12.13308	42.07	3.19935	5.765	1.5093	9.31	218.2736	10.4998	59.2517	102.7056	0
13-May-14	43.07542	439.1	4.14919	24.05	1.4522	9.7	151.0784	10.9361	75.5934	102.3757	5.6
14-May-14	1.303604	7.045	0.515167	2.216	2.1085	9.02	242.5896	11.9254	59.6064	102.3188	0.3
15-May-14	2.656	11.53	0.9855	8.36	1.2438	5.782	180.823	8.88201	61.4928	102.3208	1.6
16-May-14	6.644979	19.69	1.97821	6.173	1.4524	5.978	212.8853	11.5244	52.5615	101.3771	0
17-May-14	6.747458	21.91	2.83025	5.878	2.3988	11.07	264.1498	13.4346	49.7165	100.8715	0
18-May-14	12.73335	35.43	4.03038	9.64	1.368	10.29	214.399	12.2874	46.2142	100.5944	0
19-May-14	5.842493	31.33	1.11643	6.1	1.5415	7.448	232.8718	12.6356	47.3249	100.9431	0
20-May-14	2.273986	28.07	0.0277778	4	1.8367	10.09	199.3671	10.0524	52.4231	101.0799	0
21-May-14	263.0028	1501	9.95233	82.8	3.9116	14.11	168.9476	10.9558	58.5093	100.8667	0
22-May-14	279.7088	1501	19.3054	82.8	4.1026	12.15	159.2874	11.4629	70.9018	100.5271	0.2
23-May-14	6.092361	109.3	0.769903	12.61	1.3696	8.72	197.7583	8.28706	73.9717	101.0847	5.3
24-May-14	9.276194	66.34	1.2179	17.32	1.7874	8.82	207.589	9.34778	59.9317	101.4632	0
25-May-14	7.124833	41.81	0.661125	7.348	1.5313	6.958	200.9573	8.56001	60.3765	101.3208	0
26-May-14	6.518542	26.91	0.933208	6.15	1.3657	5.88	166.4848	14.1116	39.9665	101.5632	0
27-May-14	15.59933	65.39	1.81508	4.674	1.2946	10	177.9209	12.396	53.5409	101.7389	0
28-May-14	7.277167	20.33	1.83904	5.328	1.2611	8.82	169.9315	13.5672	53.1419	101.3035	0.3
29-May-14	19.40938	77.01	4.55831	9.79	1.6965	12.54	200.5467	10.9918	63.2413	101.4368	0
30-May-14	21.99267	58.65	4.27327	8.59	1.7866	7.644	185.6614	12.4323	62.1393	101.475	0
31-May-14	11.59404	48.24	2.85858	8.01	1.533	7.448	250.9929	13.8565	48.8844	101.5514	0
01-Jun-14	17.03156	88.8	2.93215	20.31	1.4822	7.252	239.0501	14.5907	35.6472	101.3361	0
02-Jun-14	15.14069	83.6	3.02844	28.26	3.3363	14.99	283.6221	13.4159	57.746	100.9854	1.1
03-Jun-14	0.383	1.849	0.0204583	0.421	3.1633	11.07	318.165	7.95167	73.3543	101.4799	8.4
04-Jun-14	0.6887917	4.565	0.315	3.767	1.2646	8.13	224.5974	5.12749	78.473	102.0625	1.6
05-Jun-14	4.046146	11.2	1.57319	3.709	1.4675	6.37	191.6067	9.33297	56.3316	101.8243	0
06-Jun-14	6.147563	20.29	1.8256	6.907	1.1875	6.86	194.607	10.6408	53.4788	101.6472	0
07-Jun-14	9.823208	28.28	2.73675	7.49	1.3779	6.664	197.2179	12.7488	54.5828	101.3632	0.4
08-Jun-14	1.222667	5.632	0.440875	2.917	1.3615	9.31	185.7865	11.5073	69.6916	101.0201	6.5
09-Jun-14	1.452292	5.079	0.519917	3.303	0.92862	9.11	202.2734	10.101	68.2113	101.325	0.3
10-Jun-14	2.618	12.46	0.816625	2.842	1.4325	6.174	217.1541	12.904	57.3978	101.4889	0
11-Jun-14	11.18025	84.2	1.11292	3.525	1.6561	6.174	213.1285	14.1485	49.9967	101.2694	0
12-Jun-14	17.00025	283.6	2.8975	12.99	1.336	10.78	202.1664	14.3533	66.4058	101.1167	4.9
13-Jun-14	1.700444	13.55	0.0566944	4	1.6306	9.21	179.8543	14.9674	59.9477	100.7014	0
14-Jun-14	1.659375	32.62	0.0135	0.324	1.243	9.7	191.0292	12.0477	58.0231	100.6979	3.4
15-Jun-14	0.6402083	2.154	0.0295	0.456	2.0539	9.6	281.7566	11.9925	56.8217	100.9319	0

16-Jun-14	1.089167	4.863	0.0697083	1.225	1.3868	7.546	213.4699	13.29	59.9808	101.4139	0.1
17-Jun-14	15.03085	81.8	1.28463	4.17	1.745	8.33	215.3519	15.0856	54.9691	101.1083	0.7
18-Jun-14	6.701521	57.99	0.464396	3.211	1.5492	8.62	212.4368	10.8259	72.0662	101.1049	0.1
19-Jun-14	6.053813	54.34	0.468396	3.062	1.6349	9.31	178.4883	12.4287	82.1642	100.8257	10.3
20-Jun-14	0.964125	3.154	0.110333	1.313	1.5696	8.43	152.8716	12.1229	65.1983	101.2688	0.8
21-Jun-14	4.333292	25.24	0.440667	2.524	1.4945	8.04	192.1341	11.2262	65.6826	101.6625	0
22-Jun-14	6.933979	25.94	2.43262	15.09	0.98222	5.39	182.5492	14.1736	57.4553	101.6819	0
23-Jun-14	8.191125	24.86	2.63865	15.09	1.0547	8.92	175.3981	16.5299	66.1701	101.1583	5.6
24-Jun-14	1.5985	4.125	0.269229	1.484	1.0435	8.53	202.6579	13.6272	73.2397	101.2792	3.1
25-Jun-14	1.942083	7.256	0.206042	1.224	0.99295	4.606	185.7303	12.4315	60.748	101.0042	0
26-Jun-14	5.724625	27.71	1.22008	5.072	1.3855	5.978	226.3185	14.2	55.5572	100.3799	0
27-Jun-14	6.248396	21.11	1.95302	3.977	1.2787	7.742	171.4734	17.1647	64.6462	100.2993	0.9
28-Jun-14	2.54075	5.093	0.732854	2.875	1.2687	6.86	220.4252	14.9898	73.1318	100.8563	0
29-Jun-14	3.327792	12.16	0.849792	2.644	1.4783	6.664	199.2061	17.713	58.3366	101.6444	0
30-Jun-14	4.923083	21.19	0.674042	1.769	1.3606	6.958	188.3731	16.3975	60.1951	101.934	0
01-Jul-14	8.321646	40.79	1.8771	8.99	1.3223	6.566	228.6797	17.3069	55.3908	101.4312	0.2
02-Jul-14	3.926917	9.81	1.3556	5.896	1.141	10.09	230.8355	14.4963	84.195	101.0014	4.3
03-Jul-14	1.902938	6.795	0.375917	2.81	1.2635	9.31	208.6687	12.3517	79.5371	101.0174	3.5
04-Jul-14	1.502146	3.935	0.276542	1.676	1.1688	6.664	200.3538	13.5534	60.7059	101.0111	0
05-Jul-14	0.4655139	4	0.189889	4	0.97272	6.37	174.1938	15.5507	64.389	101.4833	0
06-Jul-14	2.886229	12.28	0.245167	1.57	1.2543	4.802	202.6162	15.8043	59.1077	101.9028	0
07-Jul-14	8.949854	29.64	0.671458	3.133	1.127	6.174	197.6083	17.82	57.7847	101.6292	0
08-Jul-14	6.32	35.31	0.371542	2.015	1.4537	6.174	225.0733	18.8062	48.7926	101.1521	0.6
09-Jul-14	0.9574375	5.595	0.095	1.318	1.5533	9.7	212.0239	15.0069	64.9042	101.3757	1.1
10-Jul-14	6.662854	37.39	2.41079	29.53	1.5259	7.938	244.1666	17.4429	56.8603	101.6264	0
11-Jul-14	28.87054	109.3	11.8692	29.57	1.2584	6.86	206.076	17.8183	57.5433	101.7139	0
12-Jul-14	19.42354	41.07	8.33256	12.98	1.308	7.252	217.989	18.9827	55.2433	101.9326	0
13-Jul-14	40.16042	88.8	25.725	35.74	1.1693	6.37	211.6551	19.6558	54.7612	101.9875	0
14-Jul-14	95.48125	176.8	75.4573	147.3	1.062	6.37	217.5842	18.4408	56.3085	101.7007	0
15-Jul-14	99.8261	279.7	81.0185	253.6	0.74153	3.92	179.8807	19.037	55.4958	101.3687	0
16-Jul-14	38.8493	132.4	20.6711	64.07	1.442	9.31	231.8141	19.2107	48.7844	101.0674	0
17-Jul-14	25.43646	75.23	14.0675	37.85	1.7736	9.51	212.0311	18.7626	61.3828	100.7326	3.4
18-Jul-14	6.801167	27.32	4.65604	23.55	1.2761	7.154	246.8769	13.0714	75.4156	100.3167	0.6
19-Jul-14	1.596375	13.09	0.608667	9.7	1.4856	8.04	242.1212	13.5998	73.7617	100.716	0
20-Jul-14	4.364958	14.81	2.13075	10.38	0.93747	5.194	208.652	15.1291	76.3132	100.9049	1.2
21-Jul-14	6.122167	14.55	2.01858	6.857	1.4325	7.644	225.0066	14.2438	73.4525	101.4604	0.3
22-Jul-14	6.78025	14.2	3.85879	10.8	1.0342	6.468	216.1239	13.7596	71.8932	101.716	0.6
23-Jul-14	6.904104	17.99	2.61229	15.54	1.3386	9.31	203.3819	15.1166	64.3891	101.1292	0
24-Jul-14	5.408646	13.2	1.93323	4.674	1.5126	6.958	238.1464	19.2128	42.2072	100.9049	0
25-Jul-14	11.86171	30.53	4.43954	20.6	1.483	8.04	193.8803	15.1901	60.8874	101.4597	0
26-Jul-14	9.747021	23.78	3.33998	11.17	1.6395	8.62	188.2866	16.7293	59.5165	101.8458	0
27-Jul-14	12.0489	32.83	3.79844	9.72	1.5022	7.742	222.7821	15.3985	64.7755	102.1069	0
28-Jul-14	21.52987	53.27	8.78869	22.43	1.3261	6.566	205.7452	17.2189	62.3699	101.7875	0

29-Jul-14	31.17842	71.53	18.7533	47.2	2.096	9.8	183.4595	20.7853	44.4901	101.716	0
30-Jul-14	18.68017	79.46	8.65515	34.79	0.94301	4.998	217.2855	14.8347	52.9161	102.0458	0
31-Jul-14	53.40681	149	39.1481	116.5	1.1492	5.39	219.0681	15.637	53.5646	102.1653	0
01-Aug-14	74.13046	148.8	57.1504	92.3	1.1499	5.39	235.6507	15.2688	60.4958	101.8271	0
02-Aug-14	92.90167	192.2	71.9915	162.2	1.0748	4.018	231.4555	15.5238	60.3365	101.6569	0
03-Aug-14	84.8325	160.4	64.3648	137.6	1.2563	6.762	245.9269	16.3497	60.8358	101.7007	0
04-Aug-14	78.93146	227.9	65.0269	199.5	1.4839	9.02	219.2544	18.2819	66.2741	101.3972	3.2
05-Aug-14	15.73451	60.45	11.9779	48.43	1.175	9.8	218.3733	15.1378	80.3615	101.3632	14.7
06-Aug-14	3.225965	28.63	2.46571	24.49	1.3684	7.252	275.087	12.7866	68.9615	101.5188	0
07-Aug-14	0.3055556	4	0.305556	4	1.2283	8.04	225.9245	13.6152	62.4938	101.4222	0
08-Aug-14	0	0	0	0	1.0761	6.762	223.43	12.5164	65.1813	101.7035	0
09-Aug-14	0	0	0	0	1.5111	8.04	169.0734	15.5974	66.4201	101.9389	0
10-Aug-14	0	0	0	0	1.1538	8.23	177.6868	17.0744	70.6712	102.0681	0
11-Aug-14	0	0	0	0	1.106	5.586	230.9796	16.8569	64.7407	101.5681	0
12-Aug-14	34.35432	174.2	28.3535	154.3	1.1443	6.174	245.8014	16.6971	64.6011	101.1444	0
13-Aug-14	22.74809	87.3	18.4579	80.9	0.91623	5.096	211.6203	17.4819	56.7928	101.2938	0
14-Aug-14	0.3055556	4	0.333333	4	0.97696	7.938	207.2583	17.1686	65.8637	101.4292	0
15-Aug-14	0.5	4	0.5	4	1.3122	7.84	192.3292	19.9195	64.1981	101.2389	0
16-Aug-14	34.72974	100.9	25.6092	87.6	1.4338	4.802	140.9892	26.6297	28.2544	101.3359	0

Table 20: 24-Hour Kwadacha TEOM Monitoring Station Data

Date	pm10	pm10_Max	pm25	pm25_Max	ws_Avg	ws_Max	WinDir	AirTemp	RH	Pressure	Rainfall
01-Jan-14	0	0	0	0	0.62253	3.332	270.3478	-9.86415	83.1421	100.6625	0
02-Jan-14	NaN	NaN	NaN	NaN	0.92483	4.214	261.95	-6.35922	87.3396	99.83194	0
03-Jan-14	0	0	NaN	NaN	0.49895	2.94	180.0868	-10.4465	80.1053	100.6618	0
04-Jan-14	NaN	NaN	NaN	NaN	0.53638	4.214	226.9497	-8.47885	82.7973	101.9826	0
05-Jan-14	NaN	NaN	NaN	NaN	1.5041	6.86	132.6986	-9.13382	83.7949	101.9521	0
06-Jan-14	NaN	NaN	NaN	NaN	0.44494	4.214	187.0815	-7.95488	85.2806	101.0972	0
07-Jan-14	NaN	NaN	NaN	NaN	0.44645	3.92	130.5506	-6.6149	87.0208	100.2764	0
08-Jan-14	NaN	NaN	NaN	NaN	0.19178	1.862	195.6352	-6.00158	87.6465	99.32708	0
09-Jan-14	0	0	NaN	NaN	0.62903	4.116	185.9001	-4.08119	90.6361	98.47708	0
10-Jan-14	0	0	NaN	NaN	0.68308	4.802	149.0915	-7.96452	82.6585	98.88681	0
11-Jan-14	NaN	NaN	NaN	NaN	0.90922	3.234	246.3376	-7.24795	85.5844	97.72778	0
12-Jan-14	0	0	NaN	NaN	1.2548	8.53	148.4899	-8.63736	83.8309	98.34514	0
13-Jan-14	NaN	NaN	NaN	NaN	0.62518	4.9	141.7145	-6.08653	87.197	99.9236	0

									2	1	
14-Jan-14	NaN	NaN	NaN	NaN	3.6495	15.58	178.7348	0.872806	85.5415	99.74306	27.9
15-Jan-14	NaN	NaN	NaN	NaN	1.5999	14.8	233.4189	1.60522	59.492	101.1035	4.2
16-Jan-14	NaN	NaN	NaN	NaN	1.5543	7.056	146.7774	-0.158444	87.2472	101.2424	0.2
17-Jan-14	NaN	NaN	NaN	NaN	0.56551	3.92	160.2384	-2.4231	92.0806	101.2375	0
18-Jan-14	NaN	NaN	NaN	NaN	1.0307	5.488	180.8854	-3.12194	89.2597	100.1757	0
19-Jan-14	0	0	NaN	NaN	0.56262	3.528	172.593	-9.04991	79.2094	100.9618	1.1
20-Jan-14	NaN	NaN	NaN	NaN	0.17036	2.254	161.3674	-10.6434	80.8751	101.6049	0
21-Jan-14	NaN	NaN	NaN	NaN	0.19019	2.058	191.4117	-6.41278	84.5212	101.6264	0
22-Jan-14	NaN	NaN	NaN	NaN	0.45717	4.508	205.6382	-3.10949	86.8034	101.6812	0
23-Jan-14	NaN	NaN	NaN	NaN	0.82694	5.194	167.6542	-1.58175	92.4569	102.0049	0.1
24-Jan-14	NaN	NaN	NaN	NaN	0.5461	4.704	204.329	-0.0779583	92.3547	102.0424	0.1
25-Jan-14	NaN	NaN	NaN	NaN	0.48702	3.332	237.9564	-2.86832	88.7453	101.7694	0
26-Jan-14	NaN	NaN	NaN	NaN	0.50572	2.352	276.5817	-5.74939	85.3478	101.9187	0
27-Jan-14	NaN	NaN	NaN	NaN	0.24651	2.156	152.7072	-3.41115	87.6243	101.5132	0
28-Jan-14	0	0	0	0	0.81053	3.724	104.7816	-4.03636	86.8191	100.9118	0.2
29-Jan-14	0	0	0	0	0.54693	4.606	219.5584	-6.98071	83.0581	100.4833	0
30-Jan-14	0	0	0	0	0.9172	4.41	323.4472	-16.7176	72.3237	100.9924	0
31-Jan-14	0	0	0	0	0.4521	4.018	216.2916	-21.2158	65.9005	101.1236	0
01-Feb-14	0	0	0	0	1.0536	4.704	241.551	-18.8993	68.2128	101.2715	0
02-Feb-14	0	0	0	0	1.0327	4.508	243.1898	-13.5044	72.7197	101.5188	0
03-Feb-14	0	0	0	0	0.63885	3.43	204.7645	-18.9103	66.4419	102.3306	0
04-Feb-14	0	0	0	0	1.1785	4.312	266.0846	-23.9271	62.5612	102.9993	0
05-Feb-14	0	0	0	0	1.3946	4.41	264.2528	-25.4705	60.4544	102.9868	0
06-Feb-14	0	0	0	0	0.70964	4.508	247.2173	-27.9915	57.1383	101.3222	0
07-Feb-14	0	0	0	0	1.0305	4.312	190.5566	-27.7657	56.339	100.9014	0
08-Feb-14	0	0	0	0	0.75444	3.626	144.4764	-25.1531	59.005	101.3396	0
09-Feb-14	0	0	0	0	0.40727	4.312	251.9949	-23.5228	57.1271	100.9243	0
10-Feb-14	0	0	0	0	1.3289	9.11	239.5737	-24.1182	60.9944	100.5201	0
11-Feb-14	0	0	0	0	0.74245	7.252	252.9598	-20.1921	62.6761	100.0319	0
12-Feb-14	0	0	0	0	0.366	3.332	201.8567	-18.6778	69.5967	98.69653	0
13-Feb-14	0	0	0	0	0.92281	4.508	229.2882	-22.209	66.6465	99.32361	0
14-Feb-14	0	0	0	0	0.37919	4.116	160.3983	-11.6995	77.2866	98.85	0

15-Feb-14	0	0	0	0	0.3851	3.234	221.617	-8.92115	83.3615	99.13333	0
16-Feb-14	0	0	0	0	0.7639	4.508	183.3029	-7.44136	79.8833	98.16944	0
17-Feb-14	0	0	0	0	0.73417	4.9	162.3338	-5.60828	83.7873	98.51111	0
18-Feb-14	0	0	0	0	0.70749	5.292	159.2748	-5.73683	84.3617	98.62083	0
19-Feb-14	0	0	0	0	1.7365	7.154	157.4448	-5.87297	79.6204	99.06944	0
20-Feb-14	0	0	0	0	1.1866	7.056	293.5573	-10.3071	72.8249	99.70417	0
21-Feb-14	0	0	0	0	0.94007	6.272	281.1474	-10.4451	64.3726	100.85	0
22-Feb-14	0	0	0	0	1.3926	7.252	312.5465	-13.2178	60.9041	101.7292	0
23-Feb-14	0	0	0	0	0.85894	4.018	255.312	-20.1501	59.4613	101.8431	0
24-Feb-14	0	0	0	0	0.5639	3.822	121.1563	-21.3296	56.5492	101.8931	0
25-Feb-14	0	0	0	0	0	0	0	-19.8475	56.594	101.8326	0
26-Feb-14	0	0	0	0	0	0	0	-17.7063	59.1152	100.9639	0
27-Feb-14	0	0	0	0	0	0	0	-11.4187	59.9162	100.7069	0
28-Feb-14	0	0	0	0	0	0	0	-17.6054	56.0124	101.409	0
01-Mar-14	0	0	0	0	0	0	0	-23.0969	51.2656	101.3361	0
02-Mar-14	0	0	0	0	0	0	0	-22.3015	44.1612	100.8299	0
03-Mar-14	0	0	0	0	0	0	0	-20.8637	54.7251	100.359	0
04-Mar-14	0	0	0	0	0	0	0	-20.8746	55.9816	100.6368	0
05-Mar-14	0	0	0	0	0	0	0	-23.2298	49.7652	100.4549	0
06-Mar-14	0	0	0	0	0	0	0	-17.7568	44.7906	100.0444	0
07-Mar-14	0	0	0	0	0	0	0	-9.62294	67.2005	100.0889	0
08-Mar-14	0	0	0	0	0	0	0	-4.14448	88.5975	98.99722	0
09-Mar-14	0	0	0	0	0	0	0	1.81983	81.1897	98.84722	9.2
10-Mar-14	0	0	0	0	0	0	0	-0.460583	62.3533	100.1625	3.4
11-Mar-14	0	0	0	0	0	0	0	0.835667	68.6894	100.5785	0
12-Mar-14	0	0	0	0	0	0	0	4.23886	53.9915	99.84375	0
13-Mar-14	0	0	0	0	0	0	0	-0.104868	54.3644	100.1326	0
14-Mar-14	0	0	0	0	0	0	0	0.582396	76.1524	99.51806	1.3
15-Mar-14	0	0	0	0	0	0	0	-1.94822	81.1623	99.72917	0.5
16-Mar-14	0	0	0	0	0	0	0	2.64987	75.1224	99.22639	0
17-Mar-14	0	0	0	0	0	0	0	0.238125	45.959	100.1903	0
18-Mar-14	0	0	0	0	0	0	0	-0.741021	69.3501	100.0285	0
19-Mar-14	0	0	0	0	0	0	0	0.715861	70.357	99.81944	0

20-Mar-14	0	0	0	0	0	0	0	-3.42411	69.7719	101.2882	1.2
21-Mar-14	0	0	0	0	0	0	0	-6.27987	52.6346	101.9097	0
22-Mar-14	0	0	0	0	0	0	0	-9.55558	54.5667	101.7049	0
23-Mar-14	0	0	0	0	0	0	0	-7.97547	52.7492	101.8569	0
24-Mar-14	0	0	0	0	0	0	0	-6.3968	51.5283	101.691	0
25-Mar-14	0	0	0	0	0	0	0	-6.01027	62.2581	100.3715	1.9
26-Mar-14	0	0	0	0	0	0	0	-8.34857	43.8928	100.0903	0
27-Mar-14	0	0	0	0	0	0	0	-12.1765	46.5533	100.3653	0
28-Mar-14	0	0	0	0	0	0	0	-10.1497	45.3475	100.0271	0
29-Mar-14	0	0	0	0	0	0	0	-5.88508	40.8092	99.87917	0
30-Mar-14	0	0	0	0	0	0	0	-7.78881	50.0316	100.4958	0
31-Mar-14	0	0	0	0	0	0	0	-7.62353	51.3681	100.5951	0
01-Apr-14	0	0	0	0	0	0	0	-5.21884	53.5028	100.1	0
02-Apr-14	0	0	0	0	0	0	0	-1.51577	58.7954	100.1597	0
03-Apr-14	0	0	0	0	0	0	0	-0.0170417	76.106	99.45486	0.4
04-Apr-14	0	0	0	0	0	0	0	-0.518993	54.7832	99.34722	0
05-Apr-14	0	0	0	0	0	0	0	0.46534	59.8723	99.37431	0
06-Apr-14	0	0	0	0	0	0	0	3.2235	60.2148	99.92569	0
07-Apr-14	0	0	0	0	0	0	0	2.92831	87.5894	99.6	6.7
08-Apr-14	0	0	0	0	0	0	0	4.65416	62.2106	99.19167	3.6
09-Apr-14	0	0	0	0	0	0	0	1.58387	61.1578	99.71181	0
10-Apr-14	0	0	0	0	0	0	0	4.72141	60.4168	99.56389	0.4
11-Apr-14	0	0	0	0	0	0	0	0.490125	69.4816	100.3743	7.1
12-Apr-14	0	0	0	0	0	0	0	-0.119563	54.1673	101.4236	0
13-Apr-14	0	0	0	0	0	0	0	1.22012	57.3134	101.3014	0
14-Apr-14	0	0	0	0	0	0	0	4.72672	52.7422	100.3181	0
15-Apr-14	0	0	0	0	0	0	0	2.45088	79.2803	100.2854	2.4
16-Apr-14	0	0	0	0	0	0	0	3.82339	57.859	100.3847	0
17-Apr-14	0.09690909	0.833	0.07488525	0.532	1.1882	7.644	71.12685	1.68978	64.4335	99.50417	0
18-Apr-14	1.5216	13.16	0.3340667	1.796	0.81994	5.782	205.238	4.0215	55.9933	99.71806	0
19-Apr-14	6.807882	43.55	2.398007	16.87	1.4363	10.88	168.2184	2.80231	59.0622	99.57986	0
20-Apr-14	2.14734	13.59	0.7939097	3.371	1.6873	8.33	143.0825	5.04902	72.9773	100.1826	0
21-Apr-14	7.872903	37.88	3.979417	15.73	0.90624	8.92	164.9367	3.76372	66.5454	100.4299	0

22-Apr-14	2.769785	17.89	0.6792778	8.51	0.85087	5.88	212.7914	2.17197	85.8293	99.73542	7.2
23-Apr-14	1.713563	7.382	0.3200972	1.108	0.70365	5.88	308.5777	1.74524	91.7188	99.61111	2.3
24-Apr-14	1.690292	9.66	0.3844236	1.723	0.68256	4.41	252.9545	4.83992	61.8605	99.67361	0
25-Apr-14	4.713667	17.56	0.9814375	2.585	0.63394	4.508	148.75	5.54163	55.5358	99.98264	0
26-Apr-14	1.579333	21.12	1.083299	5.982	1.2079	6.272	133.7996	6.9292	47.839	99.41597	0
27-Apr-14	5.468542	26.2	1.81234	4.713	0.99542	8.92	179.6807	4.60757	66.2819	99.05069	2.7
28-Apr-14	6.602264	41.65	2.089861	10.52	0.95076	6.468	192.2505	5.26089	60.4726	100.5417	0
29-Apr-14	9.614778	70.64	3.629438	19.9	1.7439	10.29	158.5805	5.20226	58.0172	101.6104	0
30-Apr-14	2.494687	20.71	1.035951	3.913	1.7315	11.17	134.7322	7.95776	81.5879	101.5292	0.7
01-May-14	3.906896	36.3	3.354625	25.1	1.322	7.742	302.3485	9.57699	54.9706	101.4965	0.1
02-May-14	4.315653	36.3	4.629778	25.1	1.0327	6.762	144.442	5.43992	44.4982	101.491	0
03-May-14	17.21317	101.1	7.918486	39.03	1.0764	7.938	182.9221	2.80749	44.584	101.0479	0
04-May-14	6.314556	60.74	7.547458	39.03	1.1374	6.566	251.9793	4.04557	40.0069	100.4521	0
05-May-14	7.976875	77.37	10.55883	48.32	1.1476	10	251.9599	6.1407	46.2508	100.1681	0
06-May-14	5.633847	77.37	12.69307	143.3	0.93747	5.782	136.88	7.09134	48.1149	100.5799	0
07-May-14	7.848708	45.05	14.40169	32.94	0.96621	6.958	167.4554	9.13271	48.0736	99.97292	0
08-May-14	5.853472	17.4	12.99965	51.96	1.0179	7.546	194.0471	10.0372	44.0763	99.56667	0
09-May-14	6.662861	20.89	15.30161	55.32	0.8578	7.742	238.5563	9.82881	46.784	99.99514	0
10-May-14	6.587153	31.66	17.87278	111	1.1623	5.684	239.0331	9.66842	40.8279	100.9521	0
11-May-14	8.581889	49.55	11.39819	55.69	0.97674	7.644	160.5151	9.04972	54.7576	101.3806	0.2
12-May-14	4.987896	18.37	8.617875	51.06	1.0921	10.78	205.7334	9.28046	65.5906	101.6917	1.6
13-May-14	3.857958	13.61	4.777125	30.48	0.95788	8.33	141.2378	9.67854	69.0546	101.684	1
14-May-14	1.567875	8.58	1.225562	5.58	1.2205	10	221.3222	10.1824	72.5567	101.2208	4.1
15-May-14	2.188479	30.88	2.512674	14.54	0.8698	5.292	236.7137	10.7379	62.9228	101.5931	0
16-May-14	3.721389	30.88	9.851875	44.38	0.88986	5.39	213.533	12.6877	51.1927	100.8535	0
17-May-14	4.412292	22.82	7.665333	38.33	0.95753	8.53	229.7261	11.3964	57.6096	100.2021	0.2
18-May-14	2.990583	17.93	6.031722	63.99	1.2519	7.35	270.3487	12.2595	52.7684	99.80764	0
19-May-14	3.689597	17.93	6.668042	63.99	0.99925	6.076	258.0617	11.7301	47.8502	99.83056	0
20-May-14	2.956099	12.02	3.794989	12.45	1.0821	10.49	202.68	10.3794	53.2638	100.0819	0
21-May-14	NaN	NaN	NaN	NaN	1.2678	8.13	200.3537	9.0219	48.1129	100.1201	0.1
22-May-14	NaN	NaN	NaN	NaN	2.7818	9.9	137.3608	11.9449	68.9824	99.58958	0.6
23-May-14	NaN	NaN	NaN	NaN	1.56	7.546	227.1324	11.498	61.8109	99.67292	0
24-May-14	NaN	NaN	NaN	NaN	1.0339	8.53	252.7596	9.23202	55.0051	100.4583	0

25-May-14	NaN	NaN	NaN	NaN	1.2112	8.23	207.3987	9.88731	51.694	100.4597	0
26-May-14	NaN	NaN	104.9	104.9	1.1087	8.04	211.8821	11.6657	44.4858	100.4215	0
27-May-14	NaN	NaN	116.4	116.4	1.0618	8.72	220.3331	12.8697	40.0028	100.8403	0
28-May-14	NaN	NaN	116.4	116.4	1.0879	7.154	204.488	14.5836	39.9509	100.5764	0
29-May-14	NaN	NaN	NaN	NaN	0.90866	6.664	258.1167	12.7124	55.3492	100.3424	0.2
30-May-14	NaN	NaN	NaN	NaN	0.81951	6.468	201.527	14.1783	50.0153	100.5375	0
31-May-14	NaN	NaN	NaN	NaN	1.1494	7.448	208.1426	14.5055	47.3608	100.5451	0
01-Jun-14	NaN	NaN	181.6	181.6	1.2558	8.04	225.6833	15.6926	37.8898	100.6201	0
02-Jun-14	NaN	NaN	181.6	181.6	1.3529	13.03	283.9609	13.7524	42.6956	100.1951	5.3
03-Jun-14	NaN	NaN	NaN	NaN	1.3254	9.02	300.2816	7.78526	78.7058	100.4271	6.7
04-Jun-14	NaN	NaN	NaN	NaN	0.87635	8.92	225.2926	7.52555	61.0388	100.8104	0.6
05-Jun-14	NaN	NaN	NaN	NaN	0.77126	4.998	186.5346	9.11256	48.4036	101.0215	0
06-Jun-14	NaN	NaN	NaN	NaN	0.82242	9.7	176.7388	11.7451	49.3943	100.7174	0.5
07-Jun-14	0	0	NaN	NaN	0.75211	5.586	146.67	13.2395	44.0653	100.6028	0
08-Jun-14	NaN	NaN	NaN	NaN	1.0589	7.938	174.4062	11.7289	62.1967	100.1479	0.7
09-Jun-14	NaN	NaN	NaN	NaN	0.91293	7.35	269.0836	11.8635	54.9042	100.2264	0
10-Jun-14	NaN	NaN	NaN	NaN	1.0653	7.056	229.2734	12.5745	50.6496	100.4938	0
11-Jun-14	0	0	2.52384	5.457	0.8966	9.9	218.2311	13.6972	49.6956	100.5028	0
12-Jun-14	0.1498333	2.001	2.76575	7.483	1.063	9.02	228.2659	12.4934	56.2542	100.2604	0
13-Jun-14	0.6047589	4.263	2.866284	11.76	1.0998	8.43	162.4595	14.8494	60.7576	100.0111	0
14-Jun-14	1.253806	4.412	2.76266	12.8	0.82097	7.448	185.5313	13.4085	53.0087	99.69097	0.7
15-Jun-14	1.318472	6.282	0.7562986	2.144	0.76176	6.076	200.5395	10.0829	66.3349	99.85486	5.6
16-Jun-14	1.064354	5.247	1.117215	4.038	1.0775	6.076	231.5686	12.4101	61.3515	100.3319	0
17-Jun-14	1.783653	7.662	2.764903	8.17	1.106	8.23	160.246	14.177	54.3042	100.3479	0
18-Jun-14	0.9912083	4.72	2.098778	10.78	0.974	8.53	135.7934	14.4019	54.0757	100.1229	0
19-Jun-14	3.01916	19.35	3.025236	13.53	1.3363	9.41	168.3236	12.0008	63.0804	100.0931	4.7
20-Jun-14	1.068271	3.941	1.651507	3.925	1.2663	9.6	156.9086	11.907	81.8605	99.88542	6.5
21-Jun-14	1.459812	10.89	1.486493	3.511	1.0223	6.37	141.651	12.572	60.6051	100.5208	0.1
22-Jun-14	3.768194	18.78	1.922556	7.375	0.77535	5.978	148.683	12.764	61.3369	100.8014	0
23-Jun-14	1.988444	9.26	1.930424	9.25	1.1406	8.23	164.5617	16.8427	54.5367	100.5208	0
24-Jun-14	2.601167	8.47	1.090382	9.25	0.79323	5.488	194.9288	14.2047	73.6141	100.2333	1.5
25-Jun-14	0.9664028	9.03	1.181542	4.07	0.83246	7.448	221.0853	13.4032	58.1487	100.2479	0
26-Jun-14	1.845813	9.03	1.733799	8.09	0.69941	5.39	150.2444	14.4823	48.9544	99.75764	0

27-Jun-14	2.291854	13.42	3.040743	10.84	1.1526	8.72	178.9139	16.423	45.6957	99.29028	0
28-Jun-14	2.408764	8.2	1.620167	6.121	0.70586	4.214	176.8156	14.9704	76.5017	99.62708	5.1
29-Jun-14	1.939847	8.52	1.054403	2.477	0.71167	5.39	166.5948	16.5873	66.5728	100.3125	0
30-Jun-14	2.731312	28.53	1.495799	5.796	0.69761	5.782	158.7915	17.4195	60.5168	100.9639	0.3
01-Jul-14	2.815486	22.36	1.818319	5.994	0.84416	6.762	129.4255	16.366	59.1694	100.8604	0
02-Jul-14	2.142938	9.79	1.698979	6.841	0.78815	5.782	265.5839	15.4919	71.3482	100.2306	5.5
03-Jul-14	0.8650972	3.369	1.300361	3.885	0.81514	10.88	214.938	13.233	82.2975	100.0708	1
04-Jul-14	0.7804097	4.327	4.14416	434	0.90417	6.076	170.3047	13.8256	71.4448	100.0292	4
05-Jul-14	1.191657	6.373	0.7574931	2.605	0.85875	5.782	166.9431	14.0772	64.4613	100.2271	0
06-Jul-14	0.1829097	2.91	0	0	0.58477	6.076	185.2602	16.2084	57.6706	100.7806	0
07-Jul-14	5.906224	30.25	0.3388182	37.27	0.67892	4.312	142.2453	17.3641	55.1735	100.9479	0
08-Jul-14	0.665416	3.294	5.30433	45.37	0.62397	8.92	194.6988	19.516	47.1849	100.4132	0
09-Jul-14	0.1807054	3.835	0.00958209	0.214	1.6047	8.82	296.9448	16.7625	40.108	100.2812	0
10-Jul-14	0.8103681	5.955	0.8410435	16.12	1.0674	7.448	233.7369	18.788	49.2863	100.6264	0
11-Jul-14	1.421186	7.701	0.7904074	21.08	0.88315	6.468	125.3589	18.9934	53.617	100.6819	0
12-Jul-14	1.695162	9.89	0.4321875	2.506	0.9098	5.488	123.5977	21.906	48.02	100.8597	0
13-Jul-14	7.729382	45.95	6.784256	28.92	0.86318	6.468	137.9448	22.7149	47.0449	101.0542	0
14-Jul-14	1.788676	9.71	108.3447	1298	0.60633	4.018	143.8969	22.5983	45.8925	100.9313	0
15-Jul-14	2.886558	11.49	0.9581882	45.77	0.74215	7.448	218.3337	21.3633	41.9469	100.5701	0
16-Jul-14	2.197272	8.77	1.258354	48.05	0.9724	7.154	282.3844	22.4378	31.0886	100.3708	0
17-Jul-14	0.9618704	8.61	1.524163	37.19	1.2497	8.72	280.5656	20.5927	36.1458	100.0181	0
18-Jul-14	0.3308525	6.393	0	0	0.70992	5.782	196.8211	14.0986	83.3894	99.48333	8.8
19-Jul-14	0.09866667	1.078	0	0	0.36227	2.646	181.1103	12.6576	81.7383	99.61042	3.3
20-Jul-14	0.07595139	0.787	0	0	0.73709	6.174	131.7835	14.2472	79.3232	99.85	1.8
21-Jul-14	0.2720417	1.995	0.01479167	0.355	0.69435	6.468	219.4307	13.6331	79.4222	100.2368	2.8
22-Jul-14	0.1860903	0.835	0	0	0.94874	7.644	235.4888	14.6891	73.834	100.7236	0.2
23-Jul-14	0.03592361	0.263	0.1999444	2.583	0.75917	4.606	184.5892	16.1524	62.7856	100.5375	0
24-Jul-14	0.2694931	2.321	3.066194	27.54	1.2523	6.37	298.3803	16.7058	51.4697	99.98333	0
25-Jul-14	0.4910069	5.661	0.2440694	5.29	0.66874	3.92	221.5327	17.4222	48.2551	100.2639	0
26-Jul-14	0.3609097	3.46	0	0	0.89442	6.174	162.4295	15.2082	55.9685	100.7174	0
27-Jul-14	1.276569	9.48	1.048928	6.217	0.69598	13.52	162.242	14.953	68.9268	101.0715	6.7
28-Jul-14	0.188608	3.758	16.94057	287.4	0.8173	5.684	158.5189	16.9747	66.6285	101.0264	0
29-Jul-14	0.5741458	8.05	0.3073194	3.595	1.0942	8.04	159.1771	18.0176	57.6377	100.6819	0

30-Jul-14	0.5605362	2.683	0.5417953	4.671	0.91769	6.174	266.2038	18.3221	39.6829	100.9868	0
31-Jul-14	0.5575139	4.884	2.017306	4.957	1.1408	6.566	247.3522	15.8547	51.3643	101.1903	0
01-Aug-14	3.299373	31.43	5.028623	10.45	0.91256	4.41	210.237	17.9275	50.2488	101.1049	0
02-Aug-14	1.568861	11.75	1.013642	38.41	0.74525	4.116	189.0148	19.0217	49.4797	100.7083	0
03-Aug-14	1.936737	12.4	22.47486	253.7	0.912	5.39	187.6522	19.3669	46.7315	100.7757	0
04-Aug-14	1.226682	10.99	1.350447	29.46	0.62581	5.292	151.8789	18.5208	56.6949	100.6229	0
05-Aug-14	0.6599478	3.871	0.2615433	3.525	0.84296	6.566	164.4247	16.7483	66.3566	100.3993	1.7
06-Aug-14	0.03690972	2.243	0	0	0.95743	7.252	213.1402	15.1669	67.2141	100.4694	0
07-Aug-14	0.1348333	1.216	0.00625	0.06	0.8284	6.468	153.0187	12.992	61.8185	100.4924	0.1
08-Aug-14	0.08160417	0.448	0.02725	0.211	0.66626	5.194	180.3657	14.45	63.745	100.5868	0
09-Aug-14	0.1371597	0.759	0.02895833	0.139	0.56083	5.292	149.577	12.9177	68.8278	100.8993	0
10-Aug-14	0.1639861	0.891	4.198056	23.94	0.59722	5.586	165.1758	14.7183	75.5501	101.0681	0.3
11-Aug-14	0.09919626	0.892	2.917047	5.151	0.58724	4.312	141.815	19.1702	66.0952	100.9215	0.1
12-Aug-14	7.08	47.85	0.2187692	1.582	0.53158	4.704	132.04	18.3565	61.2283	100.325	0
13-Aug-14	4.983459	35.63	0.1556604	1.158	0.62763	7.448	184.7027	19.3807	50.4819	100.2278	0
14-Aug-14	8.963727	47.16	0.3254375	1.515	0.68669	4.9	123.8454	20.9504	53.4151	100.4868	0
15-Aug-14	11.58987	59.43	0.458	1.799	0.80713	6.664	189.832	19.9692	60.3672	100.3528	0
16-Aug-14	7.600376	33.4	0.2604	1.116	0.78144	5.88	208.0478	21.0558	46.294	100.3917	0
17-Aug-14	7.179476	56.62	0.2803217	1.816	0.86086	4.998	161.6149	17.5431	51.7742	100.55	0
18-Aug-14	1.118493	7.343	0.04913889	0.382	0.86368	7.644	207.5423	17.8547	53.9539	99.98403	0.1
19-Aug-14	0.4365069	6.152	0.02136111	0.322	1.0358	9.02	263.9185	12.9743	59.356	100.0424	0.4
20-Aug-14	0.4543194	1.616	0.031625	0.126	0.64826	5.194	123.5503	12.5366	60.9062	100.4826	0
21-Aug-14	0.5010682	1.459	3.477614	25.97	0.42748	4.018	239.7686	12.9872	74.0031	101.1576	1.3
22-Aug-14	6.75897	10.96	3.331636	8.88	0.71082	4.508	186.1145	13.993	63.798	101.466	0
23-Aug-14	0.7669655	16.26	8.310782	13.38	0.49052	5.782	0.4372727	11.4617	66.6108	101.1701	0
24-Aug-14	0.092375	1.495	2.276458	7.578	1.1154	5.586	216.7225	14.8305	56.6645	100.8306	0
25-Aug-14	0.04808333	0.484	0	0	0.80933	5.39	121.1601	17.3217	60.2103	100.1632	0
26-Aug-14	0.2385694	0.967	0.006194444	0.062	0.83903	6.076	165.1752	13.4923	75.5589	100.1375	1.4
27-Aug-14	0.2276806	0.972	0.01226389	0.085	0.70298	6.762	211.8186	10.9861	64.716	100.4167	0
28-Aug-14	0.1506667	1.1	0.00375	0.084	0.77246	5.194	162.9094	10.712	62.919	100.4542	0
29-Aug-14	0.03729167	0.895	0.006736111	0.085	0.81789	6.958	196.5593	10.2392	67.1485	99.66528	0
30-Aug-14	0.2102986	1.271	0.02734722	0.163	0.51803	4.214	147.6577	9.64861	83.9288	99.47431	4
31-Aug-14	0.1969375	1.271	0.022125	0.102	0.6154	4.998	148.9273	9.29104	83.2059	99.84514	0.8

01-Sep-14	0.09684028	0.485	0.01577083	0.086	0.76612	6.762	141.6771	10.1762	84.5399	99.7625	2.2
02-Sep-14	0.4906528	0.967	0.036375	0.145	1.0258	8.62	279.1839	11.8532	70.284	100.084	1.7
03-Sep-14	0.2777292	1.068	0.0181875	0.113	0.65175	6.174	234.5308	8.1007	71.0452	100.5167	0
04-Sep-14	0.406125	1.654	0.03722222	0.17	0.52561	5.292	162.4032	11.2806	64.8853	100.8618	0
05-Sep-14	0.1478333	0.847	0.03393056	0.114	0.86168	5.88	145.8837	12.5655	69.7903	100.8167	0
06-Sep-14	0.03858333	0.444	0.005388889	0.05	0.7201	3.92	124.5881	11.6586	83.7025	100.5785	1.7
07-Sep-14	0.5169722	1.488	0.02076389	0.09	0.65483	5.684	249.5034	6.04614	91.636	100.3819	9.2
08-Sep-14	0.2227153	1.24	1.734486	12.29	0.48017	3.822	178.1993	3.2948	78.7368	101.0604	0.1
09-Sep-14	3.238209	21.7	1.551859	4.416	0.55168	5.978	192.9722	3.45119	73.8503	101.6243	0
10-Sep-14	3.558315	13.9	1.983402	7.409	0.82208	6.958	143.7447	3.27307	68.8462	102.0389	0
11-Sep-14	2.616549	12.47	2.487979	6.622	0.75944	6.272	194.34	7.29651	63.4125	101.475	0
12-Sep-14	2.864083	33.87	2.367326	9.25	0.90238	5.292	238.5662	10.0074	68.5499	101.4056	0
13-Sep-14	0.1022778	2.104	0.8077569	5.533	0.33893	3.234	171.9229	10.796	75.799	100.8257	0.3
14-Sep-14	0.2599167	2.706	0.01854167	0.268	0.6174	4.606	172.2766	14.1113	68.3542	100.6069	0
15-Sep-14	0.1380972	2.706	0.003625	0.038	0.58722	5.586	165.7818	10.6046	72.4443	100.4563	0
16-Sep-14	0.07736111	0.53	0.006930556	0.048	0.52883	4.802	188.318	11.6467	70.3231	100.1236	0
17-Sep-14	0.02420833	0.505	0.003569444	0.031	0.57752	5.782	142.6784	10.0004	70.6667	99.63681	0
18-Sep-14	0.01179167	0.129	0.008402778	0.139	0.65864	4.802	144.3418	6.44256	88.0582	99.15	0.2
19-Sep-14	1.346167	2.368	0.09236111	0.264	0.8502	7.252	165.0998	10.1174	77.1093	99.66528	2.8
20-Sep-14	0.1510833	1.071	0.006861111	0.071	1.4593	8.72	139.3099	10.0293	75.9407	100.5187	0.5
21-Sep-14	0	0	0.001458333	0.021	2.0471	10.58	135.5689	17.0526	58.3568	99.76458	0
22-Sep-14	0.7775139	2.637	0.02729167	0.127	1.0294	8.72	214.5316	14.5721	47.9984	99.69583	0
23-Sep-14	0.2039444	1.454	0.01158333	0.101	0.53891	4.606	183.4383	6.91432	63.6106	100.0903	0
24-Sep-14	0.4603194	1.721	0.03951389	0.198	0.77469	4.606	291.0502	6.06058	78.7569	99.53542	3
25-Sep-14	0.5022083	1.368	0.03802778	0.102	0.48626	3.528	285.5909	9.11213	78.0111	100.2764	0.1
26-Sep-14	0.3357083	1.246	0.03163889	0.133	0.72361	4.214	224.8129	9.09897	75.4985	100.6347	0
27-Sep-14	0.1529722	0.805	0.009152778	0.056	1.97	9.21	129.8378	10.269	68.8955	100.8819	0
28-Sep-14	0.01395833	0.253	0.006666667	0.06	2.2415	10.29	135.9614	13.3851	71.5508	99.96806	2.5
29-Sep-14	0.4435417	2.599	0.03416667	0.166	0.87317	8.33	224.8184	9.66079	78.1719	99.45278	3.3
30-Sep-14	0.5853611	3.073	0.03283333	0.249	0.82417	9.51	197.8938	4.89193	81.0227	99.87847	2.8
01-Oct-14	0.9215972	1.995	0.4184861	6.973	1.3895	8.23	282.317	3.23799	72.3851	100.5653	0.5
02-Oct-14	1.789333	27.23	1.055722	3.516	1.0314	7.252	186.0151	1.38167	61.6695	101.3458	0.8
03-Oct-14	0.08954167	2.259	0.002375	0.048	1.9053	7.938	151.4364	5.22076	89.8938	100.2444	4.9

04-Oct-14	0.539375	1.268	0.04125	0.131	0.79836	3.92	223.6564	7.29128	86.7675	100.3597	0.5
05-Oct-14	0.185875	1.462	0.01	0.131	0.77644	6.174	158.1317	3.97045	93.2354	100.3201	1.6
06-Oct-14	0.654625	1.49	0.05019444	0.143	0.76894	4.704	201.0988	6.57488	73.4799	100.2549	0.1
07-Oct-14	0.09226389	0.873	0.01234722	0.073	0.50422	3.332	247.8476	3.20949	69.6034	100.3701	0
08-Oct-14	0.3444444	0.989	0.025375	0.082	0.75833	5.292	247.4571	2.61457	66.8697	100.5333	0
09-Oct-14	0.3218462	1.455	5.599189	27.87	0.28504	2.254	202.6031	2.17843	89.6469	100.3846	0.3
10-Oct-14	0.5490208	1.123	3.230785	9.27	1.4089	9.8	180.9842	8.22314	86.0861	99.26597	1.1
11-Oct-14	0.6582847	1.218	4.909535	13.22	0.65402	6.076	141.2715	6.56265	84.8665	99.40069	0
12-Oct-14	0.6511806	1.433	2.056604	10.73	1.3298	7.448	135.547	6.86122	76.0911	99.93056	0
13-Oct-14	0.2131875	0.642	0.7453403	8.95	1.0799	6.958	109.685	6.49237	89.7271	99.22778	9.9
14-Oct-14	0.5293056	0.841	3.155812	8.15	0.46515	3.234	200.1666	4.99683	89.3885	99.24514	0.3
15-Oct-14	0.5241667	1.421	6.313882	24.94	0.33994	3.038	201.1726	3.95835	81.7201	99.57083	0.1
16-Oct-14	0.3290139	0.97	3.969833	16.81	1.8244	9.9	128.8982	4.51647	87.0555	99.82917	0.8
17-Oct-14	0.2355903	0.534	1.55975	6.193	1.4539	10.29	190.1744	5.25072	92.7215	99.14653	11
18-Oct-14	0.5234653	1.008	2.281361	6.331	1.7645	10.58	145.8848	7.91117	88.2314	99.07292	3.4
19-Oct-14	0.5031319	0.812	1.532243	3.675	2.4163	11.66	157.4429	9.0226	88.4757	98.82153	3.7
20-Oct-14	0.6854722	1.446	3.643715	10.12	1.8802	9.51	169.0863	8.31228	85.781	98.78403	0
21-Oct-14	0.5500139	1.445	5.41766	19.37	1.8594	8.53	165.0189	6.24667	82.0674	98.94653	0.1
22-Oct-14	3.531069	333	6.039493	31.92	0.73328	4.704	179.2029	4.47172	88.2479	98.84444	7
23-Oct-14	0.4038392	1.685	3.662951	26.65	0.77878	4.508	267.2365	-0.0858681	92.3266	99.25069	0
24-Oct-14	0.5032292	1.737	6.713701	24.05	0.40338	4.606	101.3563	1.02976	93.7694	100.1597	1.4
25-Oct-14	0.2633681	1.686	4.993556	21.07	0.73237	4.998	296.564	-0.324132	84.9635	100.0049	0
26-Oct-14	0.2990625	1.283	5.412181	24.73	1.1816	7.252	254.5063	0.14175	75.7976	100.0611	0
27-Oct-14	0.1738056	1.016	4.60675	31.55	0.61857	3.822	133.4787	-0.444931	85.8845	100.4201	0
28-Oct-14	0.1512292	0.469	3.817715	16.09	0.061104	1.764	60.29448	0.332715	93.766	99.76042	2
29-Oct-14	0.2947361	0.953	6.213868	21.61	0.17919	2.842	56.56671	0.939049	93.559	100.2694	3.9
30-Oct-14	0.1968681	0.411	3.251472	15.63	1.0743	8.23	201.4824	2.6036	93.8243	99.76597	2.8
31-Oct-14	0.7136181	2.992	10.73608	48.14	1.0783	6.566	165.2352	2.65715	83.5838	99.24861	0
01-Nov-14	0.5197778	2.27	9.098069	40.27	0.9716	8.62	165.9947	-1.89272	87.2417	99.7625	0
02-Nov-14	0.2012639	0.987	4.546042	22.32	1.8811	8.72	140.4874	2.15649	86.8708	99.72431	0.1
03-Nov-14	0.2306875	1.524	6.415833	45.48	0.61794	5.684	202.0337	-0.879681	90.2981	100.0431	0
04-Nov-14	0.3267986	1.17	6.271236	26.94	0.81855	4.312	146.4317	1.09052	92.4537	99.74583	3.1
05-Nov-14	0.2605347	1.631	6.502889	25.77	0.27762	2.45	153.0769	-1.99712	93.2819	100.334	0

06-Nov-14	3.979167	333	1.666667	4	1.4258	11.86	158.259	1.67056	87.8071	99.44792	8.9
07-Nov-14	0	0	0	0	0.14065	1.274	80.62958	-3.79565	92.6354	100.9424	0
08-Nov-14	0	0	0	0	0.15552	2.254	132.2913	-1.29144	90.849	100.7278	1.6
09-Nov-14	1	4	1	4	1.1983	4.508	308.3442	-1.01697	83.7206	100.7076	0.5
10-Nov-14	3.472222	4	3.472222	4	1.2631	6.664	216.9003	-3.62251	75.2072	101.8542	0
11-Nov-14	2.527778	4	2.527778	4	1.2402	7.644	132.3899	-7.46114	77.0397	102.4076	0
12-Nov-14	1.333333	4	1.166667	4	0.63238	3.332	185.9721	-10.1669	76.7811	102.3764	0
13-Nov-14	2.5	4	2.666667	4	1.3279	3.822	321.5056	-15.1015	72.6782	101.8326	0
14-Nov-14	0.6666667	4	0.6666667	4	0.93653	4.214	314.2913	-15.9885	72.4622	101.8931	0
15-Nov-14	1.333333	4	1.333333	4	0.45813	2.352	255.2286	-15.245	71.6658	102.1611	0
16-Nov-14	1.166667	4	1.166667	4	0.63064	2.646	258.5579	-11.4815	83.7896	102.4069	0
17-Nov-14	2.305556	4	2.138889	4	0.63962	3.136	299.3686	-11.2141	84.0556	101.9417	0
18-Nov-14	1.861111	4	1.861111	4	0.35276	2.058	240.8381	-9.94115	82.1583	101.4944	0
19-Nov-14	1.972222	4	1.638889	4	0.2603	3.136	224.4914	-5.95485	85.7664	100.6715	0
20-Nov-14	2.5	4	2.5	4	0.18924	1.764	270.7234	-3.22615	88.8799	99.475	0
21-Nov-14	1.361111	4	1.194444	4	0.08116	1.96	78.83287	-1.37153	92.441	98.55556	0
22-Nov-14	2.333333	4	2.333333	4	1.012	8.04	195.2958	-8.35487	79.145	98.80347	0
23-Nov-14	3.166667	4	3.166667	4	0.60783	2.744	287.7612	-5.37507	84.9945	99.62778	0
24-Nov-14	2.194444	4	2.194444	4	0.42655	3.038	263.8093	-4.40005	89.6514	100.0326	0
25-Nov-14	1.666667	4	1.666667	4	0.58935	3.332	216.1001	-4.83	89.5924	100.8021	0
26-Nov-14	2.694444	4	2.694444	4	0.5031	2.45	295.8251	-5.53003	88.3247	100.9868	0.1
27-Nov-14	2.472222	4	2.472222	4	1.9497	8.82	309.486	-13.2754	68.3056	100.8021	0
28-Nov-14	3.194444	4	3.194444	4	2.2997	11.27	313.879	-21.439	59.3023	100.9389	0
29-Nov-14	1.166667	4	1.166667	4	0.63907	3.724	300.5964	-28.8672	60.2382	100.8181	0
30-Nov-14	1.805556	4	1.805556	4	0.36785	2.646	298.9336	-26.6289	63.2335	101.1278	0
01-Dec-14	2.194444	4	2.194444	4	0.68903	2.94	290.7841	-21.3658	68.0612	100.5861	0
02-Dec-14	2.472222	4	2.472222	4	0.34556	2.254	268.4276	-21.4374	69.0976	100.7743	0
03-Dec-14	2.194444	4	2.194444	4	0.35231	3.038	258.2112	-14.3684	80.5238	100.4451	0
04-Dec-14	0	0	0	0	0.99926	4.606	314.4063	-12.0164	81.6819	100.7257	0
05-Dec-14	0	0	0	0	0.87553	2.94	326.0029	-17.8168	75.5781	101.0076	0
06-Dec-14	1	4	1.166667	4	0.72531	3.92	290.3778	-17.1032	74.403	100.3049	0
07-Dec-14	0.5	4	0.5	4	0.26721	1.862	186.5026	-9.75865	85.8799	100.966	0
08-Dec-14	0	0	0	0	0.16369	2.058	162.3526	-5.67972	89.4306	99.64792	0

09-Dec-14	0.9722222	4	0.9722222	4	3.1123	10	137.4228	3.14415	91.7028	98.07361	22.6
10-Dec-14	1.361111	4	1.361111	4	1.5925	10	93.93245	1.96615	88.6363	98.13681	0
11-Dec-14	2	4	2	4	0.90028	7.644	99.1514	1.26544	95.3368	98.33819	3.5
12-Dec-14	2.472222	4	2.472222	4	0.91306	4.606	278.9452	-1.0104	84.8685	99.16111	0
13-Dec-14	1.361111	4	1.361111	4	0.43069	2.352	288.6361	-3.12178	87.3688	100.7493	0
14-Dec-14	0.5	4	0.5	4	0.55165	4.704	206.3565	-3.31257	88.134	101.2806	0
15-Dec-14	0.3055556	4	0.3055556	4	0.89098	3.92	281.6241	-6.32153	83.5167	100.5542	0
16-Dec-14	0.5277778	4	0.5277778	4	0.78599	3.724	287.1036	-11.3092	78.5676	100.1424	0
17-Dec-14	0.6666667	4	0.6666667	4	0.44251	2.254	284.4156	-8.41719	81.5474	100.0236	0
18-Dec-14	0.1666667	4	0.1666667	4	0.34754	2.254	219.9992	-6.65604	84.3494	99.8875	0
19-Dec-14	0.3333333	4	0.3333333	4	0.47556	2.352	350.2647	-6.3309	85.1457	99.17222	0
20-Dec-14	0.9722222	4	0.9722222	4	1.8288	8.04	200.9685	-1.20934	90.4278	98.45417	0.1
21-Dec-14	2.527778	4	2.527778	4	0.51015	6.664	162.5269	-0.841097	93.6	98.79306	0.2
22-Dec-14	2.666667	4	2.666667	4	0.5372	3.626	188.2957	-2.52764	91.8569	100.3875	0
23-Dec-14	0.3055556	4	0.3055556	4	0.35404	4.998	145.1905	-3.71529	91.0792	99.74792	0
24-Dec-14	1.861111	4	1.861111	4	0.92578	4.9	282.0928	-5.72857	84.2342	99.60625	0
25-Dec-14	0.1666667	4	0.3333333	4	0.44918	3.92	199.6645	-15.3219	77.1397	100.5333	0
26-Dec-14	0.8333333	4	0.8333333	4	0.11178	1.47	53.40434	-13.5782	78.4384	100.9417	0
27-Dec-14	2.305556	4	2.305556	4	1.4962	7.938	299.6476	-10.6018	79.8865	100.7333	0
28-Dec-14	3.527778	4	3.527778	4	1.4832	7.84	310.3477	-10.5852	75.8473	102.4708	0
29-Dec-14	0.1666667	4	0.1666667	4	1.0651	4.41	313.3479	-22.4036	68.4365	103.4667	0
30-Dec-14	0.3333333	4	0.3333333	4	0.43406	3.136	224.9079	-23.255	68.1579	103.0903	0
31-Dec-14	1.166667	4	1.166667	4	0.66915	5.096	131.6796	-16.2077	75.2294	102.1896	0