North Pole $PM_{2.5}$ Saturation Study

Quality Assurance Project Plan

Prepared by

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1.0 QA PROJECT PLAN IDENTIFICATION AND APPROVAL (Element A1)

Quality Assurance Project Plan: North Pole PM2.5 Saturation Study

INVESTIGATORS

Signature: ______________________ Date: 2/1/17
Barbara Trost, Program Manager, Alaska DEC

Signature: ______________________ Date: 1/31/17
Tom Carlson, Project Manager, Sierra Research

Signature: ______________________ Date: 1/31/2017
Bob Baxter, Field Manager, T&B Systems

2.0 TABLE OF CONTENTS (Element A2)

LIST OF FIGURES

LIST OF TABLES

3.0 DISTRIBUTION LIST (Element A3)

Paper or electronic copies of this QAPP have been distributed to the people listed below. If the QAPP is revised, revised sections or the entire QAPP are sent to the people on this list.

Alaska Department of Environmental Conservation (DEC)
- Barbara Trost

Fairbanks North Star Borough (FNSB)
- Todd Thompson

Sierra Research (Sierra)
- Tom Carlson
- Bob Dulla

T&B Systems (T&B)
- Bob Baxter
- David Bush
- David Yoho
- Randall Baxter
- Patrick Bush

EPA Region 10
- Rob Elleman
- Chris Hall
- Keith Rose,

4.0 PROJECT / TASK ORGINIZATION (Element A4)

Sierra will be responsible for the management of the project. This includes the conduct of the three main phases of the study presented in Figure 1 and outlined below. Alaska Department of Environmental Conservation (DEC) and the Fairbanks North Star Borough (FNSB) will provide guidance on project objectives, equipment procurement, public outreach, site selection and interpretation of analysis findings.

Planning

- Define Study Objectives (Sierra) – DEC initially specified the study goal of assessing the representativeness of the North Pole Fire Station (NPFS) monitor. Additional considerations focused on the representation of the concentrations throughout North Pole.

- Review Available Guidance/Studies (Sierra/T&B) – This includes a review of 40 CFR Part 58, EPA's definition of neighborhood scale and sub neighborhood scale impacts and previously conducted saturation studies.

- Site Selection (Sierra/T&B) – Target monitoring site locations will be selected based on visual reviews of the North Pole area, EPA guidance, and practical considerations of local conditions, EPA scale definitions and study objectives. A mixture of fixed and mobile monitoring sites/pathways will be defined.

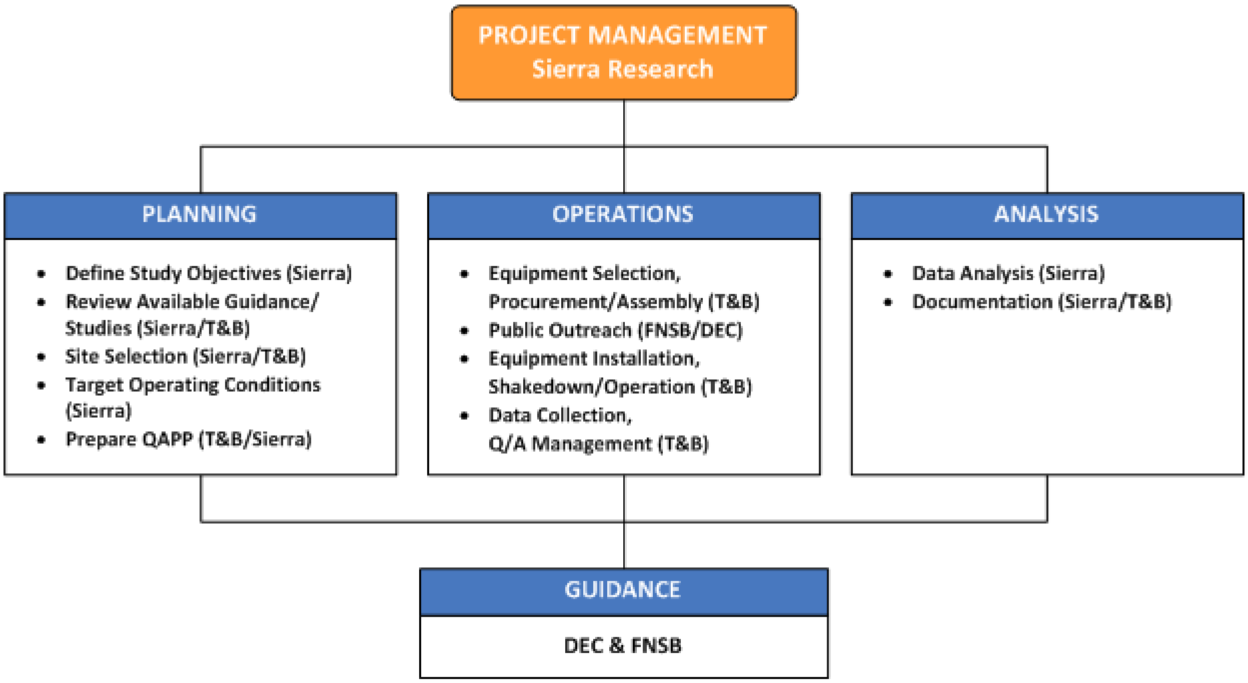


Figure 1. Project Organization.

- Define Target Operating Conditions (Sierra) – Historical ambient monitoring and temperature data from the NPFS station to identify the window of calendar days during the winter months with the highest probability of episodic, high concentration conditions.

- Prepare QAPP (T&B/Sierra) – A Quality Assurance Project Plan will be prepared which addresses project management, data acquisition, validation and analysis.

Operations

- Equipment Selection/Procurement/Assembly (T&B) – Specifications for monitoring, meteorological, communication and storage will be prepared in consultation with DEC and FNSB. Options for equipment purchase, leasing, cost, lead time and availability will be considered. All equipment will be shipped to T&B for assembly, calibration and testing.

- Public Outreach (Borough/DEC) – Information on the study purpose and operations will be prepared and distributed to the public through multiple formats. The mayor of North Pole and environmental organizations with North Pole membership will be contacted to aid information distribution and encourage owner participation.

- Equipment Installation/Shakedown/Operation (T&B) – T&B will ship assembled equipment to Fairbanks for installation at participating sites in North Pole and operation to confirm the collection and storage of valid measurements. Initial measurements will be assessed to determine if siting revisions are required.

- Data Collection/QA/Management (T&B) – Data will be collected from both fixed and mobile monitors following schedules established by T&B within the operating conditions specified for the study. The collected data will be quality assured and stored in data management system to facilitate retrieval and analysis.

Analysis

- Data Analysis (Sierra) – The collected and validated concentration measurements will be contrasted with measurements at the NPFS to assess differences as a function of distance, meteorology, and location. Data tabulations and spatial concentration plots will be prepared to summarize and show these differences. Both daily and diurnal variations will be examined and plotted along with multi-day composites intended to broadly represent prevailing or predominant conditions during high episodes.

- Documentation (Sierra/T&B) – The report will document the conduct of the study and include discussions of each of tasks outlined above.

5.0 PROBLEM DEFINITION / BACKGROUND (Element A5)

With EPA's tightening of the 24-hour $PM_{2.5}$ National Ambient Air Quality Standards (NAQQS) in 2006, on-going Federal Reference Method (FRM) monitoring within the City of Fairbanks was used to establish a design value that led to its designation as a 24-hour $PM_{2.5}$ nonattainment area and establishment of the nonattainment area boundaries that included the neighboring city of North Pole and surrounding areas as shown in Figure 2.

Ambient $PM_{2.5}$ monitoring began in the North Pole portion of the nonattainment area in 2010. Monitoring sites in North Pole were discontinued and/or relocated for a period until a site was established at the North Pole Fire Station (NPFS) in 2012 without an opportunity for a robust evaluation of the variability of $PM_{2.5}$ concentrations in the larger area surrounding the site and with that the representativeness of the site as a neighborhood scale monitoring site. Absent additional monitoring data to document monitoring scale decisions, EPA recommended designating the NPFS site as a regulatory site. When DEC complied, the NPFS site became the site providing the new design value for the entire non-attainment area. As funding became available DEC decided to conduct additional short-term, intensified monitoring in the larger area surrounding the NPFS site, to better understand PM2.5 levels across North Pole and surrounding neighborhoods.
This saturation study is also being performed in North Pole to assess the spatial scale of ambient 24-hour $PM_{2.5}$ concentrations currently being measured at the NPFS site.

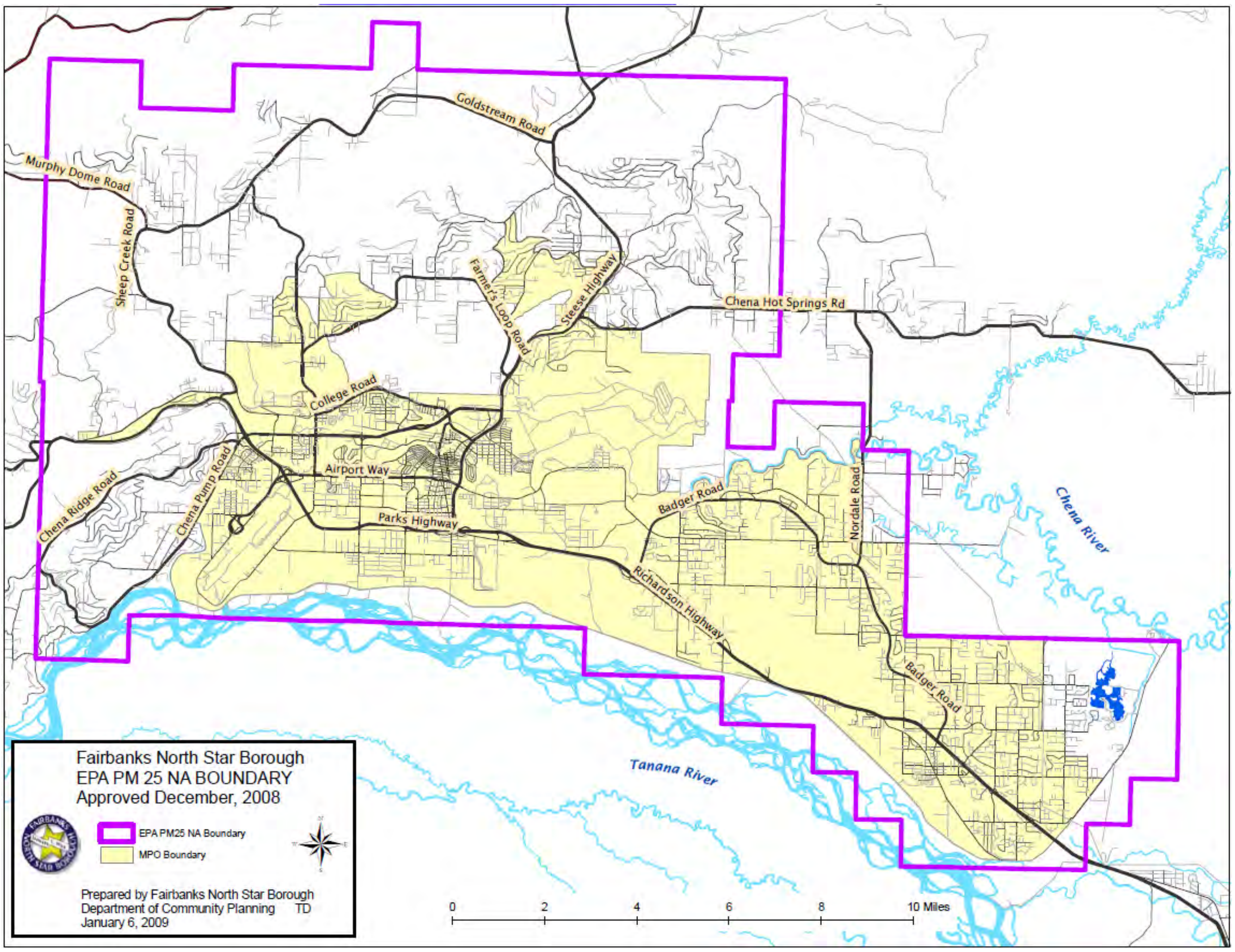


Figure 2. Fairbanks PM2.5 Nonattainment Area.

6.0 PROJECT DESCRIPTION (Element A6)

T&B Systems (T&B), working as a subcontractor to Sierra Research (Sierra), will provide high time resolution saturation network measurements to assist Sierra in this study. Detailed discussions between Sierra, DEC, and T&B have resulted in a network design consisting of both fixed $PM_{2.5}$ monitoring sites, and a mobile $PM_{2.5}$ monitoring platform. During the field study effort, up to three weeks of measurements will be made to characterize the distribution and gradients of $PM_{2.5}$ concentrations at various distances surrounding the DEC monitoring site at the North Pole Fire Station (NPFS) located on the northwest corner of Hurst Road and Dawson Road.

The goal of the saturation study is to make the needed measurements necessary for evaluating the spatial characteristics of ambient $PM_{2.5}$ concentrations across the North Pole area during wintertime episodes. The primary objectives of the study are twofold:

1. To identify ambient $PM_{2.5}$ concentrations residents are being exposed to beyond the NPFS monitor; and

2. To evaluate where a new monitor could be placed, if necessary, to better represent neighborhood scale impacts.

This plan summarizes the planned efforts and identifies the goals and responsibilities of the various team members.

7.0 QUALITY OBJECTIVES AND CRITERIA (Element A7)

The design has been optimized to fit the budget and scope of the study.

The following data quality indicators will be used for the assessment of the MQOs:

- Precision
- Bias
- Representativeness
- Completeness
- Comparability

Based on our experience with these measurements, the following data quality objectives have been assigned for this study:

- Bias, precision, and comparability (hourly averages)

  - Based on collocation data between the pDR samplers and the BAM at the NPFS, "k" factors can be developed to maximize the accuracy of the pDR readings, relative to the BAM. However, the key goal of the study is to relate measurements in the surrounding locations with the measurement made at the NPFS. With this in mind, the pDR sampler at the NPFS will in essence be designated "the standard" to which all other pDR samplers will be compared. Collocated data, from both the collocation comparisons at the beginning and end of the study and the mobile monitoring collocation passes, will thus be representative of both bias (relative to study goals) and precision. Based on our experience, we expect agreement for the fixed-site samplers to be with ±10% of the NPFS pDR sampler, and mobile monitoring data to agree within ±15% of the NPFS pDR sampler.
  - Wind speed - ±0.1 m/s (WS ≤ 5.0 m/s); ±1% of reading (WS > 5.0 m/s).
  - Wind direction - ±5º.

- Representativeness and completeness

  - 10 days of sampling characterized by periods of hourly $PM_{2.5}$ concentrations greater than 35 µg/m^3. As noted above, we have allowed up to three weeks of field measurements to achieve this goal, and will use available weather forecasts to optimize meeting this goal.
  - 80% data recovery goal for pDR sampler data.

8.0 SPECIAL TRAINING / CERTIFICATIONS (Element A8)

From a technical standpoint, no special training / certification is required for this study. All monitoring will be conducted using experienced T&B Systems personnel. However, from a safety standpoint, the extreme monitoring environment for this study introduces cold-weather conditions that require special consideration. A safety plan will be developed for this study, and all field staff will participate in a pre-study safety meeting regarding the hazards of working in environments as cold as -40ºF.

9.0 DOCUMENTS AND RECORDS (Element A9)

This QAPP will be distributed to the personnel stated in Section 3 as soon as the QAPP is approved by management. Included in this QAPP are standard operating procedures (SOPs) developed for key tasks (see Appendix). These include SOPs for the following:

- Fixed Location Installation
- Routine QC checks – Fixed Locations. Includes checklist form to be used to document routine QC activities.
- Routine QC checks – Mobile Monitoring. Includes checklist form to be used to document routine QC activities.

In addition, all field personnel will maintain a study-dedicated notebook to document all monitoring-related activities over the course of the study.

All checklists and study notebooks will be maintained at T&B Systems' Valencia office for at least five years after the study.

10.0 EXPERIMENTAL DESIGN (Element B1)

The study has been designed to a large extent based on hourly BAM data collected at the NPFS monitoring station from 2013-2015, and the special study and mobile "sniffer" PM survey data previously collected by the FNSB. Review of this data resulted in the following observations:

- From the hourly BAM data there is a clear diurnal pattern that is likely from the need to generate enhanced heating for the nighttime when people arrive home and increase the housing temperature to acceptable levels. Additionally, a morning peak is also present when heating is performed as the residence interior temperatures are increased in the morning hours.

- The sniffer measurements appear to show a fairly uniform high concentration area around the region of the NPFS monitor with occasional elevated hits likely from local sources. However, while the available seasonally averaged survey plots show fairly uniform concentrations in the region that may imply neighborhood representativeness, it needs to be recognized that the sniffer data were only collected along the primary road network and at a specific time of day. Additionally, the data processing for the FNSB sniffer plots used a nearest-neighbor approximation which does not consider topography, meteorology or source information and has not been thoroughly vetted outside FNSB. No measurements were made off the primary roads traveled to determine if the observed concentrations varied away from the roadway or at different times during the day to account for diurnal variations.

- As shown in Figure 2, the NPFS is relatively close to the roadway (although meeting the recommended roadway setback), this monitor may not represent concentrations further from the traveled road if the roadway in some form acts as either an additional source or is a channel in which drainage flow may be directed due to either terrain or topographic features such as trees or buildings. This is especially true given the very limited mixing during the episodic conditions and the low cap that may act as a lid to the upper bounds of the shallow surface layer. If the major roads throughout the NPFS region do act as a channeling "river" for potential pollutants, then gradients away from these potential sources are a valuable aspect of understanding pollution spatial gradients in the North Pole area.

- In particular, trees have the potential of acting as major barriers to the movement of air and associated pollutants during the extremely limited mixing height and low wind speed conditions associated with high concentrations. The residential areas in North Pole to a large extent consist of a series of small open patches surrounded by a barrier of trees, of which the NPFS is a good example. Thus, monitoring locations have the potential of being primarily impacted by local sources within the open patch. Concentrations in locations with no immediate local sources should be investigated.

- There is a potential that the roadway itself may provide a source of re-entrainment or increased mixing that would change the concentrations along the roadway such that those corridor measurements using the survey vehicle may be unrepresentative of the region set back from the roads.

To address the above, two types of measurements will be made – fixed-site and mobile monitoring. A key feature of both types is that they will employ the same instrument, the pDR-1500, which will minimize instrument-to-instrument variability/bias. (See Section 5 for further specifics on the pDR-1500.) These measurement types are discussed separately below:

Fixed-Site Monitoring

Twelve fixed-site monitors will be placed and operated continuously during the study period. The siting will be off the main roads and in locations away from local sources to try to capture the most representative data of a neighborhood scale within a broad area of North Pole that extend roughly 2 miles outward from the NPFS site. The principal goals of the fixed-site monitoring are as follows:

- Provide 24-hour continuous data to evaluate the spatial and temporal distribution of $PM_{2.5}$ surrounding the NPFS site using stations that are carefully sited to avoid microscale sources.

- Provide a link between the pDR-1500 measurements collected throughout the study area and the pDR-1500 deployed at the NPFS. (The pDR-1500 at the NPFS will be collocated with the existing BAM monitor. Thus a secondary goal will consist of pDR-to-BAM comparisons based on this colocation of the two measurement systems at the NPFS.)

- At the NPFS station, record sub-hourly measurements to observe if there is variability during the hour and if that variability may be related to traffic or other potential sources nearby.

- To the extent possible, determine if the NPFS site is unduly impacted by localized, sub-neighborhood scale sources.

The fixed-site monitors will be deployed as shown in Figure 2, with the following specific goals:

- As noted above, one of the pDR-1500 study samplers will be collocated at the NPFS monitoring site. While this will provide collocated data for relating pDR measurements to the station BAM measurements, its primary purpose will be to provide a normalizing base to which all other study pDR samplers can be compared.

- The majority of the sites are located within or very close to a diameter of 2 km around the NPFS monitoring site – the midpoint of the regime designated by the EPA as “neighborhood scale.” These will verify the representativeness of the NPFS site as a neighborhood scale monitoring location.

- Monitoring locations outside of this 2 km ring have been added in areas where the FNSB survey data have indicated a possibility of high $PM_{2.5}$ concentrations.

- Wind measurements will be included at two or three sites. Sites 8 and 12 have been chosen for these measurements, with key siting criteria being: 1) locations predominantly upwind and downwind from the NPFS determined from existing NPFS mintoring and meterological data; and 2) distance from potentially obstructing trees. With this in mind, Site 8 is located in an area of primary interest due to the high concentrations noted in the FNSB survey data. Site 12 provides measurements from the predominant upwind area during high $PM_{2.5}$ episodes. Note that Site 12 will not be established until the study involving Site 1A is completed (see below). Thus, wind measurements will be conducted at Site 3 until Site 12 is established.

- At the beginning of the study, one of the fixed sites will be located about 40 meters north of the NFPS monitoring site to specifically measure gradients relative to the nearby roadway (see Figure 2 close-up, Site 1A). We anticipate that this information can be collected within the first five days of the study, at which point the system will be moved to the area designated as Site 12.

Note that this sampling network may be modified as necessary to address additional goals and monitoring conditions noted in the field. Furthermore, while anticipated locations were identified during a site survey trip in October 2016, permission has not yet been obtained from the associated homeowners. DEC and FNSB will be assisting in obtaining permissions. However, if immediate permission is not obtained for a given location, all efforts will be made to secure a location in the immediate area of the target location. If such a location cannot be secured, then study resources, including mobile monitoring routes (see below), will be adjusted to cover the adequate distribution of sampling locations.

<u>Mobile Monitoring</u>

Mobile monitoring will be performed using a vehicle equipped with a real-time $PM_{2.5}$ monitor that will be used in a primary role of "virtual site" data collection. This mode of operation will use a multiple pass method to repetitively drive about 5 traverses per averaging period past the same locations. Data at these fixed locations along the traverse will be accumulated and averaged over the hour to provide hourly average concentrations at the "virtual sites." This type of sampling provides a very dense network of sites to directly address and answer questions about small scale variations that may be associated with local sources and microscale phenomena in the region. The mobile monitor will be deployed to address the following goals:

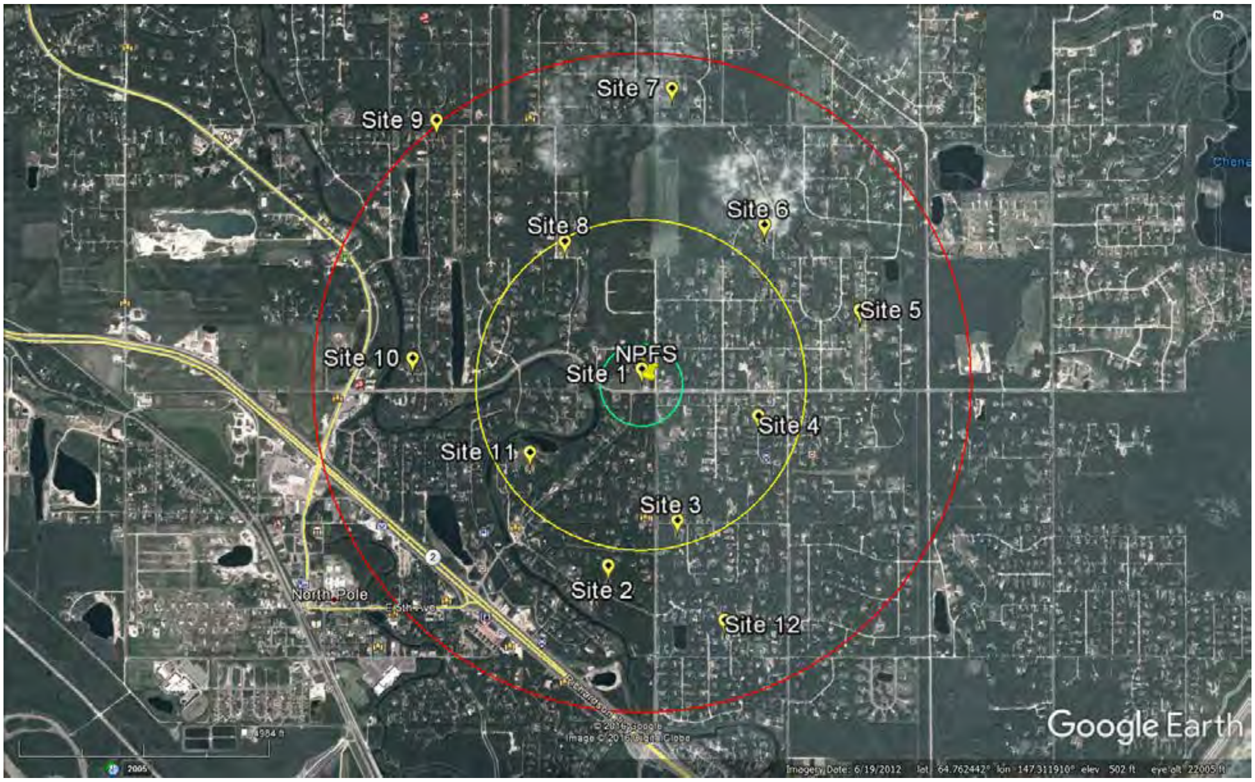
- Determine if there is a gradient in concentration when moving away from the primary roads in the vicinity of the NPFS and to what extent any observed gradient may explain the higher concentrations observed close to the roadway. This is important to determine whether there are roadway gradients to account for in monitoring siting and whether the FNSB survey vehicles are seeing general trends that may be more roadway (microscale) than neighborhood related.

- Establish repetitive routes that are along non-well-traveled roadways to collect data at "virtual sites" away from the primary roadways. This will help fill in and enhance the network of fixed locations that will be established using the fixed real-time monitors.

- Evaluate the primary roadway network around NPFS to see if there is a channeling of elevated $PM_{2.5}$ that can be associated with the roadway network and to what extent what may be driving that channeling, such as dense forested areas blocking flow, etc.

- Potentially use the mobile vehicle in a fixed site mode during the "off hours" to enhance the fixed monitoring site network at key locations. If used in this manner, we will evaluate the need to provide a source of heating or insulation to the monitor inlet within the vehicle if parked for an extended period under cold outdoor temperatures. The mobile vehicle will be equipped with cellular communications such that all data will be continuously available.

Figures 3 through 8 identify several potential routes to address the above goals. In each case, the route originates at, and repeatedly passes by the NPFS. Thus, the route's "virtual" NPFS averages can be compared with the fixed-site NPFS averages in order to fine-tune the mobile vehicle's pDR "k" factor (see Section 14), assuring comparability of all data relative to the NPFS concentrations. In designing the routes, we have assumed a vehicle speed of approximately 25 MPH. Thus, for a five-mile route, the vehicle will pass a given location approximately five times over the course of an hour. The ability to view the data collection on a real-time time basis allows study investigators to evaluate the mobile measurements relative to study goals and make immediate decisions regarding the most appropriate routes given the conditions that day.



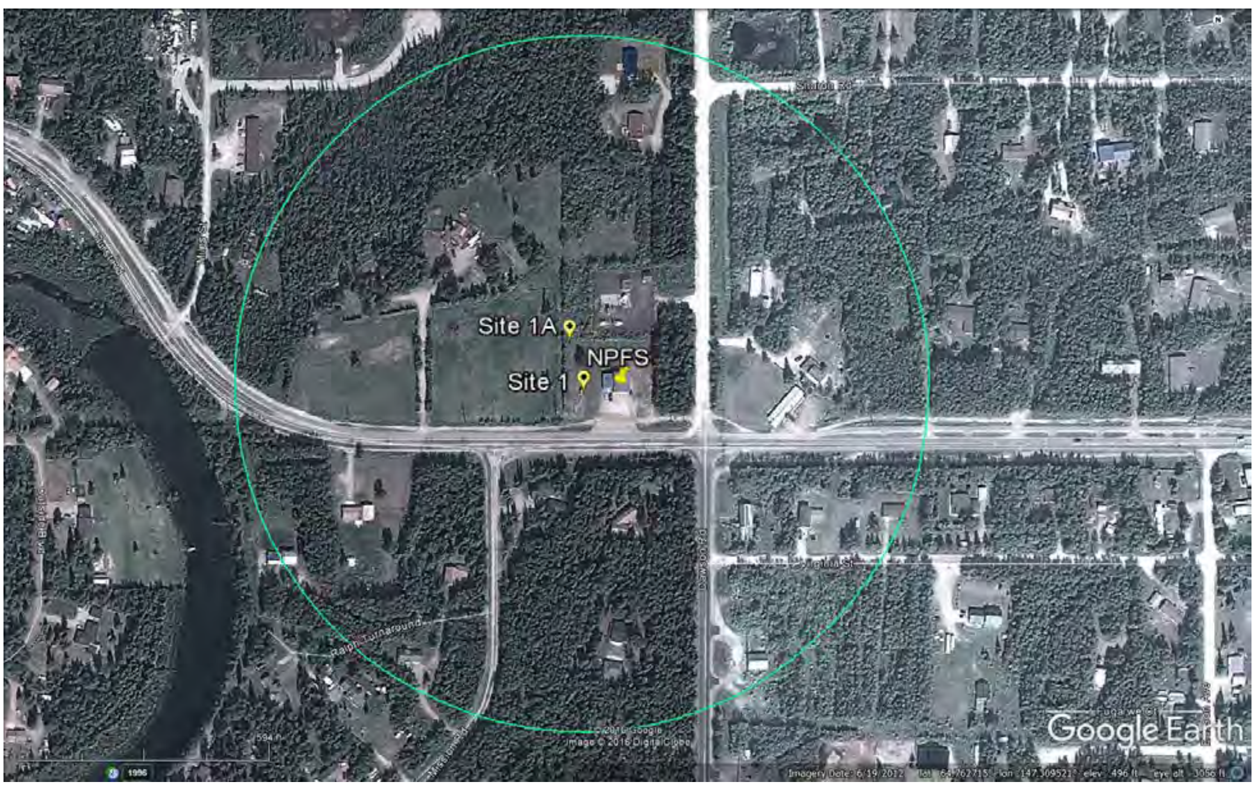


Figure 3. Locations of fixed-site monitoring locations, including close-up of NPFS area. Diameters from NPFS are as follows: Green – 500 m, Yellow – 2 km, Red – 4 km.

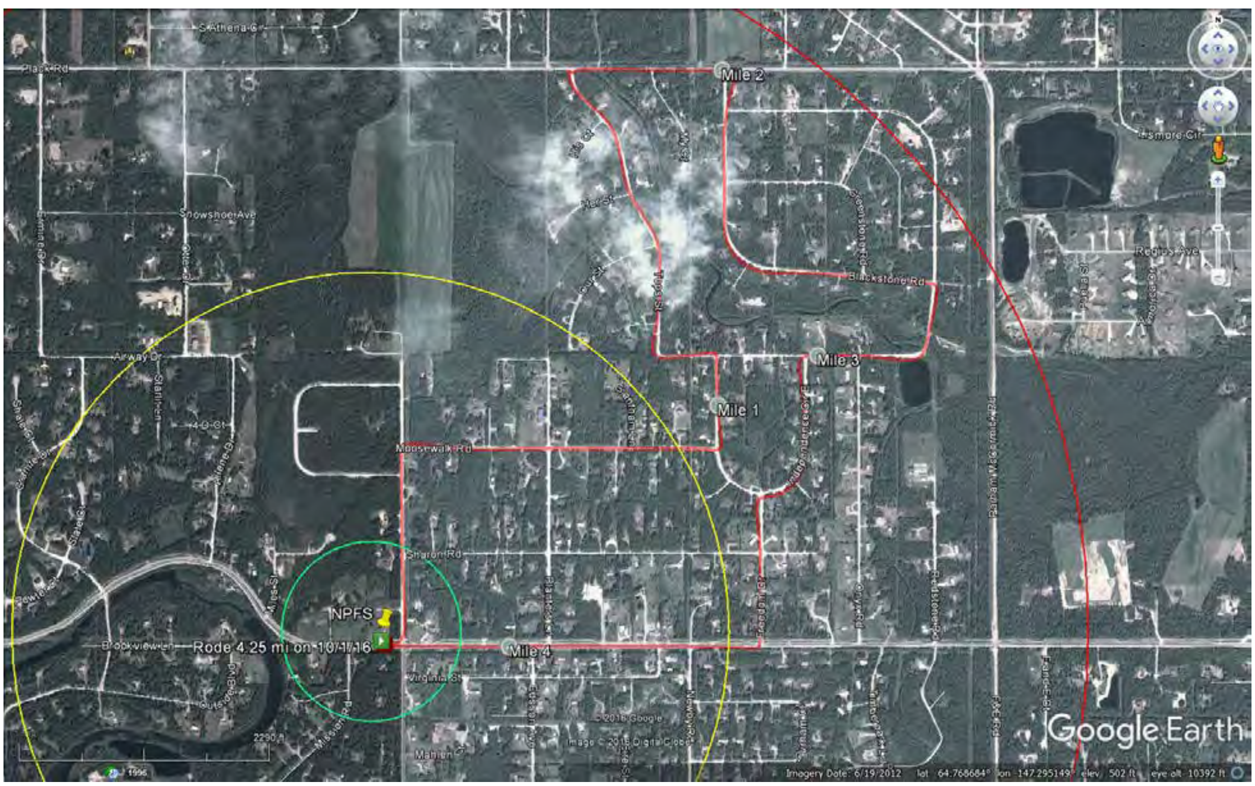


Figure 4. Possible mobile monitoring routes in the northeast quadrant of the study domain.

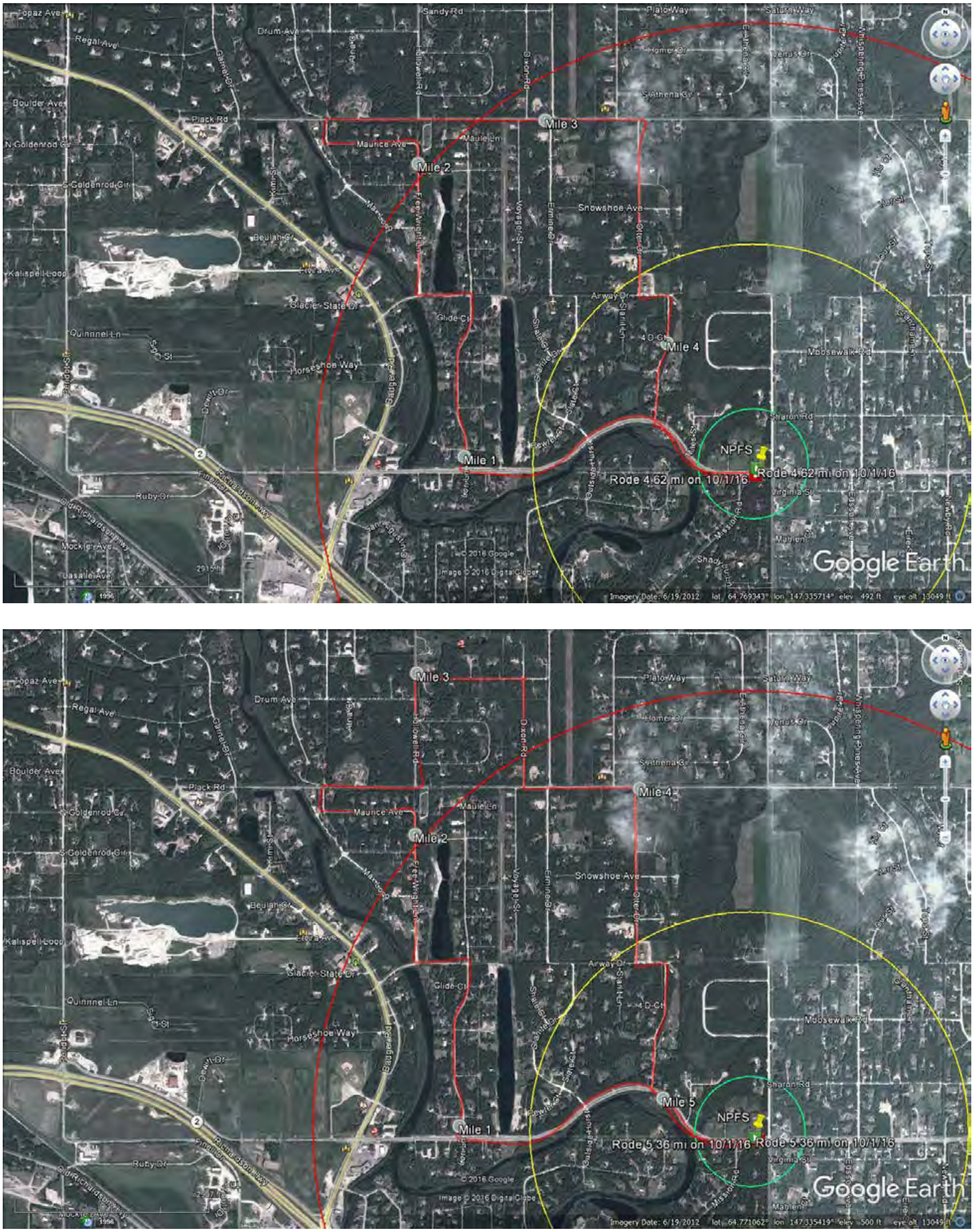


Figure 5. Possible mobile monitoring routes in the northwest quadrant of the study domain.

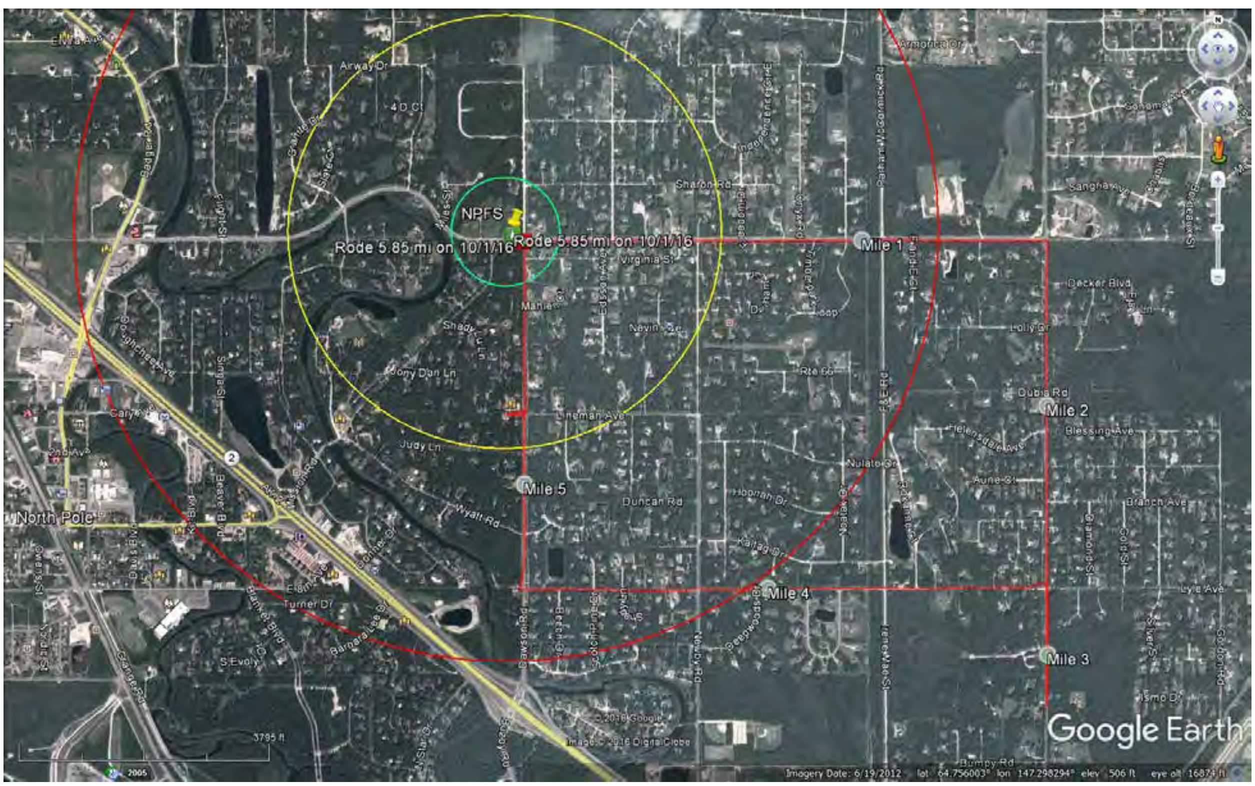


Figure 6. Possible mobile monitoring routes in the southeast quadrant of the study domain.

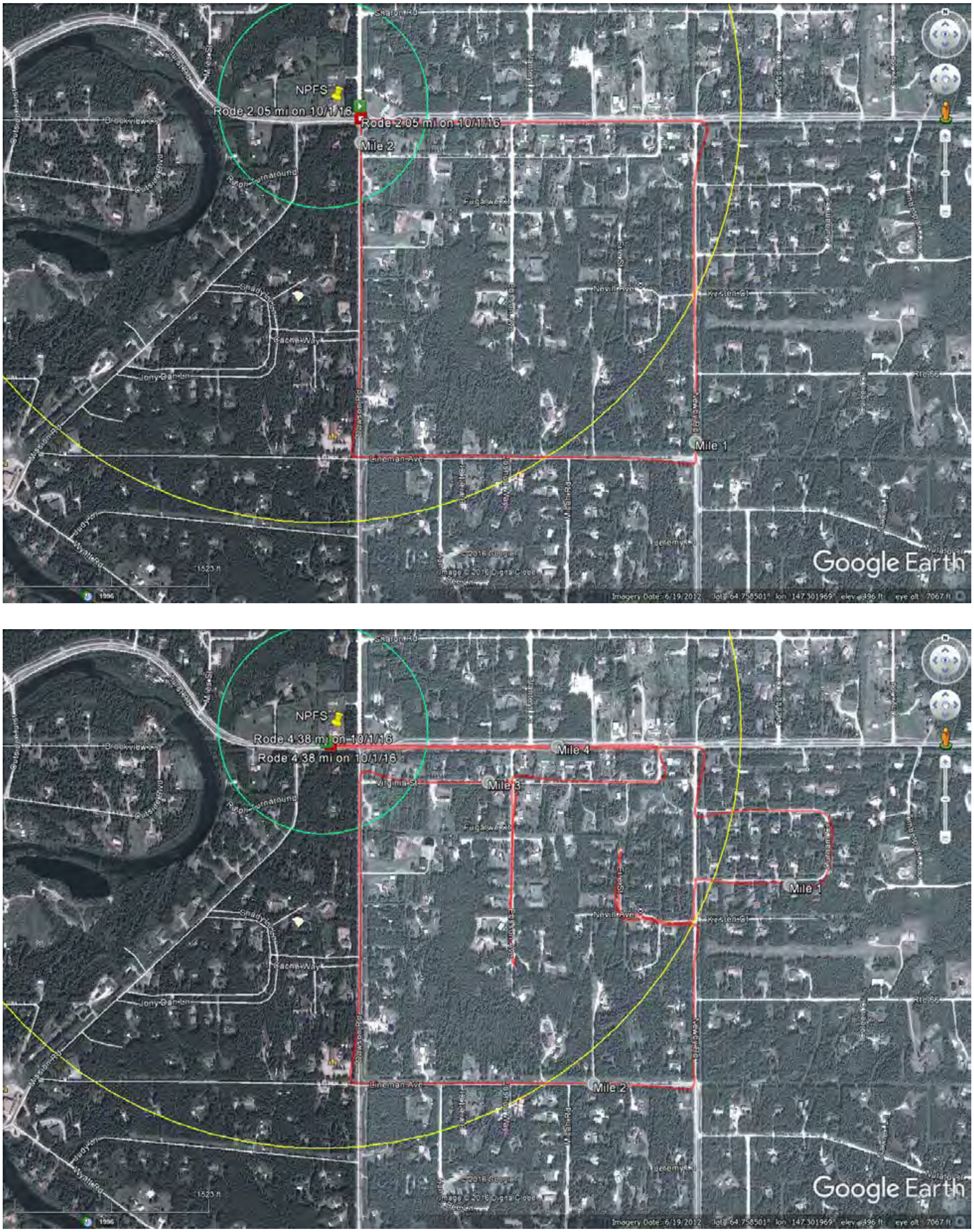


Figure 7. Additional possible mobile monitoring routes in the southeast quadrant of the study domain.

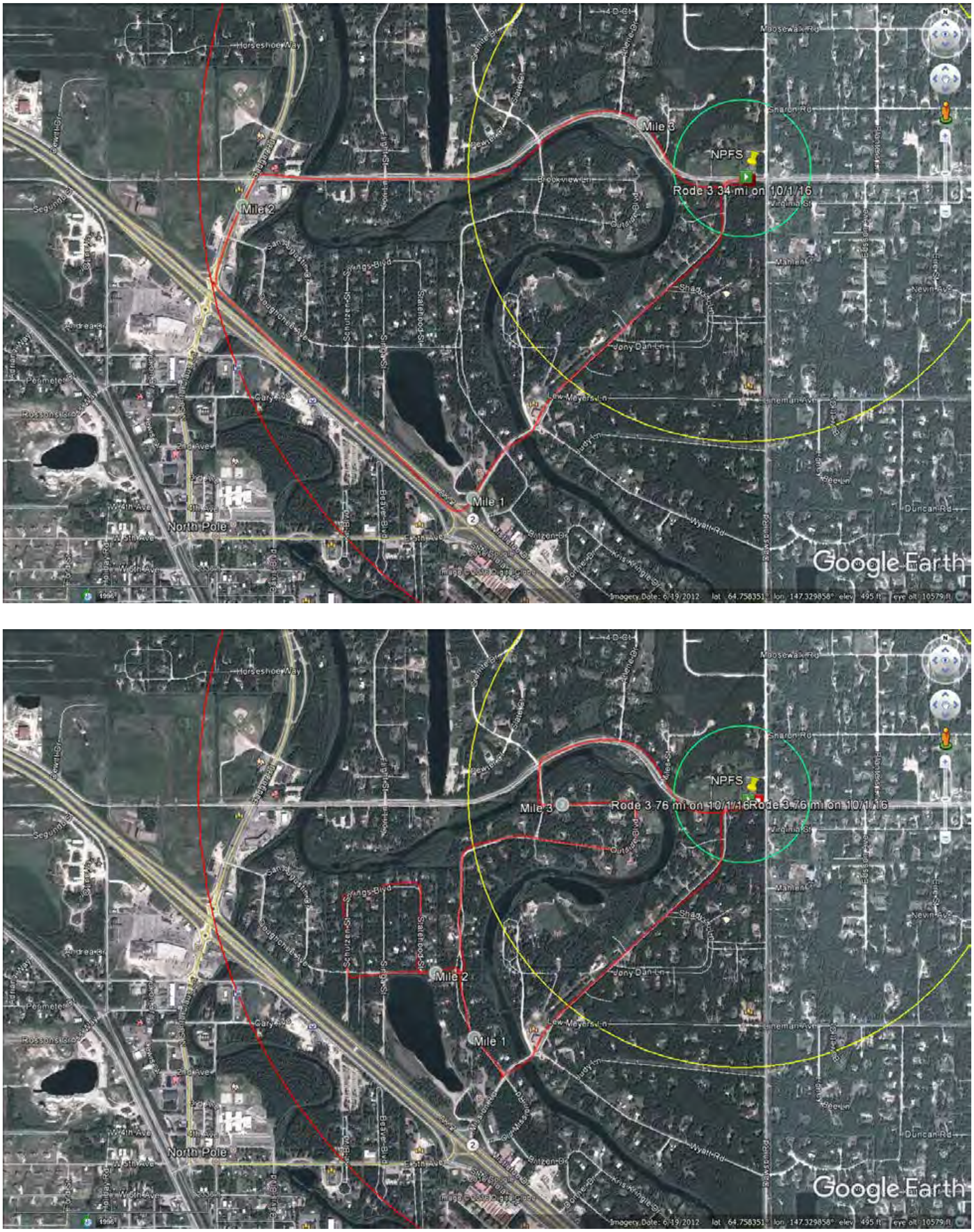


Figure 8. Possible mobile monitoring routes in the southwest quadrant of the study domain.

Measurement Schedule

A key element in design of the saturation study consisted of reviewing historical ambient monitoring and temperature data from the NPFS station to identify the window of calendar days during the winter months with the highest probability of episodic, high concentration conditions.

Hourly $PM_{2.5}$ BAM (with FRM corrections) and ambient temperature measurements collected at NPFS during the 2013-14 and 2014-2015 winter months (October through March) were analyzed to assess the best dates to start and conduct the field sampling portion of the saturation study.[1] Daily 24-hour $PM_{2.5}$ concentrations were calculated from the hourly BAM data. Similarly, average daily temperatures were computed from the measured hourly temperatures. The results from these two winters were then compiled into tabulations of the number of days for which ambient concentration and temperature thresholds within a given multi-day sampling window. A three week (21-day) sampling period was evaluated along with the following ambient thresholds:

- Daily $PM_{2.5}$ concentrations > 35 µg/m^3; and
- Daily average temperatures < -15°F.

Figure 9 presents the results of this analysis, expressed as a daily probability that either threshold is met as a function of the calendar start date and sampling window (21 days). As shown, the start date with the highest probability of measuring ambient concentrations over 35 µg/m^3 is January 26 (1/26). Over 21 days of sampling starting on that date, the probability of days > 35 µg/m^3 is 74%, meaning that roughly 16 of the 21 days are likely to have ambient $PM_{2.5}$ concentrations above that level. Although late January would be the optimal time to commence the field study, the data indicate that a three week field study could begin anywhere within window from late January through the end of the first week in February with a daily probability of concentrations > 35 µg/m^3 of 50% or higher. In other words, at least 11 of the 21 days would be expected to have concentrations above the 35 µg/m^3 threshold. After the first week in February, the probability of days above 35 µg/m^3 drop rapidly; by the end of the month daily probabilities of concentrations above the threshold drop to roughly 10%.

The likelihood of cold temperatures (defined as daily mean temperatures below a -15°F threshold) is also shown in the figure. As seen, the daily probability of cold temperatures tends to follow that of ambient concentrations above 35 µg/m^3, showing a maximum likelihood (over 76%) similarly peaking in late January.

[1] Although NPFS ambient measurement data were available through the end of calendar year 2015, the analysis was limited to the two preceding winters for several reasons. First, the 2015-16 winter data were not complete since data were not available for the first three months of 2016. Second, the 2015-16 winter was relatively mild and not representative of more typical winter conditions. Finally, since daily data collection at NPFS did not commence until 2013, the analysis was restricted to the two winters specified.

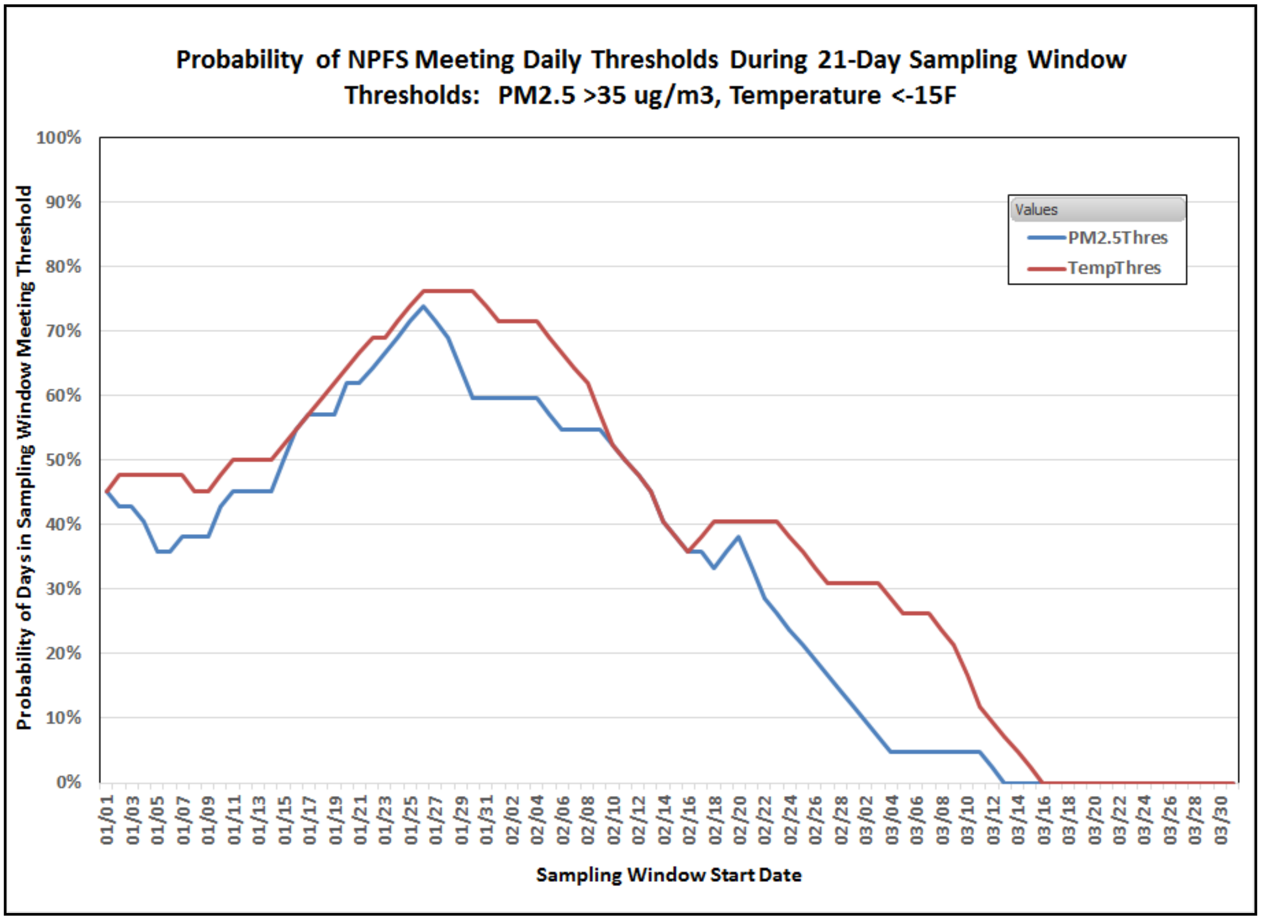


Figure 9. Daily probability of reaching either threshold for the start of the field sampling.

To summarize these findings, analysis of monitoring and meteorological measurements collected at the NPFS site over the two recent winters for which complete data are available indicates that the field study portion of the effort could begin within a period from early January through the first week of February and spanning three weeks, it likely to experience favorable sampling conditions on at least half of the deployed sampling days.

Based on the above, the study will be conducted during the months of January and February over a three-week period, with the goal of obtaining at least 10 days (240 hours) during $PM_{2.5}$ episodes where hourly concentrations consistently exceed 35 µg/m^3. Long-term weather forecasts will be monitored to identify a likely period of extended high concentrations, thus defining the actual start day of the study.

11.0 SAMPLING METHODS (Element B2)

$PM_{2.5}$ Measurement

The core measurement of the study will be $PM_{2.5}$ concentrations. Thermo Personal Data Ram (pDR) Model 1500 samplers will be used for all $PM_{2.5}$ measurements. Performance specifications for the pDR-1500 are presented in Table 1. The sampler will be equipped with a "blue cyclone", which produces a 2.5 µm cutpoint when operated at a flow of 1.5 liters per minute (lpm).

Table 1. pDR-1500 specifications.

Concentration measurement range (auto-ranging)	0.001 to 400 mg/m3
Scattering coefficient range	1.5 x 10-6 to 0.6 m-1 (approx.) @ λ = 880 nm
Precision/repeatability over 30 days (2-sigma)	± 2% of reading or ± 0.005 mg/m3, whichever is larger, for 1-second averaging time ± 0.5% of reading or ± 0.0015 mg/m3, whichever is larger, for 10-second averaging time ± 0.2% of reading or ± 0.0005 mg/m3, whichever is larger, for 60-second averaging time
Accuracy	± 5% of reading (± precision) traceable to SAE Fine Test Dust
Resolution	0.1 µg/m3
Particle size range of maximum response	0.1 to 10 µm

Adequacy of in-use performance of these pDRs has been evaluated under a 2012 New Hampshire ambient $PM_{2.5}$ study.[2] In addition, a limited comparison of pDR vs BAM performance in the nonattainment area is available based data collected by FNSB from collocation of both monitors at the NPFS in early fall 2016. (FNSB has purchased six identical pDR-1500s to those planned for the saturation study and has begun deploying them through the nonattainment area for compliance and enforcement of wintertime burning and solid fuel use restrictions.) Figures 10 and 11 show scatter plots of hourly $PM_{2.5}$ at NPFS measured by the BAM and pDR-1500 during separate three and four-day collocation periods in late September and early October. Figure 10 shows results for the three-day period during which no in-line heater was used for the pDR. Figure 11 presents a similar plot for a following four-day period during which an in-line heater was installed with the pDR. Linear regression fits of the pDR vs. BAM measurements and correlations are also shown on each figure

Comparing the results of both figures, both periods exhibited extremely high correlation (R^2 above 0.9) between the pDR and BAM measurements. Although the period without using of an in-line heater (Figure 10) showed nominally higher correlation between the two instruments, ambient concentrations tended to be lower than during the following period during which the heater was installed (Figure 11). More importantly, the latter period shows a much better slope (0.91 vs. 1.54) in representing how well-matched the absolute values of both instruments were when an in-line heater was used with the pDR. Although these collocation samples are very limited, they provide a picture of the pDR instrument performance under local conditions.

[2] "New Hampshire Mobile Air Monitoring Special Study on Small Particles ($PM_{2.5}$), 2010-2011 and 2011-2012," New Hampshire Department of Environmental Services, August 2012.

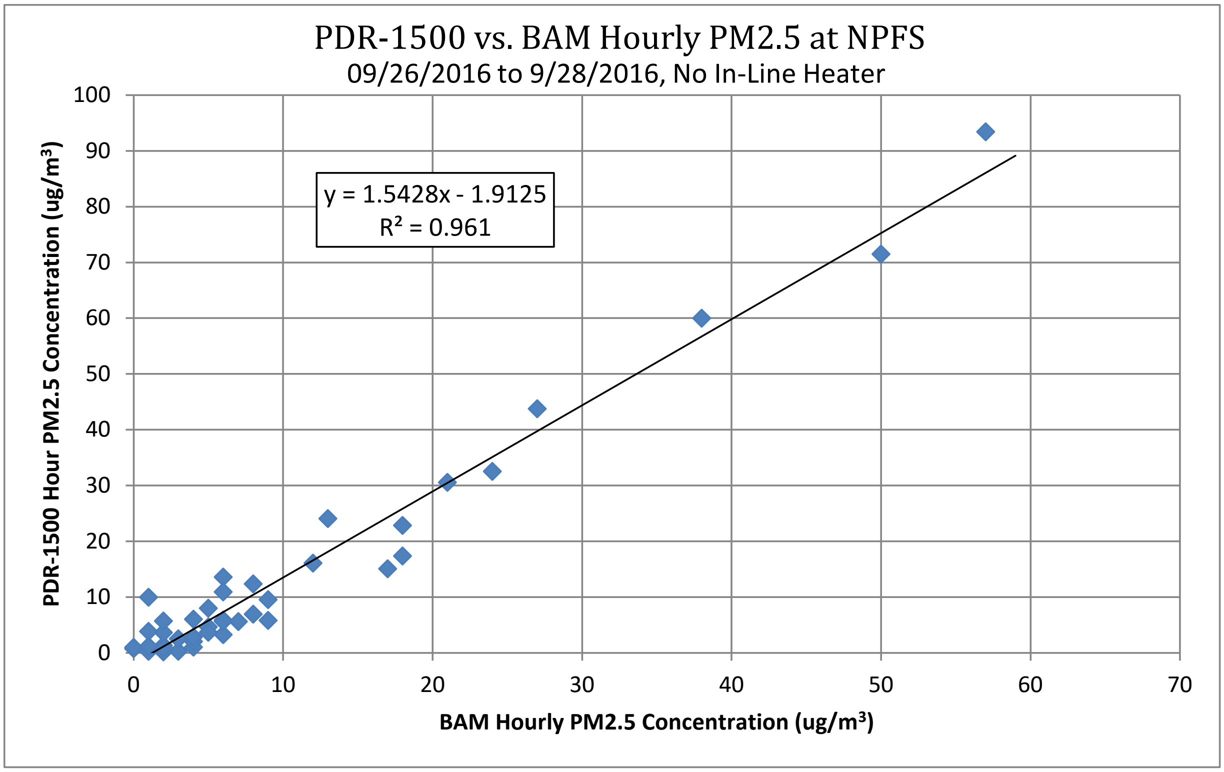


Figure 10. NPFS pDR vs. BAM Comparisons, No In-Line Heater

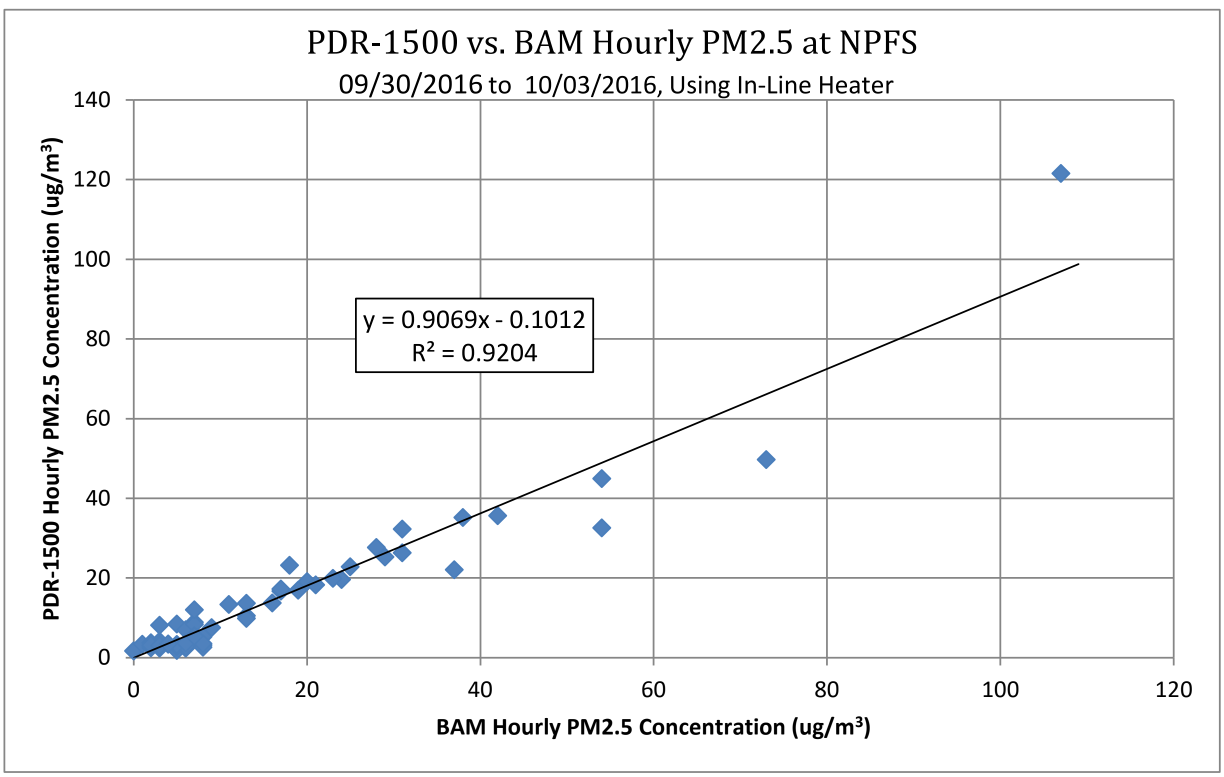


Figure 11. NPFS pDR vs. BAM Comparisons, With In-Line Heater

Fixed-Site Monitoring

Twelve fixed-site monitors will be placed and operated continuously during the study period. Added to two of the stations will be sonic anemometers to document wind flow and potential channeling of particulate matter. All data will be collected in real time using cellular communications with displays of data through an Internet interface and real-time mapping. Table 2 summarizes the equipment to be used at each fixed-site monitoring location.

Key to the fixed-site methodology will be development of a suitable enclosure for the sampling equipment, with the principal concern being the low temperatures associated with the anticipated $PM_{2.5}$ episodes. The basis of these enclosures will be a conventional portable cooler, which will provide both easy deployment, protection from the elements, and the insulation required to keep equipment warm. Figure 12 presents a diagram of the basic shelter configuration. In addition to the Thermo inlet heater that will heat incoming sample air by 15º to 20ºC prior to entering the pDR-1500, the system will include an enclosure heater that will be controlled by the data logger in order to maintain a suitable enclosure temperature.

Table 2. Equipment at Fixed-Site Monitoring locations.

Measurement	Make/Model	Sampling parameters	Equipment Source	Comments
Wind Speed and Direction, two sites	RM Young Sonic Anemometer	1-s scans (not recorded but used in the calculations), 1-min, 15-min, hourly averages, vector and scalar wind calculations	Alaska DEC	A tripod with a maximum height of about 3 meters will be provided. DEC is exploring the possibility of providing a tower for 10-m measurements.
$PM_{2.5}$	Thermo pDR-1500	Measurements at 1-s intervals stored internally in the sampler. Data will also be recorded on the data logger at the same intervals as the meteorology.	Alaska DEC/ T&B Systems	Sample inlet height for all units will be 2 meters. The DEC will likely purchase several units, with T&B supplying the remainder as rentals.
Data recording	Campbell Scientific CR300	1-s scans and 1-min, 15-min and hourly averages	T&B Systems	
Cellular telemetry	Sierra Wireless AirLink Raven XT		T&B Systems	

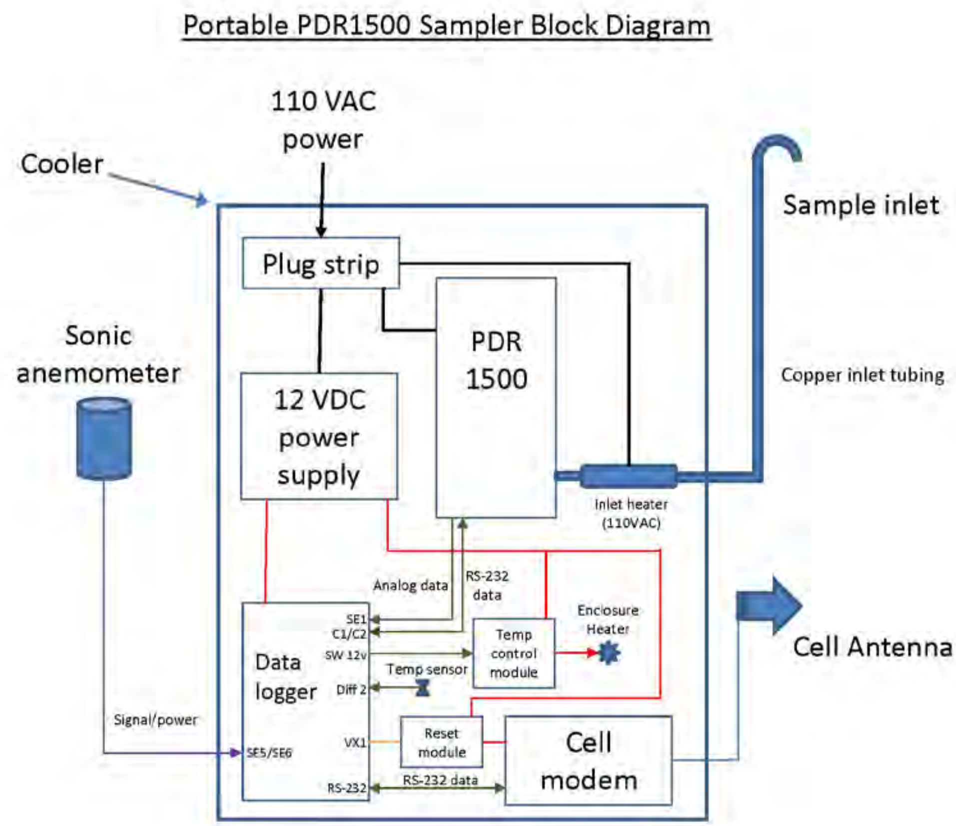


Figure 12. Sample enclosure configuration.

<u>Mobile Monitoring</u>

Mobile monitoring will be performed using a vehicle equipped with a real-time $PM_{2.5}$ monitor that will be used in a primary role of "virtual site" data collection. All equipment will be installed in a sampling vehicle that is equipped with a 12 VDC to 120 VAC pure sine wave inverter and adequate AGM batteries to power the system for at least eight hours of continuous sampling. Provisions will be made to make a rapid switch from vehicle to ground power when AC power is available. The equipment to be used and source of the equipment is identified below. All data will be collected using 1-second scans with both the individual scans and 1-minute averages recorded. Table 3 summarizes the equipment that will be used in the mobile monitoring platform.

Table 3. Equipment in Mobile Monitoring vehicle.

Measurement	Make/Model	Sampling parameters	Equipment Source	Comments
Vehicle position, speed and direction of travel	Garmin GPS	1-s scans and 1-min averages	T&B Systems	
$PM_{2.5}$	Thermo pDR-1500	1-s scans and 1-min averages recorded on CSI CR1000 logger.	T&B Systems	Sample inlet height will be approximately 2.5 meters
Data recording	Campbell Scientific CR1000	1-s scans and 1-min averages	T&B Systems	
Cellular telemetry	Sierra Wireless AirLink Raven XT		T&B Systems	
On-board data display	Windows 10 based Netbook computer	Location plots and “strip chart” plots of variables in real time.	T&B Systems	

In addition to the aforementioned New Hampshire study, the usefulness of mobile PM monitoring has been successfully demonstrated previously during an earlier Sierra Research / T&B Systems collaboration[3] investigating wintertime PM episodes along the Salt River basin in Phoenix, Arizona for the Maricopa Association of Governments (MAG). This one-month study had a significant mobile monitoring component, consisting of two SUVs, each equipped with two TSI Model 8520 DustTrak samplers (optical particulate samplers very similar to the pDR-1500 samplers being used for the North Pole Study) and GPS location equipment. Within each SUV, one DustTrak measured PM_{10}, and one measured $PM_{2.5}$. These mobile platforms were used for a number of investigative goals, most often in the survey mode for identifying “hotspots” in the study domain. However, for one day, the two SUVs were teamed up to measure potential gradients in a particular area of concern, using a series of repetitive runs along a defined route for six hours – similar to what will be performed during the North Pole study. Though not an intentional goal of the MAG study, it ended up that the routes chosen had both SUVs repeatedly traveling on the same portion of S 51st Avenue, producing a unique data set for evaluating the performance of the mobile monitoring methodology.

For this evaluation, a point (“virtual site”) was chosen on S 51st Avenue at the intersection of S 51st Avenue and Combs Road (latitude 33.4186, longitude -122.1693), producing a data set that included the following characteristics:

- Both vehicles were traveling through this section of S 51st Avenue at approximately 20 MPH, with no stopping.

- Any readings occurring within a 50-meter radius of the virtual site location were considered representative of the location. Given the traveling speed and the 2-second data logger sample rate, this resulted in typically three sample values falling within this radius during a given pass. For the purpose of this evaluation, the first of these three values was ignored to allow for the likely lag in the sampler response, and a final concentration for the pass was calculated as the average of the last two values during

[3] “PM_{10} Source Attribution and Deposition Study,” Sierra Research, Report No SR2008-03-01, prepared for Maricopa Association of Governments, March 2008, Appendix A, T&B Field Monitoring Study, T&B Systems, Appendix B, T&B Field Study/Mobile Monitoring Plots.

the pass (in essence, a 4-second average). (A similar lag adjustment will be evaluated and applied for the North Pole study based on traveling speed and virtual bin size.)

- The SUVs were not coordinated in their position at any given time on the route. The routes had both vehicles traveling in both directions on S 51st Avenue.

- Both vehicles passed the virtual site location an average of 12 times per hour.

Figure 13 shows a time-series graph of all $PM_{2.5}$ 4-second averages for both vehicles, after adjusting calibration factors for each of the samplers. There is very good agreement between the two platforms in their reported reading for the virtual site, both in the reported concentration and in the temporal variability. Combining all values within a given hour to produce an hourly average, the two platforms show almost perfect agreement, even for the much higher PM_{10} concentrations, as noted in Figures 14 and 15, for $PM_{2.5}$ and PM_{10}, respectively.

In summary, the evaluation demonstrates the applicability for using mobile monitoring to obtain average concentrations over defined averaging periods, showing that representative, accurate and precise measurements can be achieved using this method. The operational parameters for the above comparison are basically identical to those to be implemented during the North Pole study. All routes will originate at the NPFS, and thus an obvious difference is that one of the two platforms in this case never moves. However, it would seem that results for two moving platforms would be a more likely "worst case", and that comparison to a fixed sampling location will not affect the methodology performance. The other exception is that only about half of the passes per averaging period during the evaluation are anticipated during the North Pole study. However, this is more of a statistical issue than a performance issue.

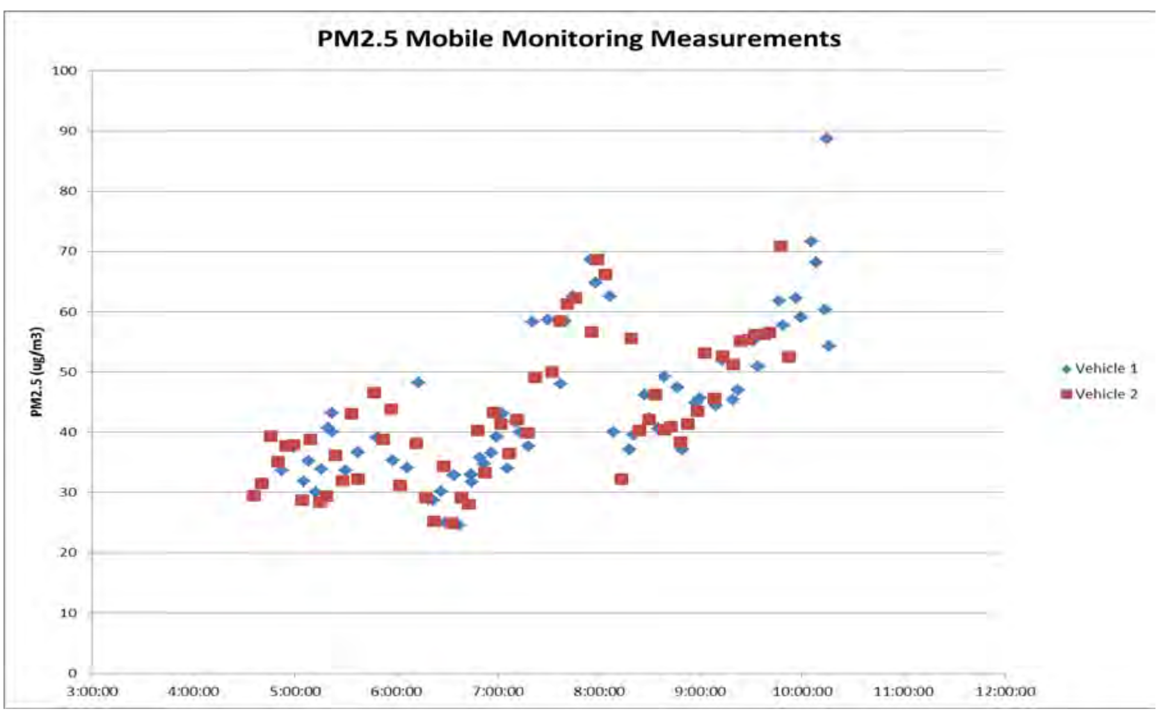


Figure 13. $PM_{2.5}$ measurements as vehicle passes designated sample location.

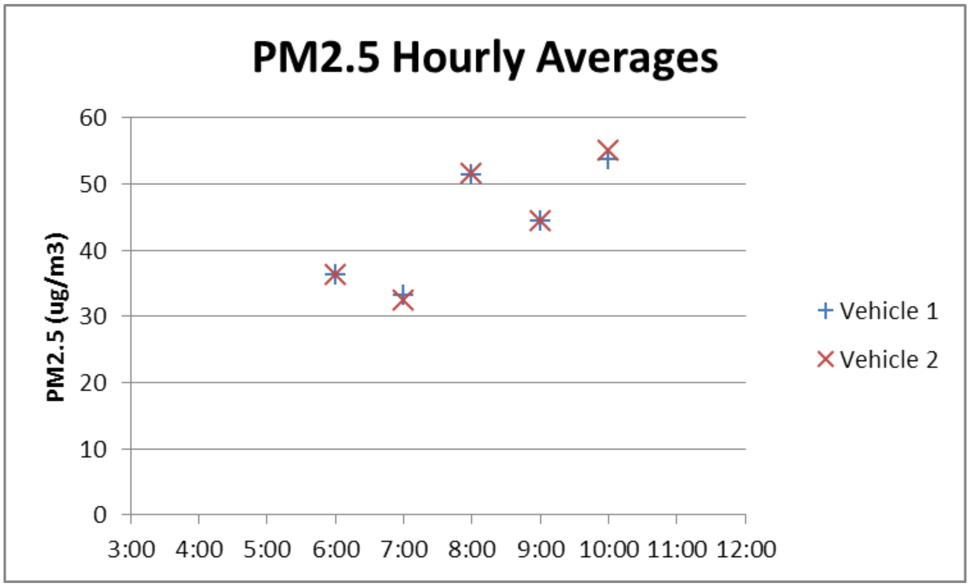


Figure 14. Resulting $PM_{2.5}$ hourly averages at designated location.

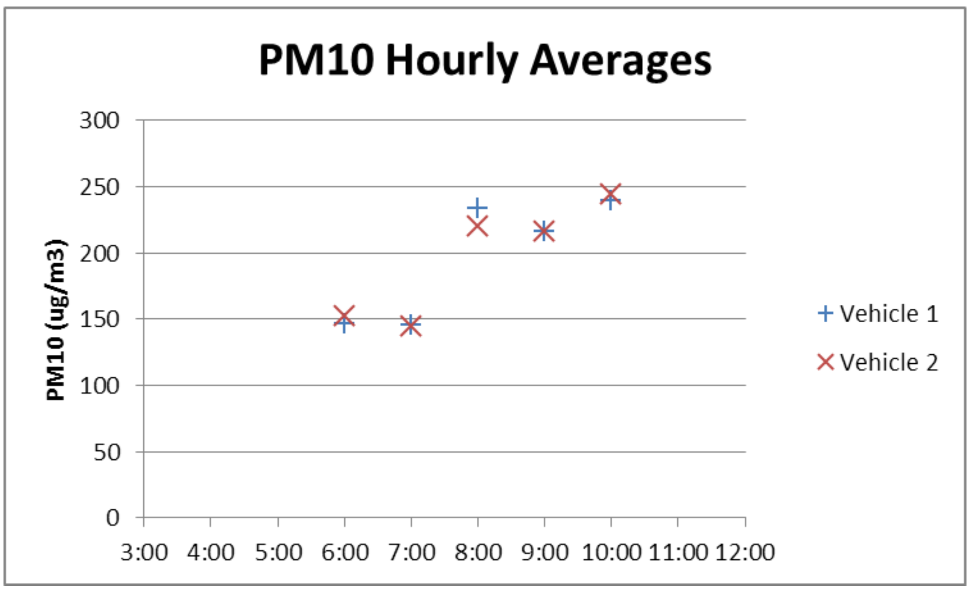


Figure 15. PM_{10} hourly averages at designated location

12.0 SAMPLE HANDLING AND CUSTODY (Element B3)

This study does not include the collection of samples requiring handling and chain-of-custody procedures.

13.0 ANALYTICAL METHODS (Element B4)

No laboratory or field analyses are needed for this study.

14.0 QUALITY CONTROL (Element B5)

The key component of the study's quality control program will be collocated measurements of all pDR-1500 samplers in order to verify sampler performance and comparability under actual field conditions. All samplers will be temporarily installed within a 10-meter radius of the NPFS $PM_{2.5}$ BAM inlet for two days prior to the field study. Based on the collected data, adjustment factors will be calculated for normalizing all samplers to the pDR deployed at the NPFS (Site 1). In addition, data will thus be available for calculating "k" factors for converting pDR readings to values comparable to the NPFS $PM_{2.5}$ BAM. The effort will be repeated for two days immediately following the end of the study period to verify that sampler response characteristics have not changed significantly. Based on our understanding of logistics at the time of the writing of this QAPP, the collocation will occur as follows:

- While "k" factors are a secondary goal relative to the need to normalize the pDR samplers relative to each other, the most representative "k" factor comparison will require that the sample inlets for the pDR samplers and the BAM sampler be essentially the same. This can be achieved by placing the pDR enclosure on the roof of the trailer next to the NPFS BAM, at an inlet height of about 4-5 meters. However, it is not certain if all 12 enclosures can fit on the roof. Therefore, given that some site locations have not yet been identified, if not all can fit then only samplers destined to go to already identified sites will be placed on the roof, including the Site 1 sampler, to which all samplers are normalized. This will provide sufficient comparison data for establishing suitable "k" factors for the pDR samplers.
- Samplers that may not fit on the roof will be placed on the ground within 10 meters of the NPFS BAM.
- The samplers will be operated in this configuration for two days of elevated concentrations.
- After two days, the samplers on the roof will be deployed to their respective site locations, including the Site 1 sampler, which will be brought down to ground level. The samplers on the ground will now be collocated with the Site 1 sampler in order to obtain collocation data, again normalized to the Site 1 sampler, for this subset of samplers. At least two days of collocated data will be obtained, after which the samplers will be deployed to their site locations, assuming that sites have been found.
- The above scenario has the added benefit of providing some vertical profiling data during the initial two days of collocation (2 meters versus 5 meters) that may be informative.

In addition to the above, the following quality control procedures will be implemented:

- Collocated data from mobile monitoring. As noted above, each mobile monitoring route will include repeated passes by the NPFS pDR sampler, providing ongoing collocation measurements that will be reviewed on a daily basis.

- Flow and zero checks of pDR samplers. Flow rates and zero responses of all pDRs will be checked at least once every three days, and adjusted as necessary. A flow rate of 1.5 lpm is necessary for maintaining a cutpoint of 2.5 µm. Flows will be adjusted if the measured flow is beyond ±0.1 lpm of this set point. Samplers will be adjusted if the zero response is outside of ±5 µg/m^3.

-

- Daily data review. All data, including the mobile monitoring data, will be uploaded via cellular modem to T&B's Vista Data Vision web-based data management system, where they will be reviewed on at least a daily basis for instrument related problems, as well as issues influencing the achievement of the study goals. This review will include the following:

  - Data from the mobile monitoring will be reviewed against fixed-site data for consistency and reasonableness in order to identify any potential instrument related problems. Similarly, the data from the entire network will be reviewed for reasonableness.
  - The interior temperature data for each fixed-sampler installation will be reviewed to verify that the heaters are functioning and that temperatures are being maintained within expectations (above -10ºC in order to meet the pDR sampler's operating environment specification).
  - The data logger voltage will be checked for any power related issues.
  - The sonic anemometer data will be reviewed for reasonableness.

  If a problem is noted, a field technician will be immediately dispatched to investigate the issues. This may include temporary collocated measurements with the mobile monitoring unit or at another fixed site in order to verify performance.

- Spare pDR sampler. One spare pDR sampler will be maintained, which can be swapped in the event that a study sampler fails for any reason. In the event that the non-functioning sampler is a rental, a replacement sampler will be ordered immediately in order to maintain a spare.

15.0 INSTRUMENT / EQUIPMENT TESTING, INSPECTION AND MAINTENANCE (Element B6)

15.1 Initial testing

All equipment will be verified to be functional and accurate at T&B's Valencia facility. Should the instrument appear to be operating out of specifications, the manufacturer is contacted for corrective action. Many of the pDR samplers for this effort will be rented, in which case the rental company will be immediately contacted to send a replacement sampler.

15.2 Preventive Maintenance

The three-week duration of this study eliminates the need for any preventive maintenance, aside from the regular changing of the inline filter in each of the pDR samplers.

16.0 INSTRUMENT CALIBRATION AND FREQUENCY (Element B7)

As noted above, the collocation efforts serve as the means of calibrating the response of each of the pDR samplers. This is performed at the beginning and the end of the study period.

Verification of the sonic anemometer performance can only be accomplished through comparisons with a collocated standard. This will be difficult to achieve in field conditions during the study. However, a collocated functional check to an audit standard to verify instrument operations will be conducted during the equipment checkout at Valencia.

17.0 SUPPLIES AND CONSUMABLES (Element B8)

The only consumables needed for this study are the inline filters necessary for the pDR samplers. A supply of 200 filters has been order for the study. This supply will be inspected prior to being shipped to the study area. Due to the short duration of the study and the lack of any "in the field" troubleshooting/repairs, there are no spare parts associated with the pDR samplers. However, as noted in Section 14, a spare pDR has been ordered for the study in the event of a sampler failure.

18.0 NON-DIRECT MEASUREMENTS (Element B9)

This section addresses data not obtained by direct, study-specific measurements. It is anticipated that routine data collected by the Alaska DEC and the FNSB will be used during analysis. These additional "non-direct" data will include the following elements:

- pDR sampling conducted by FNSB using identical instrumentation within the western portion of the North Pole area to support its on-going control program compliance monitoring (Quantitative use of this data will necessitate additional QA procedures, including collocation with one of the study pDR samplers and review of the FNSB QC procedures);

- Estimates of gridded emissions (1.33 km cell resolution) from episodic inventories being prepared to support development of the Serious Area SIP;

- Identification of localized solid fuel burning emission source within the saturation study domain based on on-going FNSB compliance reconnaissance (as available): and

- Collection of GPS-based position data (fixed sites and mobile monitors) referenced to datum WGS84.

19.0 DATA MANAGEMENT (Element B10)

As noted above, the data will be uploaded into Vista Data Vision. This system provides the data polling, processing and real-time display capabilities that allows comprehensive and efficient data review and analysis of air quality and meteorological data as it is collected. Operational integrity is maintained through automated daily backups to additional on-site servers, and offsite data backups nightly. The system provides automatic screening of data as it is collected and can email notifications in the event of an "out of tolerance" event.

Upon completion of the field sampling, the data will be reviewed and validated to provide a data set with any needed calibrations applied, and invalid data removed. "k" factors for each pDR sampler will be finalized based on the results of the collocated monitoring and applied to the data. Comma delimited files will be generated for all data, with “time-ending” time stamps. The data from the fixed-location samplers and the meteorological towers will be provided for each reporting interval (1-min, 5-min, hourly). The mobile vehicle data will include data files that provide one-second interval scans, and one-minute averages. Data for “virtual locations” will be calculated from the mobile data using the following process:

- Based on an initial review of the data, a defined set of “virtual locations” will be selected based on study goals.

- The sample response time for the mobile sampling system will be estimated during the field study. Based on this evaluation, the mobile monitoring readings will be shifted relative to the recorded GPS coordinates in order to more accurately represent the spatial conditions.

- Coordinates for a 30m radius around each defined location will be calculated, and data collected while in these circles will be sorted out for calculation of averages at each location. Based on a 25 MPH vehicle speed, radius will allow for 5 seconds of readings during each pass.

The validated, quality-assured data will then be transmitted to Sierra Research and Alaska DEC for analysis and long-term data storage.

20.0 ASSESSMENTS AND RESPONSE ACTIONS (Element C1)

All measurement platforms will be available for assessment by the Alaska DEC and/or the FNSB. This could include the following:

- Independent measurement of pDR sampler flow rates
- Collocation measurements using the FNSB “sniffer” platform
- Inspection and review of installations, QC activities, and QC documentation

Noted issues will be forwarded to Bob Baxter via email at bbaxter@tbsys.com. T&B Systems will respond within 24 hours to any issues noted.

21.0 REPORTS TO MANAGEMENT (Element C2)

The following reports will be submitted to management:

- Field Status Reports – Brief status reports will be emailed to key management staff on a daily basis during the field study period. These will included and update on the status of all monitoring equipment, and a discussion of any problems affecting the monitoring effort.

- Management Conference Calls – Conference call will be held twice a week (on Monday and Thursday) between T&B Systems and key management staff to discuss the progress of the study relative to study goals. This will provide an opportunity for management to adjust monitoring strategies based on collected data and forecasted weather/pollution conditions.

- Collocation Report – A report detailing the results of the collocation testing of the pDR samplers will be provide within two weeks of the end of the study.

- Data Submittal Report – This report will coincide with the submittal of the finalized data set collected during the field study. The report will detail the data validation effort and describe the structure of the submitted data set.

22.0 DATA REVIEW, VERIFICATION, AND VALIDATION (Element D1)

Data validation is a combination of checking that data processing operations have been carried out correctly and of monitoring the quality of the field operations. Data validation can identify problems in either of these areas. Once problems are identified, the data can be corrected or invalidated, and corrective actions can be taken. As noted in sections above, the data will be reviewed on a daily basis, during which most data validation issues will be identified.

Data will only be invalidated for known, identified instrument issues, as documented by the field technicians. In averaged data must contain valid data points for at least 75% of the averaging period. As there is a possibility of slight negative drift in the responses of the pDRs, negative values will not be altered.

23.0 VALIDATION AND VERIFICATION METHODS (Element D2)

The primary mean of validating the collected data will be through review using Vista Data Vision. This program allows for the displaying of data in a variety of ways to facilitate the review process. Again, the validation process is a daily, ongoing effort throughout the monitoring period. The review process will incorporate the following:

- Range checks
- Internal consistency between samplers
- Reasonableness checks based on reviewers experience
- Consistency with QC documentation

A checklist will be developed and used for each monitoring site to assure that validation of the data is documented and performed consistently.

24.0 RECONCILIATION WITH USER REQUIREMENTS (Element D3)

T&B and Sierra will prepare a project summary report which will include a description of the process used for reconciling project results with project objectives and will discuss any limitations on use of data.